York University - Lassonde School of Engineering

ENG 4000: Capstone Project

34: Low Print Solar Farm

Team Members
Osama Badran, 218267849

Mohammad Gorjian, 215141633

Naweedullah Hussaini, 218284216

David Luu, 216157463

Kevin Nguyen, 217228255

Thivian Varnacumaaran, 216377624

Report Submission Date Monday, 21 April 2025

Table of Contents

1.) Executive Summary 3
2.) Final Review of Needs and Requirements (Waterfall Methodology) 6
3.) As-Built Design 7
4.) As-Built Design Compliance Analysis (Waterfall Methodology) 12
5.) Project Management Updates (Waterfall Methodology) 15
- **5.1.) As-Built Work Breakdown Structure (WBS)** 15
- **5.2) Work Package Description** 16
- **5.3.) As-Built Resource Allocation Matrix (RAM)** 30
- **5.4.) As-Built Project Schedule (Gantt Chart Updates)** 33
- **5.5.) Project Procurement/Equipment/Travel List** 35
- **5.6.) Risk Register** 39

6.) Preliminary Business Case (Waterfall Methodology) 43
7.) Deviations from Plan 44
8.) Failure Report 48
9.) Lessons Learned 49
- **9.1.) Team Member 1 Reflections** 49

10.) Conclusions 52
11.) Acknowledgements 53
12.) References 54
13.) Appendices 55
14.) List of Figures 55
15.) List of Tables 57

1.) Executive Summary

In today's world, solar energy stands out as one of the most promising and sustainable options for generating renewable power. In this project, our engineering team aims to design a low-impact solar farm that minimizes land usage while leveraging advanced technology to maximize energy production. A key challenge guiding our work is: *How can we design a visually seamless, environmentally sensitive solar energy system that effectively powers a student wellness campus while preserving the natural beauty and ecological integrity of the surrounding forest?* This question has inspired our engineers to combine creativity with technical expertise in developing innovative, sustainable solutions.

Imagine a lush, verdant landscape dominated by towering trees, where sunlight filters through the canopy, casting dappled shadows across the forest floor. This vibrant, biodiverse ecosystem forms the backdrop for our proposed low-impact solar panel farm in Alberta. More than just a renewable energy initiative, this project represents an opportunity to set a precedent for sustainable development that harmonizes with the natural environment. While designing an efficient solar energy system in a region densely covered with mature trees presents significant challenges, it also inspires innovative thinking. Our team is committed to leveraging advanced engineering principles to develop a model that not only minimizes ecological disruption but also reflects our dedication to environmental stewardship and preservation.

This project aims to blend cutting-edge solar technology with outdoor recreational spaces with a requirement of producing 2KW-hr of solar energy, offering a unique retreat for both energy production and community engagement. By integrating these two seemingly disparate elements, we envision a multifunctional space that promotes ecological stewardship, enriches the visitor experience, and enhances the quality of life for local residents.

Throughout this project, a key factor in achieving our objectives was designing a system that minimizes land use while generating over 2 kWh of power to meet the project's energy requirements. This initiative aims to seamlessly integrate sustainability, aesthetics, and minimal environmental impact to power a wellness campus. After evaluating several innovative solutions, our team identified four core concepts: flower-shaped solar panels, floating solar panels in a pond, mobile solar panels, and shade-providing solar panels along walkways. These solutions not only reduce land usage but also maximize energy production and integrate renewable energy into the campus's overall design. This approach establishes a model for sustainable, wellness-oriented development. In the following sections, we will delve deeper into the design and benefits of the flower-shaped solar panel system.

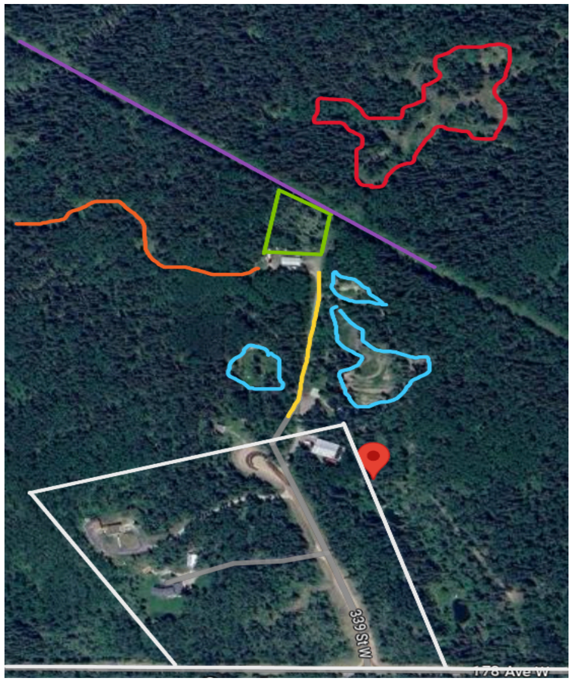


Figure 1.1: The Google map View of the facility along with the marked desire

Figure 1.2, and 1.3: Flower Solar Panel system design [1] and Mobile solar panels design [2].

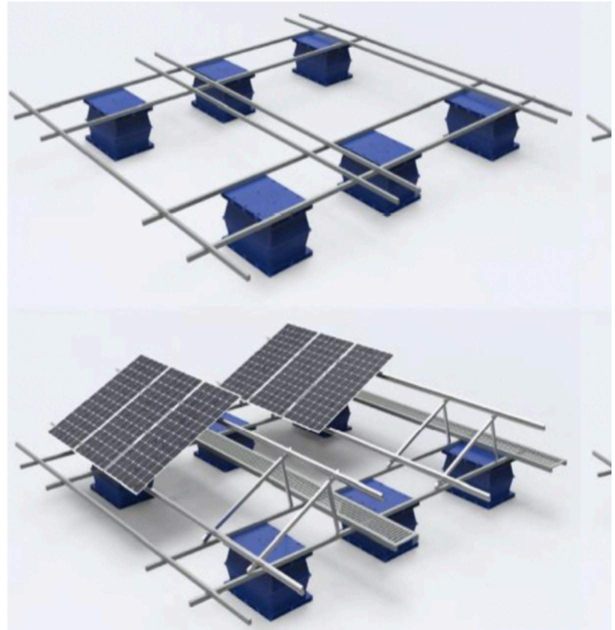


Figure 1.4, and 1.5: Umbrella Solar Panel system design [3] and Floating solar panels design [4].

The final design of the low print solar farm model incorporates eight strategically designed solar panels, offering a highly feasible solution that efficiently meets the energy production requirements of the wellness campus. This system not only maximizes energy output but also aligns with the project's goals of sustainability, minimal land use, and aesthetic integration, providing a reliable and environmentally responsible energy source for the campus.

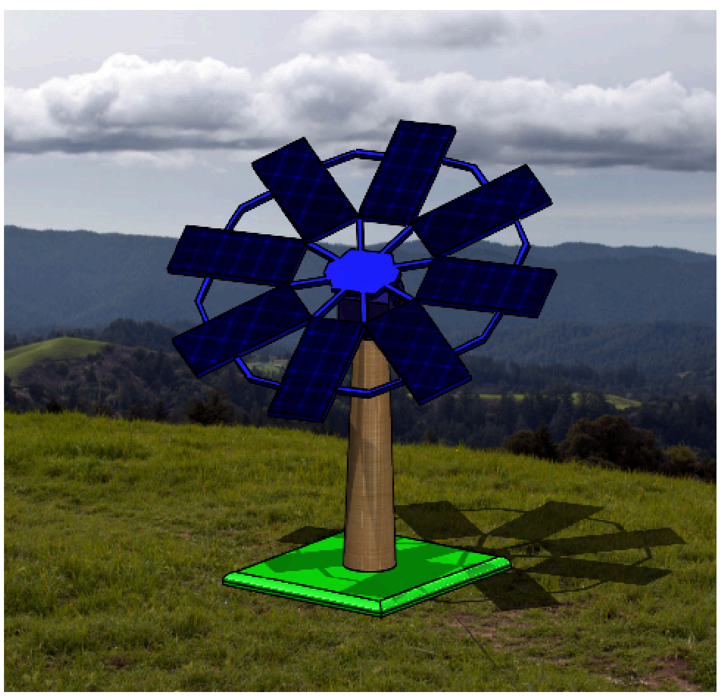


Figure 1.6: Final model design for the Flower shaped solar farm.

2.) Final Review of Needs and Requirements (Waterfall Methodology)

Table #1: Final Waterfall Final Requirements List

Requirement Identifier	**Description**	**Rationale**	**Validation**
REQ-COMP-01 **Status:** **Completed**	The solar farm shall maximize its output to achieve the best amount of energy in ideal conditions.	Solar farms must take full advantage of generating as many solar cells as possible throughout the day.	Monitoring the solar flower's movement relative to the sun.
REQ-COMP-02 **Status:** **Completed**	The solar flower's solar collecting component shall take the installation site into consideration.	Gives users an inside look of the environment of where the solar farms will be installed.	Implement VR software using ArcGIS as the environmental ground.
REQ-SOFT-01 **Status:** **Completed**	The solar farm shall collect data from sunlight intake.	Constant monitoring of solar flower performance.	Testing and use-cases of data monitoring software.
REQ-MECH-01 **Status:** **Completed**	The solar farm structure shall be aesthetically pleasing to the park users.	Solar farm needs to make it visually pleasing towards users of the land.	Verifying constantly through the project that the solar farm is designed around it.
REQ-MECH-02 **Status:** **Completed**	The solar farm structure shall be built with environment-friendly materials.	Less costs and more environmentally friendly.	Constant verification of materials being used.
REQ-MECH-03 **Status:** **Completed**	The solar farm shall be integrated with its surrounding landscape and environment.	Solar farm must produce the least amount of carbon footprint as it can while minimizing environmental destruction.	Calculate space needed for installation of solar farm. Monitoring carbon output of solar farm.

REQ-ELEC-01 __Status:__ **Completed**	The electrical circuit shall interact with data-collecting and monitoring software.	Connecting the hardware and software components together.	Configure solar panels with software tools. Constant testing.
REQ-ELEC-02 __Status:__ **Completed**	The solar panel shall maximize gathering sunlight.	Solar farms need not lose energy on non-conversion processes.	Calculations on solar cell size and monitoring of sunlight intake via software.

3.) As-Built Design

The Low Print Solar Farm addresses the challenge of delivering a sustainable, aesthetically pleasing, energy system within forested land while generating at least 2 kWh/day. The goal was to blend solar infrastructure into the area's natural surroundings without disturbing the local environment. The project's focus is sustainability and energy independence. Stakeholders include the Foundation of the Energy Collective (FEC), York University, students, and the public.

The system is broken down into 2 main subsystems (Figure 1): Outside subsystem and Shed subsystem. Outside subsystem components are any components which are required to be located outside for the functionality of the system or are weatherproof. Shed components are components which need to be located inside as they may be damaged by conditions such as rain, snow, or other forms of harsh weather. Within the 2 main subsystems, the system is further broken down into the following

a. Solar Collection Subsystem

Components within this subsystem function together in order to make the generation of solar electricity possible. This subsystem begins with 8 100 w, 12 v solar panels connected together in series, in the shape of a solar flower. Each solar panel, under standard test conditions of 100 W/m^2 and 25 $^{\circ}$C, is able to produce 100 Wh of energy within an hour. This means under ideal conditions, the system is able to produce 800 kWh of electricity within an hour. This means that within just 2.5 hours of peak sunlight, the goal of 2 kWh/day. The next components within the Solar Collection subsystem, the stepper motors, ensure that not only is the 2 kWh/day achieved, but it is exceeded by controlling the panel's elevation and azimuth angles to optimize the amount of energy production at any time during the day by giving the solar panels the maximum required exposure to the sun (SAM simulations in figure 2). The stepper motors are operated using a rechargeable LiPo battery. Using the voltage generated by operating the solar panels, a buck converter is connected in parallel with the solar panels in order to step down to a required voltage, and then the output is connected, once again in parallel, to the battery. This ensures that the battery is never out of charge, and that the stepper motors function at all times. The battery is then connected to another buck converter, which is then used to operate the Arduino Uno and Node

Red in the next subsystem.

b. System Control and Monitoring

Components within this subsystem are responsible for moving the stepper motors, through the stepper drivers, when necessary. The Arduino is given a real-time clock. Using the time of day, the approximate location of the sun can be calculated. That position is then sent to the stepper drivers, and the motors move the solar panels into the best positions in order to maximize sunlight exposure. The Arduino data is integrated with the Node-Red servers, which then output power production during the specific time of day. These numbers can then be viewed by the client, Sebastien using the server developed by the software engineering team, as well as the computer engineering team (Figure 3).

c. Electrical Harvesting

These components are responsible for taking the energy produced by the solar panels and integrating them back to the main grid (the smart grid which is being developed by another team of engineers hired by the client). The solar panels produce electricity in the form of direct current (DC). The main grid operates on alternating current (AC). So in order to connect to the main grid, the conversion must be made using a split-phase inverter. First, CEC Rule 64-056 required that disconnect switches be installed to ensure safe isolation. This is why a DC switch has been installed between the inverter and the panels before connection, as well as why an AC Disconnect switch has been installed before connecting the inverter to the main breaker panel. The panels are then connected to Maximum Power Point Tracker (MPPT) ports within the inverter in order to achieve the maximum voltage and current required to produce the maximum power. The split-phase inverter is required over a single-phase inverter due to the client specifying that the building operates on 120/240 v. This means that the transformers being used to step-down voltage from the main grid operates on 120/240 v. The output of the inverter is then connected to the main breaker panel, which supplies the household or building through its connection to the main grid.

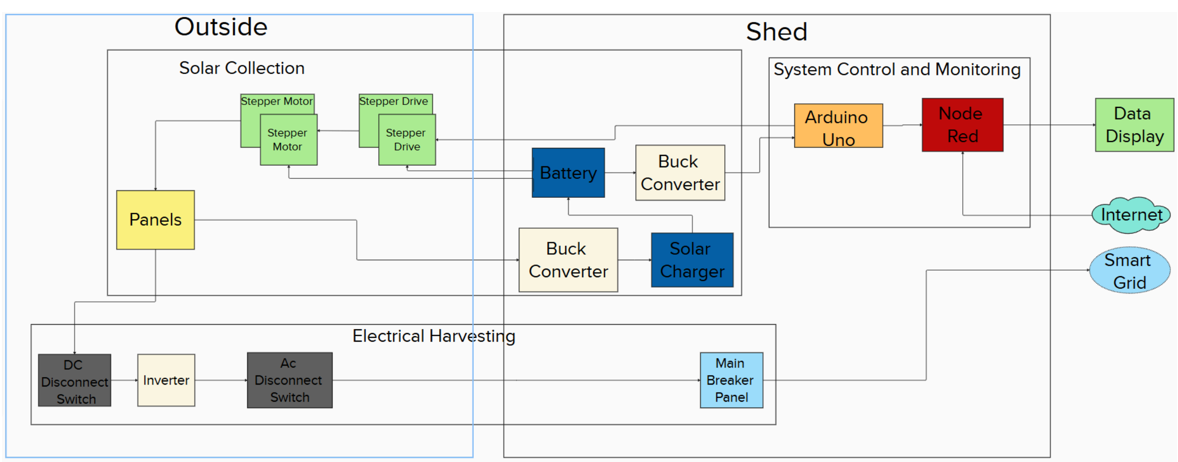
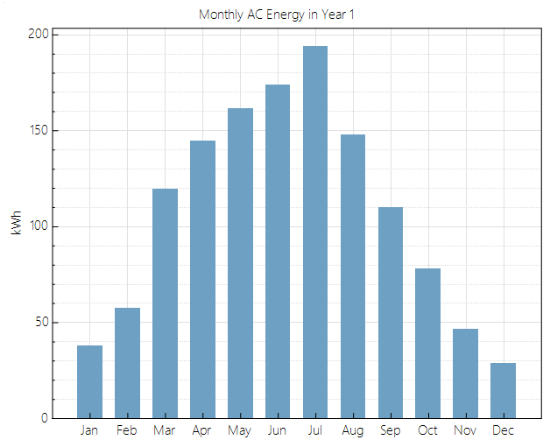


Figure 3.1: Low Print Solar Farm Block Diagram

Metric	Value
Annual AC energy in Year 1	1,300 kWh
DC capacity factor in Year 1	14.8%
Energy yield in Year 1	1,300 kWh/kW
Performance ratio in Year 1	0.67
LCOE Levelized cost of energy	18.87 ¢/kWh



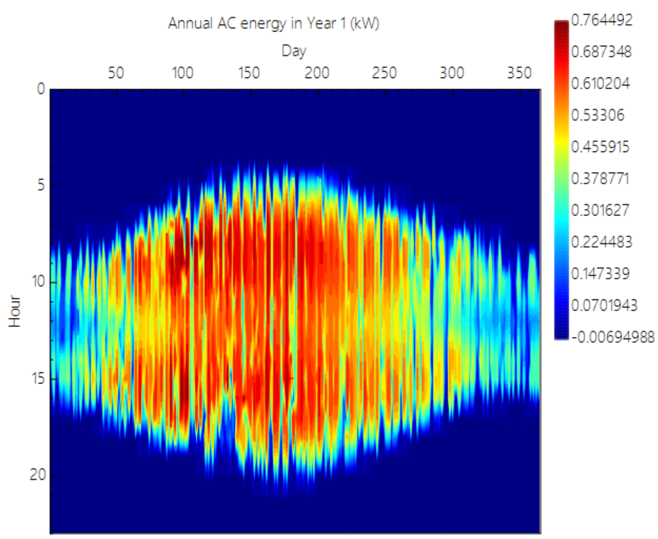


Figure 3.2: SAM Simulation

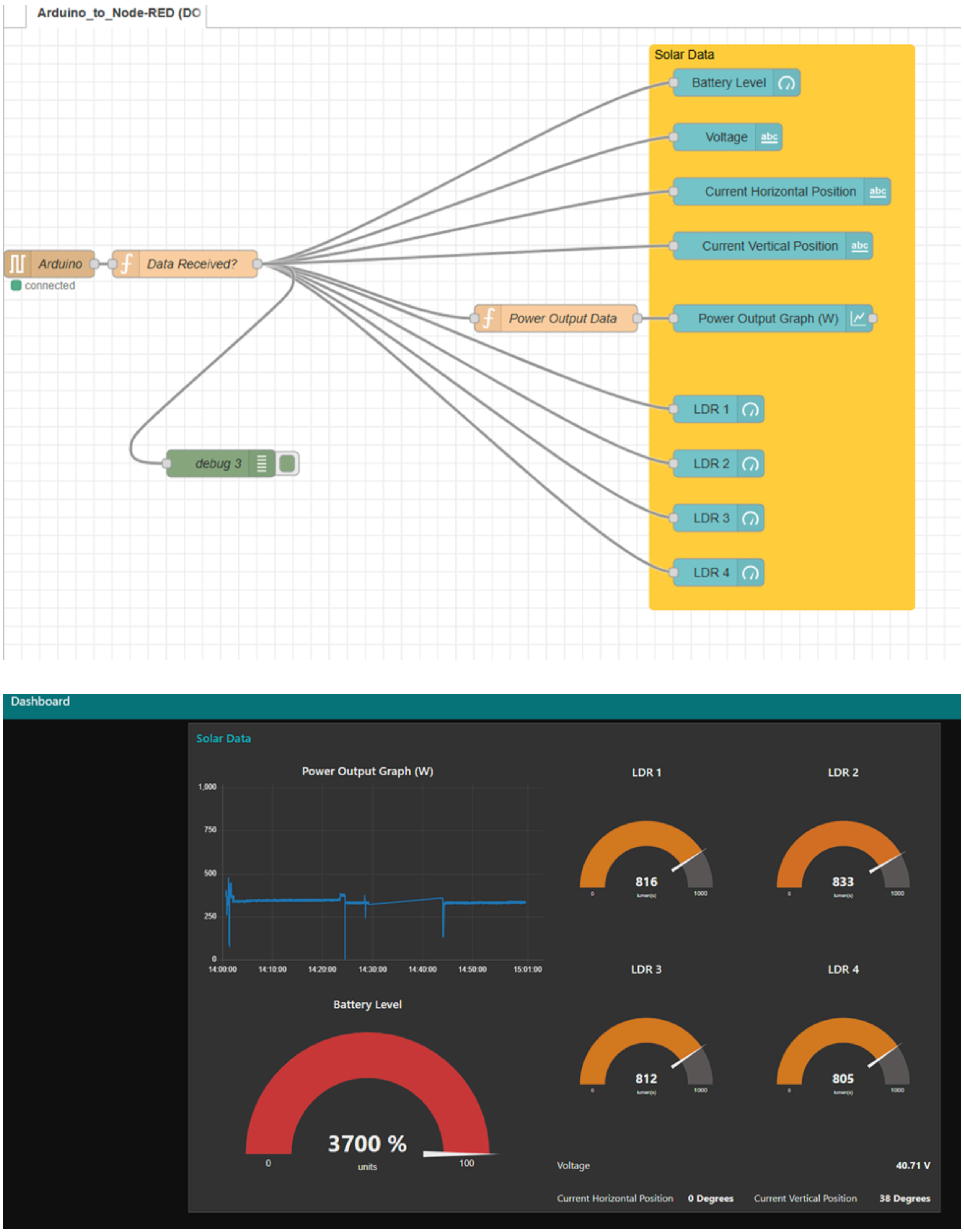


Figure 3.3: Node RED Interface

Static & Thermal test:

One of the significant advantages of utilizing SolidWorks in the design process was its powerful Computer-Aided Engineering (CAE) tools, particularly for conducting static and thermal simulations. These features enabled us to not only visualize the geometry of our design but also to evaluate its structural performance under realistic loading conditions. For this project, we applied these tools to a conceptual model of a flower-shaped solar panel, an innovative design that combines aesthetics with functionality.

The simulation focused on assessing how the structure would respond to gravitational forces—accounting for the panel's own weight—as well as wind loads, which are a critical factor in the design of any outdoor solar installation. These analyses are especially important given the unique petal-like structure of the panel, which could potentially amplify stress at the outer edges due to leverage effects and surface exposure.

The results of the static simulation revealed that the tips of the solar panel petals are the most critical stress points under maximum load conditions. This is expected in designs with extended or cantilevered sections, where material at the outermost edges tends to bear the greatest bending and torsional stresses. Despite these concentrations, the current design remains within acceptable limits for structural safety. The model did not show any indications of material failure, excessive deformation, or instability, even under worst-case loading scenarios.

Furthermore, the thermal simulation allowed us to assess how the panel would behave under varying temperature conditions, which is essential for solar applications, as exposure to sunlight can lead to significant thermal expansion. Fortunately, the materials chosen for the model exhibited good thermal resistance and dimensional stability, minimizing the risk of warping or stress accumulation over time.

In conclusion, the use of SolidWorks provided invaluable insight into the structural and thermal behavior of our solar panel design before any physical prototype was constructed. This not only accelerated the design iteration process but also ensured that potential weaknesses were identified and addressed early on. The current version of the model is well-optimized to withstand environmental loads, laying a strong foundation for future development and physical testing.

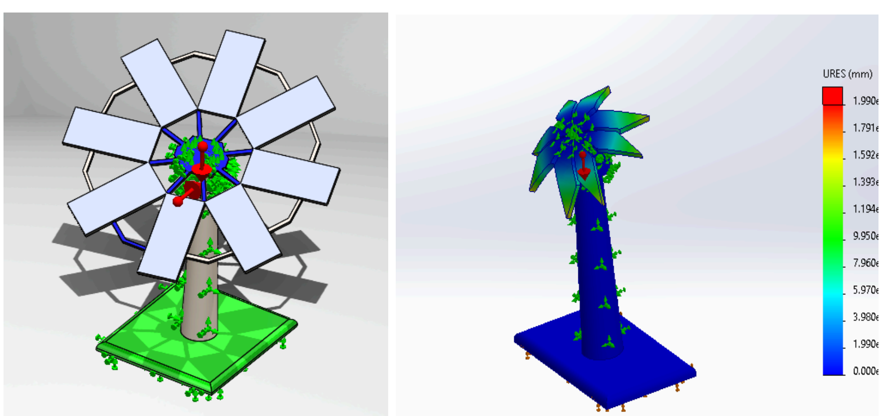


Figure 3.4: *Thermal and static stress analysis of the flower-shaped solar panel in Solidworks*

4.) As-Built Design Compliance Analysis (Waterfall Methodology)

Various solar farms were considered at the beginning, with other solutions being a floating solar farm, umbrella solar farm, and a mobile solar farm. After weighing each system, the solar flower shaped solar farm offered the most upside out of all other options given its efficiency and its aesthetics over other designs. While the solar flower solar farm offered the most upside, it also has some limitations. The following table looks at the few main areas which this project is concerned with, and addresses their strengths and limitations. Recommendations are then made as to how to solve/mitigate the system's limitations.

Table 2: Strength and Limitation For The Design

Area	**Strengths**	**Limitations**	**Recommendations**
Power Generation	Exceeds 2 kWh/day as shown by SAM simulations	Reduced performance in winter months	Implement more solar panels during winters
Sustainability	No trees are cleared due to the construction of this solar farm	The system as a whole is more complex than typical solar farms	As this project progresses and more funding is acquired, a mount could be designed for this specific project, making future installations easier
User Interface	Node-RED is visual and intuitive	May require additional training	Provide short training module or a set of instructions to client

Mechanical Durability	Structures designed taking various weather conditions into consideration	Moving parts may require maintenance. In addition to this, the tree which the system is mounted on should also be inspected periodically, ensuring it is stable and safe for operation	Add checklists and develop protective covers

The solar farm project was also constructed with a set of requirements in mind which span all fields within the team. As seen within requirements listed in section 2, the final design successfully incorporates all requirements as shown below:

Table 3: Compliance Notes

Requirement Identifier	**Status**	**Compliance NOTES**
REQ-COMP-01	Completed	The tracking system (Arduino + stepper motors) maximizes output. Verified through SAM simulations.
REQ-COMP-02	Completed	Installation adapted to natural, uneven terrain. Designed with integration into forested parks.
REQ-SOFT-01	Completed	Node-RED successfully collects and displays voltage, current, and power in real time.

REQ-MECH-01	Completed	Node-RED successfully collects and displays voltage, current, and power in real time
REQ-MECH-02	Completed	Environmentally friendly materials used (e.g., anodized aluminum, low-impact supports)
REQ-MECH-03	Completed	No deforestation required. Installation integrated with existing park landscape
REQ-ELEC-01	Completed	Arduino successfully interacts with sensors and Node-RED dashboard
REQ-ELEC-02	Completed	MPPT inverter setup extracts maximum available power. Verified through voltage and power readings.

5.) Project Management Updates (Waterfall Methodology)

This project was managed using a traditional Waterfall approach, progressing through clearly defined phases from planning and analysis to implementation and testing. The original Work Breakdown Structure (WBS) and Work Package Descriptions (WPDs) remained consistent throughout, requiring only minor clarifications to task details and effort estimates. The Resource Allocation Matrix (RAM) effectively tracked team responsibilities, and the as-built Gantt chart closely followed the initial schedule, with only small timing adjustments to accommodate lab access and prototype integration.

The project transitioned from an FEC-scale solar flower concept to a Capstone-appropriate prototype, maintaining functionality while staying within the $2,000 budget constraint. Procurement was adjusted accordingly, and risks—particularly around component costs, sensor integration, and structural stability—were monitored and mitigated. These outcomes demonstrate strong project control, budget alignment, and effective risk management. The team also recognized the importance of early alignment with Capstone constraints and sponsor expectations, which will inform future planning in similar large-scope engineering projects.

5.1.) As-Built Work Breakdown Structure (WBS)

Since the Preliminary Design Review (PDR), the Work Breakdown Structure (WBS) has remained largely consistent, with no major structural changes required. The original breakdown effectively supported the project's timeline, scope, and task management needs throughout development. Minor adjustments were made to task descriptions and effort estimates for clarity and tracking purposes, but all primary phases—including prototyping, testing, and implementation—were already incorporated in the original structure. This continuity reflects the strength of the initial planning and its alignment with Engineering Capstone deliverables and subsystem responsibilities.

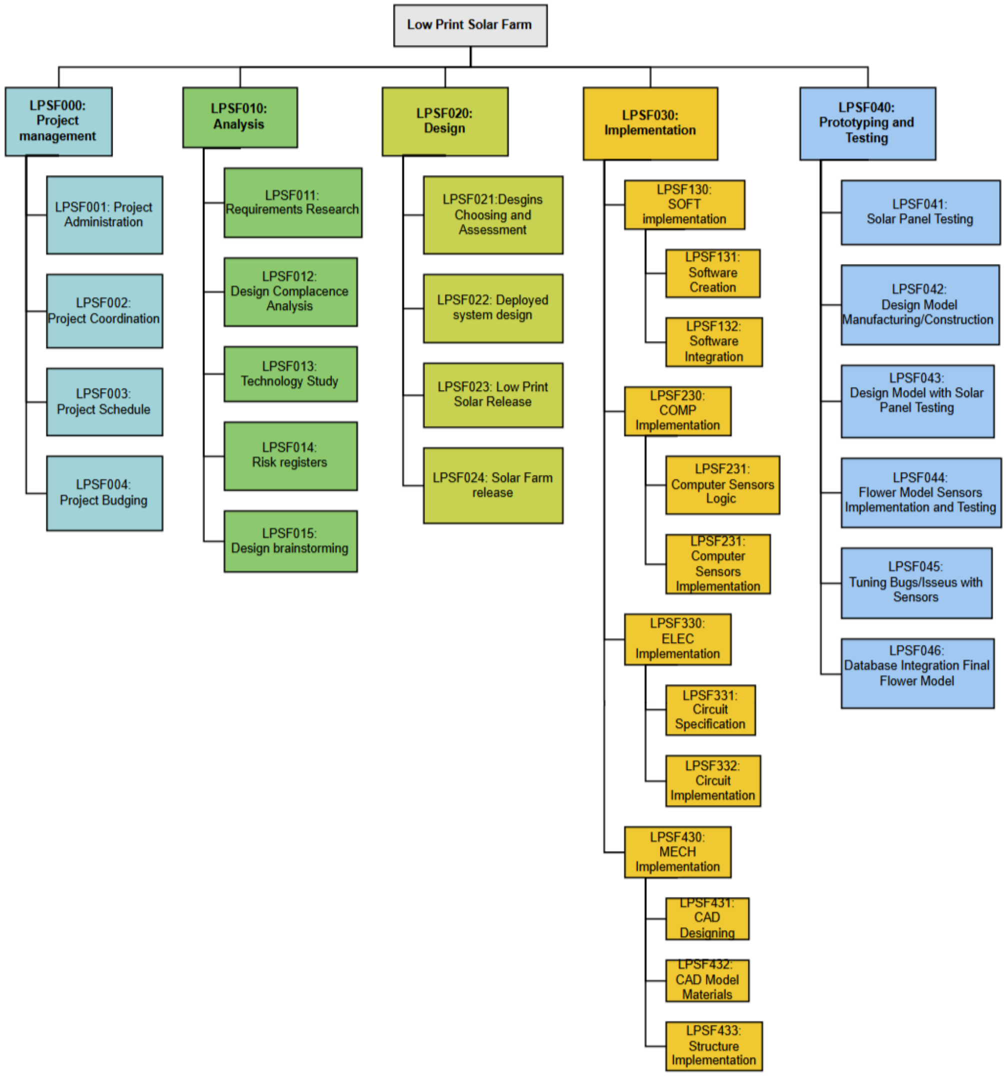


Figure 5.1.1: Work Breakdown Structure for the implementation of the Low-Print Solar Farm

5.2) Work Package Description

The Work Package Descriptions (WPDs) developed during the initial planning phase remained largely unchanged throughout the course of the project. Each work package continued to reflect its original scope, with clearly defined deliverables, assigned team members, effort estimates, and required inputs and outputs. The alignment with the Waterfall methodology ensured that tasks were sequential, traceable, and phase-specific.

Overall, the strong alignment between the original and as-built WPDs is a reflection of robust early planning. The WPDs served as reliable artifacts for tracking task-level execution and individual responsibilities.

Table #4: Project Management Work Package Description

LPSF000 Project management				
WP ID	LPSF001	LPSF002	LPSF003	LPSF004
WP Name	Project Administration	Project Coordination	Project Schedule	Project Budgeting
Resources	Naweedullah Hussaini, Thivian Varnacumaaran	David Luu, Kevin Nguyen, Thivian Varnacumaaran	Thivian Varnacumaaran	Mohammad Gorjian, Osama Badran, Thivian Varnacumaaran
Estimated Hours	8	12	10	14
Expected Start Date	September 20, 2024	September 23, 2024	September 30, 2024	October 2, 2024
Expected End Date	October 20, 2024	October 20, 2024	October 20, 2024	October 20, 2024
Inputs Needed	Project requirements, stakeholder expectations	Defined milestones and resource availability	Baseline project plan and deliverable deadlines	Cost estimates for all project phases
Description	Manage and oversee project tasks, ensure alignment with project	Coordinate team efforts, schedule meetings, and	Develop a detailed project schedule outlining all tasks,	Create a detailed project budget considering labor, materials, and overhead

	objectives, and provide administrative support.	manage team communication to ensure timely completion of tasks.	deadlines, and dependencies.	costs.
Outputs	Established project administration and documented progress updates.	Coordinated schedules and communication plans.	Completed project schedule with dependencies and milestones.	Approved project budget document.

Table #5: Analysis Work Package Description

LPSF010 Analysis					
WP ID	LPSF011	LPSF012	LPSF013	LPSF014	LPSF015
WP Name	Requirements Research	Design Compliance Analysis	Technology Study	Risk Registers	Design Brainstorming
Resources	Kevin Nguyen	Thivian Varnacumaaran	Naweedullah Hussaini	Entire Team	Entire Team
Estimated	16	12	20	10	15

Hours					
Expected Start Date	October 15, 2024	October 27, 2024	November 5, 2024	November 8, 2024	November 18, 2024
Expected End Date	November 24, 2024	November 24, 2024	November 24, 2024	November 24, 2024	November 24, 2024
Inputs Needed	Stakeholder input and technical specifications	Regulatory standards and design plans	Existing technology solutions and innovation research	Identified project risks and mitigation strategies	Team collaboration and research inputs
Description	Research and document the project requirements based on stakeholder feedback and technical needs.	Analyze the design for compliance with technical and regulatory standards.	Conduct a study to identify and evaluate existing technologies applicable to the project.	Develop and maintain a register of potential risks and associated mitigation strategies.	Facilitate brainstorming sessions to generate and evaluate innovative design ideas.
Outputs	Comprehensive list of requirements with justifications.	Compliance report with recommendations.	Technology evaluation report.	Risk register document with mitigation strategies.	List of innovative design ideas and evaluation outcomes.

Table #6: Design Work Package Description

LPSF020 Design				
WP ID	LPSF021	LPSF022	LPSF023	LPSF024
WP Name	Designs Choosing and Assessment	Deployed System Design	Low Print Solar Release	Solar Farm Release
Resources	Entire Team	Entire Team	Entire Team	Entire Team
Estimated Hours	18	25	15	20
Expected Start Date	November 24, 2024	November 25, 2024	November 28, 2024	December 1, 2024
Expected End Date	December 20, 2024	December 20, 2024	January 11, 2025	January 11, 2025
Inputs Needed	Generated design options and evaluation criteria	Approved design and deployment plan	Deployment plan and marketing strategy	Final design, testing results, and operational guidelines
Description	Select the best design based	Create a	Prepare for the	Implement the release of the

	on evaluation criteria and project requirements.	detailed design for the deployed system, addressing all technical and logistical aspects.	release of the low-print solar system, including marketing and customer communication.	solar farm system design, with the operational and customer support design.
Outputs	Chosen design with assessment reports.	Finalized deployed system design.	Successful release campaign and promotional materials.	Released solar farm system with full operational support.

Table #7: Implementation Work Package Description

LPSF030 Implementation				
WP ID	LPSF130	LPSF230	LPSF330	LPSF430
WP Name	SOFT Implementation	COMP Implementation	ELEC Implementation	MECH Implementation
Resources	Software Team	Computer Team	Electronics Team	Mechanical Team

Estimated Hours	20	30	50	40
Expected Start Date	January 12, 2025	January 12, 2025	January 5, 2025	November 24, 2025
Expected End Date	March 30, 2025	March 10, 2025	March 30, 2025	March 29, 2025
Inputs Needed	Project requirements, design documents	System hardware specifications and software components	Circuit designs and electrical component specifications	CAD designs and materials for the mechanical components
Description	Implement software systems for the solar farm, including system logic and control algorithms.	Implement and test computer systems, including sensors and logic integration.	Develop and implement the required electrical systems for the solar farm.	Design and assemble the mechanical components, including support structures and enclosures.
Outputs	Fully implemented software system.	Fully functioning computer systems.	Completed electrical systems.	Fully assembled mechanical systems.

Table #8: SOFT Implementation Work Package Description

LPSF130 SOFT Implementation		
WP ID	LPSF131	LPSF132
WP Name	Software Creation	Software Integration
Resources	Software Team	Software Team
Estimated Hours	15	5
Expected Start Date	January 12, 2025	February 12, 2025
Expected End Date	March 11, 2025	March 30, 2025
Inputs Needed	Project requirements, design documents	Created software modules and integration plan
Description	Functional requirements and software tools such NX, ArcGIS and other software required	Integrate software modules into a cohesive system and test for functionality.

Outputs	Completed software modules.	Integrated and tested software system.

Table #9: COMP Implementation Work Package Description

LPSF230 COMP Implementation		
WP ID	LPSF231	LPSF232
WP Name	Computer Sensors Logic	Tuning Bugs/Issues with Sensors
Resources	Computer Team	Computer Team
Estimated Hours	20	30
Expected Start Date	January 12, 2025	February 2, 2025
Expected End Date	March 10, 2025	March 30, 2025

Inputs Needed	Sensor specifications and system logic	Testing results and system diagnostics
Description	Develop and implement logic for computer sensors to interact with other components.	Identify and resolve any bugs or issues in sensor integration.
Outputs	Fully functioning sensor logic.	Debugged and optimized sensor systems.

Table #10: ELEC Implementation Work Package Description

LPSF330 ELEC Implementation		
WP ID	LPSF331	LPSF332
WP Name	Circuit Specification	Circuit Implementation
Resources	Electric Team	Electric Team
Estimated Hours	20	30

Expected Start Date	January 5, 2025	January 12, 2025
Expected End Date	March 9, 2025	March 30, 2025
Inputs Needed	Design documents and component lists	Circuit specifications and testing tools
Description	Specify circuit designs and select necessary components.	Assemble and test circuits to ensure functionality.
Outputs	Detailed circuit specifications.	Debugged and optimized sensor systems.

Table #11: MECH Implementation Work Package Description

LPSF430 MECH Implementation			
WP ID	LPSF431	LPSF432	LPSF433
WP Name	CAD Designing	CAD Model Materials	Flower Model Structure Implementation
Resources	Mechanical Team	Mechanical Team	Mechanical Team

Estimated Hours	20	30	30
Expected Start Date	November 24, 2025	January 20, 2025	February 23,2025
Expected End Date	February 10, 2025	March 20, 2025	June 30, 2025
Inputs Needed	Initial design concepts and CAD software	CAD designs and material specifications	Assembled components and CAD models
Descriptio n	Create detailed CAD models for mechanical components.	Acquire and prepare materials required for mechanical assembly.	Assemble the flower model structure based on CAD designs.
Outputs	Finalized CAD models.	Materials ready for assembly.	Fully assembled flower model structure.

Table #12: Prototyping and Testing Work Package Description

LPSF040 Prototyping and Testing						
WP ID	LPSF041	LPSF042	LPSF043	LPSF044	LPSF045	LPSF046
WP Name	Solar Panel Testing	Design Model Manufacturin g/Constructio n	Design Model with Solar Panel Testing	Flower Model Sensors Implementation and Testing	Tuning Bugs/Issues with Sensors	Database Integration Final Flower Model
Resources	Electric Team	Computer Team, Mechanical Team	Electric Team, Mechanical Team	Electric Team, Mechanical Team	Electric Team, Mechanical Team	Software Team, Electric Team
Estimated Hours	20	30	50	40	20	50
Expected Start Date	January 8, 2025	January 26, 2025	January 30, 2025	March 6, 2025	March 25, 2025	April 10, 2025

Expected End Date	April 25, 2025	April 25, 2025	April 25, 2025	April 25, 2025	April 25, 2025	April 25, 2025
Inputs Needed	Project requirements, design documents	System hardware specifications and software components	Circuit designs and electrical component specifications	CAD designs and materials for the mechanical components	Sensor calibration data, bug reports	Database specifications, integration plans
Description	Test solar panel functionality and performance.	Build and assemble the physical model based on design specifications.	Combine the design model with solar panel testing to assess integration.	Implement and test sensors in the flower model for data acquisition.	Troubleshoot and resolve sensor-related issues in the flower model.	Integrate sensor data with the database for the final flower model setup.
Outputs	Test results, performance data.	Assembled design model.	Solar panel testing data, design adjustments.	Fully operational sensors integrated into the flower model.	Resolved issues and optimized sensor functionality.	Final database-integrated flower model.

5.3.) As-Built Resource Allocation Matrix (RAM)

The Resource Allocation Matrix (RAM) established during the early planning phase remained consistent throughout the project. The original task distribution and workload estimates accurately reflected each team member's area of expertise and responsibilities, requiring no major changes. Minor reassignments occurred organically during execution to balance workload and assist with critical tasks, but these did not alter the overall structure or intent of the matrix. The RAM continued to serve as a reliable tool for tracking participation across project phases and remained aligned with the Work Breakdown Structure (WBS) and Work Package Descriptions (WPDs), reinforcing the robustness of the original project planning.

Table #13: Resource allocation matrix breaking down responsibilities of each team member.

Task/Assignee	Osama Badran	Mohammad Gorjian	Naweedullah Hussaini	David Luu	Kevin Nguyen	Thivian Varnacumaaran
Project management						
Project Administration	M	M	H	M	M	H
Project Coordination	M	M	M	H	H	H
Project Schedule	M	M	M	M	M	H
Project Budging	H	H	M	M	M	H

Analysis						
Requirements Research	H	H	H	M	M	H
Design Complacence Analysis	M	M	H	M	M	M
Technology Study	H	M	M	H	H	M
Risk registers	L	L	L	H	H	L
Design brainstorming	H	H	H	M	M	H
Design						
Designs Choosing and Assessment	M	M	H	M	M	H
Deployed system design	H	M	H	M	M	H
Low Print Solar Release	M	M	M	H	H	M
Solar Farm release	M	M	H	L	L	H
Implementation						
SOFT Implementation	M	I	I	H	H	L

COMP Implementation	H	L	L	M	H	L
ELEC Implementation	L	H	M	I	I	H
MECH Implementation	I	L	H	I	I	L
Prototyping and Testing						
Solar Panel Testing	L	H	M	L	L	H
Design Model Manufacturing/Construction	M	M	H	M	M	H
Design Model with Solar Panel Testing	H	H	H	H	H	H
Flower Model Sensors Implementation and Testing	M	H	H	M	M	H
Tuning Bugs/Issues with Sensors	H	M	M	H	M	M
Database Integration Final Flower Model	H	H	H	H	H	H

Table #14: Legend for the resource allocation matrix.

Code	Expanded Code	Significance
L	Low-Work	Knows the basics level of what is required or has contributed to it.
M	Medium-Work	Worked and was supervised by H to complete the task.
H	High-Work	Was the lead/major part of the work done by this.
I	Inform	Gave feedback and recommendations for tasks.

5.4.) As-Built Project Schedule (Gantt Chart Updates)

The as-built project schedule remained largely consistent with the original Gantt chart developed during the planning phase. All major phases—Project Management, Analysis, Design, Implementation, and Prototyping & Testing—were executed in their intended order with no changes to the overall structure or dependencies. Minor refinements to task start and end dates were made to account for resource availability and testing timelines, but these did not impact milestone completion of project delivery. The final schedule confirms the effectiveness of the original plan and reflects the team's adherence to the Waterfall methodology.

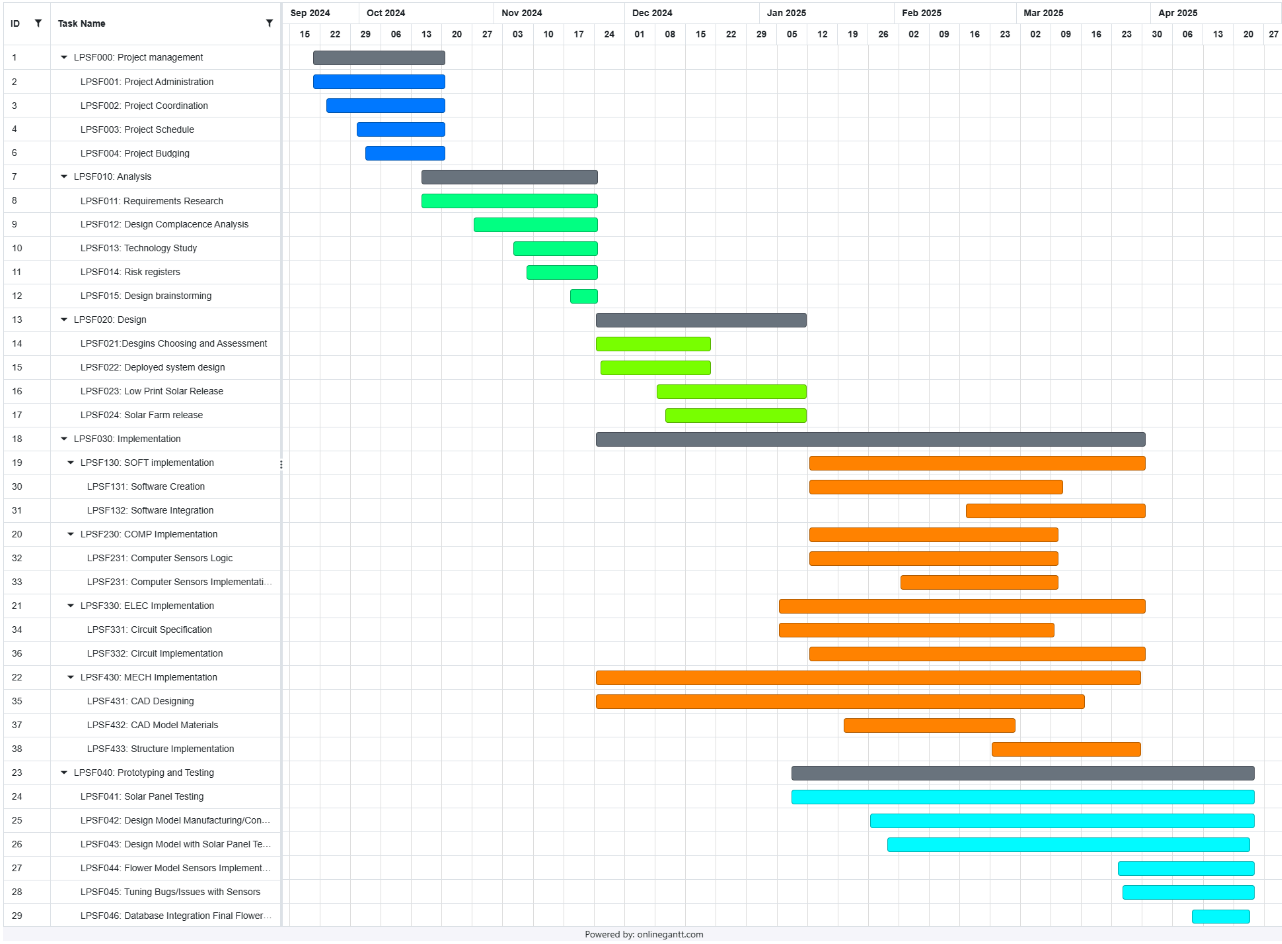


Figure 5.4.1: Gantt chart for the low print solar farm

(Refer to Section 13.3 to access the full Gantt chart)

5.5.) Project Procurement/Equipment/Travel List

While the initial budget was based on a $10,000 FEC grant, the Engineering Capstone course imposed a strict $2,000 spending threshold. As a result, the project team reprioritized procurement to focus on essential components—such as solar panels, sensors, and structural materials—for building a functional prototype of the solar flower. This adjustment reinforced the importance of early alignment with Capstone constraints. A clearer understanding of these financial limitations from the outset would have supported more efficient planning and resource allocation for both this and future hardware-focused initiatives

Table #15: Solar flower FEC we will be getting to produce.

Expenses	Type	Dimensions	Cost	Quantity	Justification	Source
100W 12V Monocrystalline Solar Panel	Part	1m * 0.5m Ideally (monocrystalline)	$99.875	8	Primary power-generating component.	Eco-Worthy
MUST PV3300 TLV 1 kW Inverter- 24V 120/240V Split Phase	Part	-	$655	1	Converts DC to AC, supporting hybrid operations.	MUST Store
RPVU90 PV Wire - 10 AWG/6mm, per Meter	Materials	~50 Meter	$171.76	1	Connects solar panels to the power system.	Frankensolar
6 Black Stranded CU SIMpull THHN Wire	Materials	~30.48 Meter/100ft	$141.1	1	For electrical connections to system components.	Home Depot

60 Amp Non-Fusible Metallic AC Disconnect	Part	-	$14.67	1	Provides AC circuit disconnection for safety.	Home Depot
Solar Disconnect Switch, DC Isolator Solar Switch PV Solar Disconnect Switch Overvoltage IP65 Waterproof Miniature Circuit Breaker 63A 1000V	Part	-	$28.74	1	Provides DC circuit disconnection for safety.	Zerone
Concrete	Materials	3 ft diameter, 4.5 ft dept	-	1	Used to anchor the pole supporting the solar flower.	
Pole body (wood)	Materials	0.8 m diameter, 3.5 meter heights	-	1	Central structural support for the solar flower.	
Gimbal Mount	Materials	0.5m diameter ideally	-	1	Enables solar panel rotation for optimal sunlight capture.	
Storage area for circuit	Materials	Metal, 0.5m * 0.5m, 0.4m height	-	1	Houses sensitive electronics securely.	

Solar panel base	Materials	Metal, 2.2m diameter, 0.2m thickness	-	1	Foundation for solar panel assembly.	
Sensor for solar tracking	Part	-	-	1	Full tracking system includes Arduino UNO and LDR sensor.	LDR Sensor

Table #16: Solar flower parts bought/borrowed to produce a prototype.

Expenses	Type	Dimensions	Cost	Quantity	Justification	Source
ELEGOO PLA Filament 1.75mm Dark Blue	Materials	-	\$26.99	1	Bought in order to 3D print main body	
ELEGOO PLA Filament 1.75mm Black	Materials	-	\$23.99	1	Bought in order to 3D print main body	
Elegoo 120pcs Multicolored Dupont Wire 40pin Male to Female, 40pin Male to Male, 40pin Female to Female	Part	-	\$12.99	1	Bought to have connections with Ardunio and extend wires length	

Breadboard Jumper Wires Ribbon Cables Kit for arduino						
AOSHIKE 10Pcs 5V 60MA Epoxy Solar Panel Polycrystalline Solar Cell for Solar Battery Charger DIY	Part	68x37mm	$28.08	1	Bought to demo solar farm	
Miuzei 20KG Servo Motor High Torque Digital Servo Metal Gear Waterproof	Part	-	$35.99	1	Bought for future iteration to have waterproof design	
ELEGOO ESP32 2pcs ESP-WROOM-32 Development Board, USB Tyce-C, 2.4GHz Dual Mode WiFi+Bluetooth Dual Core Microcontroller for Arduino IDE,	Part	-	$19.99	1	Bought for future iteration to have multithreadi ng	
Freenove Ultimate Starter Kit for Raspberry Pi 5	Kit	-	Borrowed	3	Used for stepper motors, resistors, breadboard and wires	
Arduino UNO	Part	-	Borrowed	1	Used to have the solar	

					tracking and NodeRed server	
GL5516 Light Sensitive Resistor (LDR)	Part	-	Borrowed	8	Used for solar tracking by varying values	

5.6.) Risk Register

The risk register helped the team monitor and mitigate both anticipated and emerging challenges. The structured mitigation approach ensured that no risks escalated beyond manageable levels, and design decisions—such as scaling down from the full FEC build—were driven by practical considerations identified in the risk assessment.
Rk 1 Programmatic Risks:
Rk 1.1: Changes in regulations and environmental policies jeopardizing the project.
Mitigation: Demonstrate the project to regulators and governing officials for approval and validation.

Rk 2 Technical Risks:
Rk 2.1: Solar panels not functioning properly.
Mitigation: Conduct testing under harsh conditions (e.g., spraying water on panels to check waterproofing).

Rk 2.2: Failure of sun-tracking sensors.
Mitigation: Thoroughly test sensors and consider redundant systems.

Rk 2.3: Structural instability.
Mitigation: Design the structure with stability factors in mind; test prototypes.

Rk 2.4: Inverter or transformer failure.
Mitigation: Use reputable components and perform rigorous testing.

Rk 2.5: System incompatibility with the power grid.
Mitigation: Test integration setups before installation.

Rk 2.6: System maintenance difficulties.
Mitigation: Design for modular repairs and provide user-friendly manuals.

Rk 3 Environmental Risks:

Rk 3.1: Solar panels damaging local ecosystems and wildlife.
Mitigation: Use eco-friendly, recyclable materials such as wood for the solar structures.

Rk 4 Financial Risks:

Rk 4.1: Budget overruns due to unforeseen material costs.
Mitigation: Secure sponsors and donations to cover material costs.

Rk 4.2: Over-budget on components.
Mitigation: Discuss budget increases with supervisors or scale down design elements

Rk 5 Project-Related Risks:

Rk 5.1: Delays in material sourcing.
Mitigation: Identify multiple suppliers and secure early sponsorship.

Rk 5.2: Unexpected weather conditions.
Mitigation: Ensure structures are weather-resistant; modify installation timing if needed.

For the table 7.5 below rating is done based on likelihood*Impact if its within 25 and 19 its Red color, 18 to 14 its orange.

Table# 17: Updated risk matrix from preliminary design report.

Risk ID	**Risk Event**	**Likelihood**	**Impact**	**Rating**	**Response and Contingency Plan**	**Trigger**

Rk 2.2	Failure of sun-tracking sensors.	4	5	20	Test sensors and consider redundancy.	Sensors fail during initial testing.
Rk 4.2	Over-budget on components.	3	4	12	Discuss budget or scale design.	Quotes exceed the allocated budget.
Rk 2.3	Structural instability.	3	5	15	Test prototype structures under various conditions.	Structure fails stability tests.
Rk 2.4	Inverter or transformer failure.	3	5	15	Use reputable components and test rigorously.	System fails to convert or adjust voltage properly during testing.
Rk 1.1	Regulatory changes jeopardize the project.	2	5	10	Engage regulators early in the project cycle.	New regulations introduced affecting solar projects.
Rk 5.2	Unexpected weather conditions.	3	4	12	Use weather-resistant designs and modify schedules.	Severe weather conditions reported during the installation phase.
Rk 3.1	Ecosystem damage from materials.	2	4	8	Use recyclable and eco-friendly materials.	Complaints from environmental agencies or visible impacts

						during testing.
Rk 4.1	Budget overruns due to material costs.	3	3	9	Secure sponsorships and donations.	Vendor pricing updates show increased costs.

6.) Preliminary Business Case (Waterfall Methodology)

Table 18: Key Stakeholders for the Solar Flower Design

Stakeholders	Strength	Weakness	Opportunity	Threat

Name				
FEC- Sebastian Chabot	- - Primary contributor to the project - - Will provide resources and materials if the proposal is successful	- - Limited technical expertise related to the project specifics	- Provides a platform to showcase our work to a broader audience	- Project approval is contingent on demonstrated effort and quality of work
Lassonde School of Engineering	- - Financial support for materials and prototype development - - Provided accommodations for project presentations	- Insufficient time allocation for project completion	- Opportunity to present the project to academic and professional audiences	- Limited capacity for mass production of the final design within existing resources
Residence and Tourist	- - Support with local procurement of resources - - Assists in maintenance efforts	- Lack of technical input to improve the design	- Can aid in promotion and outreach of the project within the community	- Risk of vandalism or tampering if security measures are not implemented effectively

The importance of this project is that it shows a concrete move toward climate action, tech innovation and community empowerment." With the recent onslaught of extreme weather from forest fires to typhoons around the world, and the fast-approaching call for a net-zero emissions future, the urgency to adopt clean energy solutions has never been greater. This challenge is directly tackled by our solar farm, which includes in-build, scalable technology — the likes of 100W high-efficiency monocrystalline panels, hybrid inverters & durable grounding system —

that can be seamlessly put in both urban and rural contexts.

The project is also an educational prototype—demonstrating how it's possible to build a renewable infrastructure with readily available components, both physical and digital. That makes it a learning opportunity for students, engineers and local communities interested in sustainable development. By including a demo model that works, we are making abstract climate targets tangible — providing a physical, functioning system that people can handle and learn from.

7.) Deviations from Plan

Over the course of the eight-month project and through extensive coordination with the team, we identified and made several modifications to the initial design. These adjustments were crucial in enhancing our understanding of the model's capabilities, the limitations of the materials, and other critical factors. Below, we outline some of the key deviations from the original plan:

Initially, the team decided to design a single horizontal axis of rotation that would rotate approximately 210 degrees, covering the expected movement of the sun from east to west throughout the day. In addition, the vertical axis was fixed at a 45-degree angle to track the sun's position, as the sun typically reaches about 45 degrees in the sky during peak daylight hours. After extensive calculations and design adjustments, the team successfully implemented a dual-axis rotation system—both horizontal and vertical. This allowed the solar panels to track the sun from sunrise to sunset, significantly boosting energy production by 40%. This improvement represents a substantial increase in daily energy output, enhancing the overall efficiency of the solar farm.

In addition to optimizing the design for energy efficiency, the team focused on cost-saving measures to ensure the project remained within budget. To reduce expenses, we collaborated closely with stakeholders to explore opportunities for utilizing existing materials on-site. One of the most significant and innovative solutions was repurposing the mature trees already present on the property as utility poles for the solar panel structure. These trees, which had strong, sturdy trunks, were able to provide the necessary support for the top solar panel components, eliminating the need for additional, costly steel or concrete poles. Not only did this reduce material costs, but it also aligned with our sustainability goals by minimizing the environmental impact of transporting and manufacturing new materials. The design incorporated these trees in a way that maintained the structural integrity of the solar panel array, allowing the system to function efficiently while simultaneously cutting costs. By leveraging the natural resources already available on-site, we were able to create a more cost-effective and eco-friendly solution, further enhancing the overall sustainability of the project."

On the other hand, several changes were made to the initial equipment specifications to enhance the efficiency and longevity of the model, ensuring it would perform optimally over time. The team decided to upgrade the model of solar panels to more advanced, durable versions, using materials that not only boosted the strength of the structure but also helped reduce overall costs. Additionally, the design was adapted to allow for seasonal assembly and disassembly. Given that the solar farm wouldn't be fully functional during the harsh winter months, we incorporated a modular system that could be reassembled and optimized for use in other seasons, maximizing energy production throughout the year. Alberta typically experiences around 312 sunny days annually, providing ample opportunity for solar power generation even during the colder months, when the panels can still capture sunlight at reduced efficiency. This seasonal adaptability ensures the system is both cost-effective and sustainable year-round, maintaining high energy output during peak seasons while offering flexibility during the off-season.

Furthermore, the team decided to build a working prototype of the model to showcase the functionality of the design and demonstrate how the system operates in practice. This prototype would serve as a tangible representation of the entire solar panel mechanism, allowing us to test and refine the design's efficiency and functionality. By assembling a prototype model, we were able to observe how the system responds to various conditions, including the movement of the Sun (light) throughout the time, and to ensure that the rotational mechanisms function as intended. This hands-on approach not only validated the design but also provided valuable insights into the real-world application of the system, helping us to make further optimizations before full-scale implementation.

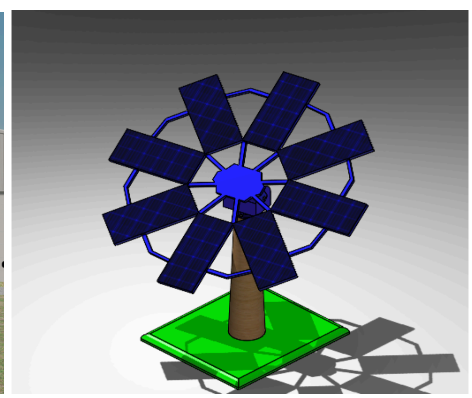



Figure 7.1 and Figure 7.2: The Initial Design of the Model and the Final Design.

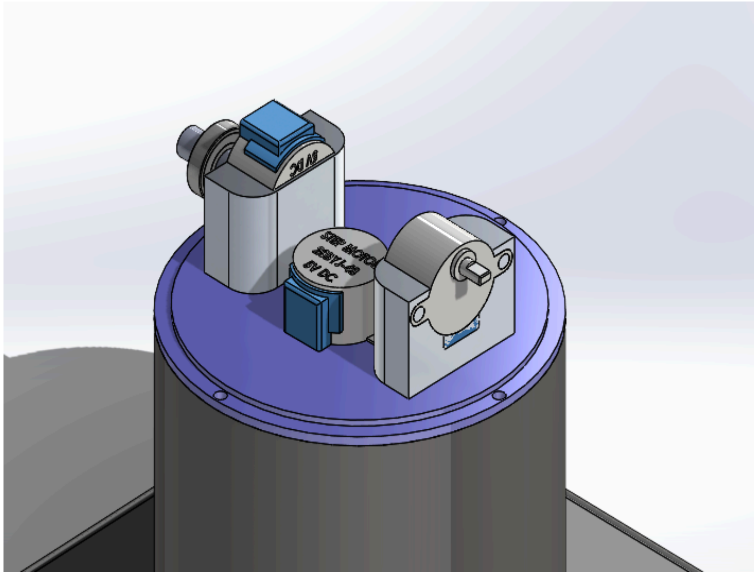
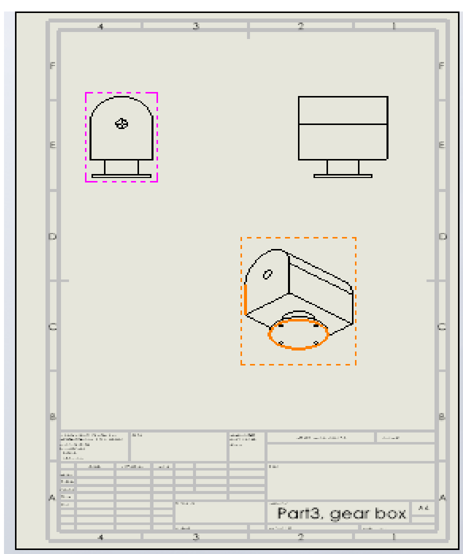
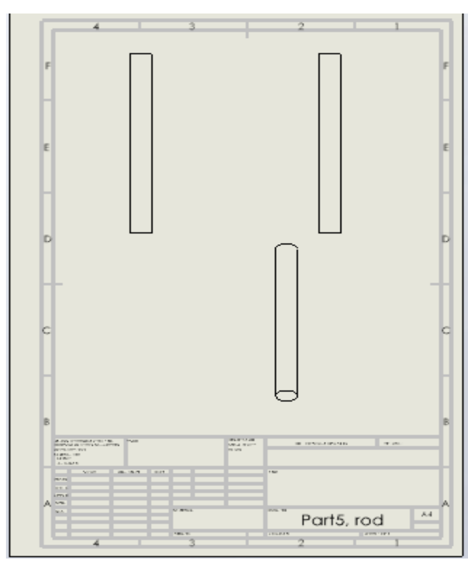
 

Figure 7.3 and 7.4: The prototype model under consideration and changes.

The following section presents the schematics and detailed model drawings of the individual components and the complete assembly, all developed using SolidWorks. These drawings illustrate the dimensional accuracy, design intent, and mechanical relationships between parts within the flower-shaped solar panel system. Each part was carefully modeled to ensure compatibility during assembly and to account for structural integrity under environmental loads. The assembly drawings also reflect considerations for ease of manufacturing and maintenance, serving as a foundation for both prototyping and future design iterations.





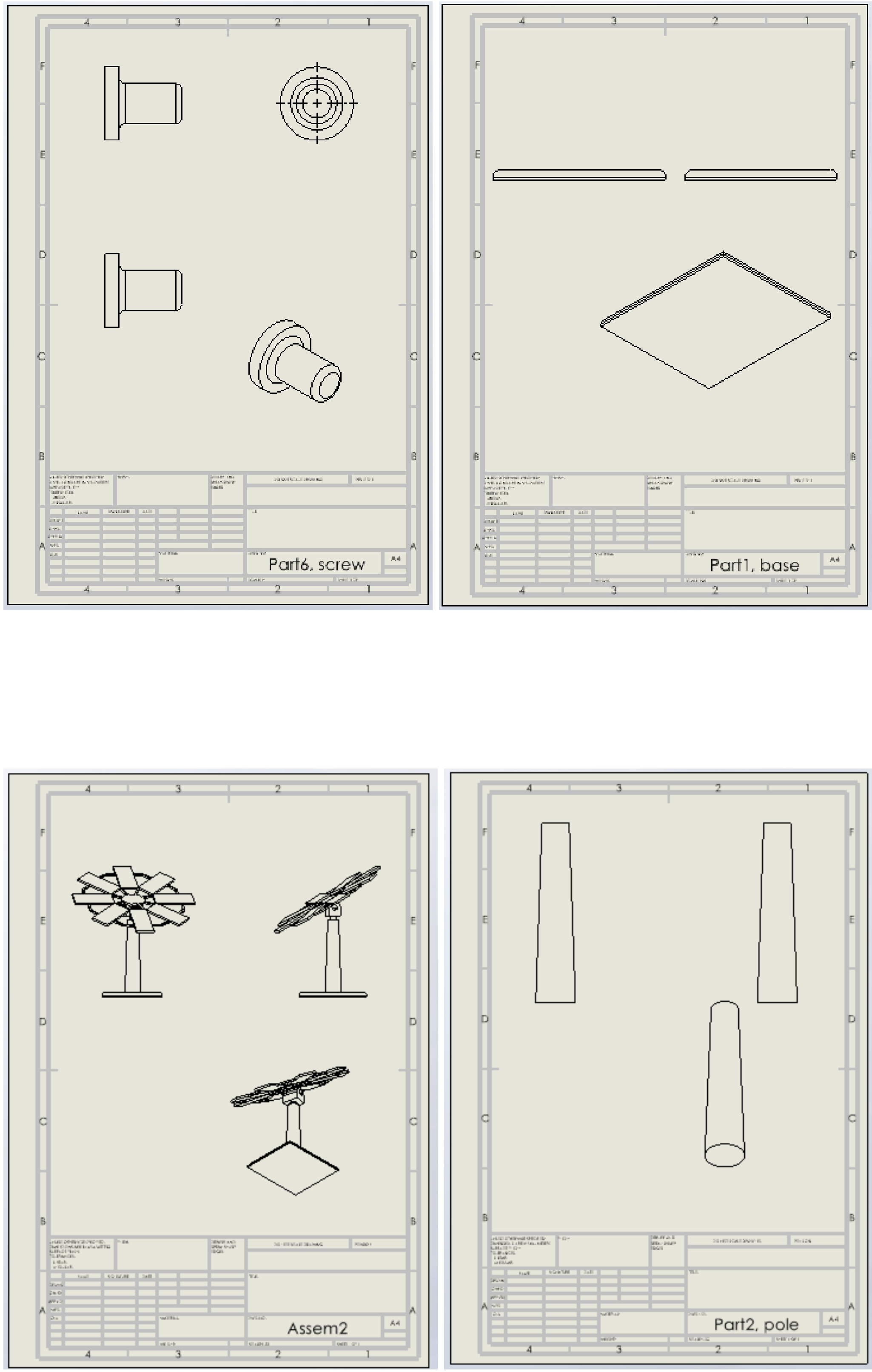


Figure 7.5, 7.6, 7.7, 7.8, 7.9 & 7.10: Schematics and Model drawings of the parts and assembly.

8.) Failure Report

Throughout our progress of the report we found ourselves in various issues that may have hindered progress and caused several setbacks for us. Some of these issues were issues with the strength of the stepper motors for prototypes, sensor tracking issues, over-budget on some components, integration challenges, and mechanical design constraints.

1. *Lack of strength of the stepper motor for the prototype:*
   The initial versions of the solar flower prototype originally had 2 stepper motors (1 stepper motor for the vertical movement and 1 stepper motor for the horizontal movement). During our early assembly of the prototype, we tested the motors and they were able to freely move in all directions. Then, we added the 6 solar panels on top of the solar flower prototype. The vertical motor was struggling to lift the flower up from 0 to 90 degrees. We understand that we did not take into account the strength of gravity and the weight of the solar panels that has an effect on the vertical stepper motor. **Solution:** We added one more stepper motor for the vertical movement. In total we have 3 stepper motors to operate the solar flower prototype. **Lesson:** We need more calculations to take in account of outside factors that might affect the stepper motors.
2. *Sensor Tracking Issues:*
   One of the most significant issues that occurred during the integration of the LDRs and sun-tracking mechanism with the Arduino control system. Early versions of the sun-tracking mechanism had sensor inaccuracies to where the light was. Each LDR sensor had different values or resistance when exposed to various levels of lighting. There was a need for debugging and redundant calibration testing. **Lesson**: Build in more simulation time and consider dual-sensor systems for reliability. Make sure we use the same model of LDR sensors so each sensor can be more consistent with each other.
3. *Budgetary Constraints:*
   Originally scoped under the assumption of a $10,000 FEC grant, the project was later restricted to a $2,000 budget due to Capstone requirements. This forced prioritization of essential components and abandoning advanced iterations like waterproof servos and multithreading microcontrollers. **Lesson**: Align design expectations with actual budget constraints early on.
4. *Integration Challenges:*
   The interfacing between Node-RED, Arduino, and sensor systems introduced integration delays. Data visualization did not initially reflect real-time values. These issues delayed testing and verification and required iterative coordination between the software and electronics teams **Lesson**: Integration planning should begin earlier in the timeline, with parallel testing.

5. *Mechanical Design Constraints:*
   The solar flower's structure was originally supposed to be more mechanical intensive and have more moving parts, but Sebastian wanted the solar flower to be easy to maintain and easy to use. **Lesson**: Making sure that components in the solar flower are easy to assemble, repair and replace.

Despite these failures, each challenge provided insights that strengthened the final implementation.

9.) Lessons Learned

9.1.) Team Member 1 Reflections

Previous Rubric & Success Criteria from Progress Report 2:

1. ITPMetrics feedback completed for every team member

9.1.1.1) David (Completed)

David has been improving his communication skills among his peers since the last Progress Report. He still needs to be more comfortable to announce different problems during the project.

9.1.1.2) Osama (Completed)

Osama has completed working in collaboration with the Computer and Software departments to finish his parts. He now needs to quickly finish the VR as soon as he can in tandem with his exams.

9.1.1.3) Kevin (Completed)

Kevin has completed working in collaboration with the Computer and Software departments to finish his parts and continuously arrived at meetings in a timely manner. He now needs to quickly finalize his parts.

9.1.1.4) Mohammad (Completed)

Mohammad has almost integrated his part with the overall project and tightened his bond with almost all of the other team members. He needs to continue to tighten his bond with the remaining team members.

9.1.1.5) Thivian (Completed)

Thivian has become a stricter leader to the overall team, asking why parts are not done and also encouraging team members to finish their parts. He needs to continue to monitor the group and do check ups if necessary.

9.1.1.6) Naweedullah (Completed)

Naweedullah has almost completed testing and integration for his part of the overall project. He needs to quickly update the other team members and finalize his part for prototyping on Capstone Day.

<u>Previous Rubrics & Success Criteria from the Fall Semester Report:</u>

The team formation plan has a diverse set of engineering principles for the overall project goal of building a solar panel. Our team consists of two Electrical (Thivian & Mohammad), two Computer (Osama & Kevin), one Mechanical (Naweedullah), and one Software Engineering (David) student(s). The Electrical Engineering members are responsible for the internal components and hardware, the Computer Engineering members are responsible for connecting the hardware and software components together, the Mechanical Engineering member is responsible for the external components and structure, and the Software Engineering member is responsible for the software component.

Each member has shown themselves to be able to work, collaborate, and communicate effectively with each other by peer evaluation through both within and outside of this project. As well as some of our members having different technical skills to benefit the team. As such, one of our members (Naweedullah) has previous experience working on a solar panel project, therefore this will give this team an advantage and an opportunity to improve our project's design by providing insight and knowledge. One of our members (Thivian) has vast knowledge of team building and leadership. This will help the team manage and organise different tasks among this project.

Our team has many channels of communication (Discord, Whatsapp, and Microsoft Teams) as well as different chat rooms for appropriate members. Each member can give their inputs and produce contributions for the project and compromises for when other team members are not available at certain times. This team is willing to help each other if team members have difficulties in their tasks. For synergies in our group, the Electrical and Mechanical Engineering members can collaborate on the hardware aspects while the Computer and Software Engineering members can collaborate on the software aspects. Continuing, the Computer and Engineering members can collaborate on translating the software aspects onto the hardware aspects.

Each team member has individual intrinsic motivations about choosing this project. Naweedullah has an opportunity to improve his skills from his previous experience working with solar panels and is passionate about his knowledge and insight about solar panels. Thivian has an opportunity to lead the team and gain new knowledge about team dynamics, organisation, and management of tasks. Kevin has interest in different ways of adapting this project into a new way to achieve the same goals under different environments. David is motivated by understanding all the interconnecting components of the solar panel. Osama is motivated by the opportunity to work with different software tools that are specifically designed for solar panels. Mohammad is interested in circuit and solar cell design.

All team members have access to all created channels of communication via Microsoft Teams. For emergencies, members will use Discord and/or Whatsapp. Files and resources are uploaded to Microsoft Teams and all members have access to them as well as Google Slides for presentations and Asana for the project timeline. Every member of the team is willing to communicate with each other and assist one another. Thivian and Kevin have access to rooms for team meetings and prototyping if needed by the team.

Key Point:

- A final reflection on how the team would run each project phase differently if they had hindsight available to them now and what they would suggest doing differently on their next project. **Note:** This process repeats for the other 5 team members.

- David: If he has the hindsight, he would've been able to change the rotation of the solar panel by smoothing out the transition and plan out the code more carefully.

- Kevin: If he had the hindsight, he would've not bought a lot of necessary material in order to make the prototype and suggest compatible designs.

- Osama: If he had the hindsight, he would have been able to quickly finish the VR demo in order to help with the Computer and Software Departments more frequently.

- Thivian: If he had the hindsight, he would improve the strengths of other team members through more encouragement and have the SAM site actively working more recently.

- Mohammad: If he had the hindsight, he would have made improvements to the block diagram and researched alternative materials and methods for the real world design.

- Naweedullah: If he had the hindsight, he would have made the real world shell design more quickly and efficiently as well as refining certain parts of the prototype.

Self Evaluation

The entire team needs to work together and discuss their final capstone course progress in the table below.

Table #19: Self-Evaluation of our Current Progress

Criterion	Self-Evaluation Ranking	Justification
Identify each criterion expected for this deliverable.	Use the rubric provided to rank your group as not meeting, marginally meeting, meeting, or exceeding.	Provide references to specific paragraphs/sections in the report to justify each ranking.
Prototype for display	Exceeding	- Code not fully finalized - Minor issues with small parts
VR for demoing	Meeting	- Need to fix bugs
Bristol board	Marginally Meeting	- Need to finalize ideas - Need to quickly finish placing in each section of the board

10.) Conclusions

The Low Print Solar Farm project was a successful attempt at creating a small, eco-friendly solar system that blends into natural spaces while generating at least 2 kWh of energy per day. The final prototype design met all the required goals, including solar tracking, data monitoring, grid connection, and sustainability. The system uses solar panels, stepper motors, an Arduino, and Node-RED to track the sun and display real-time energy data. From a project management view, the team followed the Waterfall method, staying close to the original plan with only a few tweaks. The team also managed risks well and made smart changes when facing budget or design challenges. Working as a multi-disciplinary team, each member contributed based on their background whether in electrical, mechanical, computer, or software engineering. Everyone collaborated closely and helped each other when needed. Even though there were some miscommunications and arguments throughout the whole 2 semesters. We were able to make amends and understand each other's differences on the approach of this project. In the end, this prototype is more than just a project. It shows how solar energy can be built with simple parts and great planning. With more support, this idea could grow into a full system for parks, campuses, or small communities.

11.) Acknowledgements

FEC Canada

This is the company who came up with the idea of our project. They are the ones who decided which aspects of the project they want to be included in the final design when they will build a life-sized version of our prototype. This company is the one that our group answers to if we have any questions and concerns.

York University

This is the university that approved the FEC Canada's idea of the project. They are responsible for our group to be compensated for materials that we used during the project. They are also there to help us guide along our journey of what expectations they want from our report and the capstone as a whole.

Sebastian Chabot

This is the CEO of FEC Canada. He decides on which ideas get approved from our group while giving some insight on what he wants best for his stakeholders. He is the representative of the company that guides us what needs to be done and is active throughout the capstone.

Hugh Chesser

This is our supervisor of our project. He is a professor at York University with special interests in mechanical engineering and has done solar panel work in the past. He is the one we respond to the most, is willingly engaging as a mentor for our capstone, and is actively helping us out when we need from Sebastian and how to get there as a group.

12.) References

[1] **ECO-WORTHY**, "100W 12V Monocrystalline Solar Panel," [Online]. Available: https://ca.eco-worthy.com/products/100w-12v-monocrystalline-solar-panel. [Accessed: Dec. 5, 2024].

[2] **Iparu**, [Online]. Available: https://iparu.com/. [Accessed: Dec. 5, 2024].

[3] **Foothills County**, "Land Use Bylaw," [Online]. Available: https://www.foothillscountyab.ca/development/land-use/land-use-bylaw. [Accessed: Dec. 5, 2024].

[4[**Google Maps**, "Alberta," [Online]. Available: https://www.google.com/maps. [Accessed: Dec. 5, 2024].

[5] **U.S. Department of Energy**, "Solar Panel Technologies: Bifacial and Flexible Solar Cells," Energy.gov, [Online]. Available: https://www.energy.gov/. [Accessed: Dec. 5, 2024].

[6] **Solar Power World**, "Floating Solar Panels: A New Opportunity for Clean Energy," [Online]. Available: https://www.solarpowerworldonline.com/. [Accessed: Dec. 5, 2024].

[7] **U.S. Department of Energy**, "Cost Analysis of Solar Energy Systems," [Online]. Available: https://www.energy.gov/. [Accessed: Dec. 5, 2024].

[8] **Project-Management.com**, "Waterfall Project Management Methodology," [Online]. Available: https://project-management.com/waterfall-project-management-methodology/. [Accessed: Dec. 5, 2024].

13.) Appendices

13.1.) List of Meeting Minutes Since the Progress Report

For getting access to the Meeting Minutes on Google Drive since the second Progress Report, use this link:

https://docs.google.com/document/d/1HxDCn9-jG2IDjgShRbuKI-xfbLAhzYJ4/edit?usp=sharing&ouid=106489202022741993407&rtpof=true&sd=true

13.2.) Updated Work Package Descriptions (WPDs)

Refer to 5.2 as the information has been provided within that section

13.3.) Shared External Links to Supporting Files

1) Use the link provided to access the file: https://drive.google.com/file/d/1TB8xpbj6Erzi4z1LPJfuv34PXnQyO0js/view? usp=sharing
2) Use the link here to go to the website and upload the Gantt chart: https://www.onlinegantt.com/#/gantt

14.) List of Figures

Figure Name	Summary	Page Number
Figure 1.1: The Google map view of the facility along with the marked desire	This provides the locations where we would have our solar farm designs in.	4

Figure 1.2: Flower Solar Panel system design.	This is one of our designs for our solar farm.	4
Figure 1.3: Mobile solar panels design	This is another design for our solar farm.	4
Figure 1.4: Umbrella Solar Panel system design	This is another design for our solar farm.	5
Figure 1.5: Floating solar panels design.	This is another design for our solar farm.	5
Figure 1.6: Final model design for the Flower shaped solar farm.	This is the final design of our solar flower product.	5
Figure 3.1: Low Print Solar Farm Block Diagram	This is the block diagram for our full scale design.	8
Figure 3.2: SAM Simulation	This is the calculations in regards to energy and Levelized Cost of Energy	9
Figure 3.3: Node RED Interface	This Displays the LDR and the battery level of the prototype design	10
Figure 3.4: Solidworks Static and thermal test.	Thermal and static stress analysis of the flower-shaped solar panel in Solidworks	11
Figure 5.1.1: Work Breakdown Structure for the implementation of the Low-Print Solar Farm	This is the work breakdown structure within our design. It is broken down to different subsections, Project Management, Analysis, Design, Implementation, and Prototype and Testing.	16
Figure 5.4.1: Gantt chart for the low print solar farm	This is the Gantt chart for our project. This highlights the	34

	steps we need to take to complete the project.	
Figure 7.1: The initial design of the Model	What the model looked like before.	44
Figure 7.2: Final Design	What the model looks like now.	44
Figure 7.3: The prototype model under consideration and changes.	What the motor of the prototype looks like	45
Figure 7.5, 7.6, 7.7, 7.8, 7.9 & 7.10: Schematics and Model drawings of the parts and assembly	Schematics and model drawings that was created in solidworks that illustrates the specification of the parts and the assembly	46 & 47

<u>**15.)** List of Tables</u>

Table Name	Summary	Page Number
Table #1: Updated Waterfall Requirements List	This is our requirement list update.	6
Table #2: Strength and Limitation For the Design	This is a comparison of the design made within the project	12
Table 3: Compliance Notes	This is suppose to showcase what each requirement was complied or not	13
Table #4: Project Management Work Package Description	This is where we go into detail on the work package description based on the	17

	task needed to do for project management.	
Table #5: Analysis Work Package Description	This is where we go into detail on the Analysis work package description. We specify the different roles and task needed to be done for the section.	18
Table #6: Design Work Package Description	This is where we go into detail on the design work package description. We specified the different roles for the section	20
Table #7: Implementation Work Package Description	This is where we go into detail on the implementation work package description. We specified the different roles for the section	21
Table #8: SOFT Implementation Work Package Description	This is where we expand of the implementation of the software implementation work package description	23
Table #9: COMP Implementation Work Package Description	This is where we expand of the implementation of the computer implementation work package description	24
Table #10: ELEC Implementation Work Package Description	This is where we expand of the implementation of the electrical implementation work package description	25
Table #11: MECH Implementation Work Package Description	This is where we expand of the implementation of the mechanical implementation work package description	26
Table #12: Prototyping and Testing Work Package Description	This is where we go into detail on the Prototype and testing work package description. We specified the different roles for the	28

	section	
Table #13: Resource allocation matrix breaking down responsibilities of each team member.	This is where we indicate the amount of work that each member of the project is required to do. The Scale is indicated by Table #15	30
Table #14: Legend for the resource allocation matrix.	This is the legend for the terms that we used for Table #14	33
Table #15: Solar flower FEC we will be getting to produce	The expenses of equipment and their description along with cost	35
Table #16: Solar flower parts Bought/ Borrowed to produce a prototype	This is the cost of materials needed for the Solar Flower.	37
Table# 17: Updated risk matrix from preliminary design report.	This is the updated risk for the following design that we are using for the solar flower.	41
Table# 18: Key Stakeholders for the Solar Flower Design	This is for a comparison for the stakeholder	43
Table #19: Self-Evaluation of our Current Progress	This is the self evaluation for the current progress within our project.	52