PNW Energy

February 28, 2018

Mr. Steve Whitmore
School of Engineering Science
Simon Fraser University
Burnaby BC
V5A 1S6

Re: ENSC 405 Capstone Requirement Specifications: OptimSolar

Dear Mr. Whitmore,

The following document outlines our requirement specifications of a solar panel mounting production unit for ENSC 405W (Project Documentation, User Interface Design, and Group Dynamics). The project will involve constructing a universal solar panel mounting unit capable of solar tracking/concentration, cooling, and performance monitoring.

This document will outline the differences between our proposed proof of concept and prototype. An in-depth look at the needs for each version is included in the requirements section. This document can be used throughout the production process of both models of OptimSolar to reference these goals. After that, further sections include engineering standards, and safety and sustainability considerations.

PNW Energy consists of three 5th year engineering students. Each of whom are eager and motivated to continue designing and producing a proof of concept.

If you have any questions about this document, please contact Cole Patterson by email at colep@sfu.ca.

Thank you,

Cole Patterson
Sam Swerhone
Jacob Cheng

# OptimSolar

## Requirement Specifications

OPTIMIZING SOLAR SYSTEMS USING CONCENTRATION AND COOLING,
2/28/2018

Group 15:

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## Glossary

| | |
|---|---|
| **MCU** | Microcontroller Unit |
| **I2C** | Inter-Integrated Circuit |
| **CSA** | Canadian Standards Association |
| **UI** | User Interface |
| **PCB** | Printed Circuit Board |
| **GPS** | Global Positioning System |
| **LCD** | Liquid-Crystal Display |
| **LED** | Light-Emitting Diode |
| **VCC** | Rail Voltage |
| **GND** | Ground |
| **SDA** | Serial Data |
| **SCLK** | System Clock |
| **IEEE** | Institute of Electrical and Electronics Engineering |
| **YAW** | See Appendix I |
| **PITCH** | See Appendix I |

## Abstract

With renewable energy continuing to grow as an industry there are complementary markets that result from the rapid improvements in renewable energy efficiency [1]. The OptimSolar product is a solar panel complement that improves solar panel power outputs and reduces installation inconveniences and costs. Hot climates can see up to a 70% improvement in power production, and colder climates could see up to a 45% improvement [2].

OptimSolar provides a universal mount that will encourage the growth of the residential solar industry. By implementing low power computing and optimizable tracking and cooling in a universal and easy-to-install companion product, homeowners and residential installer will have a ‘go-to’ product for solar system installations worldwide.

## Introduction/Background

With the effects of climate change becoming more apparent each year, there is a worldwide trend toward sustainable and renewable energy sources, as countries move away from greenhouse gases [1]. As fossil fuels continue to burn, the risk of permanent and irreversible damage to the planet increases [3]. Luckily, scientific advancements in photovoltaics are being made at an unprecedented pace, allowing us to move toward a world where renewable energy is the primary source of electricity.

The motivation for OptimSolar is simple, encourage more customers into the solar market by increasing performance and easing the installation process. OptimSolar can be described as a universally compatible solar energy optimization unit.

OptimSolar will greatly increase the performance of the mounted solar panel by tracking the Sun's path with respect to the mount and by maintaining an adequate ambient surface temperature of 25°C. The product will have a universal mounting design, compatible with standard residential solar panel sizes. Several sensors will be placed in corner locations to provide the system’s microcontroller the necessary data to adjust the mount with a 2-axis motor gimbal system to track the Sun effectively.

OptimSolar will greatly improve solar harnessing by maintaining the solar panel plane perpendicular to the Sun’s solar rays, a process known as tracking or concentration. The tracking ability can improve performance by up to 45% [2]. The OptimSolar unit will also offer cooling and temperature regulation using hydro-cooling and exhaust techniques commonly used in household electronics. Overheated systems can rapidly degrade performance (by as much as 25%) and shorten the lifespan of solar panels [4]. Lastly, the OptimSolar system may have an add-on performance display option, which will inform users of the current power output and notify them of any drop-offs due to unexpected issues. It should be noted that this display will not always be situated on the solar panel; it can be moved to easily accessible areas or implemented as a smart phone application.

## Scope

This document will provide the reader with necessary information to fully understand the scope of the project. The product requirements will be listed for all major components of OptimSolar for both proof of concept and prototype. Safety, sustainability, engineering standards, and a system overview are all presented concisely throughout the document to give a comprehensive review of the OptimSolar unit created by PNW Energy.

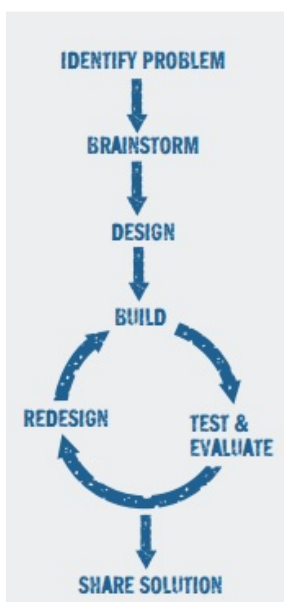
## Audience

OptimSolar is a companion product designed to be incorporated seamlessly into existing solar panel systems or to be purchased as an easy installation method for a photovoltaic systems. OptimSolar provides the consumer with a universal solar tracking and temperature controlled mounting unit that is easy to use and perfect for home owners, DIYers, and solar panel enthusiasts.

## Classification and Design Process

PNW Energy will segment the design process into two parts: proof of concept and prototyping. The proof of concept lays the foundation for a successful prototype, and the prototype builds on the successes and/or corrects the shortcomings of the proof of concept. The proof of concept process is currently underway, and bridging the gap between the brainstorming and design stage, see Figure 1. The target date for sharing the proof of concept is April 5th, 2018. The prototyping stage will start towards the end of April.

**Figure 1: Engineering Design Process [5]**



This document makes an effort to identify the requirements for each segment. For an overview of the different design paths for the proof of concept see Figure 2, for the prototype see Figure 3. The paths are very similar and will benefit from modularized components and interface planning. Within the many build stages it is expected that testing, evaluation, sharing, and redesign will take place. Therefore, modular components should be verified and integration will be streamlined.

**Figure 2: Proof of Concept Design Process**

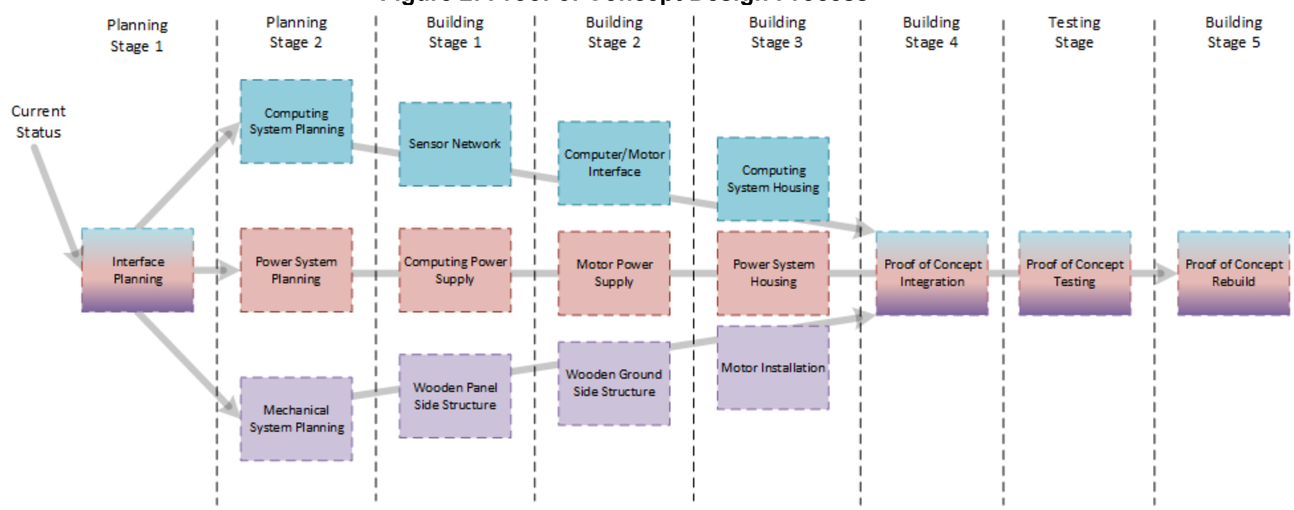
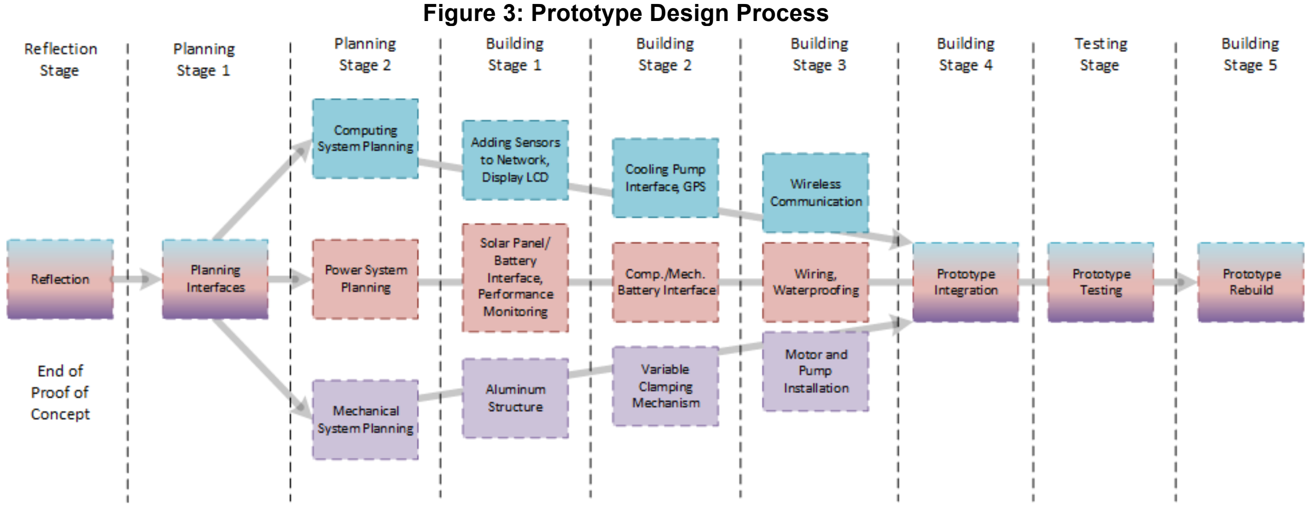


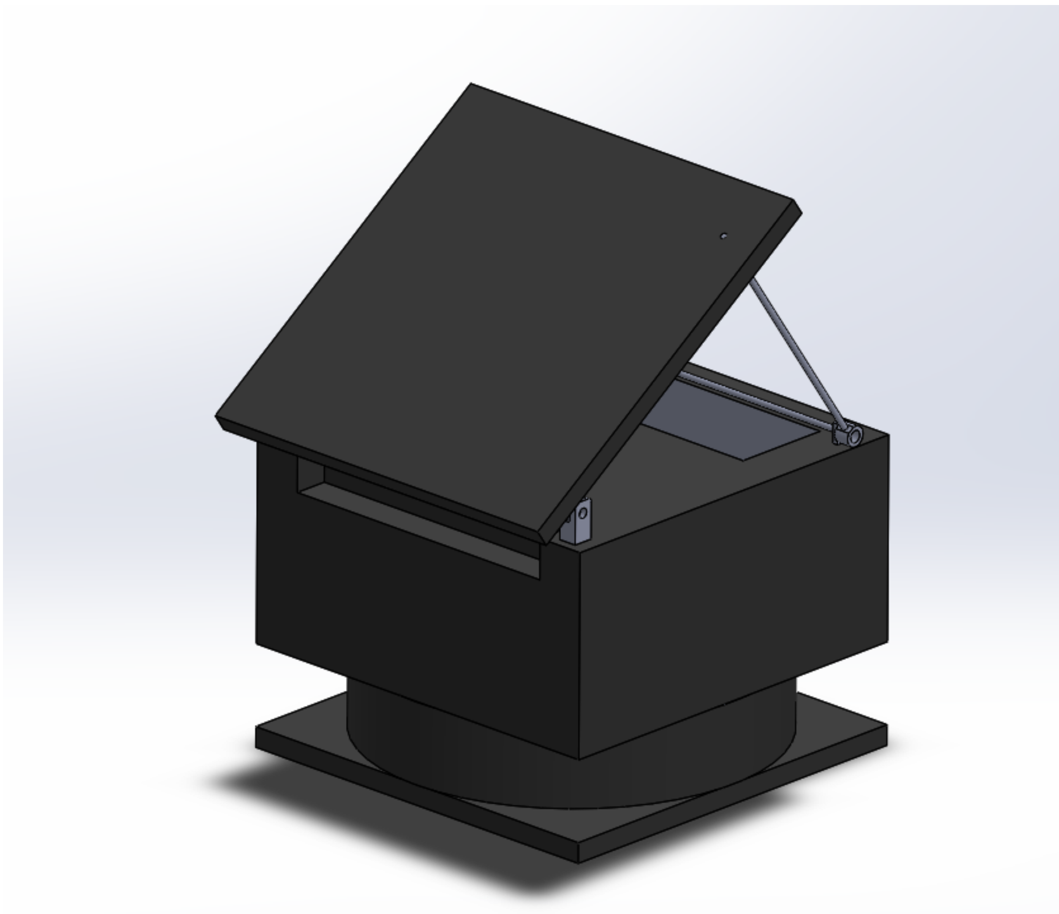

**Figure 3: Prototype Design Process**



## System Overview

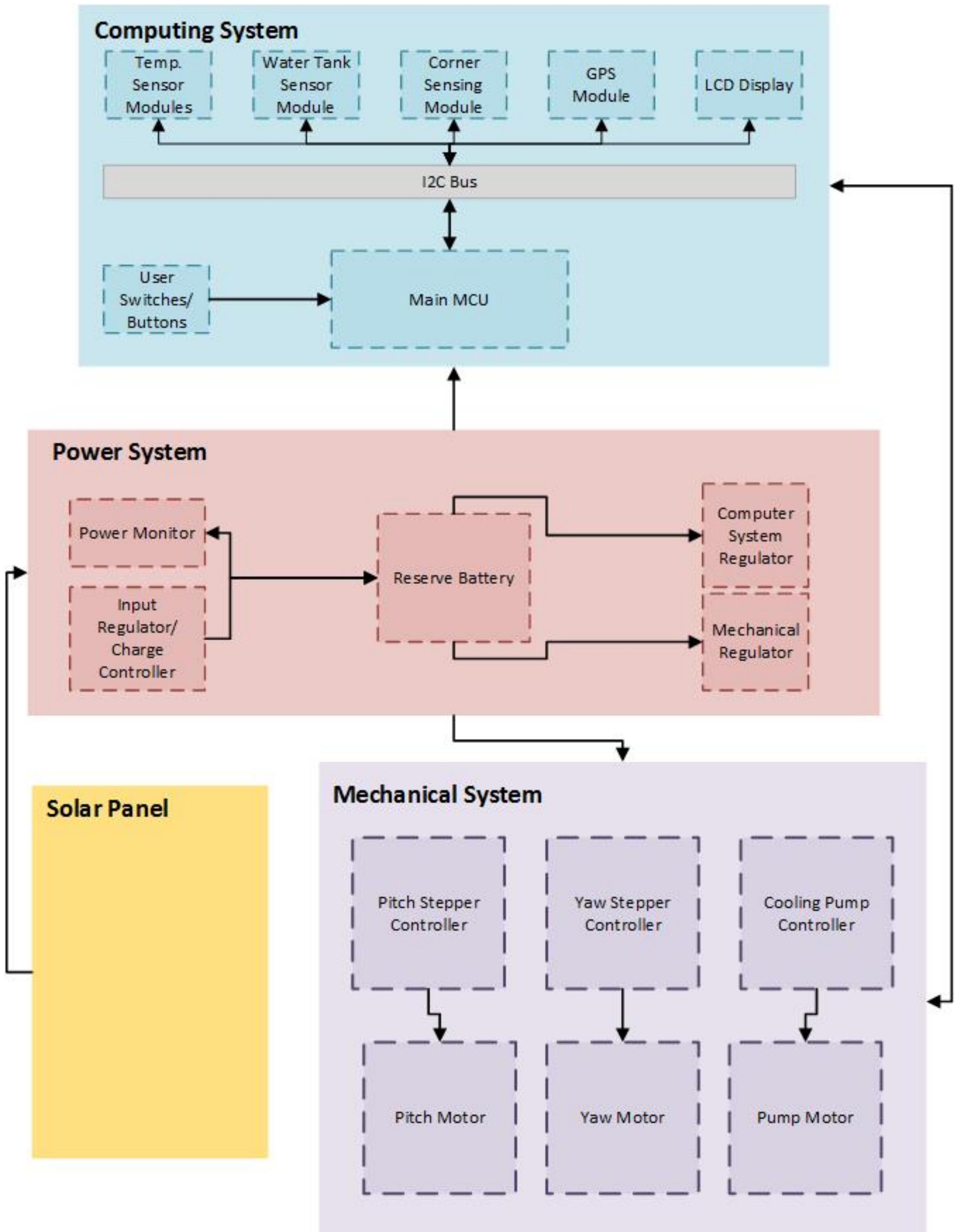
The OptimSolar device may look similar to the mockup below (Figure 4).

**Figure 4: OptimSolar Mockup**



OptimSolar's many systems can be modelled based on the system overview diagram shown in Figure 5.

**Figure 5: System Overview**



There are two design stages to consider, the proof of concept and the prototype. The proof of concept will be used as the final deliverable for ENSC 405, whereas the prototype will be used as the final deliverable for ENSC 440. Because of the time and financial constraints, each model will have a different set of requirements. The major differences are: the proof of concept will be made of wood, will not be weatherproof, and offer less computing features. Since it will not be waterproof, the cooling system cannot be included either (which includes a sprinkler to cool the panel via evaporation). Lastly, the proof of concept model will be designed on a breadboard whereas the prototype will utilize PCBs. Comparatively, the prototype is expected to meet the majority* of requirements and features seen in Figure 5.

Since the proof of concept will not have a cooling system, ENSC 405 tests will be solely based on solar tracking. Testing the expected 45% increase in average power generation, entails mounting two identical solar panels in the same environment. PNW Energy's testing method will be a comparison study, comparing a panel mounted on the OptimSolar proof of concept with the same panel on a stationary mount. After several days of testing, the results should indicate that solar tracking greatly increases average power generation.

**There are man-hour limitations due to PNW Energy consists of only three students. The prototype plan includes features that can will only be added if time permits. Some of these aspects are: GPS/compass positioning to determine Sun's path and/or wireless communication of performance data and user control.*

## Functional Requirements

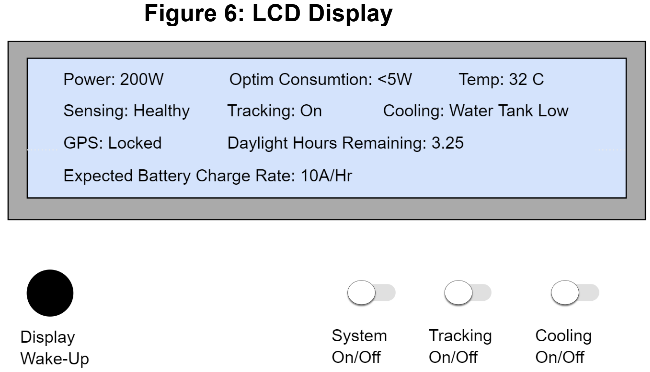
*Sections marked A will be present for proof of concept presentation, sections marked B relate to prototype.*

**1. User Interface**

OptimSolar's user interface will be simple, but should still offer users enough control of performance options. The priorities of the user interface are low power consumption and simplicity. The design should follow good UI conventions, offering labeled and obvious controls. Along with an intuitive UI, the system will include a user manual outlining appropriate use and control.

1.1. [B] LCD Display (40 characters, by 4 rows) (see Figure 6)

**Figure 6: LCD Display**



1.1.1. [B] LCD sleeps unless user wakes with push button
1.1.2. [B] Display Wake-up button has a response time of <5ms
1.1.3. [B] Displays panel temperature (°C)
1.1.4. [B] Displays subunit status (sensors, MCU's, motors, cooling system)
1.1.5. [B] Displays solar power production
1.1.6. [B] Displays instantaneous power consumption of OptimSolar
1.2. [A,B] Rocker switches (on/off) for tracking, cooling system, and power
1.3. [B] System includes web-based and hardcopy user manual
1.3.1. [B] Manual will inform of safety hazards
1.3.2. [B] Manual will inform of appropriate use
1.3.3. [B] Manual will define each display output and control switch/button

## 2. Computing System

The computing system consists of a central MCU, LCD, GPS, Computer-Motor Control Interface, Computer-Wireless Communication System Interface, and various peripheral sensor modules that form the I2C Network. The computing system prioritizes low power consumption over speed. The software base will be developed by PNW Energy, but offered as an open source code base to facilitate continued development and support as well as user alteration.

2.1. [A,B] The computing system will have a main MCU as data processor, I2C Master, and PWM driver
2.2. [A,B] Uses 8MHz Clock for reduced power consumption
2.3. [B] External port for user programming options and updating firmware
2.4. [B] External port for additional I2C slave devices
2.5. [B] Two mode operations for reducing average power consumption
2.5.1. [A,B] Has a Full Operation Mode
2.5.1.1. [A,B] In Full Mode for a short period (<2min) twice per hour, during daylight hours
2.5.1.2. [A,B] Wakes all slave devices (temperature sensors, sensor modules)
2.5.1.3. [A,B] Reads each sensor five times, for redundancy, via I2C protocol
2.5.1.4. [A,B] Calculated required PWM or Cooling Signals
2.5.1.5. [A,B] Adjusts PWM outputs
2.5.2. [B] Has a Standby Operation Mode
2.5.2.1. [B] In Standby Mode when not in Full Mode
2.5.2.2. [B] Sleeps all slave devices (sensor modules)
2.5.2.3. [B] Turns LCD backlight, changes LED indicators to low lit
2.5.2.4. [B] Interrupted by timer, toggling of user switches/buttons
2.5.2.5. [B] When interrupted the system enters Full Mode
2.5.2.6. [B] Locks motor position in Standby Mode
2.6. [B] Full Mode/ Sleep Mode duty cycle can be input by user
2.7. [A,B] Uses an I2C Sensor Network
2.7.1. [B] Each sensor module can be easily disconnected
2.7.2. [B] Uses redundant sensors for improved accuracy and spatial resolution
2.7.3. [A,B] Phillips standard I2C protocol (5V operation, 8MHz SCLK)
2.7.4. [A,B] Four temperature sensors
2.7.4.1. [A,B] Will provide data for calculating Mean Radiant Temperature
2.7.4.2. [A,B] 5V compatible
2.7.4.3. [A,B] Typical accuracy within ± 1 °C
2.7.4.4. [A,B] Low typical power consumption per unit, < 300μA
2.7.4.5. [A,B] Standby power consumption per unit, < 5μA

2.7.5. [A,B] Contains four “Corner Sensing Modules”
2.7.5.1. [A,B] Only four ports, VCC (5V), GND, SDA, SCLK
2.7.5.2. [A,B] Contains a photoresistor and a contact switch as sensors
2.7.5.3. [A,B] Contains a LED as an indicator
2.7.5.4. [A,B] Each module contains an MCU, acting as I2C Slave
2.7.5.5. [A,B] Contains a built in I2C extender to overcome long cable lengths (high capacitance)
2.7.5.6. [A,B] When signaled to Sleep Mode by main MCU, the slave MCUs wait for Full Mode interrupt signal
2.7.5.7. [A,B] When signaled to Full Mode, the local MCU reads photoresistor and contact voltage switches
2.7.5.8. [A,B] When in Full Mode, MCU polls for Master’s I2C start signal, when received it sends sensor data
2.7.5.9. [B] When in Sleep Mode, LED is lowly lit
2.7.5.10. [A,B] When in Full Mode, LED is blinking
2.7.6. [B] Contains a GPS/Compass module
2.7.6.1. [B] Uses a GPS/Compass chip for relating position to the Sun
2.7.6.2. [B] GPS/Compass chip interfaces via I2C
2.7.6.3. [B]GPS/Compass send Latitude/Longitude and heading to main MCU
2.7.6.4. [B] Accuracy of ±3m
2.7.7. [B] Water Tank Sensing Module
2.7.7.1. Identical to corner sensing module except it contains a water level sensor instead of photoresistor and contact switch
2.8. [B] Contains an LCD Interface
2.8.1. [B] The main MCU will control the LCD display via I2C connection
2.8.2. [B] The LCD will turn on for the five minutes following push button activation (displaying UI described in requirement section 5)
2.9. [B] Contains a tracking motor interface
2.9.1. [B] Interfaces via PWM to motor control units
2.9.2. [B] During daylight, main MCU signals motor adjustment each half hour (based on sensor and GPS information)
2.9.3. [B] At night, and between Full Mode periods, main MCU signals motor control unit to lock axes
2.10. [B] The system will offer wireless connectivity
2.10.1. [B] The system will offer WiFi or Bluetooth connection options
2.10.2. [B] The performance monitoring outputs will be accessible
2.10.3. [B] The system controls will be accessible
2.10.4. [B] Wireless connectivity will be secured via password

**3. Power System**

The power system changes considerably between proof of concept and prototype. The proof of concept will be independently powered via two batteries. Comparatively, the prototype will be powered from solar panel production, and have a battery reserve. The foremost priority of the OptimSolar (and specifically the power system), is that the system will provide more energy gains than it consumes.

3.1. [B] The system will provide more energy gains than reductions
3.2. [A] The system will run off two different batteries, not charged by solar panel
3.2.1. [A, B] Computing system will not consume more than 75mA
3.2.1.1. [A] Processing/Computing module will require a 9V lithium ion battery
3.2.1.2. [A,B] All electrical processing/computing running on 5V

3.2.1.3. [A,B] Uses a 5V voltage regulator (max current output 1.5A)

3.2.2. [A, B] Mechanical system power will not consume more than 6A

3.2.2.1. [A] A four cell lithium ion battery will power mechanical system

3.2.2.2. [A] 16V from lithium ion battery will be stepped down to 12V

3.2.2.3. [A] Four cell lithium ion battery will provide 40Whr of power to run stepper motors

3.2.2.4. [A] Stepper motors will draw 1.7A of current at max load

3.2.2.5. [A] Cut off switch at a battery voltage level of 10V to prolong life of the lithium ion battery

3.3. [B] The prototype's computing and mechanical systems will be powered from mounted solar panel

3.3.1. [B] The system will have a reserve battery for periods of low power production

3.3.2. [B] The system will come with a MC4 splitter, to allow for users other parallel loads

3.3.3. [B] OptimSolar's main power cable will have a MC4 connector

3.3.4. [B] The system will draw power from solar panel and step it down to 5V for the computing system and 12V for the mechanical system

## 4. Mechanical System

The mechanical system is required to actuate solar tracking and cooling capabilities while maintaining structural integrity and meeting size and loading constraints. There are many differences between the proof of concept and prototype, including the mounting of OptimSolar, structural materials used, and cooling capabilities.

4.1. [A,B] The system will have two stepper motors responsible for solar tracking

4.1.1. [A,B] One motor will be responsible for rotation of the yaw axis

4.1.2. [A,B] One motor will be responsible for rotation the pitch axis

4.1.3. Stepper motors will have at least 200 steps per revolution (1.8° steps)

4.1.4. [A,B] Yaw axis will have 360° degrees of rotation

4.1.5. [A,B] Pitch axis will have at least 180° degrees of rotation

4.1.6. [A,B] The system will have one small hydro pump responsible for the cooling system

4.1.7. [A,B] Motor actuation will be controlled by PWM input

4.2. [A,B] The cooling system will operate when temperature sensors determine the solar panel has surpassed a threshold temperature (roughly 35℃)

4.2.1. [A,B] The unit contains a water storage unit from which the water is drawn

4.2.2. [A,B] The unit will be filled by the user when empty

4.2.3. [B] The water storage unit will not pump water when empty

4.2.4. [B] The cooling system will be able to run for 1 week (12 hrs a day) without water refilling

4.2.5. The cooling system will spray a mist onto the face of the mounted panel

4.3. [B] The mount will be able to hold up to 100lbs

4.4. [B] The mount will be able to hold a solar panel ranging between 30-45" width, and 50-75" height

4.5. [B] The mount will have bolting and/or staking holes for grounding at standard roof rafter locations

4.6. [B] The mount will have slidable clamping (for variable sizes)

## Engineering Standards

OptimSolar requires an interdisciplinary approach, combining computing, electrical, and mechanical engineering standards. Some of the standards referred to in this section are: [6, 7, 8, 9, 10]. The system will meet all IEEE and Canadian Advisory Council on Electrical Safety (CACES) standards applying to photovoltaic systems [11]. Before product release, the system will be subject to Environmental Compliance Approval (ECA) and Renewable Energy Approval (REA). OptimSolar will be required to meet electrical and mechanical product standards within Canada and US, as it will originally sell in these countries. Most Canadian and American standards overlap, particularly computing and electrical standards.

The computing system will follow IEEE standards for interfacing and grounding. It will follow the Phillips I2C Protocol, with standard pins for connecting additional I2C slaves. OptimSolar's ATMega Firmware will be open source, allowing for users to update/alter use as well as PNW Energy's avoidance of intellectual property litigation due to any potential reused open source libraries or programming/debug tools. The main processing unit will have a standard on-chip serial programming port, sensor modules will not support programming options.  Any wireless communication present in the prototype will meet standards of IEEE 802.

The electrical or power system will follow CACES and IEEE standards. The system will meet all residential housing safety standards, as the unit maybe mounted and electrically connected to a residential structure. IEEE outlines standards that apply to standalone and grid tied (distributed generating) photovoltaic systems.

### 5. Engineering Standards Requirements [12]

*Sections marked A will be present for proof of concept presentation, sections marked B relate to prototype.*

5.1. [B] All steel used will be of quality satisfying the CSA standard G40.20/G40.21-98
5.2. [B] All welds will be inspected or performed to meet the CSA standard B167-96 [13]
5.3. [B] All bolt patterns will meet CISC bolt configuration standards to maximize strength [14]
5.4. [B] Mounting system will be designed to meet standard installation practices as per CanadianSolar standards [15]
5.5. [B] Electrical components will be kept in enclosure that satisfy the CSA standard 6-212
5.6. [B] Electrical components will be marked and labelled in a conspicuous, legible, and permanent manner as in CSA standard 6-214

5.7. [A, B] All electrical components will not exceed 80% of rating overload to abide by CSA standard 8-102
5.8. [A, B] Electrical components will be grounded correctly as per CSA standards 10-114
5.9. [B] All non-current carrying metals shall be grounded in accordance to CSA standard 10-402
5.10. [A, B] All electrical connections will be bonded correctly following CSA standards 10-610
5.11. [A, B] All wired connections will be in accordance with CSA standard 12-010
5.12. [B] Fuses will be used to cut power in case of surges in accordance with CSA standard 14-202
5.13. [B] Fuses will be rated appropriately for current drawn by system as per CSA standard 14-208
5.14. [A,B] Control devices (MCU) will have sufficient ratings for current drawn by system to meet CSA standards 14-400
5.15. [B] Power switch will be rated as per CSA standard 14-508
5.16. [B] System will have over current switch satisfying CSA standard 14-606
5.17. [B] Electrical components will be protected from the elements (rain, wind, snow, etc.) as per CSA standards 18-002
5.18. [B] Electrical connections will be colour coordinated as per CSA standard 26-002
5.19. [B] All batteries will be stored correctly and sealed properly as per CSA standard 26-544

## Sustainability

PNW Energy is a strong advocate for renewable energy. This is the reason OptimSolar is designed as a companion product to work hand in hand with solar panels. OptimSolar will reflect our environmental stance throughout the design process, from proof of concept, to prototype, and manufacturing stages. PNW Energy will do its part in reducing waste throughout the process of developing OptimSolar.

OptimSolar will require the fabrication of a large mounting unit. The proof of concept will be constructed using reclaimed lumber. Reclaimed lumber will retain its structural value as well as freshly felled wood would; however, it has been reclaimed from demolished structures or products and reworked into new wood [16]. On top of using recycled wood, PNW Energy plans to donate any unused or scrap pieces to the SFU workshop where the wood can be reused for other academic projects. Another key component of the proof of concept is the electrical system; this will include multiple batteries, sensors, microcontrollers, motors, and other miscellaneous components. PNW Energy plans to design the proof of concept so that all the electrical components can be reused for the prototype, thus limiting overall waste.

The prototype will also require considerations for the sustainability of OptimSolar. As mentioned above, the electrical components from the proof of concept will be reused for the prototype, preventing as much waste as possible. PNW Energy will be recycling any damaged or unharvestable components at a local electronic recycling depot. Transitioning the wood frame over to the prototype will not be feasible as the prototype will require a stronger and more robust mounting system. This mounting system is planned to be made out of steel and aluminum. These two metals are being used for many structural purposes as well as sustainability purposes, steel and aluminum are among the world's most recycled metals [16]. The prototype of OptimSolar will be made of recycled metals from the Metal Supermarket in Vancouver. As a companion product to solar panels, OptimSolar is being designed to last in the elements and maintain useable for the duration of the lifespan of solar panels. With that in mind, the decommissioned OptimSolar prototype will be recycled and reused for the next generation of our product.Throughout all processes (even during the manufacturing), PNW Energy will continue to use recycled materials, reuse electrical components when capable, and recycle all scrapped or damaged supplies.

The safety requirements listed below will help ensure that humans, foreign objects/structures, solar panels, and the OptimSolar unit will not be harmed or damaged. The design has the potential to cause serious harm or damage from falling, uncontrolled rotations, and electrocution. By following the CSA standard requirements and the requirements below, PNW Energy will limit risk and liability.

## Safety & Reliability Requirements

### 6. Safety and Reliability Requirements

*Sections marked A will be present for proof of concept presentation, sections marked B relate to prototype.*

#### 6.1 Mechanical Safety

- 6.1.1. [A,B] The mount should be securely fastened to ground or structures
- 6.1.2. [A,B] Moving parts should be halted when objects obstruct their path
- 6.1.3. [B] The mounting equipment should not negatively affect the structural integrity of the base on which it is mounted (i.e. the roof should structurally damaged)
- 6.1.4. [B] The base of the mount will have a large surface area to increase contact with the mounting surface
- 6.1.5. [B] Appropriately sized stainless steel mounting bolts will be provided
- 6.1.6. [B] Stainless steel ground stakes will be provided for ground mounting
- 6.1.7. [B] Panel clamps will have locking mechanism to prevent the solar panel from falling off
- 6.1.8. [B] All metal will be professionally welded together
- 6.1.9. Metal will be treated with a protective anti-rust enamel to ensure longevity

6.1.10. [B] Rotational components will have locking mechanisms to prevent back EMF and unnecessary strain on motors and joints
6.1.11. [B] Yaw rotational components will be on a ball bearing system to prevent additional wear on moving parts
6.1.12. [B] The grade of metals will be taken into consideration for each application
6.1.13. [A,B] Sensor modules will be located on all four corners of the mount to sense any obstacles that could damage or be damaged by the movement of the solar panels
6.1.14. [A,B] The mount will move at slow speeds to prevent any major injuries if sensors fail
6.1.15. [B] The corners of the mount will be padded with rubber to prevent injuries
6.1.16. [B] The corners of the mount will be painted with a color that will stand out
6.1.17. [A,B] All edges will be smoothed and abrasives removed to prevent injury
6.1.18. [B] All rotating components will be appropriately sealed and contained to prevent pinching of limbs and other related injuries

**6.2. Electrical Safety**

6.2.1. [B] The system will be waterproof
6.2.1.1. [B] All electrical components will be waterproofed
6.2.1.2. [B] The display and user control switches/buttons will be secured in a waterproof circuit box (similar to Figure 7)
6.2.1.3. [B] External wires will be sealed with cable glands
6.2.1.4. [B] Electro-mechanical components will be shielded from rain
6.2.2. [B] Wiring will not be wrapped around the mount due to rotations

**6.3. Reliability**

6.3.1. [A,B] All components have an operating temperature range between -20 to 85 °C
6.3.2. [B] The motors' holding torque will be able to withstand environmental loads (up to 50 km/hr winds and 0.5 m of snow)
6.3.3. [B] Containing box will have a spot for a padlock and will be tightly sealed when shut

**Figure 7: Containing Box**

6.3.4. [B] Only the battery will be accessible to owners, all other electrical components will be sealed to prevent electrocution

6.3.5. [B] Warning labels will be placed on electrical components to discourage user from tampering

## Conclusion

PNW Energy is committed to designing a universally compatible solar panel mount, capable of providing dramatic performance improvements. OptimSolar recovers efficiency losses due to stationary panel mounting and panel overheating. The requirements outlined in this document describe the direction of PNW Energy and the expected capabilities of OptimSolar during proof of concept and prototyping stages. The design’s foremost requirement is providing greater energy harvesting improvement than energy consumption. As highlighted throughout, the design features low power consumption, safety, reliability, and user friendliness along with substantial performance increases. By offering a cheap, easy-to-install product, PNW Energy trusts that OptimSolar’s demand will grow with the soaring solar market.

PNW Energy’s design roadmap emphasizes planning ahead, and minimizing the alterations required by transitioning from proof of concept to prototype. The design fosters high velocity prototyping and remediation, by requiring system modularity and interface standardization. PNW Energy plans to use engineering standards that will allow for incorporation of pre-manufactured components and external connectivity. Solving small scale renewable energy require technological innovation as well as environmental conscientiousness. PNW Energy is conscientious of energy consumption from daily use as well as during manufacturing. The OptimSolar unit will meet strict sustainable manufacturing regulations.

# References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## Appendix I: Defining Rotations

From a mechanical system standpoint yaw and pitch are shown below in Figure 17. Astronomical angles are shown in Figure 18. Yaw correlate to the "Azimuth" angle and pitch correlates to the "Altitude" angle.

**Figure 5: Mechanical Rotations [17]**

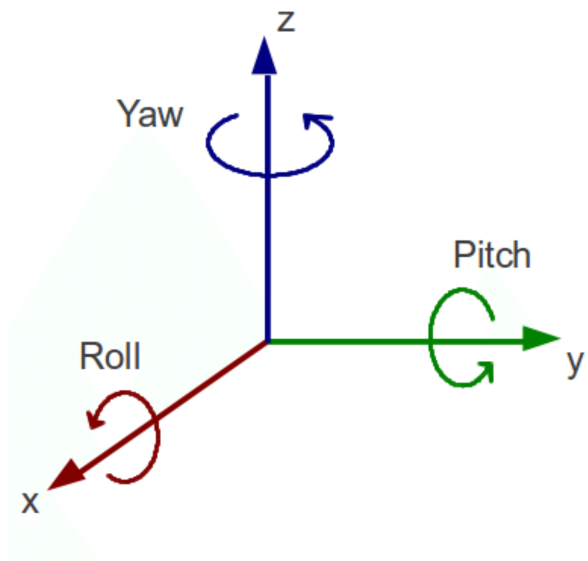
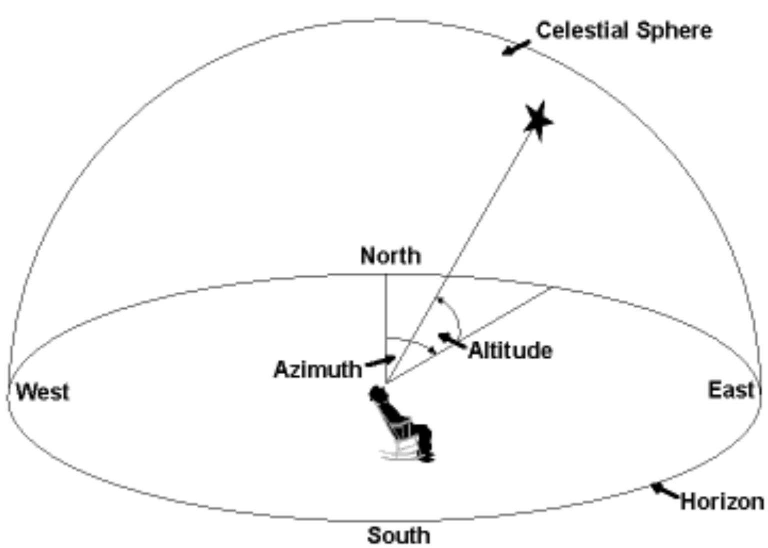



**Figure 5: Azimuth Angle [18]**



## Appendix II: Functionalities for Proof of Concept Presentation

| | |
|---|---|
| **2.1** | The computing system will have a main MCU as data processor, $I^2C$ Master, and PWM driver |
| **2.7** | Uses an $I^2C$ Sensor Network |
| **2.7.4** | Four temperature sensors |
| **2.7.4.1** | Will provide data for calculating Mean Radiant Temperature |
| **2.7.4.2** | 5V compatible |
| **2.7.4.4** | Low typical power consumption per unit, < 300μA |
| **2.7.4.5** | Standby power consumption per unit, < 5μA |
| **2.7.5** | Contains four “Corner Sensing Modules” |
| **2.7.5.2** | Contains a photoresistor and a contact switch as sensors |
| **2.7.5.3** | Contains a LED as an indicator |
| **2.7.5.4** | Each module contains an MCU, acting as $I^2C$ Slave |
| **3.2** | The system will run off two different batteries, not charged by solar panel |
| **3.2.1** | Computing system will not consume more than 75mA |
| **3.2.1.1** | Processing/Computing module will require a 9V lithium ion battery |
| **3.2.1.2** | All electrical processing/computing running on 5V |
| **3.2.1.3** | Uses a 5V voltage regulator (max current output 1.5A) |
| **3.2.2** | Mechanical system power will not consume more than 6A |
| **3.2.2.1** | A four cell lithium ion battery will power mechanical system |
| **3.2.2.2** | 16V from lithium ion battery will be stepped down to 12V |
| **3.2.2.3** | Four cell lithium ion battery will provide 40Whr of power to run stepper motors |
| **3.2.2.4** | Stepper motors will draw 1.7A of current at max load |
| **4.1** | The system will have two stepper motors responsible for solar tracking |
| **4.1.1** | One motor will be responsible for rotation of the yaw axis |
| **4.1.2** | One motor will be responsible for rotation the pitch axis |
| **4.1.4** | Yaw axis will have 360° degrees of rotation |
| **4.1.5** | Pitch axis will have at least 180° degrees of rotation |
| **4.1.6** | The system will have one small hydro pump responsible for the cooling system |
| **4.1.7** | Motor actuation will be controlled by PWM input |
| **4.2.4** | The cooling system will operate when temperature sensors determine the solar panel has surpassed a threshold temperature (roughly 35°C) |
| **5.7** | All electrical components will not exceed 80% of rating overload to abide by CSA standard 8-102 |
| **5.8** | Electrical components will be grounded correctly as per CSA standards 10-114 |
| **5.10** | All electrical connections will be bonded correctly following CSA standards 10-610 |
| **5.11** | All wired connections will be in accordance with CSA standard 12-010 |
| **6.1.1** | The mount should be securely fastened to ground or structures |
| **6.1.2** | Moving parts should be halted when objects obstruct their path |

**6.1.13** Sensor modules will be located on all four corners of the mount to sense any obstacles that could damage or be damaged by the movement of the solar panels

**6.1.14** The mount will move at slow speeds to prevent any major injuries if sensors fail

**6.3.1** All components have an operating temperature range between -20 to 85 °C