

# Design Release Review

The Development of a Low Cost Pyranometer



# Objective: Create a competitive pyranometer prototype for Kilowatts for Humanity



- Accurate solar irradiance readings
- Simple to build and install
- An affordable alternative

# Background



KILOWATTS  
FOR HUMANITY

## Provided services:

- Refrigeration
- Device charging
- Offline servers



# Value Proposition

## Problem:

Affordable method to monitor rooftop solar projects

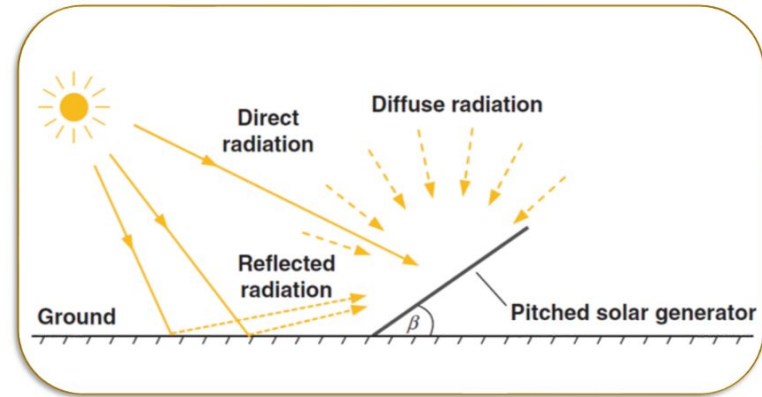
- Weather
- Dirt
- Aging



## Solution:

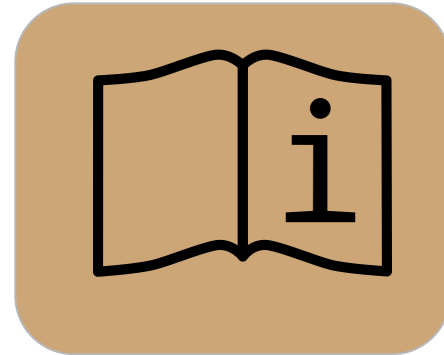
Monitor light energy with our pyranometer prototype

Solar Irradiance:  $W/m^2$



# Product Requirements

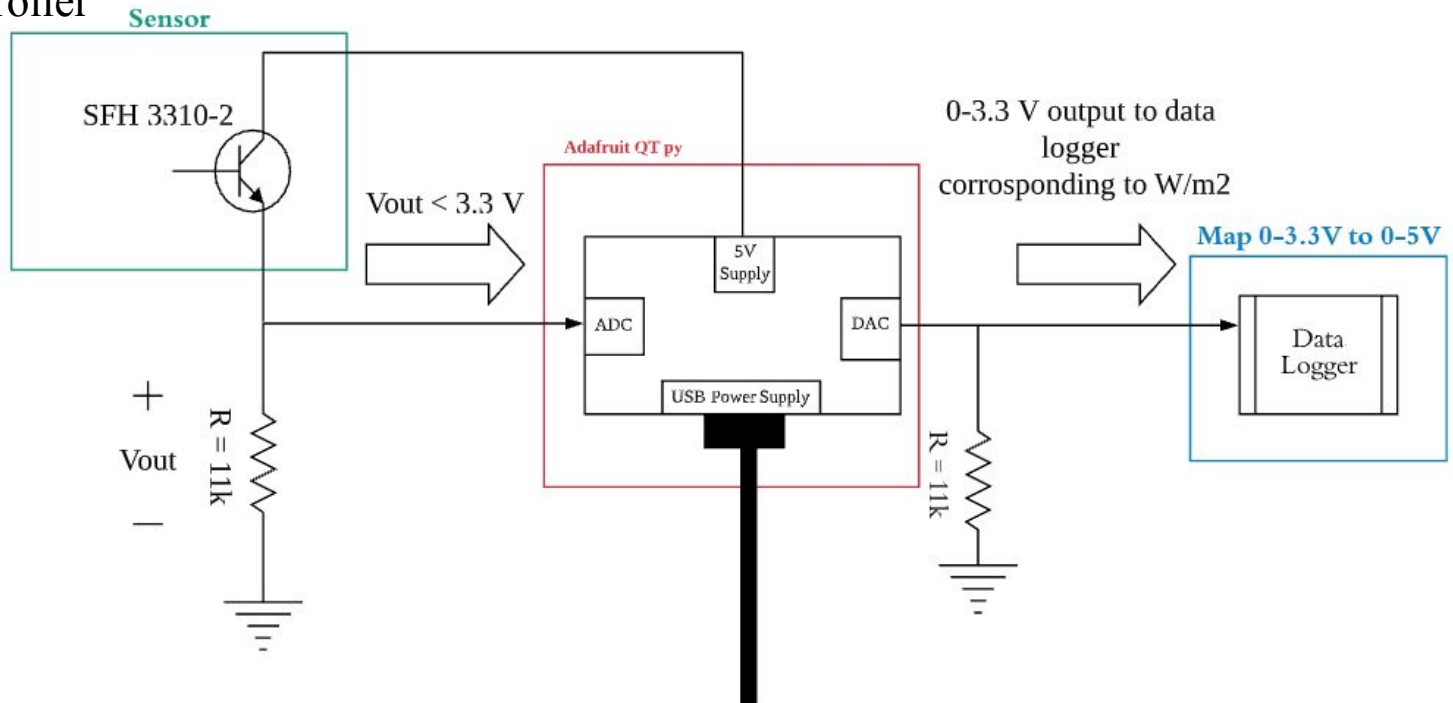
- Affordable: \$20 - \$80.
- Accurate: less than 15% error.
- Concise: Include instructions



# Preliminary Proof of Concept

Our prototype can be broken up into three subsystems:

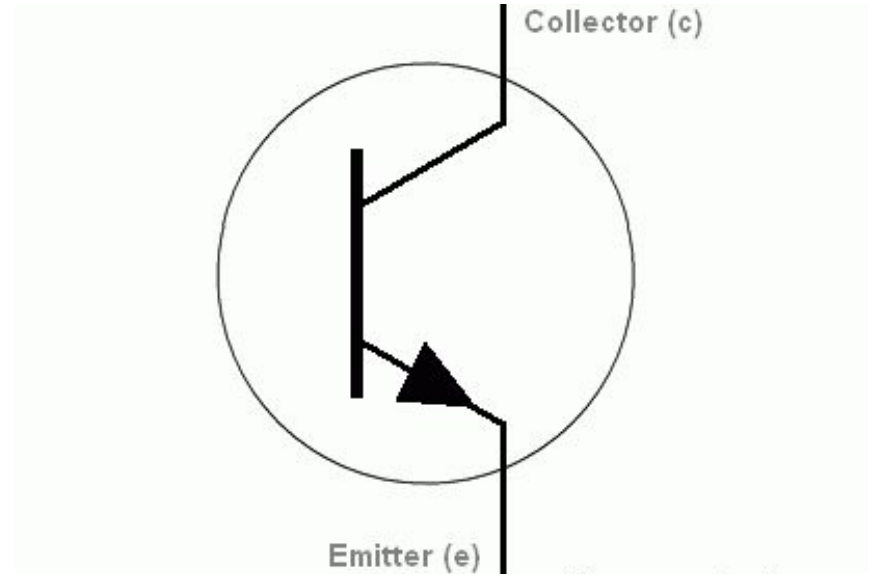
- Sensor
- Microcontroller
- Output mapping



# The Sensor

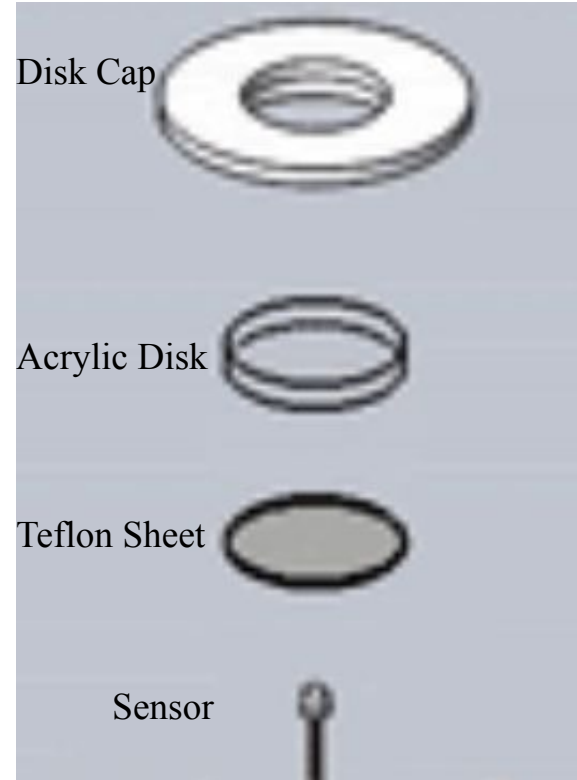
## SFH 3310 Phototransistor

- Light-sensitive transistor
- 150° field of view
- Cost: \$0.64 per unit
- Wavelengths: 350 nm to 970 nm



# Light Attenuation

- Use a Teflon Sheet to attenuate light.
  - This will keep our sensor from saturating
- Teflon protected with Acrylic Disk.
- All of this is secured with a Disk Cap

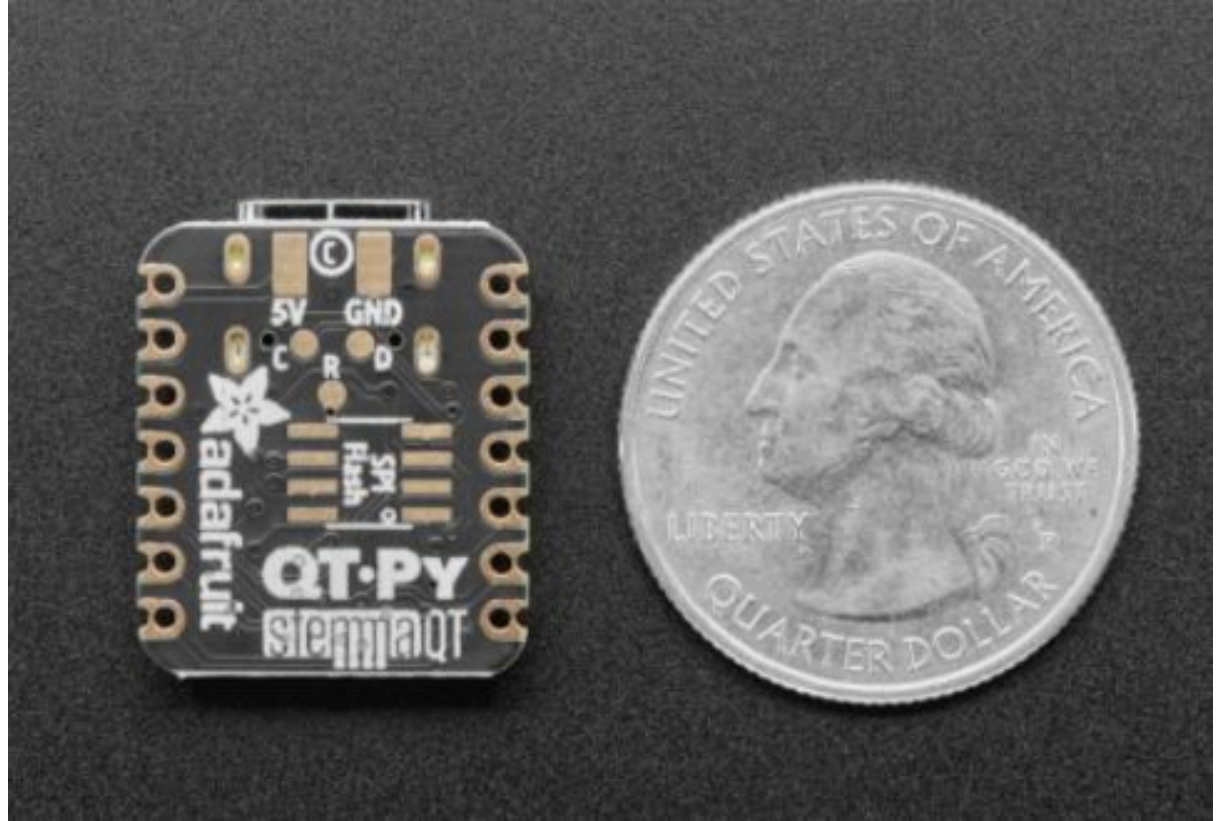




# The Microcontroller

## Adafruit QT py

- 0-3.3V
- 12-bit Input
- 10-bit DAC Output
- 256 kB flash memory
- 32 kB RAM
- Affordable: \$6.00



# Output Mapping

Uses a process called Linear Interpolation.

- Using the formula:

$$B = \frac{(A - a_0)(b_1 - b_0)}{(a_1 - a_0)} + b_0$$

A on range  $(a_0, a_1)$

B on range  $(b_0, b_1)$

We can map the value, A, on one range to its equivalent value, B, on another.

- Map our 0-3.3V output to the required 0-5V output by programming our data logger

# Project Management: Schedule

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	TASK COMPLETE	Jan. 25, 2021		Feb. 1, 2021		Feb. 8, 2021		Feb. 15, 2021		Feb. 22, 2021		Mar. 1, 2021		Mar. 8, 2021					
							M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W
<b>1</b>	<b>Project Conception and Initiation</b>	<b>Lukas</b>																						
<b>2</b>	<b>Prototyping</b>	<b>Adriana</b>																						
2.01	Create funding proposal	Lukas and Adriana	10/5/20	10/10/20	5	100%																		
2.01.2	Order Initial Supplies	Lukas will email Dr. Li	10/26/20	10/30/20	4	100%																		
2.02	Update Budget	Lukas V	10/7/20	10/23/20	16	90%																		
2.03	Design Case Prototype	Nick B.	11/30/20	2/19/21	79	80%																		
2.035	Simulate Case Durability	Nick B.	2/15/21	2/19/21	4	100%																		
2.04	Start Code for the Microcontroller	All sailors	11/9/20	3/1/21	112	60%																		
2.05	Assemble Circuit	Lukas, Brady, Adriana	11/30/20	3/1/21	91	35%																		
2.06	Assemble Prototype	All Sailors	2/10/21	3/13/21	33	10%																		
2.07	Test Pyranometer accuracy	All Sailors	3/15/21	4/3/21	18	0%																		
2.08	Print Case Prototype	Nick B.	2/22/21	3/1/21	9	0%																		
2.09	Refine Prototype Design	All Sailors	2/8/21	5/8/21	90	20%																		
2.1	Create Updated Parts list, if needed	Nick B.	1/6/21	2/17/21	41	100%																		
<b>3</b>	<b>Refining Design</b>	<b>Brady</b>																						
3.01	Order Updated Parts List	All Sailors	1/6/21	2/17/21	41	100%																		
3.02	Construct Updated Circuit	Lukas, Brady, Adriana	2/15/21	3/12/21	27	0%																		

# Low Cost Pyranometer for KiloWatts for Humanity

Project: KiloWatts- Developing a low-cost pyranometer (One unit)

Last Updated 02/17/21

Expense Items (\$)	Year								Item Total
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Equipment/Tools:									\$0.00
Travel:									\$0.00
Gas									\$0.00
Supplies / Parts / Services:									\$0.00
Teflon Sheets						\$12.30			\$12.30
3D printing filament						\$20.69			\$20.69
Acrylic Disks						\$20.00			\$20.00
Fasteners									\$0.00
Arduino Nano Every Headers			\$4.99						\$4.99
Resistors			\$6.99						\$6.99
Capacitors			\$4.92						\$4.92
Op Amp NJM5532DD - 10 pack			\$10.50						\$10.50
Photo Transistor SFH 3310			\$8.57						\$8.57
Electrical wiring									\$0.00
Adafruit QT py-4 count					\$24.00				\$24.00
Arduino Nano Every - 6 pack			\$55.80						\$55.80
Weather proofing									\$0.00
Shipping costs/postage			\$19.05		\$9.59	\$15.18			\$43.82
Circuit Board									\$0.00
Expo Costs									\$0.00
Taxes			\$0.85			\$1.98			\$2.83
									<b>Expenses Subtotal</b>
									\$215.41
Shop Usage (Hrs):									Hours
3D Printing									0
Prototype construction				2	2	2.5			6.5
Solar lamp calibration(?)									0
Prototype field testing									0
									0
									0
									Shop Overhead
									\$10.00
									10% Error
									\$21.54
									<b>Totals</b>
									\$246.95
									\$400.00
									\$153.05
									Costs Budget Excess

# Our Budget

# Cost Per Unit

- Goal: \$20-80

QT py design			
Current Cost Per Unit			
Item	Total Cost	Quantity	Cost for 1 Unit
11k Resistors (200)	\$3.60	200	\$0.04
Adafruit QT py	\$24.00	4	\$6.00
3D printing filament*	\$20.69	1	\$1.00
Photo Transistor SFH 3310 (10 count)	\$8.57	10	\$0.86
Acrylic Disks	\$20.00	10	\$2.00
Teflon Sheet*	\$12.30	1	\$3.08
			Current Cost Per Unit
*Estimate			\$12.98

# Bill of Materials

## Capstone Design

Combined BOM and Manufacturing Plan: Low-Cost Pyranometer

Indented Bill of Materials (BOM)			Manufacturing Plan						Cost		
Part No. or Assy No.	Description	Quantity	Make or Buy?	Source (or Fabrication Location)	Fabrication Technique (if appl.)	Is the Drawing Avail.?	Is the Material Avail.?	Who will lead (Name)?	Target Completion Date	Unit Cost (\$)	Extended Cost (\$)
<b>Full Assy 1</b>											\$ -
Subassembly 1	Sunlight Capture	1									\$ -
Subassembly 2	Microcontroller	1									\$ -
Subassembly 3	Output to Data Logger	1									\$ -
Subassembly 4	Case	1									\$ -
<b>Subassembly 1 Sunlight Capture</b>		<b>1</b>									\$ -
Part 1	SFH 3310 Phototransistor	1	Buy	Mouser	N/A	No	Yes	Lukas V.	1-Mar	\$ 0.86	\$ 0.86
Part 2	Teflon Sheet	1	Buy	ePlastics	N/A	No	No	Lukas V.	1-Mar	\$ 3.08	\$ 3.08
Part 3	Acrylic Disk	1	Buy	USplastics	N/A	No	No	Lukas V.	1-Mar	\$ 2.00	\$ 2.00
Part 4	Resistor	1	Buy	Mouser	N/A	No	Yes	Lukas V.	1-Mar	\$ 0.02	\$ 0.02
<b>Subassembly 2 Microcontroller</b>		<b>1</b>								\$ -	\$ -
Part 5	Adafruit QT py	1	Buy	Adafruit	N/A	No	Yes	Adriana O. and Brady J.	1-Mar	\$ 6.00	\$ 6.00
<b>Subassembly 3 Output to Data Logger</b>										\$ -	\$ -
Part 6	Resistor	1	Buy	Mouser	N/A	No	Yes	Lukas V.	1-Mar	\$ 0.02	\$ 0.02
<b>Subassembly 4 Case</b>										\$ -	\$ -
Part 7	Circuitry Housing	1	Make	Personal Equipment	3D Print from PETG	Yes	No	Nick B.	1-Mar	\$ 0.20	\$ 0.20
Part 8	Housing Lid	1	Make	Personal Equipment	3D Print from PETG	Yes	No	Nick B.	1-Mar	\$ 0.20	\$ 0.20
Part 9	Acrylic Disk Cap	1	Make	Personal Equipment	3D Print from PETG	Yes	No	Nick B.	1-Mar	\$ 0.20	\$ 0.20
Part 10	USB Cord Seal: Upper Piece	1	Make	Personal Equipment	3D Print from PETG	Yes	No	Nick B.	1-Mar	\$ 0.20	\$ 0.20
Part 11	USB Cord Seal: Lower Piece	1	Make	Personal Equipment	3D Print from PETG	Yes	No	Nick B.	1-Mar	\$ 0.20	\$ 0.20
<b>Total BOM Cost</b>										<b>\$</b>	<b>12.98</b>

# Material Selection 3D Printing (ABS vs PETG)

## ABS

- Higher temperature
- Strength characteristics
- Cheaper
- Toxic

Recommendation: use ABS when cost is a significant concern and you have the proper printing setup.

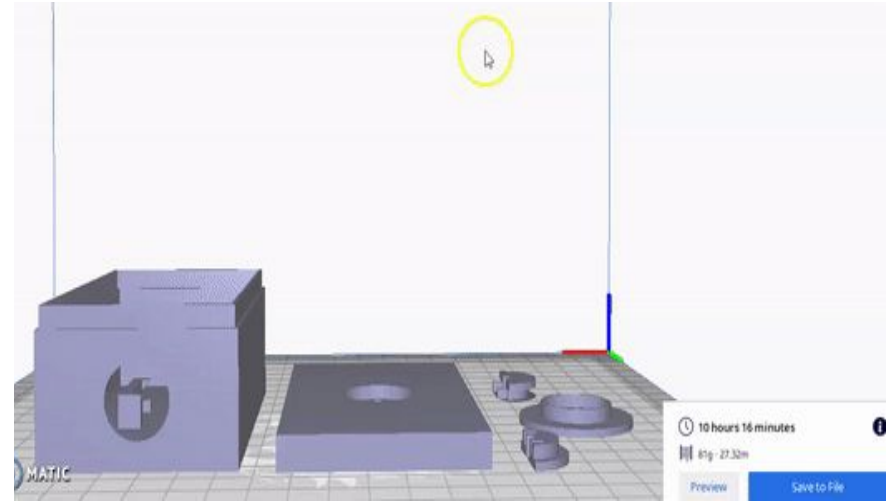
## PETG

- Solar resistance
- More expensive.
- Intermediate print difficulty

Recommendation: use PETG when economically and structurally possible since its UV resistance makes up for its downsides.

# 3D printing

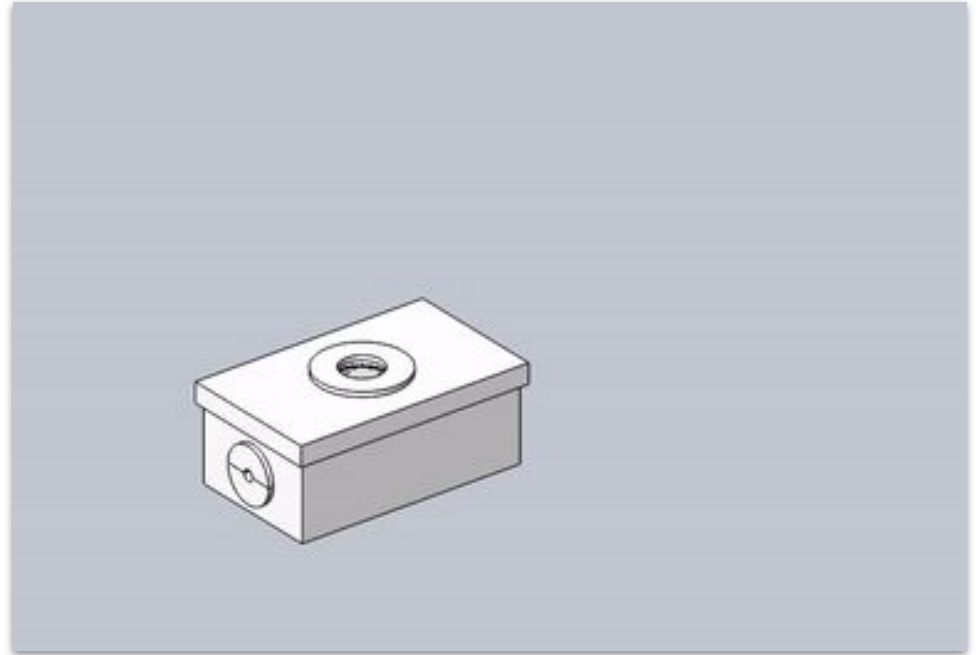
- Overhangs can not exceed 45 Degrees
- Max tolerance is  $\pm 0.4\text{mm}$
- Print time estimated to be about 10hrs
- Printed via Anycubic Kossel Linear Plus





# Case Design

- 3D printed made with PETG
- Currently uses press fittings to save on cost and make it easy to assemble
- Cost per case assembly is roughly \$1.00
- The wire clamp and the glass holder will be held in place using adhesive



# Case Validation (Shear)

PETG:

Yield Strength: 6.95KSI

Shear Strength: 4.75KSI

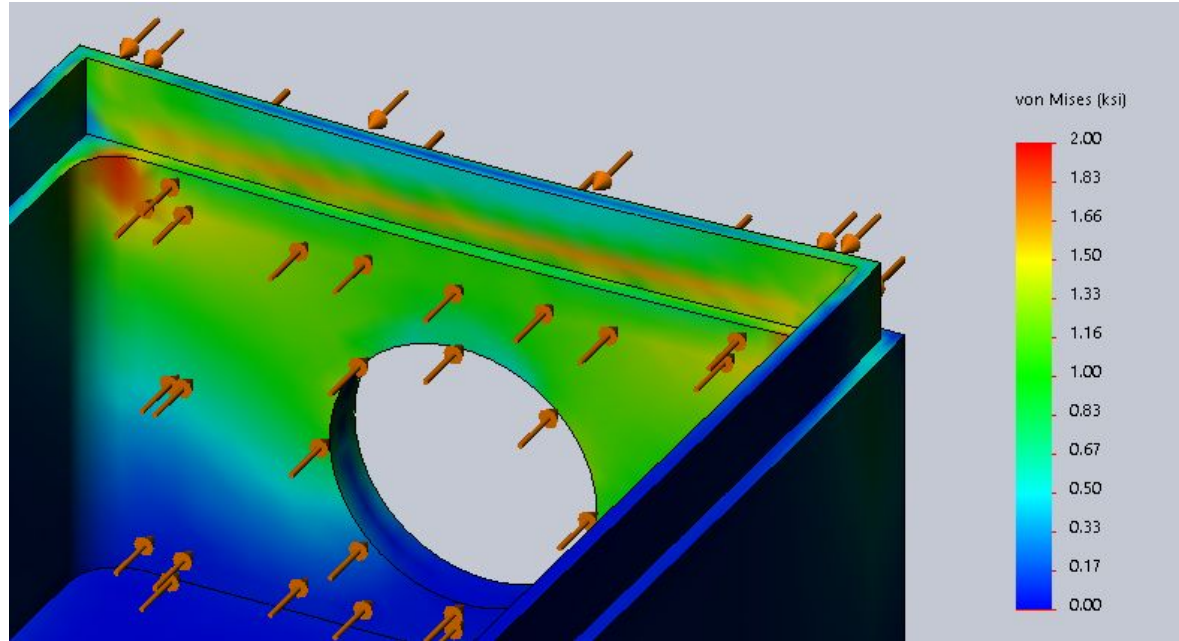
Factor of Safety: 2

Load Conditions:

20lbf on the flange and the main body to  
result in shear

Results

Max Stress: 2KSI



# Case Validation (Drop)

PETG:

Yield Strength: 6.95KSI

Shear Strength: 4.75KSI

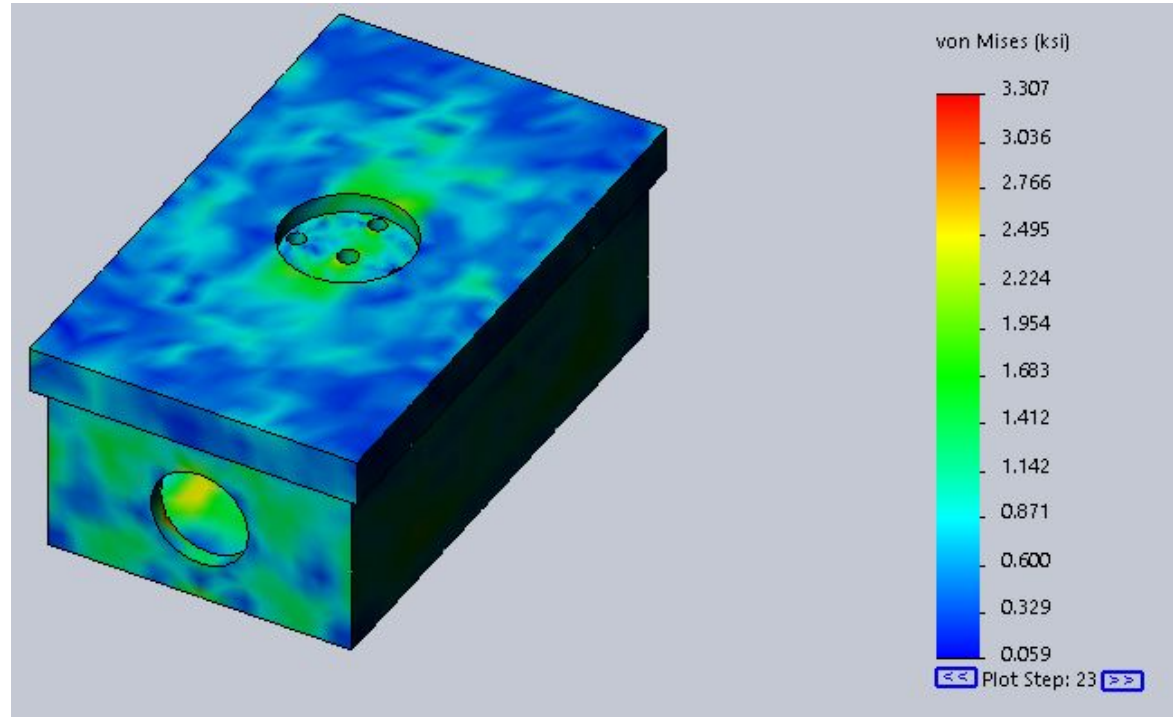
Factor of Safety: 2

Load Conditions:

The case starts from rest and is then dropped from 6ft and impact a fixed surface.

Results

Max Stress: 3.307KSI



# Design Validation Plan

## Virtual Testing

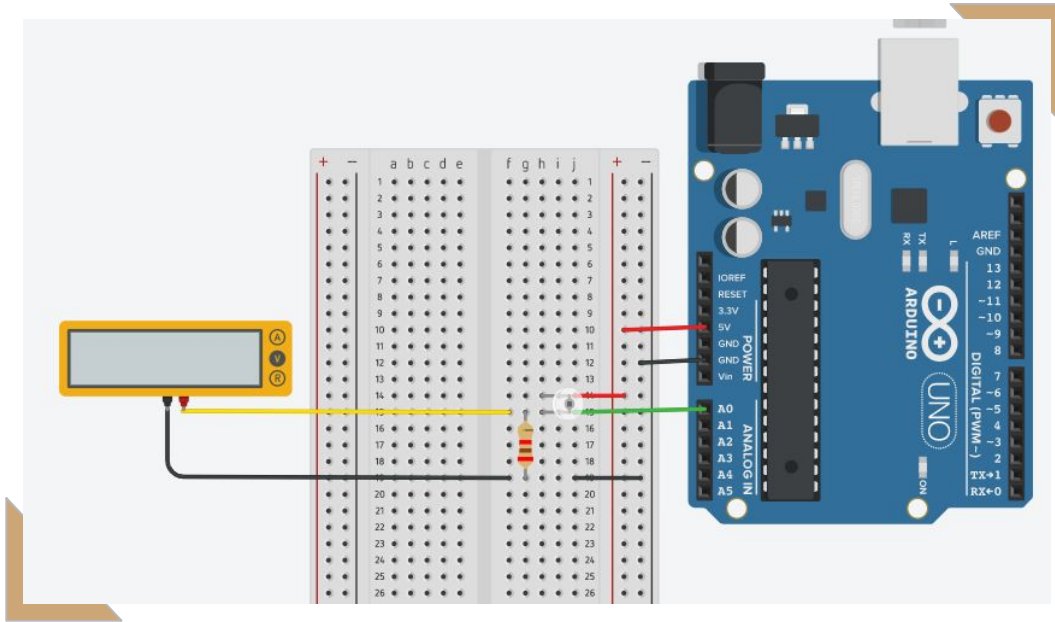
- TinkerCAD simulations
- Case testing, such as the impact tests

## Physical Testing

- Q-Sun Xenon Tester
  - Irradiance and temperature tests
  - Environmental:
    - Weather testing against water, heat, etc
- Compare with other pyranometers
  - Observe outputs and readings



# TinkerCAD Simulations



# Risk Management

## Sensor Oversaturation

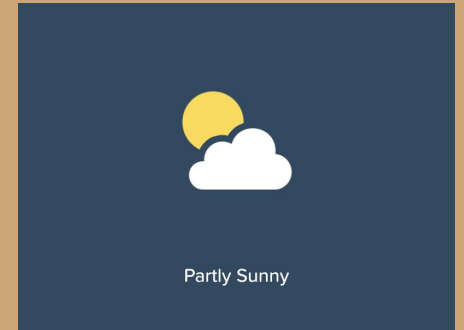
- Teflon sheet to allow for better transmittance
  - Ratio of light energy on a body to energy transmitted
  - Good at diffusing the incoming light

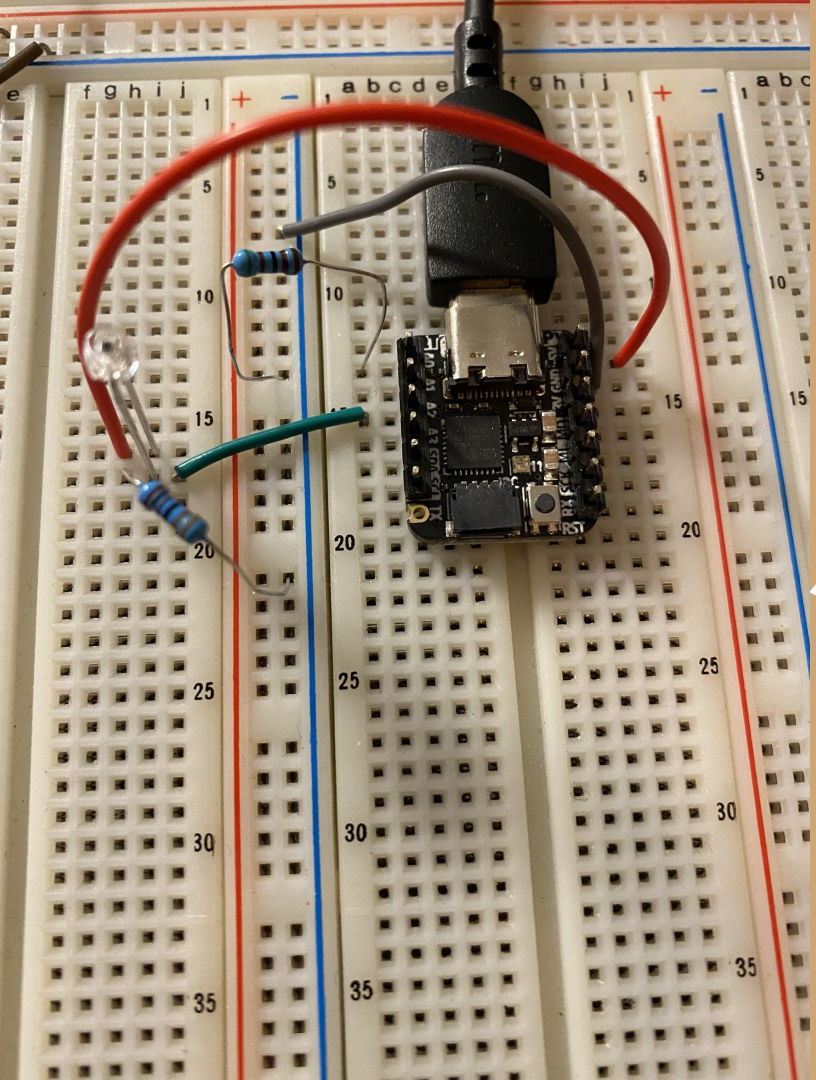
## Environmental Risks

- Weather-proof exterior, and protected components
  - Acrylic holder, sealing lid, etc

## Broken/Malfunctioning Parts

- Removable casing to easily replace parts





# Our Circuit

*Any Questions?*