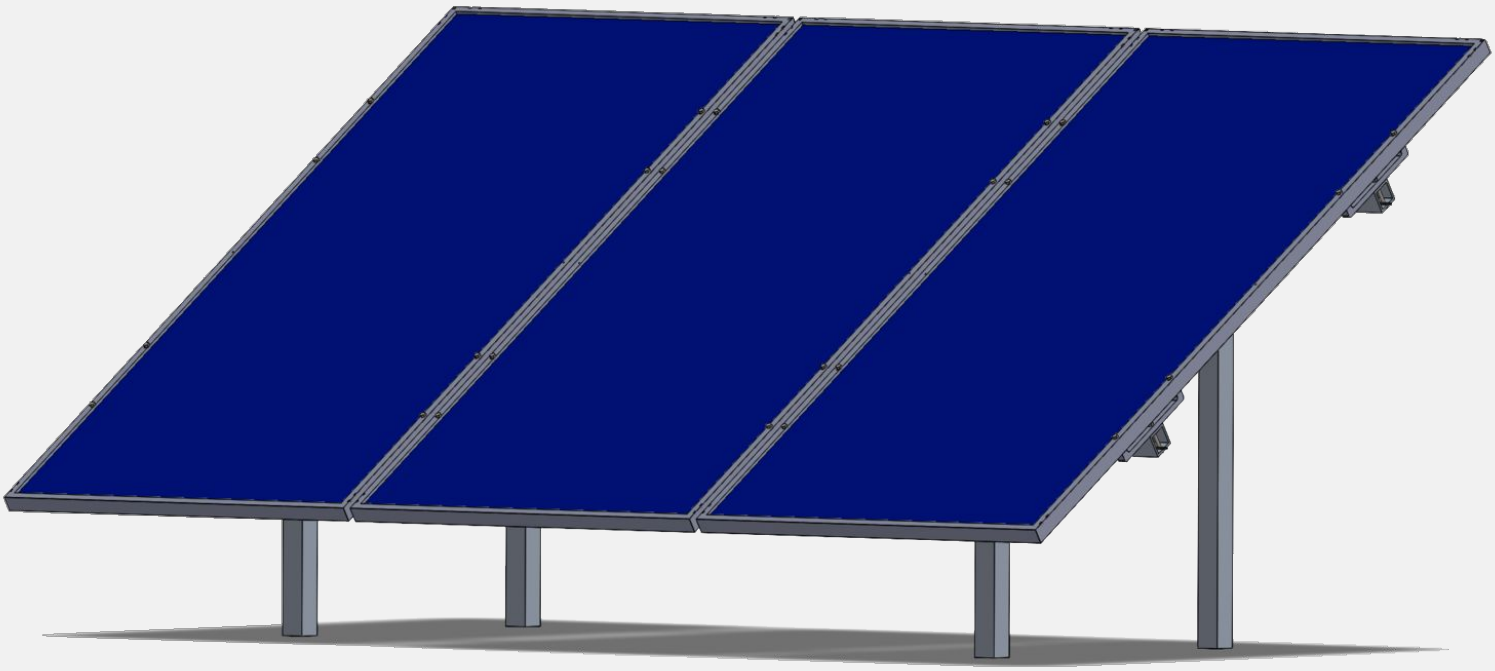
SOLAR FARM **CONSTRUCTION MANUAL**



A **complete** construction guide for a one-hectare solar farm designed for any environment.

This manual was made possible by Worcester Polytechnic Institute, the University of Haifa, Ort Braude College of Engineering, and the Mityaalim Foundation.

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Introduction

Why Solar Power?

A solar farm of this size can be very beneficial to a community. Such farms, while requiring funding to build, have the ability lower the cost of power bills from the main power company. A solar farm like this is also able to allow more remote and less developed cities to have a reliable source of energy that requires minimal maintenance. Solar farms like this design are able to reduce the demand of power from the larger power plants that utilize fossil fuels and other non-renewable methods to produce electricity. Compared to other forms of renewable energy solar panels require much less money and maintenance to continue operating. This design has very few proprietary parts meaning that if some pieces need to be replaced or repaired, there are several options for substitutes that are not OEM (original equipment manufactured) parts. Lastly compared to other forms of renewable energy, Solar farms are far more modular and can continue to run if specific portions of the farm are damaged or broken.

Important Details

Please note that we are *not* responsible for any potential liabilities with undertaking this project. Please approach this project with caution and care.

This guide is meant for the construction company.

The goal of this handbook is to eliminate your need for hiring engineers to design your solar farm. However, the assembly process requires professional work to ensure material safety and stability. The mounting assembly requires welding, and the ground support requires a secure concrete foundation. A qualified construction company should be hired to build this plant.

This solar farm is modular and changeable.

The design provided here accommodates 3627 panels on a single hectare of land. However, this can be scaled up or down to any size.
Additionally, this farm was designed for building in northern Israel. See the Appendix for details on adjusting the solar panel angle for different latitudes. Assuming the location receives 6 hours of sunlight per day, this farm will generate 7616.7 kWh or roughly 1.2 MW of power.

Material Breakdown

Material List

01	Heliene 144HC M6 Monofacial Solar Module
02	60mm x 60mm x 6mm Aluminum 6063 Square Tubing
03	Custom-milled Aluminum 6063
04	M8-1.25x80mm 8.8 Hex Cap Screw
05	M8-1.25x50mm 8.8 Hex Cap Screw
06	M8-1.25 A4-80 Hex Nut
07	M20-M40 Concrete
08	Growatt 10kW Grid-Tie MIN10000TL-XH-US Inverter
09	USE-2 Aluminum Underground Service Cables
10	(Optional) Galvanized Aircraft Cable

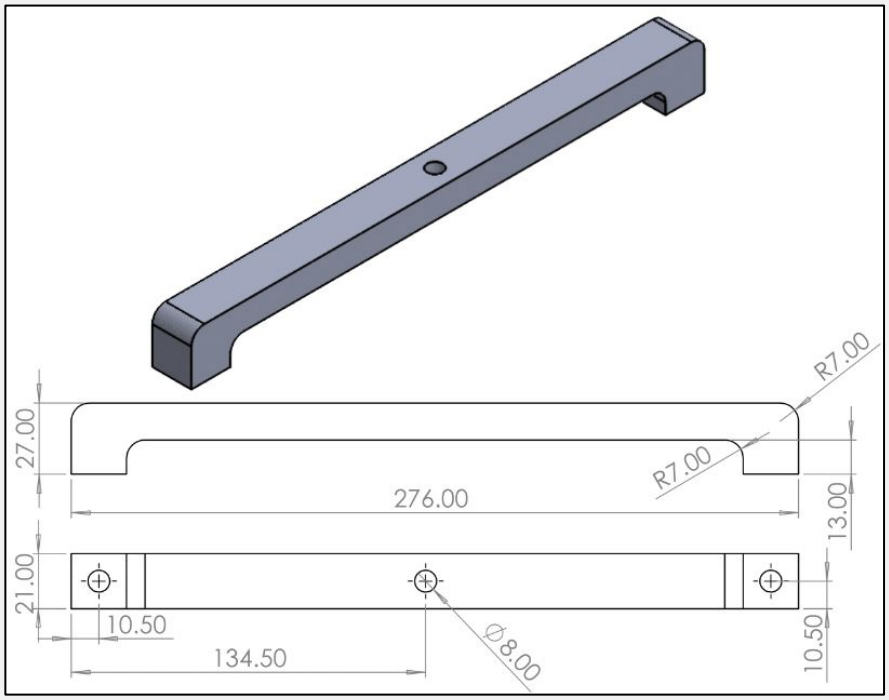
Important Notes

Material	Notes
Hardware (hex bolts and nuts)	Finish color does not matter, however it is important that the material type chosen is rust-resistant. Stainless steel is recommended.
Aluminum	6063-T5 is the recommended alloy of aluminum. However, most types of 6063 aluminum should be fine.
Concrete	M20-M40 grade concrete should be used to ensure stability.
Service Cables	Copper cables can be used, however aluminum cables are advised to deter cable theft.

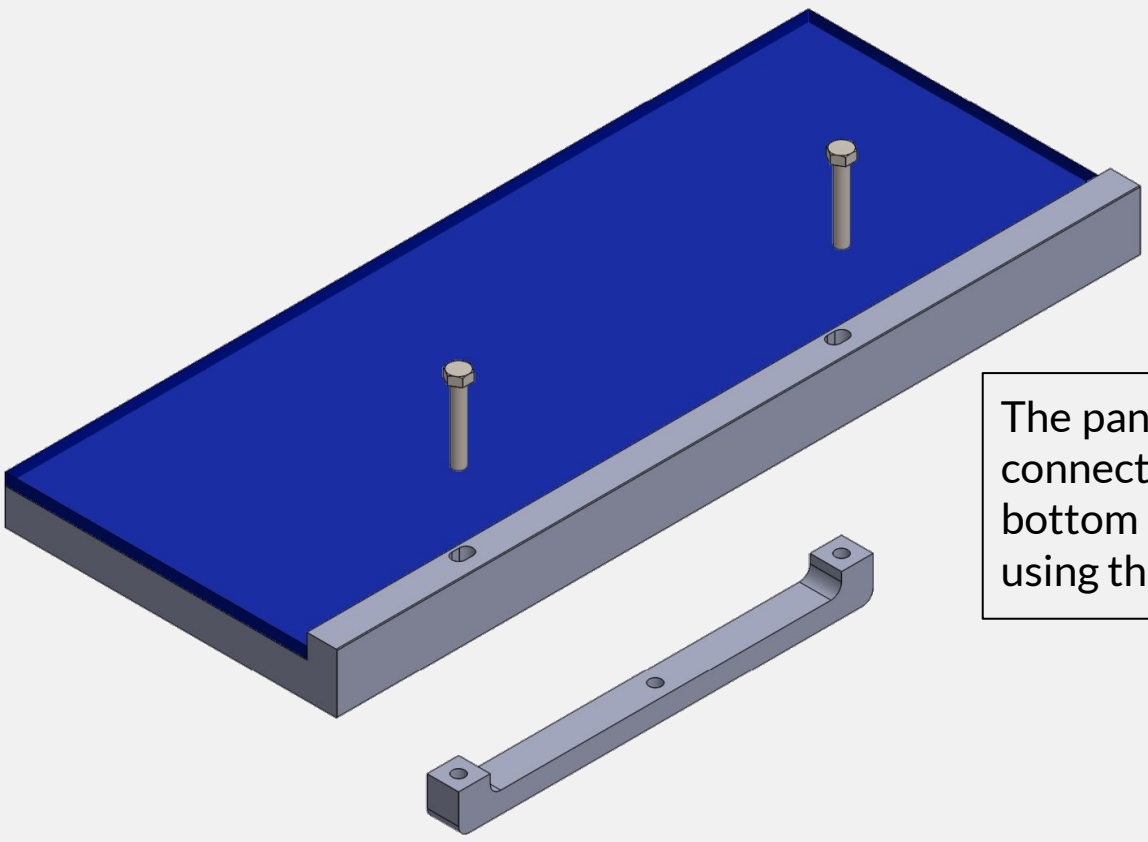
Assembling the Mount

1. Panel Handles

The panel handles need to be **custom CNC-milled** to fit the Heliene solar panels. The full part drawing for these handles can be found in the appendix. **Four** of these handles will need to be attached to **every solar panel**. It should be noted that the two bottom holes must be **threaded**.



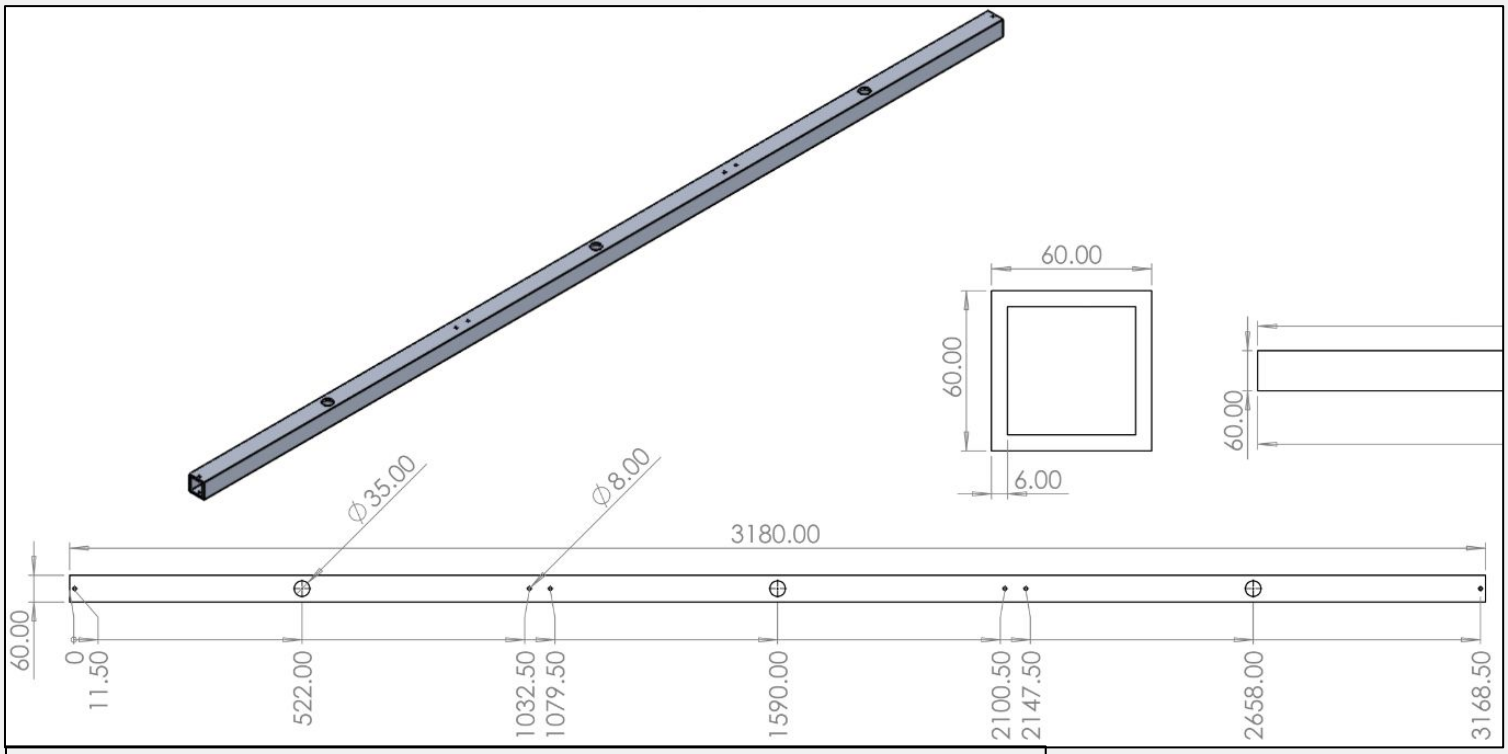
FULL PARTS DRAWINGS available in the appendix.



The panel handles are to be connected **underneath** the bottom of the panel frame using the **50mm bolts**.

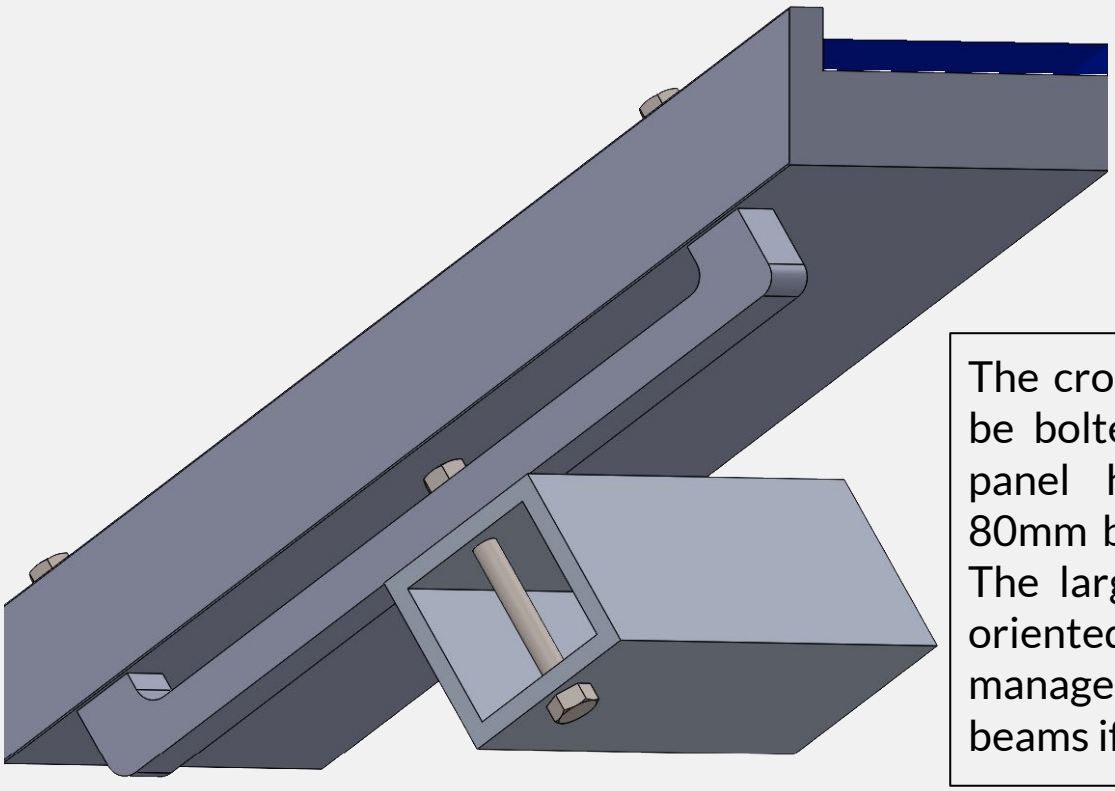
Assembling the Mount

2. Cross-Panel Beam



The cross-panel beams connect three panels together, and are to be made with the square aluminum tubing. The full part drawing for these handles can be found in the appendix. **Two** of these beams will need to be attached to **every triple-panel rig**.

FULL PARTS DRAWINGS available in the appendix.

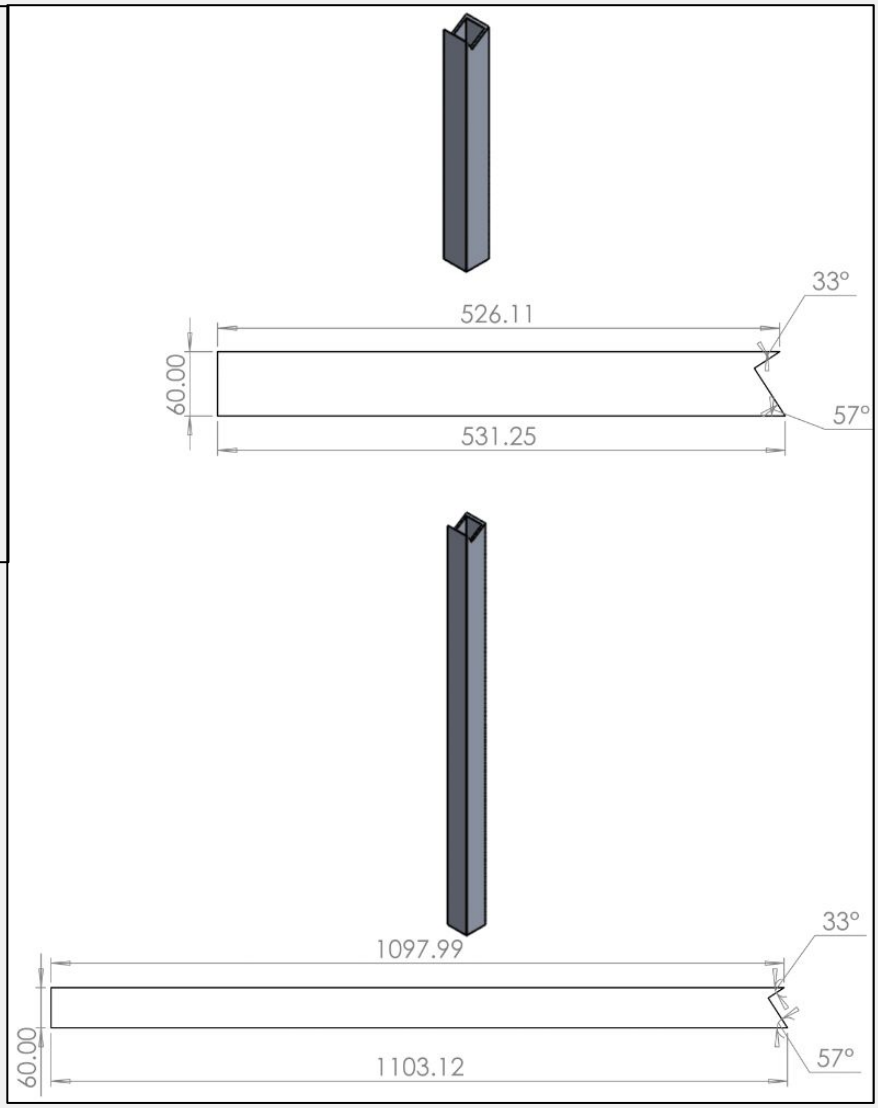


The cross-panel beam is to be bolted **underneath** the panel handles using the 80mm bolts and a hex nut. The large holes should be oriented **upwards** for cable management through the beams if desired.

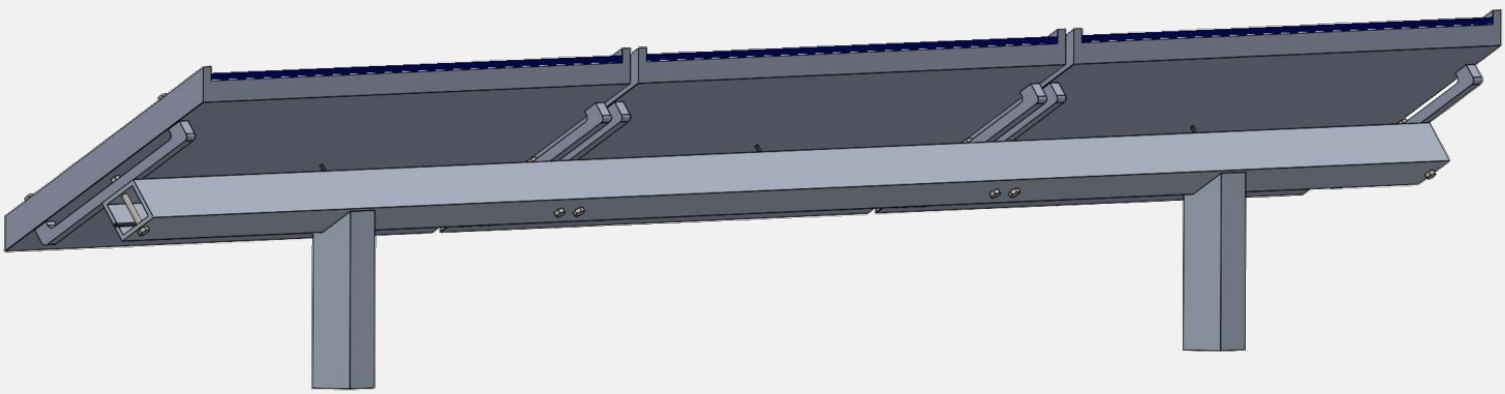
Assembling the Mount

3. Support Beams

These support beams hold up the rig, and are also to be made from the square aluminum tubing. The full part drawing for these handles can be found in the appendix. **Four** of these beams will need to be attached to **every triple-panel rig**, two of the **tall** ones and two of the **short** ones.



FULL PARTS DRAWINGS
available in the appendix.

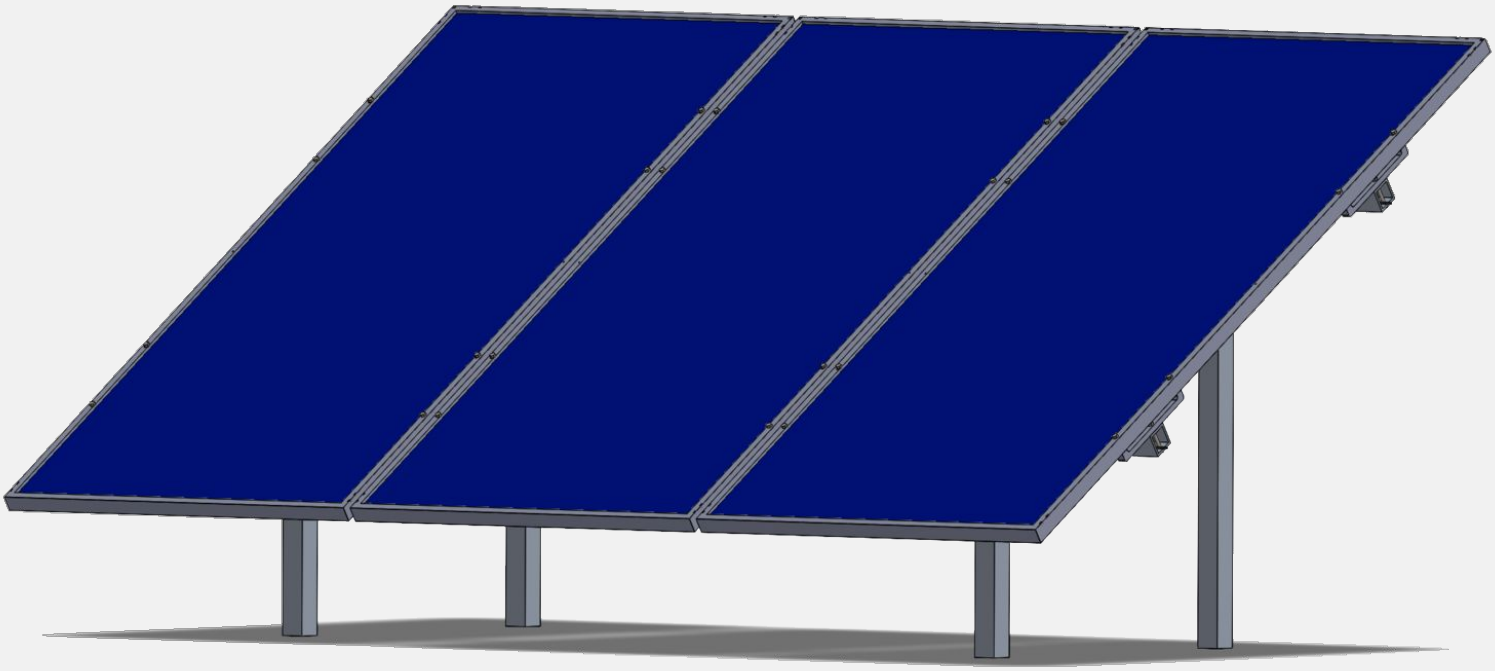


The support beams are to be welded to the support beams such that the panels are centered across the support beams. The tall support beams are to go on the back, as to angle the panels towards the sun.

Assembling the Mount

4. Completed Assembly

A full module should now be complete and ready to be mounted. There are a few checks that can be made to ensure that the module was built correctly. When level, the panels should make roughly a 33º angle with the ground. The panels should be centered between the support legs, and nothing should be free to move in any way.



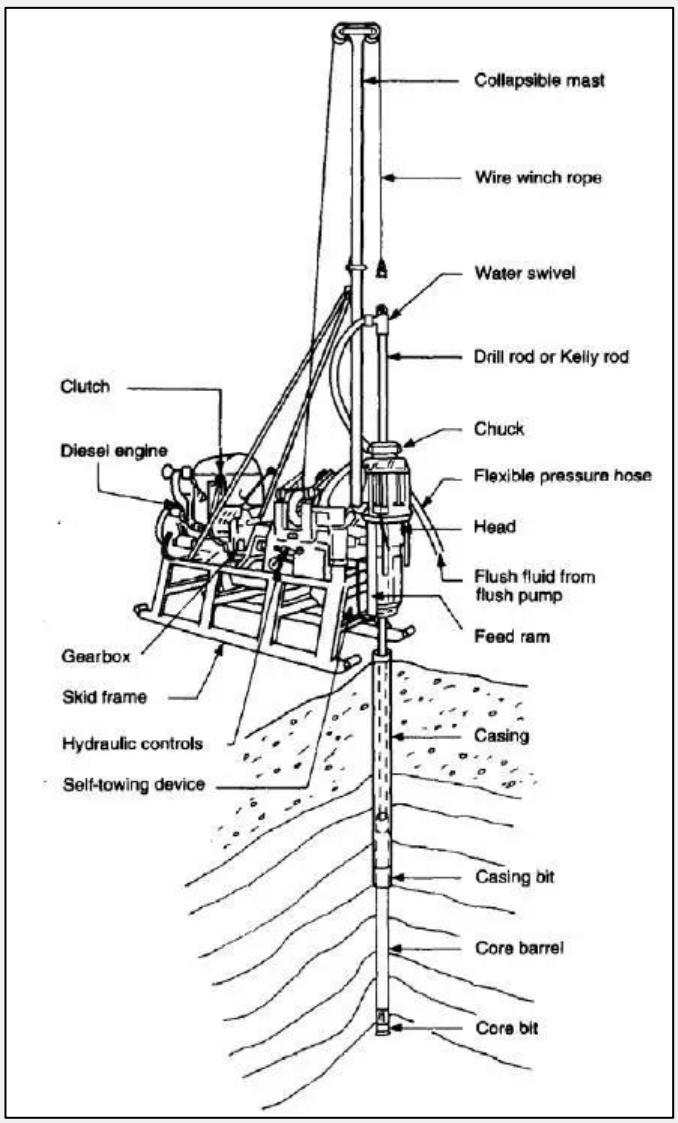
These are the total materials required for one completed assembly:

01	Solar Panel	3 count
02	Aluminum Square Tubing	9.63 meters
03	CNC-Milled Aluminum	2.9 kg
04	80mm Bolt	12 count
05	50mm Bolt	24 count
06	M8 Hex Nut	12 count

Mounting the Panels

1. Boring Holes

This step is very important to the longevity of the construction of this solar farm. Before any construction begins, a full soil analysis should be conducted by a geotechnical drilling engineering firm. The depth of the foundational piles under each panel will be determined by the type of soil. For locations with suitable soil and loam, holes should extend be 1.5 meters into the ground. For locations with weaker soil or sand, holes should be dug down to 3 meters. Additionally, for areas in colder climates, it must be insured that the piles extend below the frostline in order to prevent uplift. There will be 4836 holes.



Geotechnical drilling machine for **soil analysis**.

A mechanical auger would the most effective method for excavation before placing in the concrete form tubes. For adaptation to more remote areas or difficult terrain, a skid steer can be utilized with this auger, as shown in the image above.

Mounting the Panels

2. Setting Concrete Forms

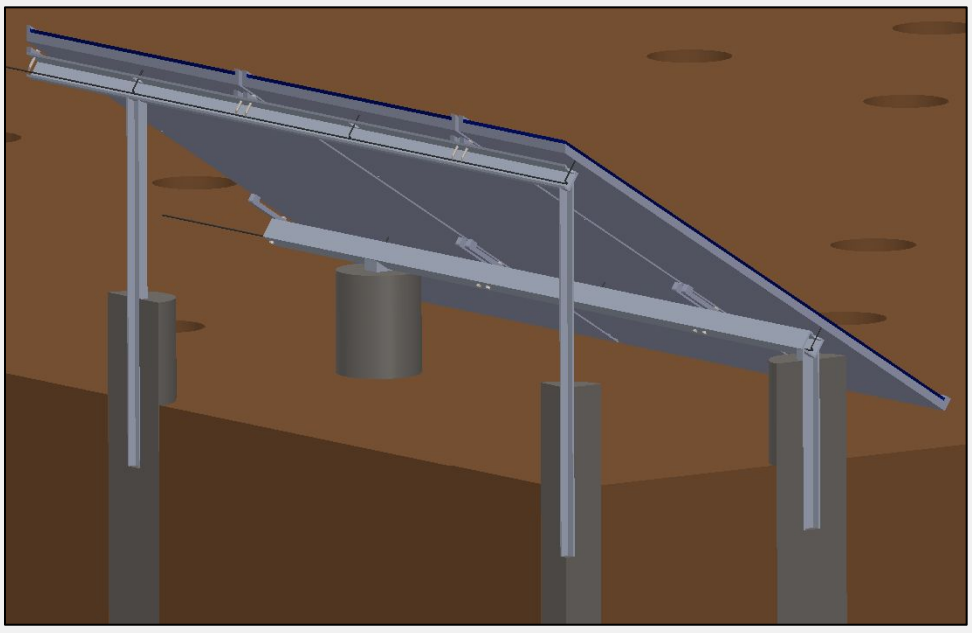
After all the holes have been mapped out and excavated, fiber laminated concrete form tubes can be placed in the holes. Hold the tube forms level and pour dirt into the hole on the *outside* of the tube to keep it vertical. The tube should also be protruding at least 30 centimeters above the ground level. Each tube will have a diameter of 250mm.

Once the tubes are set in place, begin filling them with concrete. Shake the tube as it is being filled to prevent voids and air pockets. A concrete truck would be ideal for this job, however a secondary pumping truck (as shown above) could also work if the terrain is too difficult. Pouring by hand should be a last resort option.

Mounting the Panels

3. Setting Concrete Forms

Once the concrete has been poured into the tubes the vertical members of the panel assembly are placed into the wet cement. These posts should be 0.5 meters into the concrete to prevent shifting. Optionally brackets can be mounted into the concrete (shown on the right) compared to the entire post. These brackets allow further adjustment, removal or up-grades, but decrease durability.



A **cut view** of the inside of the concrete pilings.

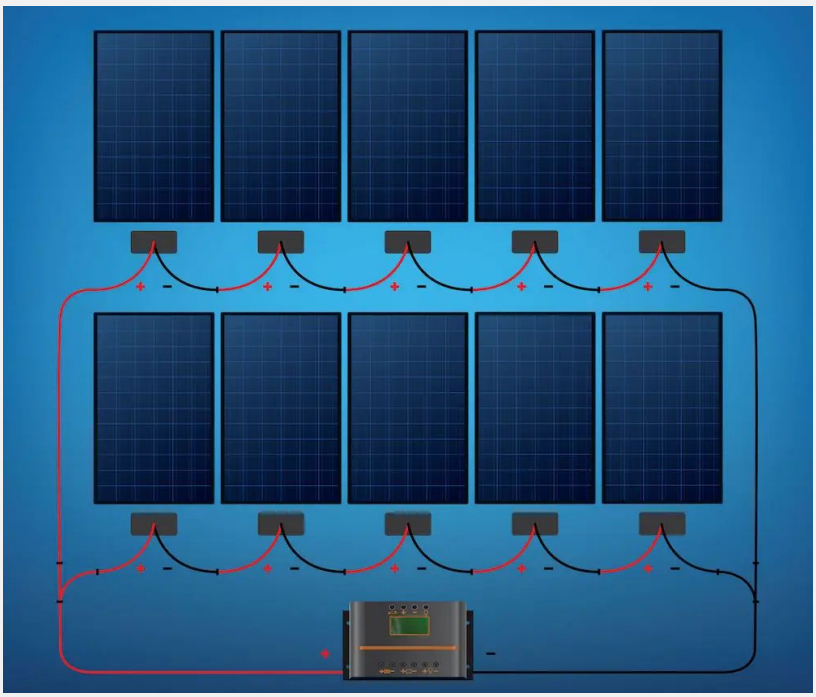
Once the vertical posts are determined to be level and perfectly straight, temporary wood bracing can be used to hold the structure level for the drying process. After about 2 days the temporary clamp structure can be removed and the concrete will fully cure after 28 days.

Wiring the Solar Panels

1. Panels to Inverters

On the underside of the panels are the output cables. These output cables allow each panel to directly connect to each other. Connect this panels together in chains of 14 panels each, as this is the maximum amount that the inverters can handle. Connect an inverter to the end of each one of these 14-panel chains.

(Left) Example of one of the Growatt string inverters used in this model



The panels in this wiring formation will reach the max operational capacity of these inverters. Along with being efficient, they are wired in such a way if that one panel is not functioning it can simply be bridged. By removing the faulty panel from the wiring system, the farm could still operate and this would suffice as a temporary fix. These cables should be buried to prevent theft and sun damage.

Wiring the Solar Panels

2. Panels to Substation

Once the system is connected with the inverters, run the wires together at the edge of the farm so the power company can easily connect to the grid The local power company purchasing the power will be responsible for connecting the plant to the grid/ distribution center. Once all the cables merge to at one point, the power company will install meters and connect the cables to main service lines. Any cable after the power meter is property of the power redistribution center and any maintenance will be their responsibility past that point.

A dual meter (seen right) keeps track of the usage of electricity as well as how much electricity is being generated and recorded through the meter

Optionally, these service cables can be spiral wrapped in galvanized (seen below) aircraft cable to prevent theft, though this is not necessary, especially if aluminum service cables are being used.

Appendix

Reference Materials

On the following pages, you will find the parts drawings for the custom cut and milled parts, along with an assembly drawing. Heliene's CAD drawings for the solar panel are also provided.

All the SolidWorks files have also been uploaded for your convenience here:

https://www.dropbox.com/s/gyd41nb6bayqhbt/Solar%20Farm%20Drawings%20.zip?dl=0

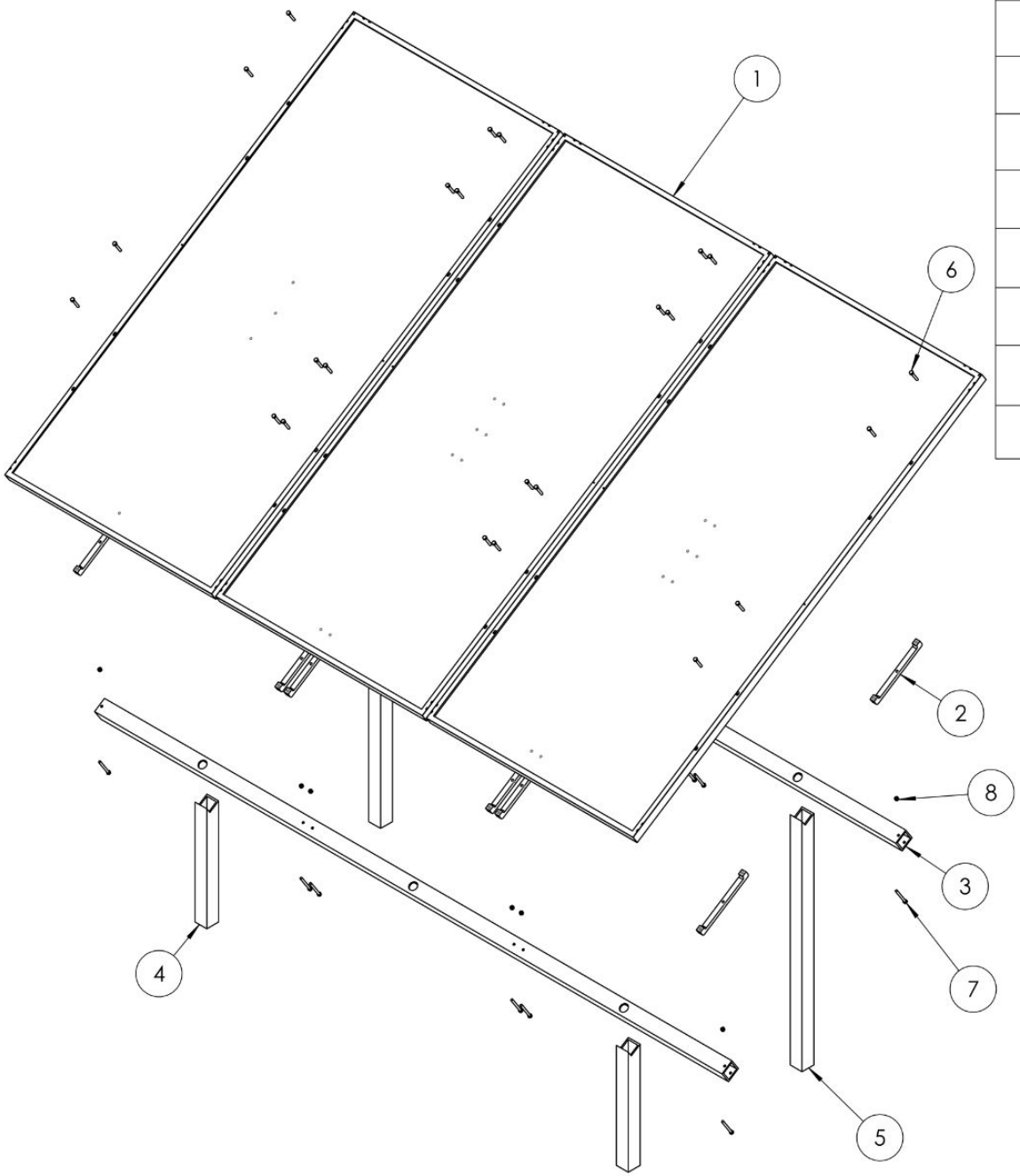
Adaptability

This design is made for usage in Israel. However, this design can be applied anywhere, as long as the angle is changed accordingly. The angle of the solar panels must match the latitude of the location for the best year-round results. Increase or decrease the height of the back legs in order to change the tilt accordingly.

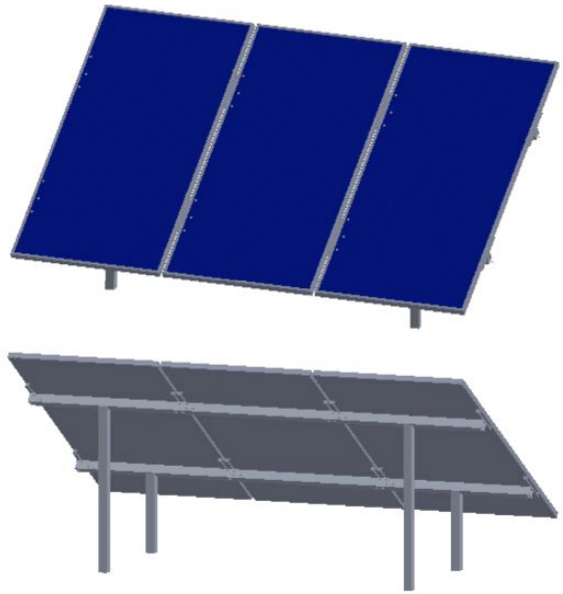
Additionally, make sure to account for soil changes, as is discussed in the Mounting the Panels section.

Contact Us

Wish to contact us? Send us an email at gr-SolarC23@wpi.edu.



ITEM NO.	PART NUMBER	MATERIAL	WEIGHT (KG)	QTY.
1	Heliene 144HC M6 Solar Panel	N/A	25.00	3
2	Attachment Handle	6063-T5	0.24	12
3	Cross-Panel Beam	6063-T5	11.07	2
4	Front Support Beam	6063-T5	1.82	2
5	Back Support Beam	6063-T5	3.82	2
6	M8 x 1.25 x 50 Hex Head Screw	Steel	0.0027	24
7	M8 x 1.25 x 80 Hex Head Screw	Steel	0.0031	12
8	M8 x 1.25 Hex Nut	Steel	0.0047	12



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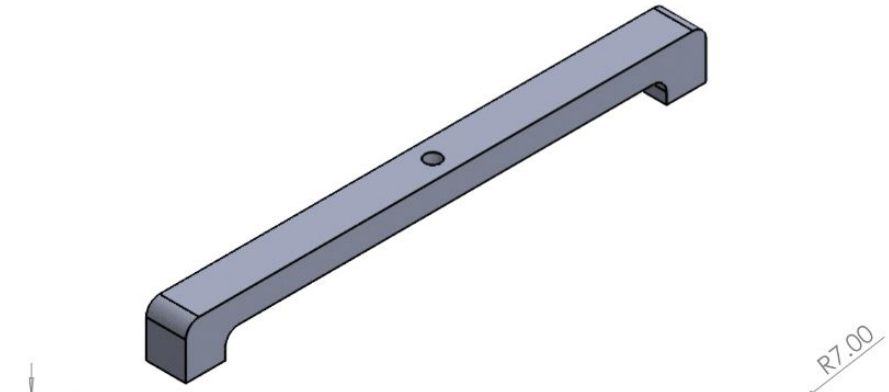
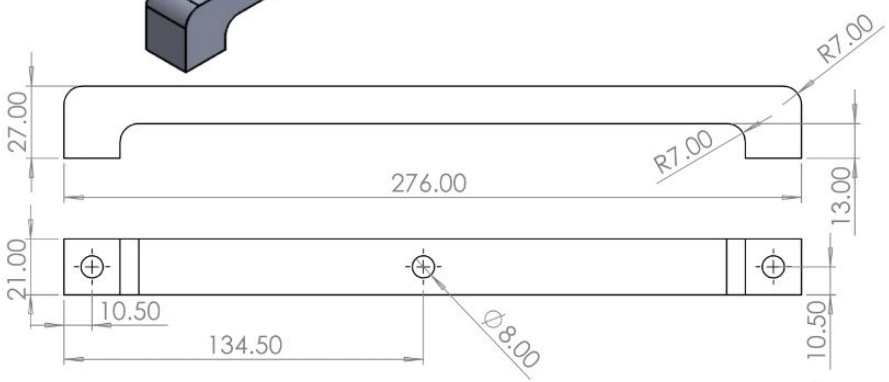
TITLE:
Three-Panel Rig

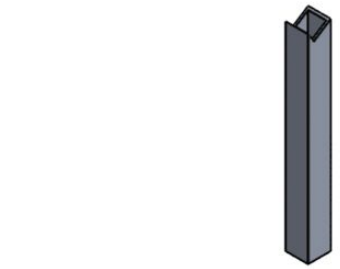
WEIGHT: 111.46 kg

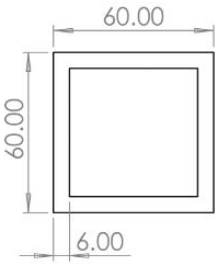
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS

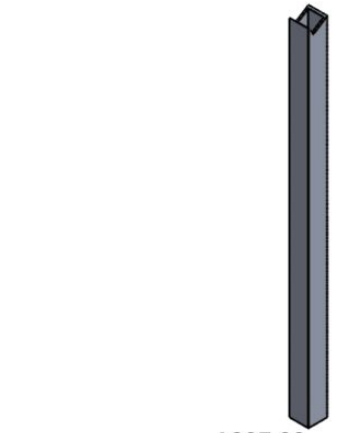
DATE: 4/16/2023 | SHEET 1 OF 2

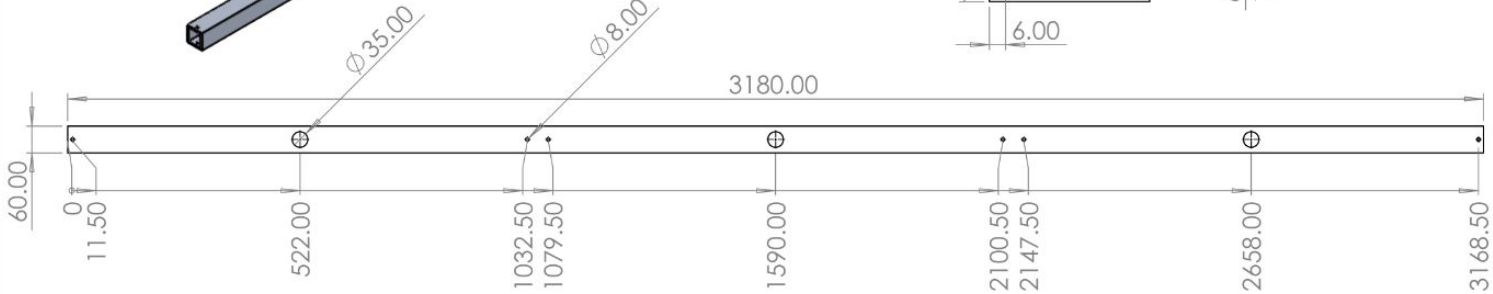












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TITLE:
Solar Panel Parts

MATERIAL: 6063-T5 Aluminum

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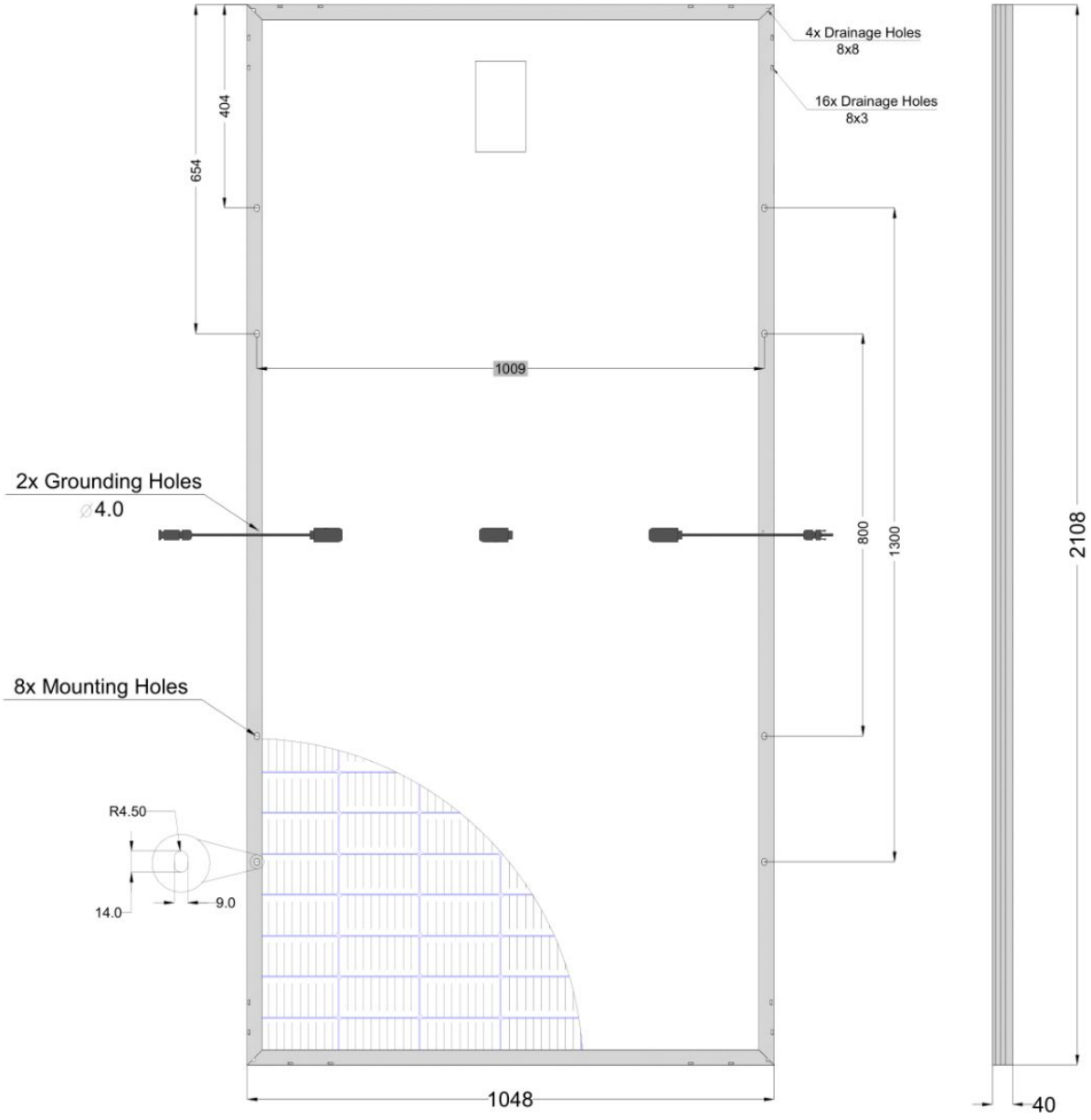
DATE: 4/16/2023 | SHEET 2 OF 2

REV.	DESCRIPTION	DATE
00	INITIAL RELEASE	2021-03-25



NOTES:

ALL DIMENSIONS IN "MM" UNLESS SPECIFIED OTHERWISE.
FOR 1500V PRODUCTS, EDGE SPACING (LIVE PARTS TO THE ACCESSIBLE EDGE OF THE MODULE) NEEDS TO BE MORE THAN 15MM.
FOR 1000V PRODUCTS, EDGE SPACING (LIVE PARTS TO THE ACCESSIBLE EDGE OF THE MODULE) NEEDS TO BE MORE THAN 12.7MM.

HELIENE PHOTOVOLTAIC MODULES	DOCUMENT TITLE: HELIENE_144_M6_SPEC_REV.00	DRAWN BY: XINYAN BAI	DATE: 2021-03-25
	DRAWING NUMBER: N/A	REVIEWED BY: GLEN MARSHALL/ CONNOR COVERT	DATE:
REVISION: 00	TOLERANCES: REFER TO HELIENE LAYOUT DRAWING	APPROVED BY: RICARDO GUADARRAMA	DATE:
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