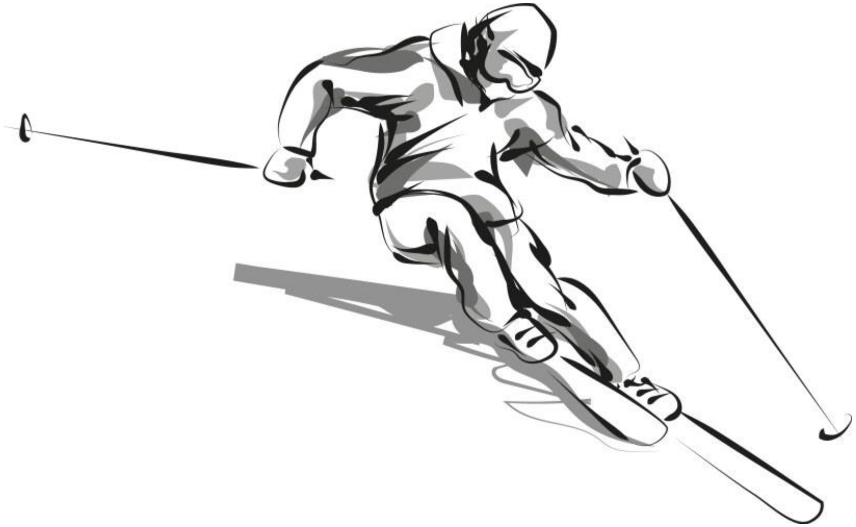
JumpGuard Preliminary Design Review



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Advisor: Dr. Kevin Repasky

Date: 10/31/2024

Problem Statement

Problem Motivation:

Many ski resorts today have terrain parks, which are collections of jumps and obstacles that can be ridden by athletes. Depending on the size of terrain park jumps, athletes can't always see the landing area before committing to the jump. So, if an athlete crashes on the bottom of a larger jump, athletes uphill may not be aware of the risk of collision awaiting them at the bottom of the jump.

Project Description:

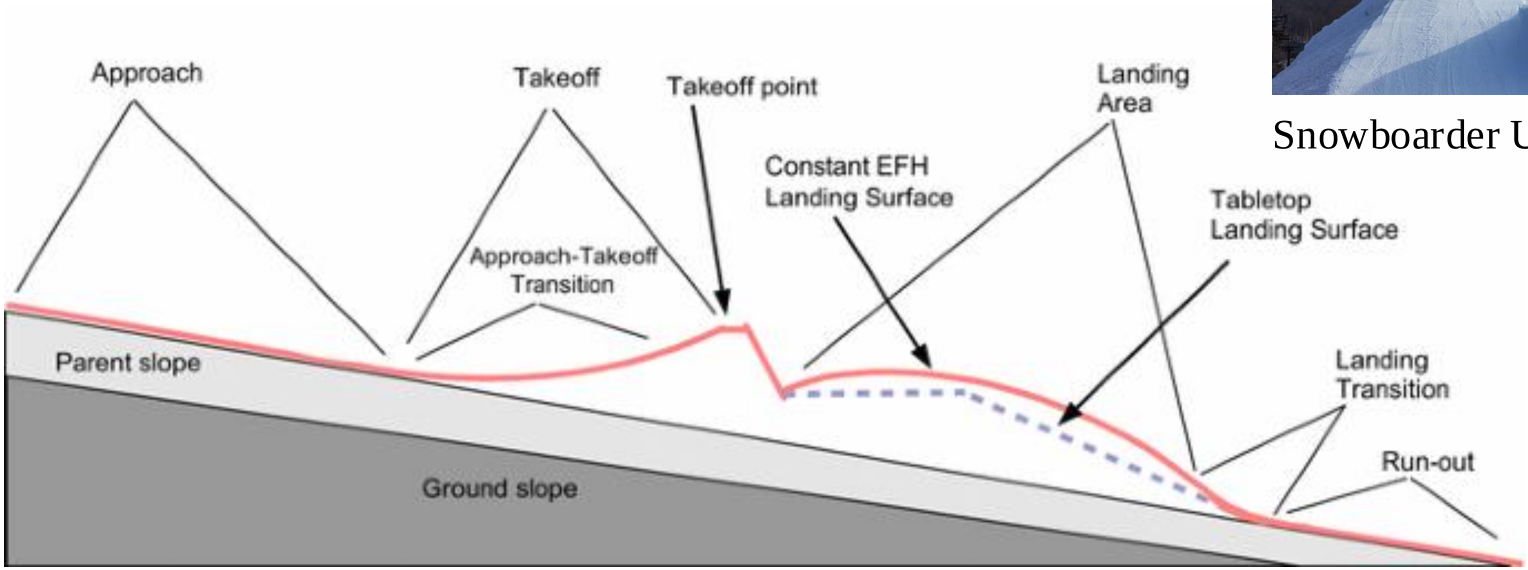
A system will be designed to detect when the landing area is clear before notifying the next athlete that it is safe to proceed from the top of the hill.

Objectives:

This system will determine whether the landing area below a jump is clear, and then report the status to athletes uphill from the landing area. The system must operate in inclement weather throughout the ski-season. The system will operate on a stand-alone power system to avoid running power lines to the system, which could create unnecessary hazards.

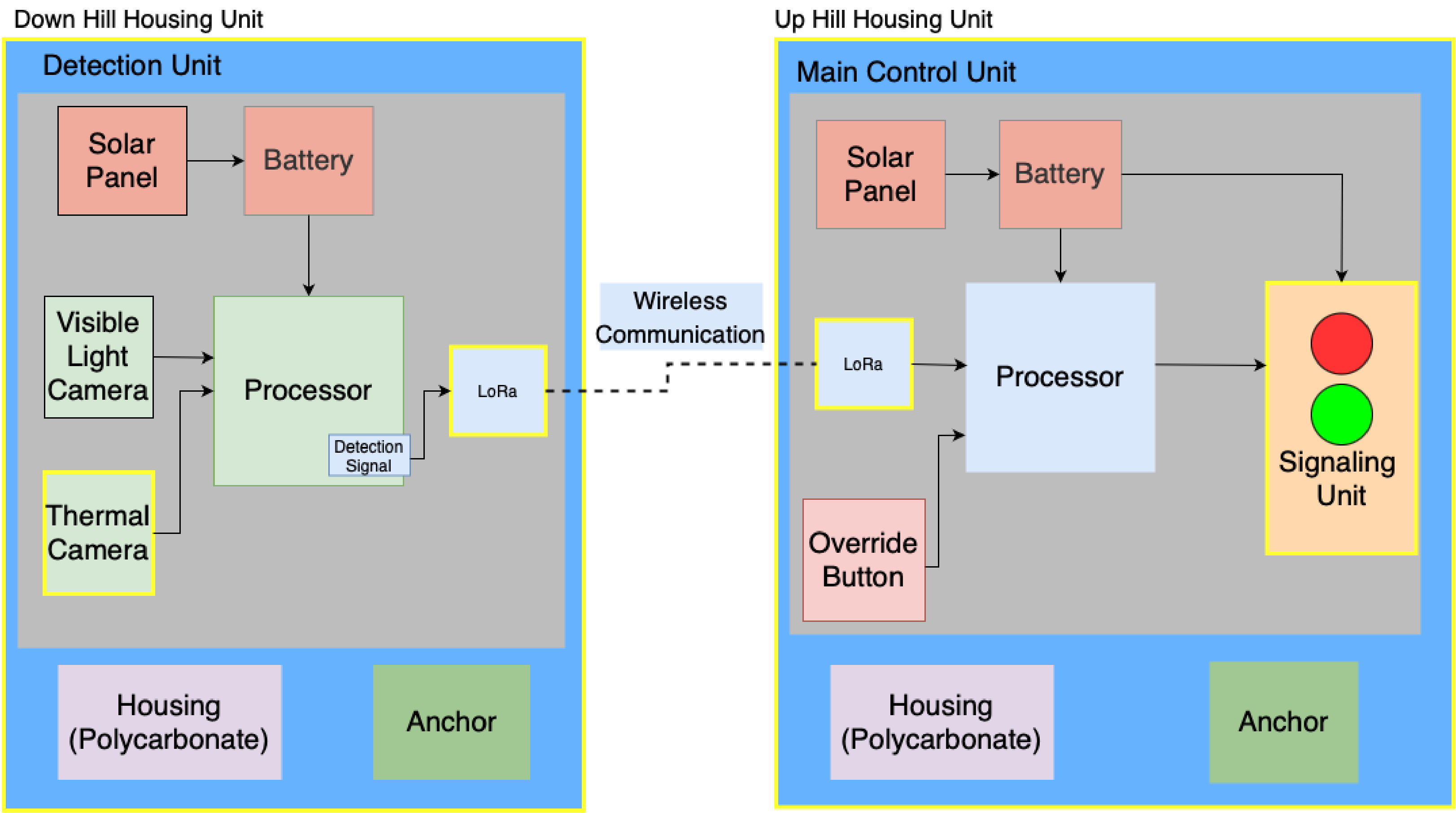
Necessary Background

Snowboarder Using Large Jump



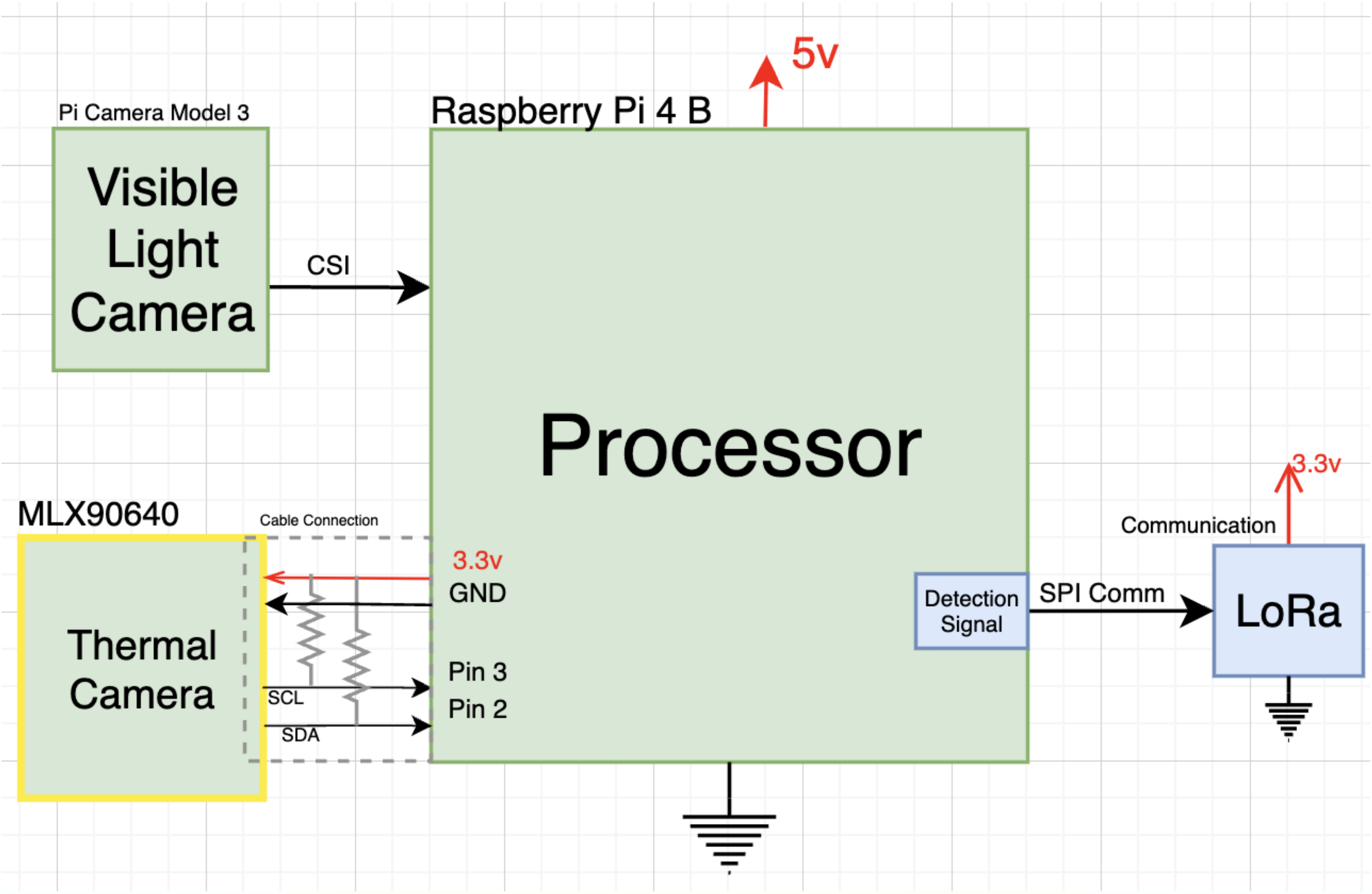
Terrain Park Jump Diagram

Project Design Concept



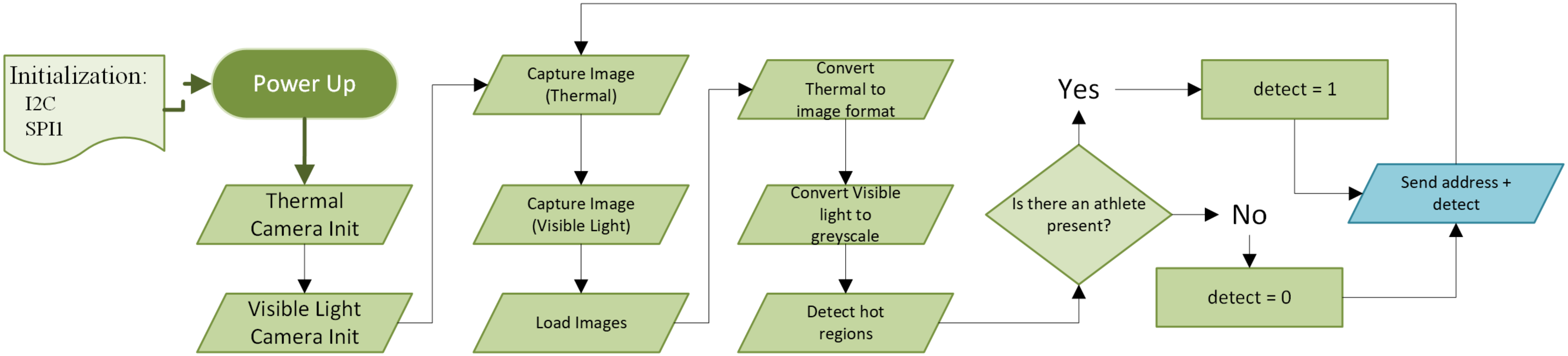
Conceptual Block Diagram

Design Solution: Detection Unit



Detection Unit: Software Design

Thermal Camera



I2C slave address	0x33
RAM start address	0x0400

Detection Unit Preliminary Prototype

Issue/Risk:

- I am unfamiliar with image processing, and how to interpret images in MATLAB

Prototype:

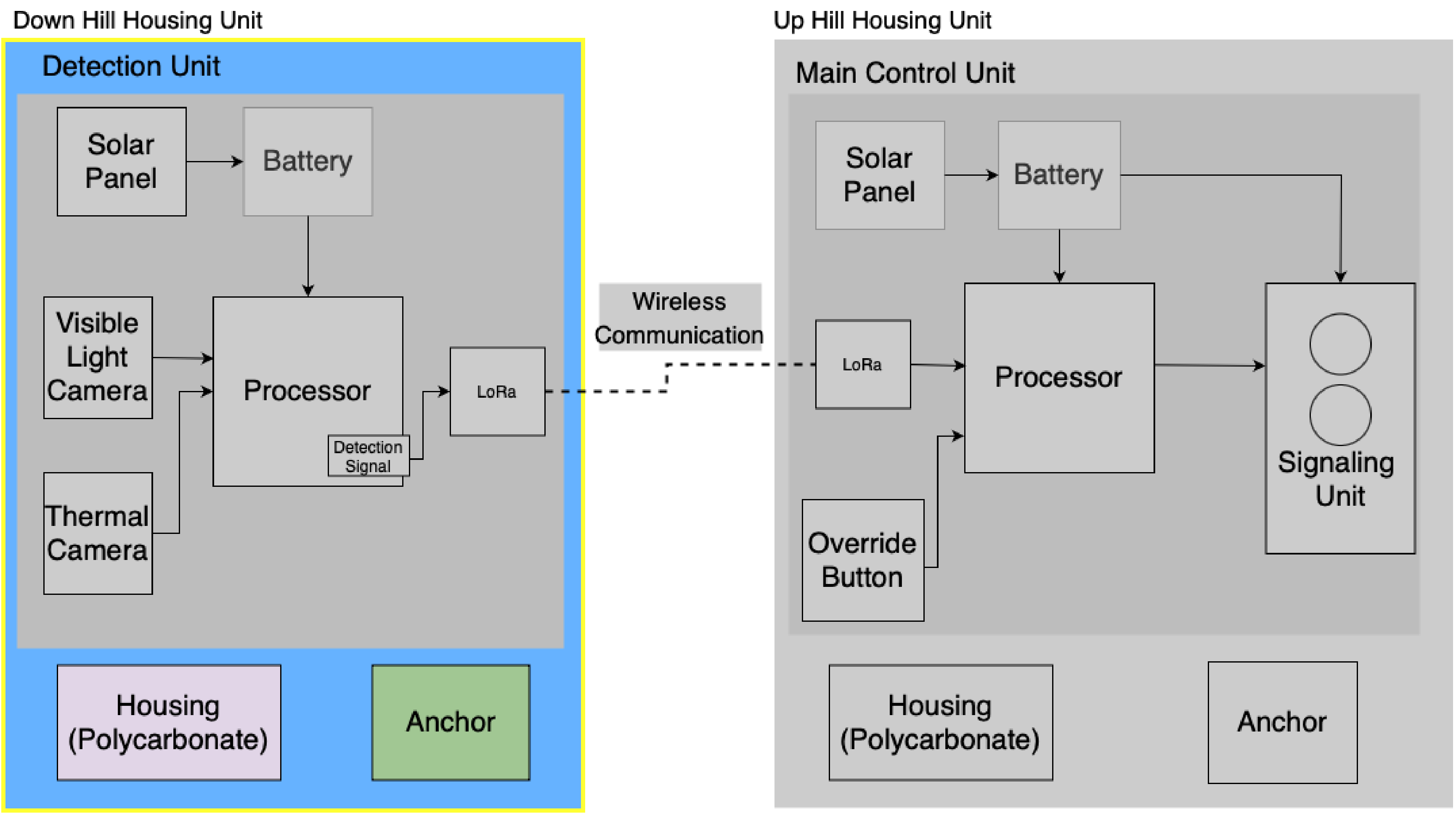
- Gain familiarity with MATLAB image processing toolbox.
- Interpret images in MATLAB (Determine presence of athlete)
- The data to be collected will be the accuracy between different layers of clothing. (Threshold of 95%)

Benefits:

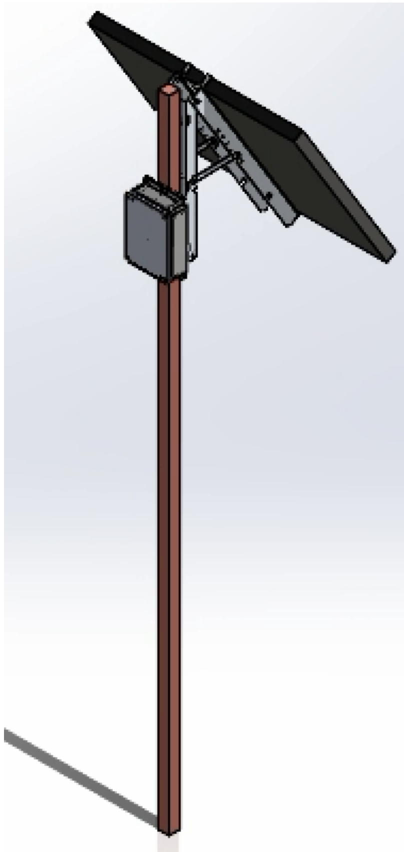
- Doing this will ensure the successful interpretation of the images from the cameras once they are sent to the raspberry pi
- The data will be used to create the program to run the subsystem

Spec 1.1.1) Detection system must be able to detect athletes within a 30x30 ft area within the landing area

Downhill Housing Subsystem



Design Solution: Downhill Housing



3D model of the downhill components mounted on the Polystake

Downhill housing from PolyCase
- Weatherproof
- Clear cover for detection system visibility
- Custom machinability
- Fully adjustable on the stake using U-bolts

6.73 x 4.76 x 2.17 inch case

PolyStake from FallLine
- Same stakes used for marking at resorts such as Bridger Bowl
- Made to bend if ran into by a skier or snowboarder
- 1.25” x 1.25” x 6’ Stake, providing the necessary height for adjustment

Downhill Housing Preliminary Prototype

Issues/Risk:

- The exact solar panel and battery to be mounted is unknown, as we are still determining needed power for the detection unit

Prototype:

- Will test the ability of the Detection Unit to detect through the clear polycarbonate cover
    - Done by collecting images at various decreasing temperatures and comparing them to a test image
    - Data will be analyzed by examining the contrast and the change in dimensions of the gridlines
    - Plot the analyzed data as a function of temperature

Benefits:

- Allow us to make sure the downhill housing fully cooperates with the detection system

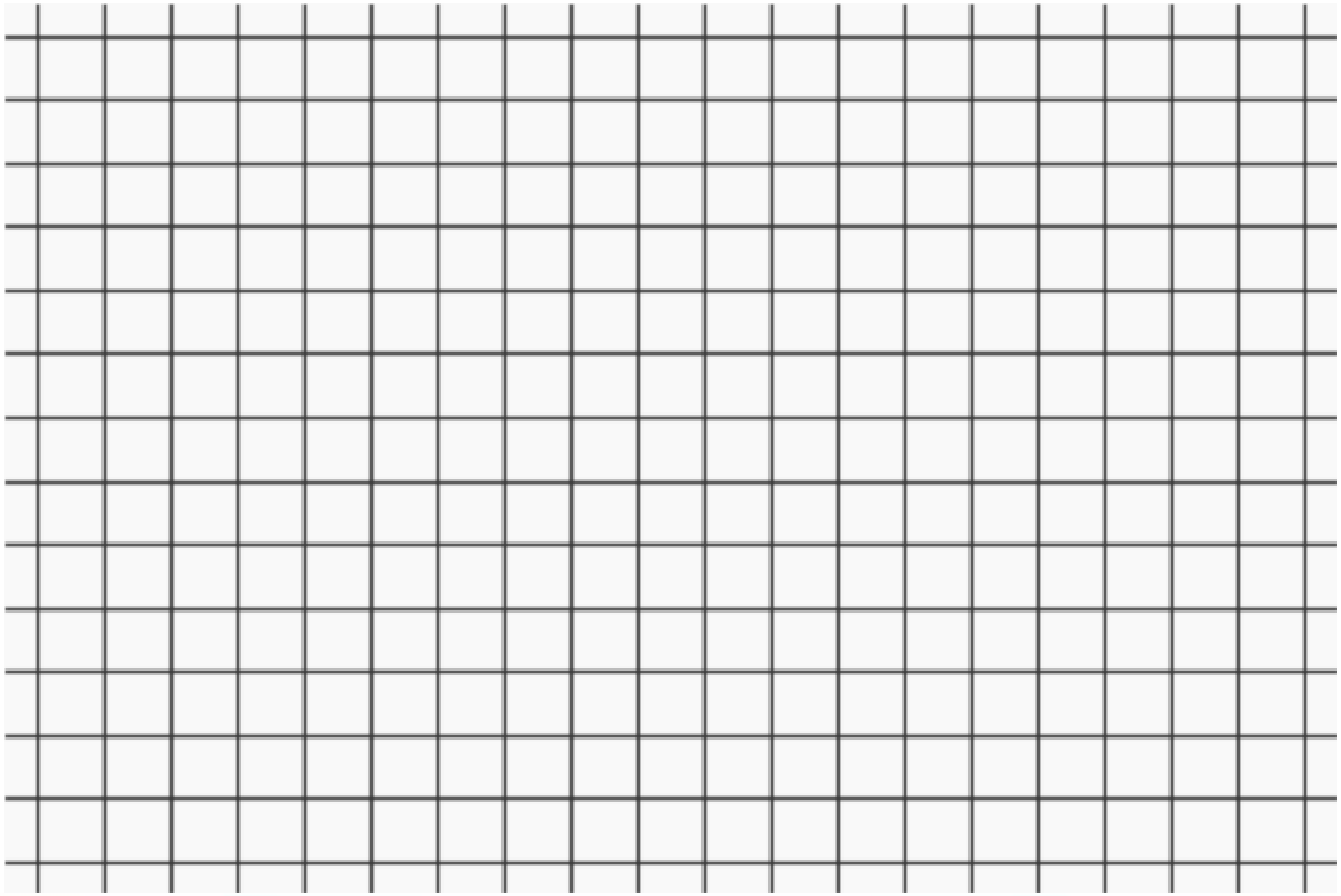
Req 2.1) Must have housing material capable of protecting electronics while ensuring operation in varying weather conditions

Spec 2.1.1) Must be able to withstand and function in temperatures $\geq$ 0°F

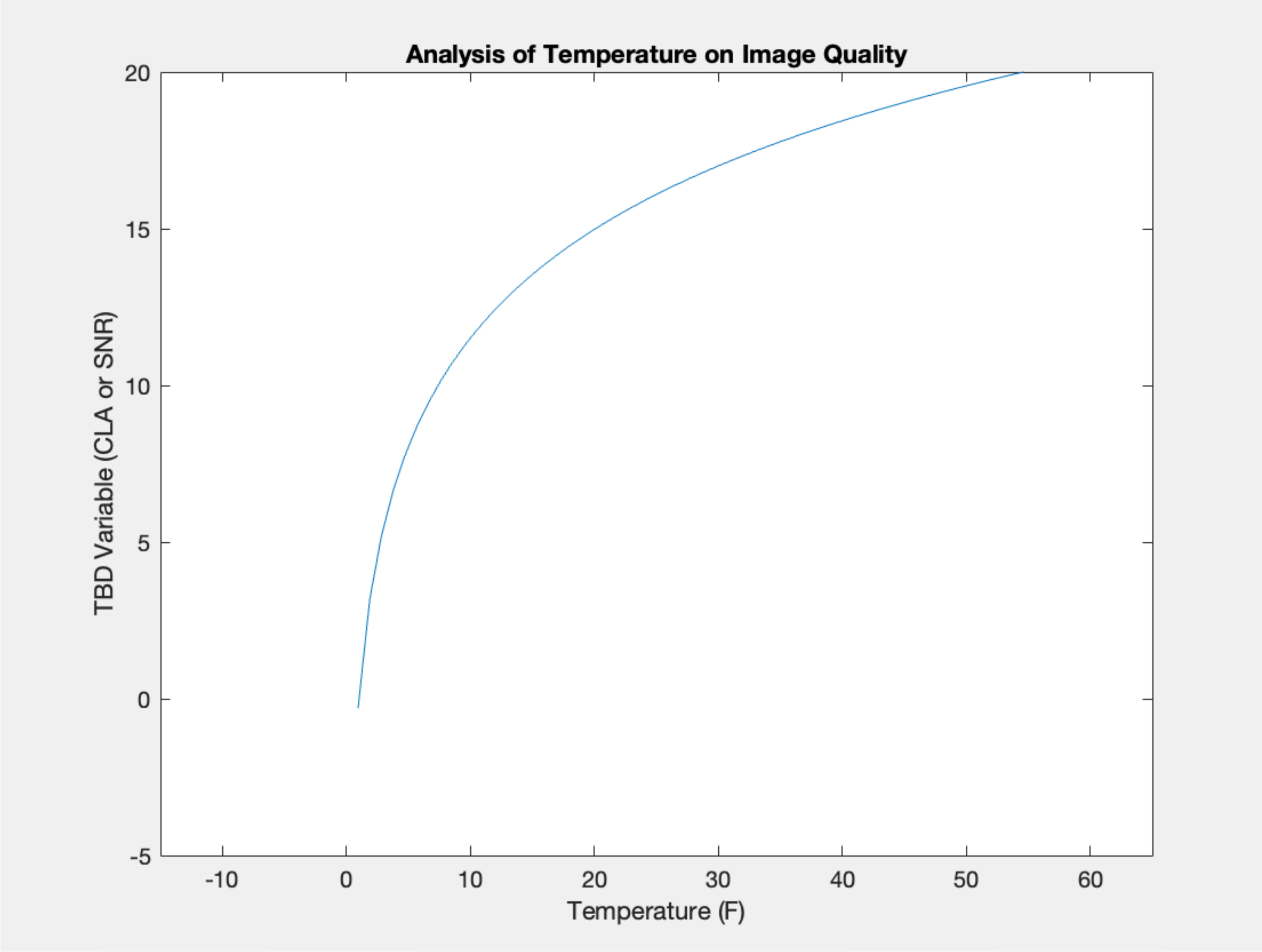
Spec 2.1.2) Must be able to operate in winds up to 20 mph

Spec 2.1.3) System is not meant to operate in visibility lower than 30 ft or

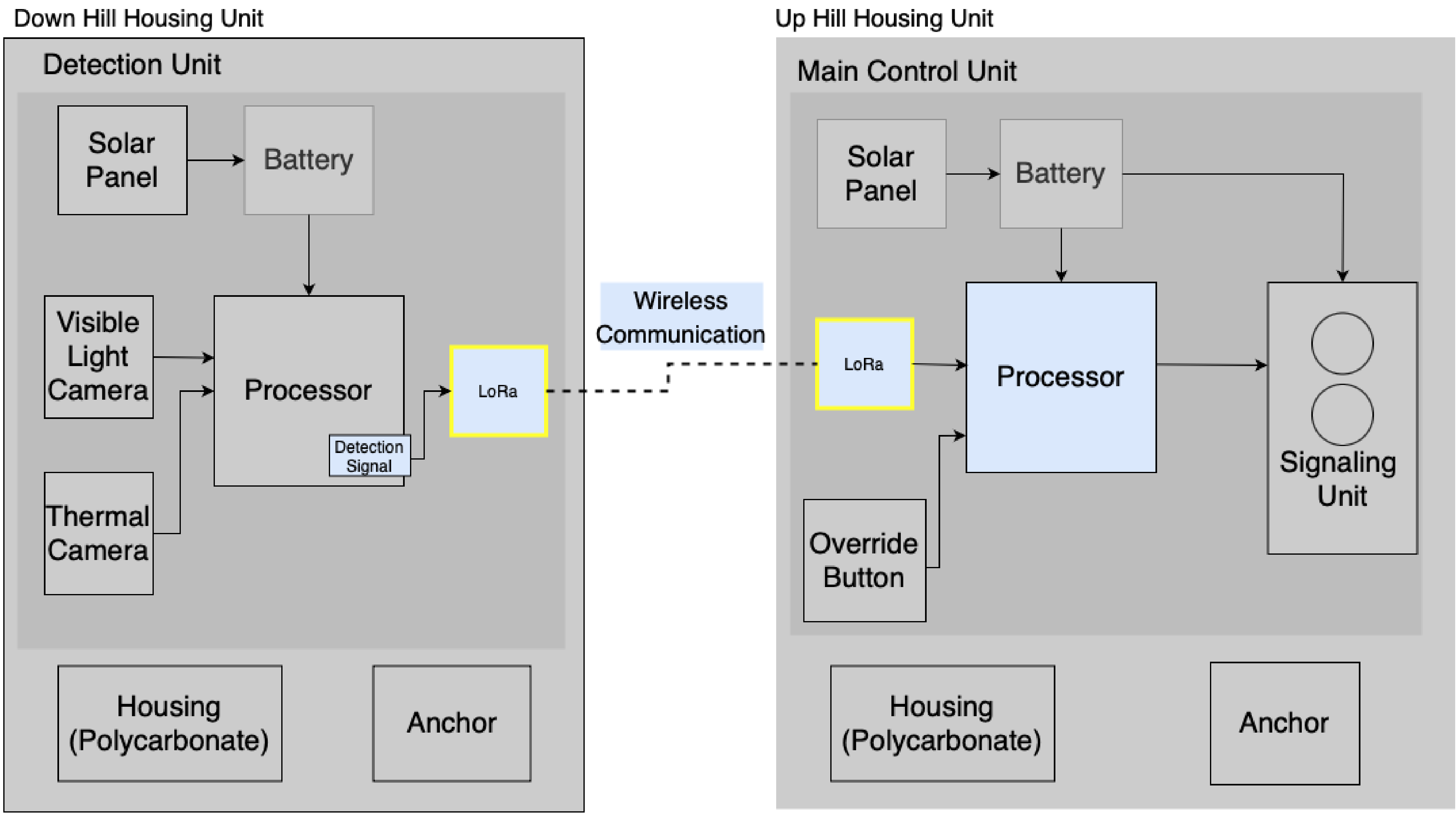
Example Test Image



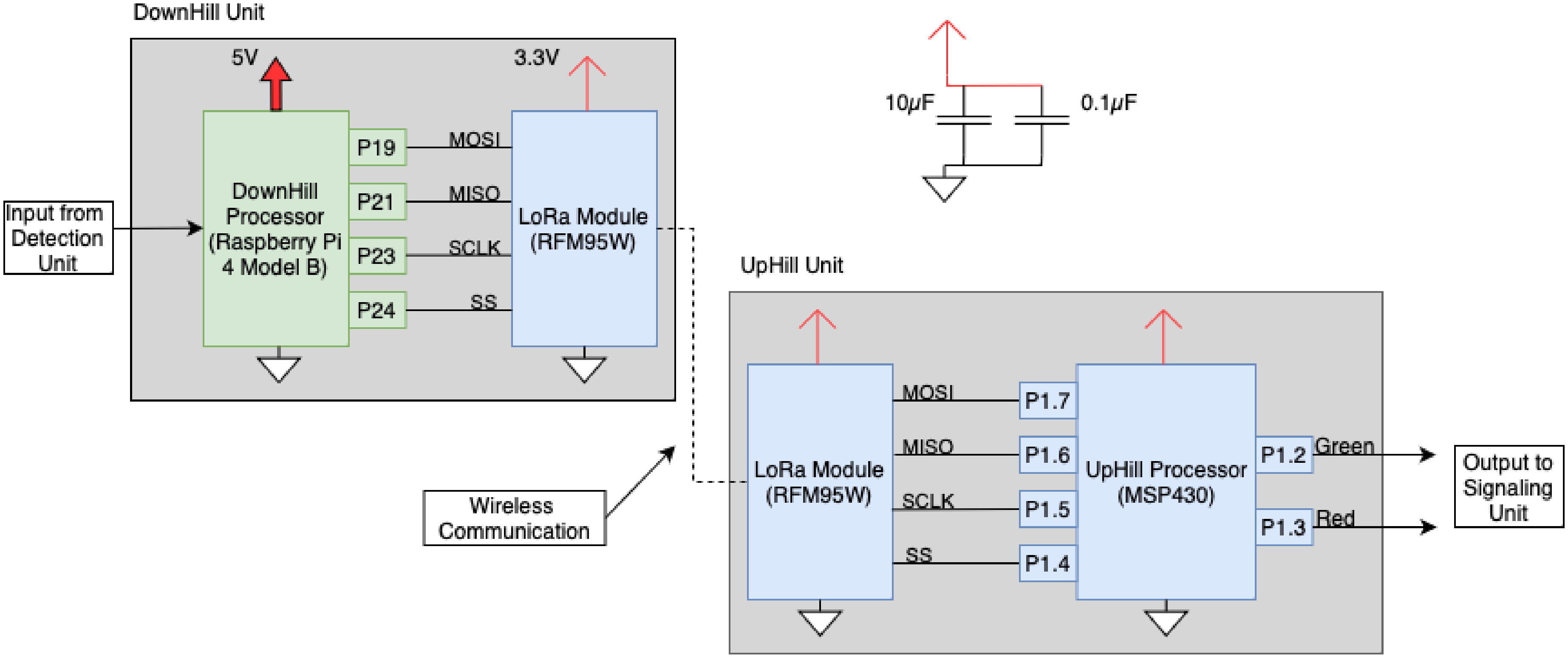
Theoretical Results Plot



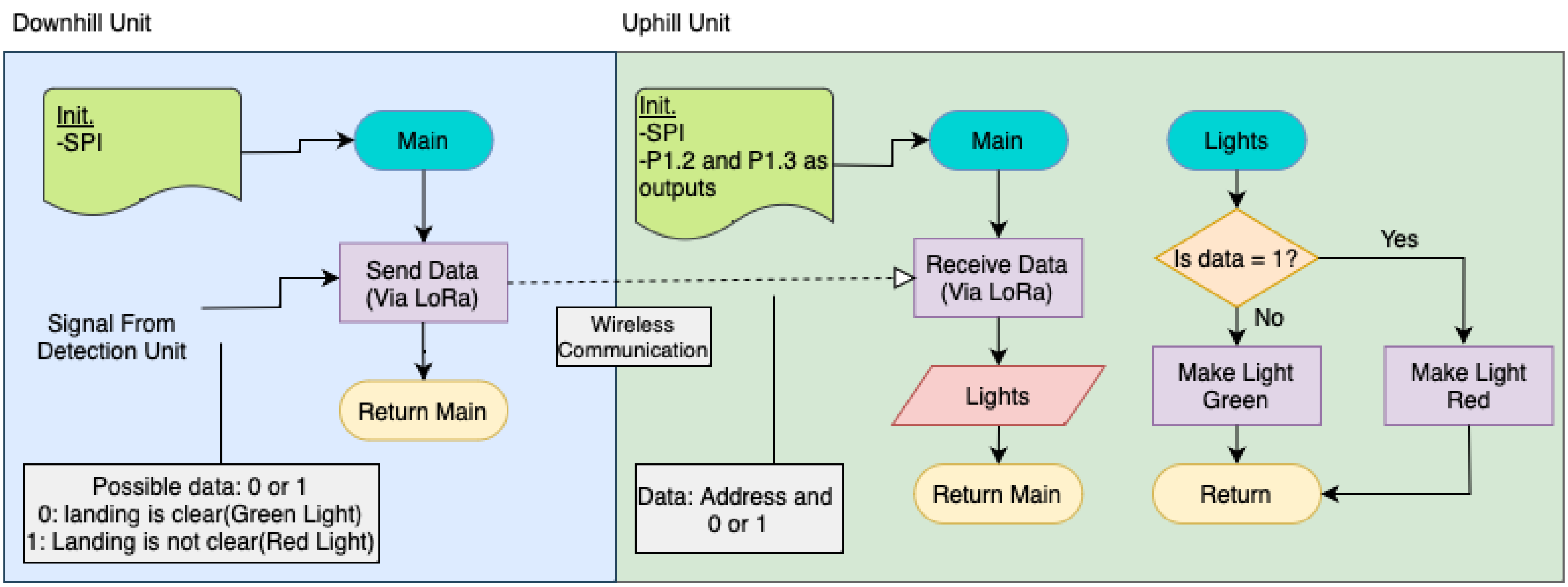
Communication Subsystem



Design Solution: Communication



Design Solution: Communication Flow Chart



Communication Preliminary Prototype

Risk:

- Unfamiliarity with LoRa
- Latency
- Data loss during transmission

Prototype:

- Build the uphill and downhill units, including LoRa modules and processors.

Testing/Data:

- Starting at 60 ft test:
  - Latency: will be plotted as a function of distance
  - Packet loss: will be plotted as a function of distance
- Then test at a range 10ft – 200ft, and without direct line of sight.
- This data will then be used to verify a working subsystem and reveal weaknesses in the system, such as signal strength, latency and packet loss.

Req 1.2) Communication between units must be wireless

Spec 1.2.1) Latency from when the sensor triggers to when the signaling unit triggers must be less than 0.5s

Spec 1.2.2) Dropout rate of information must be less than 2%

Spec 1.2.3) Sensors must communicate with signaling unit from a maximum distance of 60 ft away with a direct line of sight

Communication Preliminary Prototype

To collect latency:

- Send a packet of data from downhill unit to uphill unit.
- Once received, send an acknowledgement back to downhill unit

To measure latency:

- Start a timer on downhill unit before packet is sent and stop timer when acknowledgement is received.
- Start a timer when uphill unit received data and stop timer when ack is sent.

DH timer – UH timer = 2x Latency
Goal: latency $\leq$ 100 ms

To collect Packet loss:

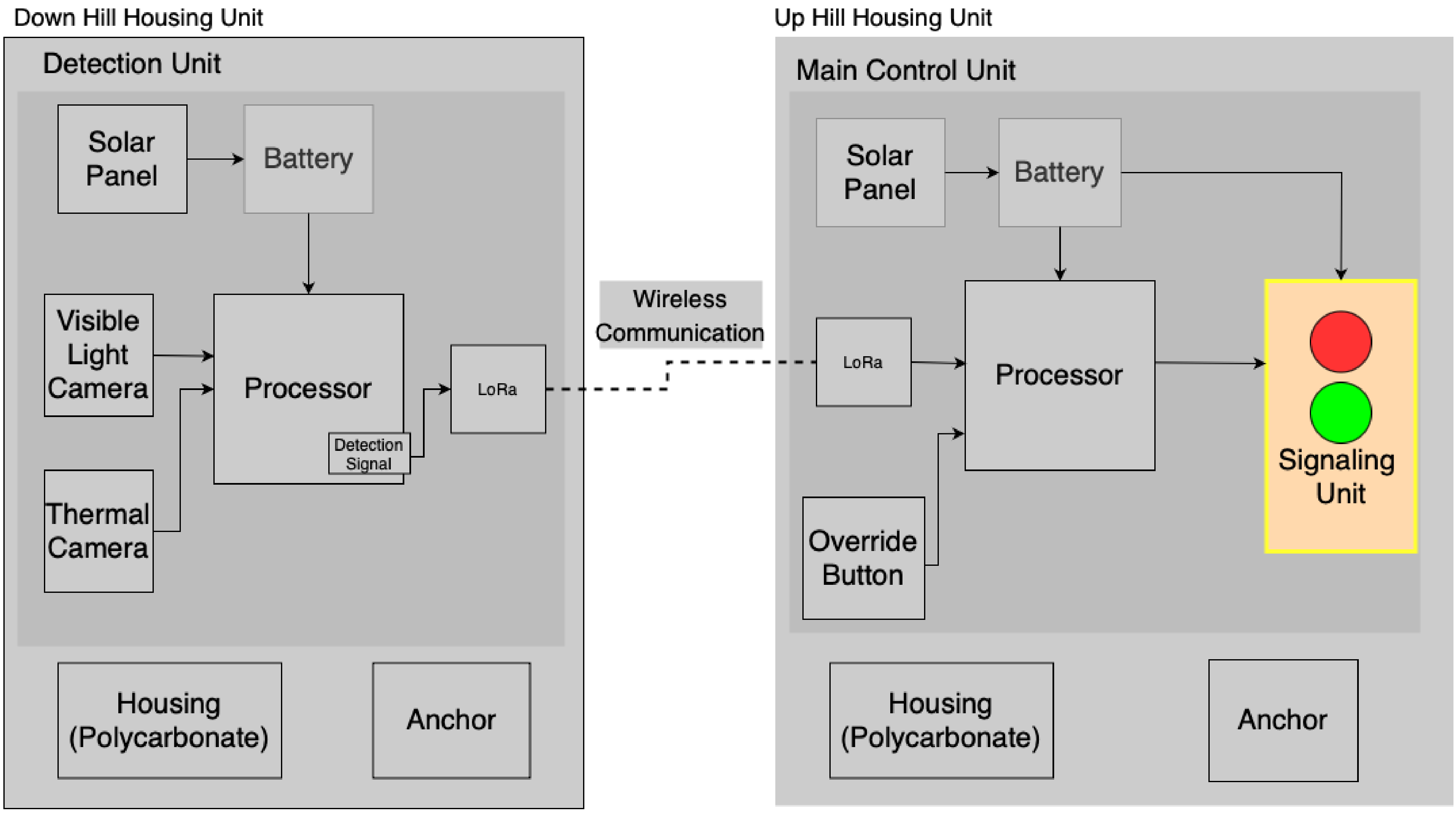
- Send one packet 500 times

To measure packet loss:

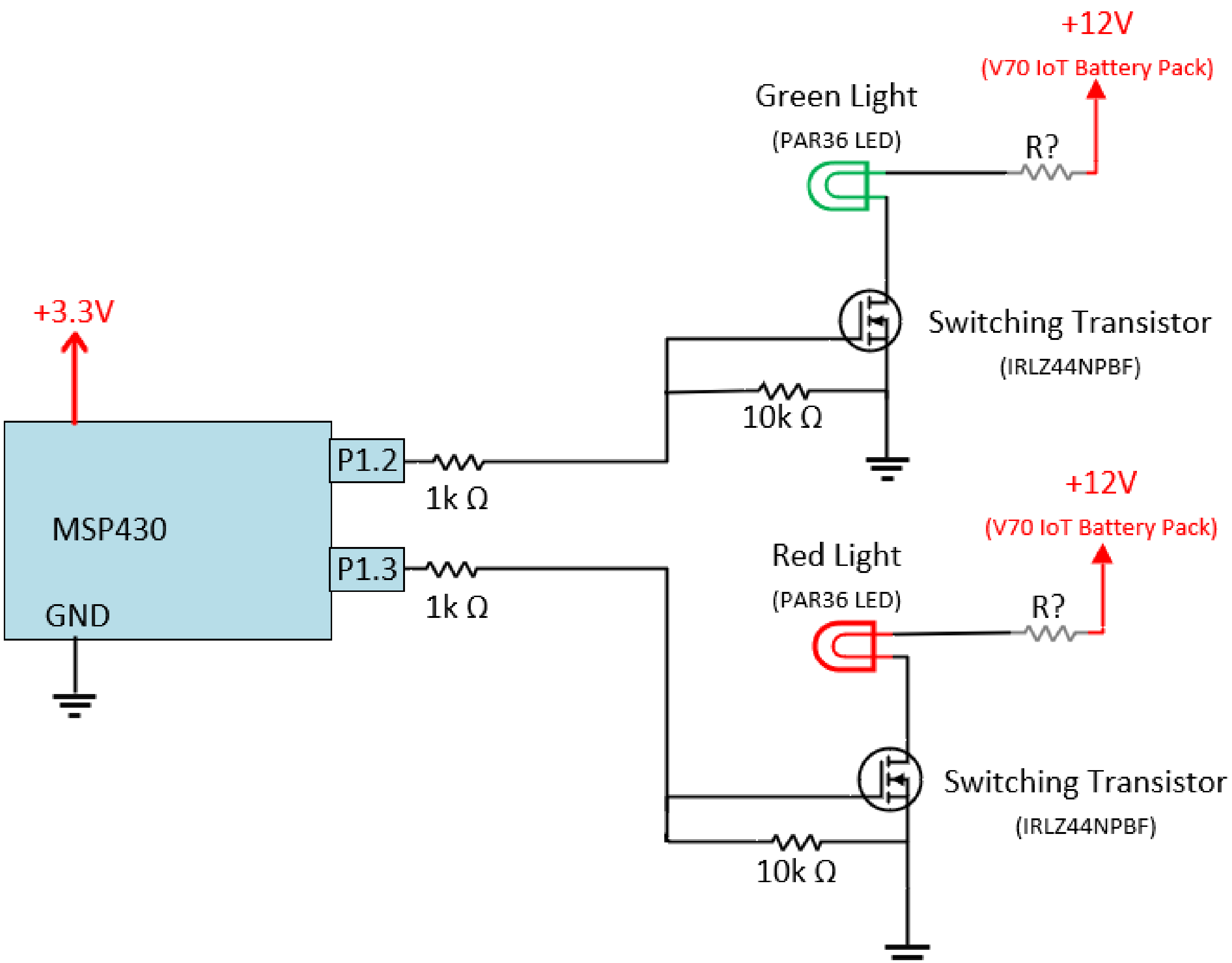
- Measure how many packets were received
- Measure the inaccuracy of packets received

Packet loss % + inaccuracy % $\leq$ 2%

Lighting Unit Subsystem



Design Solution: Signaling Unit



- Control signal from microcontroller will control light color
- Each transistor acts as switch
- High control signal will turn on a light
- Lights will be primarily powered by solar battery, with a backup battery capability

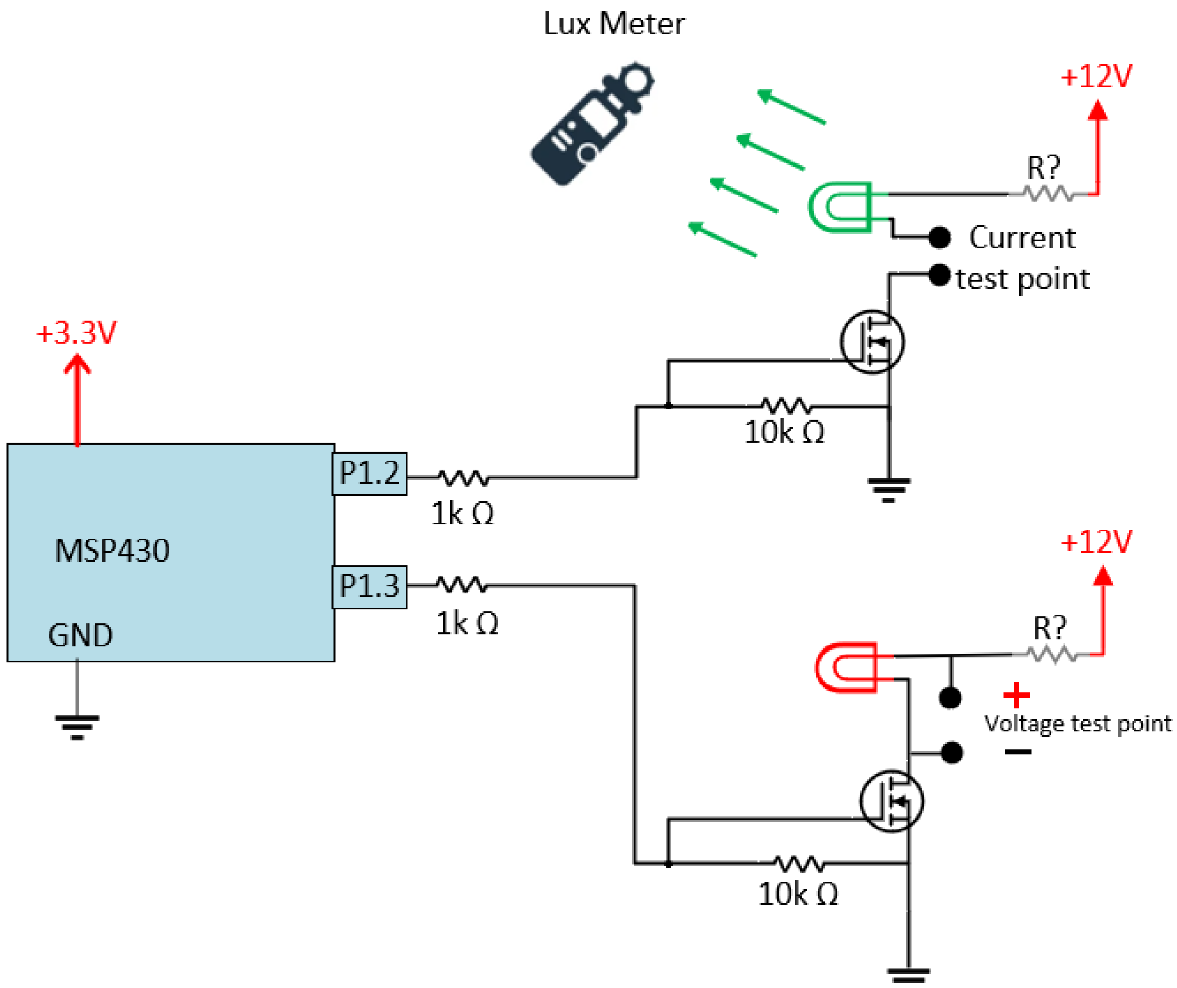
Signaling Unit Preliminary Prototype

Issues/Risk:
- Exact current draw from the lights is unknown
- Visibility of lights

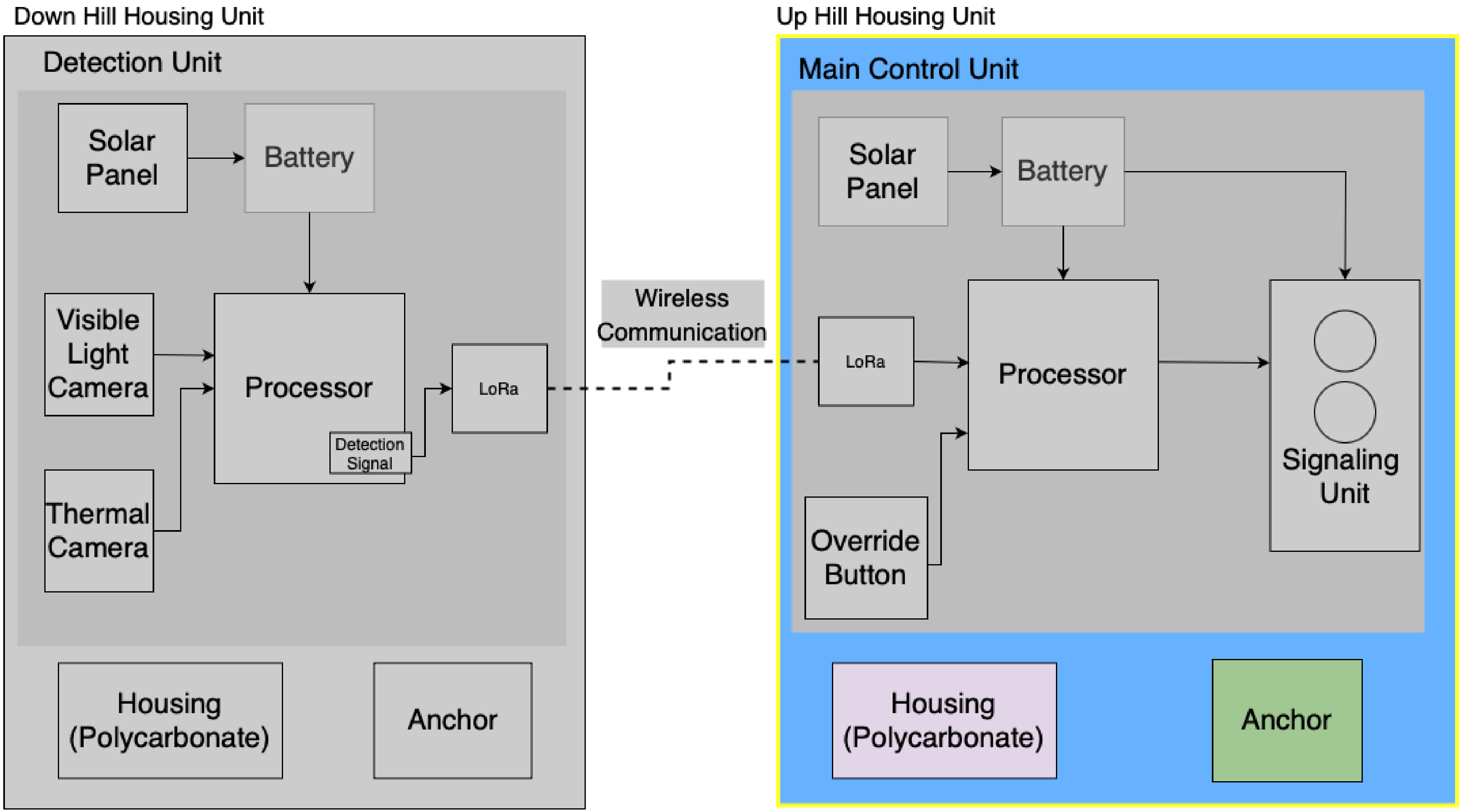
Prototype:
- Test lumen count
- Measure voltage across each light
- Measure current through each light
- Measure current and voltage through each transistor (on and off)
- Measure gate voltage and current

Benefits:
- Knowing the amount of current through the lights will allow us to finish power calculations and pick a backup battery
- If lumen count is high enough, we can potentially add a current limiting resistor to increase power efficiency

Signaling Unit Preliminary Prototype



Uphill Housing Subsystem



Design Solution: Uphill Housing

Render of components mounted on Critical Component: PolyStake

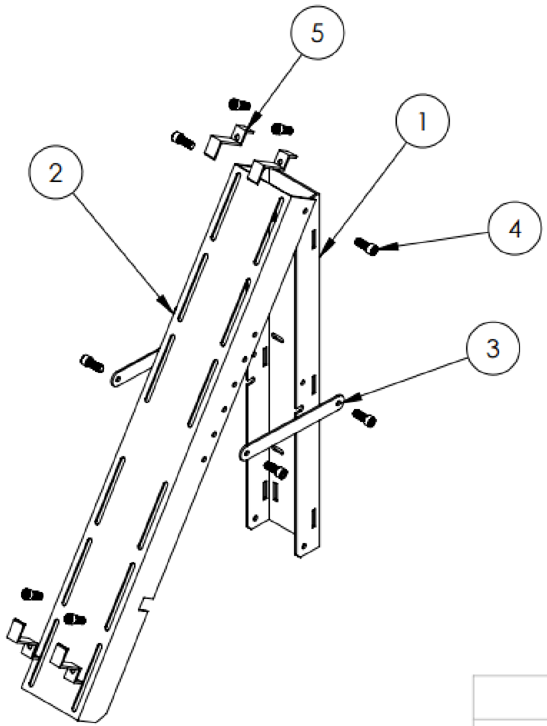
Lighting Housing from PolyCase
- Weatherproof
- Customizable
- 10x7x4 in
- Clear cover for color filters
- Built in PCB mounts

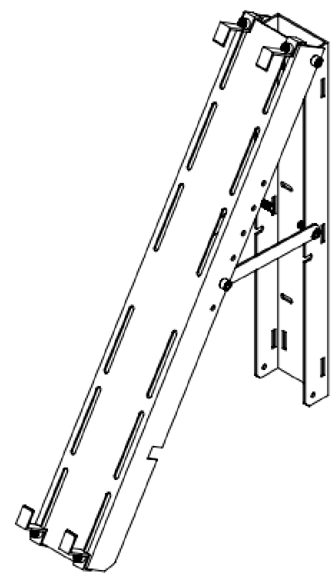
Fully adjustable along length of stake using U-bolts

Note: Attaches to post with U-bolts
(McMaster Carr #2936T36)

Material: 2.5mm Aluminum 5052

PART NUMBER	DESCRIPTION	QTY.
1	Post Mounting Plate	1
2	Solar Panel Plate	1
3	Support Bar	2
4	Black-Oxide Alloy Steel Socket Head Screw (90044A203)	10
5	Solar Panel Clamp	4





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL± 1/16"
ANGULAR: MACH± 5 BEND ± 1
TWO PLACE DECIMAL ± 0.03"
THREE PLACE DECIMAL ± 0.005"
INTERPRET GEOMETRIC TOLERANCING PER:
COMMENTS:

	NAME	DATE
DRAWN	Trevor J	10/23/24
CHECKED		
ENG APPR.		
MFG APPR.		

MATERIAL
VARS

NEXT ASSY

DO NOT SCALE DRAWING

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MSU M.& I.E. DEPT.

TITLE:
Solar Panel Mount

SIZE A | DWG. NO. 1 | REV

SCALE: 1:5 | WEIGHT: 1.52 | SHEET 1 OF 1

5 4 3 2 1

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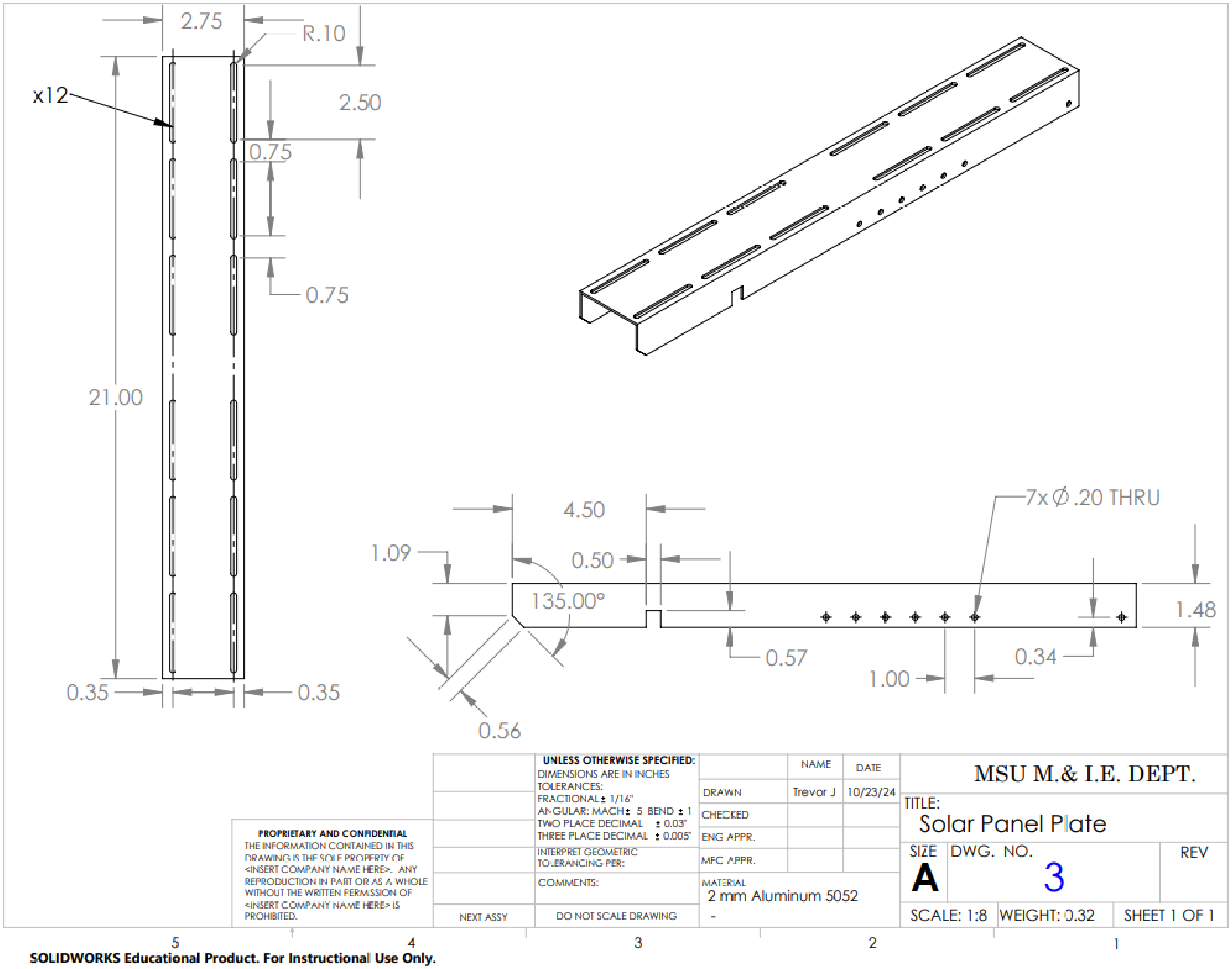
2.75
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16"
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NAME
DATE
DRAWN
Trevor J
10/23/24
CHECKED
ENG APPR.
MFG APPR.
MATERIAL
2 mm Aluminum 5052
-
MSU M.& I.E. DEPT.
TITLE:
Solar Panel Plate
SIZE
A
DWG. NO.
3
REV
SCALE: 1:8
WEIGHT: 0.32
SHEET 1 OF 1
5
4
3
2
1
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Uphill Housing Preliminary Prototype

Issue/Risk:

- Mounting Stake must be able to support the weight of solar panel, solar panel mount, lighting unit, and battery/housing

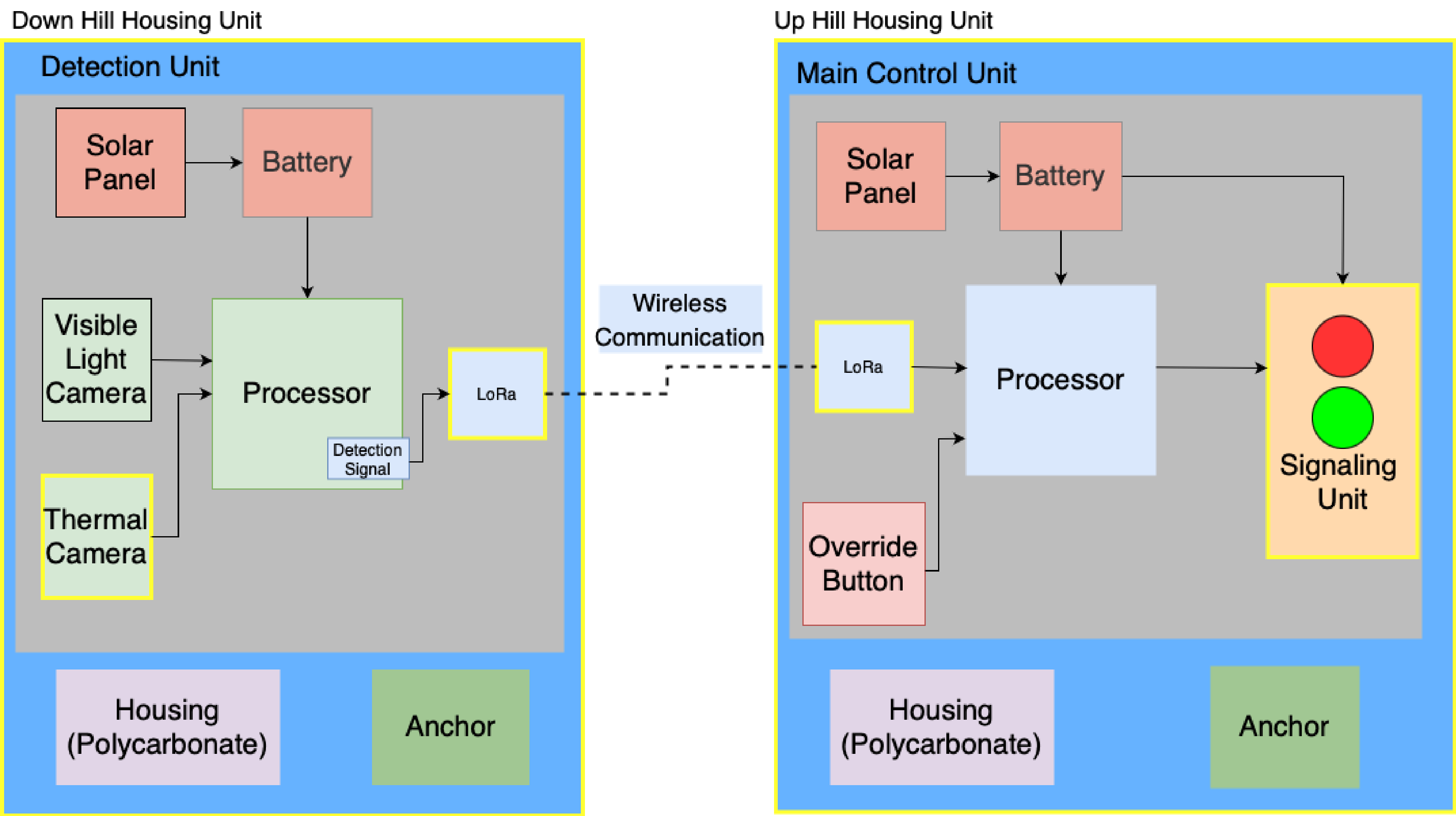
Prototype:

- The displacement at the top of the stake vs incremental loads (1 pound per measurement) will be measured and analyzed
- Will test a few pounds over the equivalent load calculated to ensure reliability
- A sandbag will be tied to the top of the stake to simulate the load
- Stake inserted in sand water mix to simulate snow

Benefits:

- Accurate data on how much weight our stake can withstand
- Potentially will need to reinforce the stake

Ideation of Complete System Design



Additional Subsystems

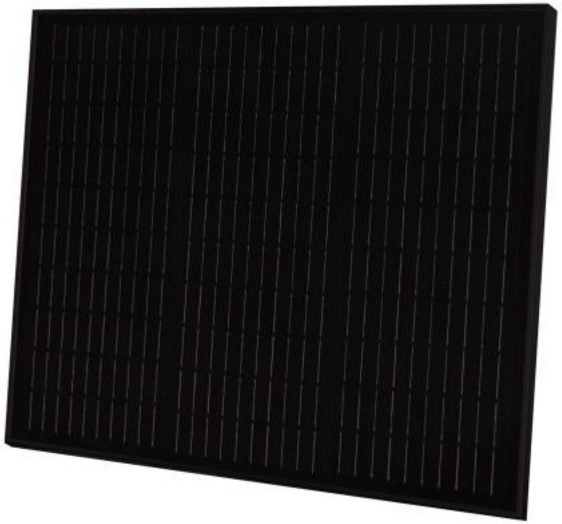
Power Subsystem

Uphill Unit:

- 50 Watt 18 Volt Solar Panel (Voltaic)
- 12V Lithium-ion battery (Ah needed unknown)
- Charge controller
- 12V to 3.3V DC/DC converter

Downhill Unit:

- Expected Wattage 15W (5V and 3A)
- 12V to 5V DC/DC converter



Uphill Solar Panel
(23 x 20 x 1.2 in)

Estimated Budget

Team 13Jump Budget - $1750

SubSystem	Excepted Costs
Communication	$104
Detection	$185
Stoplight	$43
Uphill Housing	$130
Downhill Housing	$75
Power	$200
Other	$426
Expected Total	$1163
Budget Remaining	$587

Key Items Costs:

- LoRa - $75
- Thermal Camera - $75
- Visible Light Camera - $35
- Raspberry Pi 4 - $75
- Stoplights - $28
- Uphill housing - $40
- Solar panel and battery - $200

Summary

- This project aims to enhance skier safety by providing real-time information about the landing zone's clarity, reducing collision risks and promoting smoother traffic flow in terrain parks. With the design phase complete, we are preparing to begin prototype testing.
- Our progress is supported by our expertise, resources, and commitment to improving safety. We have designed a robust system that integrates thermal and visible light imaging technologies for accurate monitoring of the landing area.
- The potential to significantly reduce accidents makes this project valuable. As we test the system, we believe it will effectively prevent collisions, and we will make necessary adjustments to optimize its performance in real-world conditions.

QUESTIONS?

ADDITIONAL SUPPORT SLIDES

Objective 1: Determine whether the landing area below a jump is clear, and then report the status to athletes uphill from the landing area

- Req 1.1) System must detect when the landing area is clear
  - Spec 1.1.1) Detection system must be able to detect athletes within a 30x30 ft area within the landing area
  - Spec 1.1.2) Must have ≥ 95% detection rate
- Req 1.2) System must communicate detection results to uphill athletes
  - Spec 1.2.1) Latency from when the sensor triggers, to when the signaling unit triggers, must be ≤ 0.5s
  - Spec 1.2.2) Dropout rate of information must be ≤ 2%
  - Spec 1.2.3) Sensors must communicate with signaling unit from a maximum distance of 60 ft away with a direct line of sight
- Req 1.3) System must notify the next athlete it is safe to proceed
  - Spec 1.3.1) Signal must produce a green light when the landing area is clear
  - Spec 1.3.2) Signal must produce a red light when the landing area is not clear
  - Spec 1.3.3) The latency of the light changing states after a signal is received must be ≤ 0.5 seconds
  - Spec 1.3.4) Must have a manual override to send the system to the "stop" state in case of emergencies or other events

Objective 2: The system must operate in inclement weather throughout the months of December through April

Req 2.1) Must have housing material capable of protecting electronics while ensuring operation in varying weather conditions

- Spec 2.1.1) Must be able to withstand and function in temperatures ≥ 0°F
- Spec 2.1.2) Must be able to operate in winds up to 20 mph
- Spec 2.1.3) System is not meant to operate in visibility lower than 30 ft or when the terrain park is not operational

Req 2.2) Signaling Unit must be visible to athletes in varying weather conditions

- Spec 2.2.1) Must be able to see signaling unit from 30 ft away uphill
- Spec 2.2.2) Lights on the signaling unit must produce at least 1000 Lumens
- Spec 2.2.3) Adjustable between 0 - 5 feet with height increments by ± 6” for every adjustment

Objective 3: The system will operate on a standalone power system to avoid running power lines to the system which could create unnecessary hazards

Req 3.1) Power source must be reliable in varying winter conditions

- Spec 3.1.1) Must operate continuously for 7.5 hours
- Spec 3.1.2) Must have sufficient backup power to operate normally for 21 operational hours

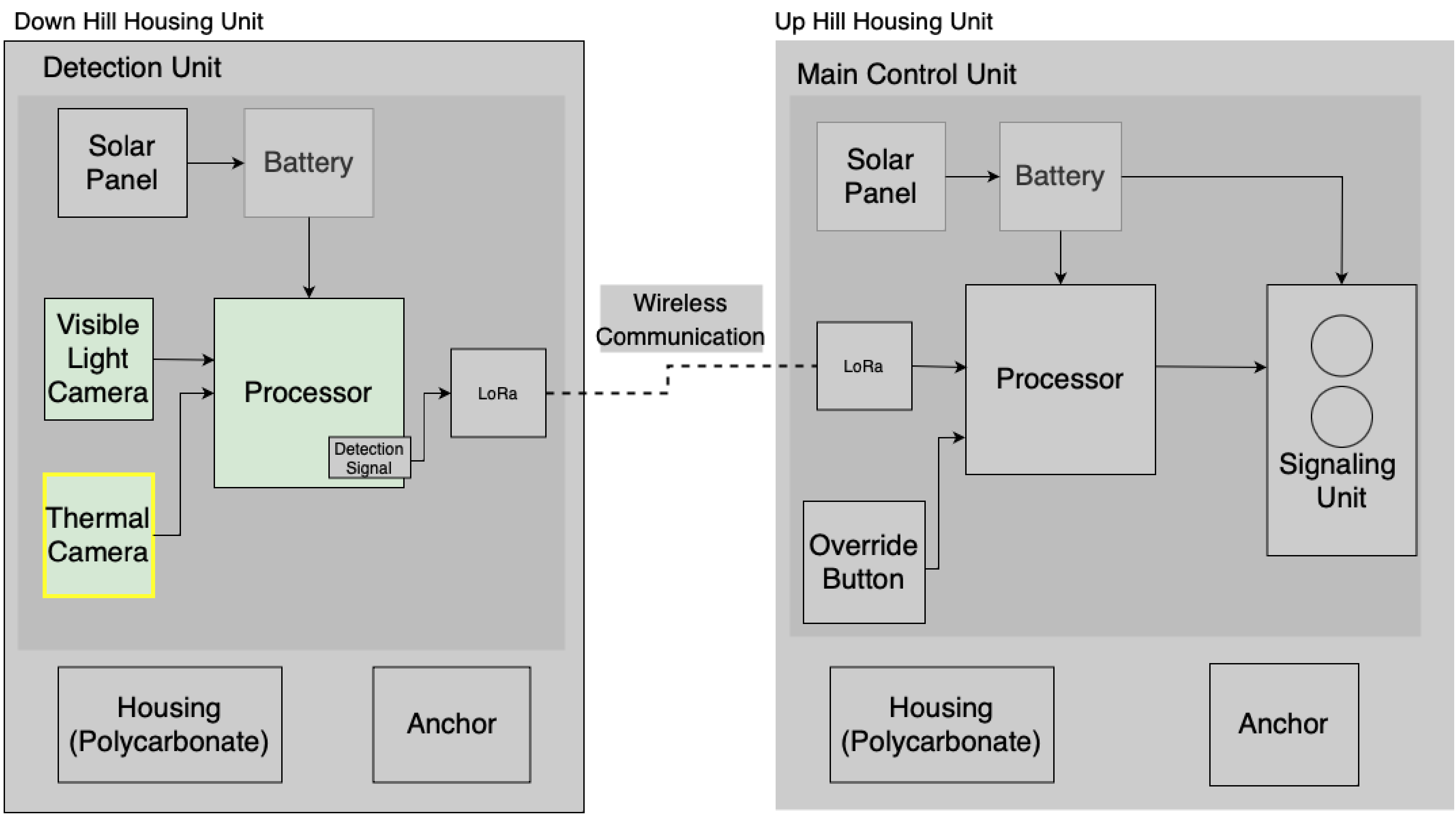
Req 3.2) The system must have the ability to recharge both primary and secondary power sources

- Spec 3.2.1) Can recharge for a 7.5 hour operational day with 3.5 hours of peak sunlight
- Spec 3.2.2) Backup power can be recharged through an external source in 8 hours for the system to operate for 21 operational hours

Team 13 - JumpGuard

#	Date of purchase	Date of Reimbursement	Purchased by	Expense	Expected Expense (PLANNING)		Actual Cost (EXECUTION)			
					Expected Cost	Savings	Supplier	Quantity	Item Cost	Total Cost
					Expected Budget:	$1,750			Actual Budget Provided:	$1,750.00
Wirless Commuication										
1	mm.dd.yy			LoRa Module (RMF95W)	$75.00	$0.00				$0.00
2	mm.dd.yy			MSP430 launchpad	$25.00	$0.00				$0.00
3	mm.dd.yy			MSP430FR2111	$4.00	$0.00	DigiKey			$0.00
Detection System										
5	mm.dd.yy			Thermal Camera (Adafruit MLX90640 24x32 IR Thermal Camera Breakout - 110 Degree FoV)	$74.95	$0.00	Adafruit	1	$0.00	$0.00
6	mm.dd.yy			Visible Light Camera (Raspberry Pi Camera Module 3 Standard - 12MP Autofocus)	$35.00	$0.00	Adafruit	1	$0.00	$0.00
8	mm.dd.yy			Processor (Raspberry Pi 4 Model B)	$75.00	$0.00	Adafruit	1	$0.00	$0.00
9	mm.dd.yy			Wires (STEMMA Cable - 4 Pin JST-PH 2mm Cable–Female/Female - 150mm/6" Long)	$0.75	$0.00	Adafruit	1	$0.00	$0.00
Stoplight System										
9				Lights	$27.98	$0.00	Amazon	2		$0.00
10				Transistors	$14.60	$0.00	DigiKey	10		$0.00
Uphill Housing										
13				Mounting Stake	$20.00	$0.00	Bridger Bowl			
14				Signaling Unit Housing	$45.00	$0.00	PolyCase			
15				Solar Panel Mounting	$50.00	$0.00	Voltaic			
16				Battery Mount	$15.00	$0.00	Amazon			
Downhill Housing										
17				Mounting Stake	$20.00	$0.00	Bridger Bowl	1		$0.00
18				Detection Unit Housing	$35.00	$0.00	PolyCase	1		$0.00
19				Housing Mount (2xU-bolts)	$20.00	$0.00	Hardware Store (TBD)	1		$0.00
20						$0.00				$0.00
Power										
21				Solar Panel	$89.00	$0.00	Voltaic	1		$0.00
22				Solar Battery	$119.00	$0.00	Voltaic	1		$0.00
OTHER SYSTEM LEVEL COMPONENTS (these might include bulk wiring, shipping, PCB manufacturing)										
25				Custom PCB for downhill Unit	$200.00	$0.00				$0.00
26				Shipping (all)	$200.00	$0.00	N/A			$0.00
27				Light tint (Green/Red)	$18.00	$0.00	Amazon			$0.00
Summary				Planned Budget Remaining:	$586.72	$1,163.28			Actual Budget Remaining:	$1,750.00
				Planned Total Cost:	$1,163.28	$1,163.28			Actual Total Cost:	$0.00

Block Diagram of Detection



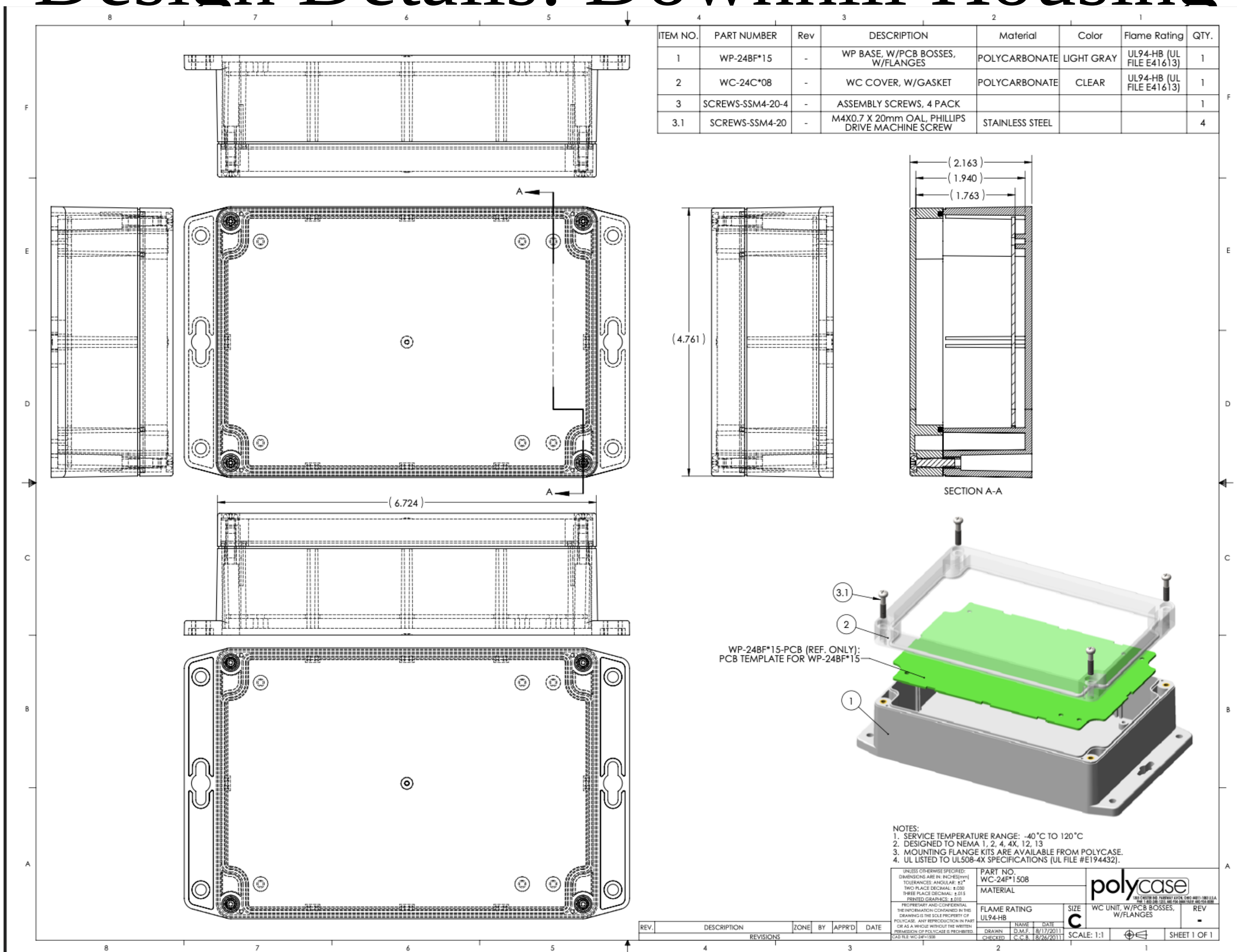
Alternative Analysis Thermal Camera

Thermal Imaging Camera Analysis				
Characteristics	*Weight*	FLIR Lepton 3.5 (500-0763-01)	MLX90640 (MLX90640)	SEEK Thermal Compact
Cost	5	$164.00	$75.00	$45.00
		3	4	1
Resolution	4	160x120 Pixels	32x24 Pixels	156x206 Pixels
		4	2	5
Integration for Serial Peripherals	3	SPI	I2C	USB
		2	4	3
Size and Weight	2	<1g	<5g	10g
		5	4	2
Power Supply	3	5V	3.3v-5v	5
		4	5	4
Power Consumption	4	150 mW	20 mW	280 mW
		3	5	1
Field of View	3	57º	75º	36º
		3.5	5	2
Operating Temperature	1	-10ºc-80ºC	-40ºC to 85ºC	-20ºC to 80ºC
		3	5	4
Final Score:		84.5	103	64

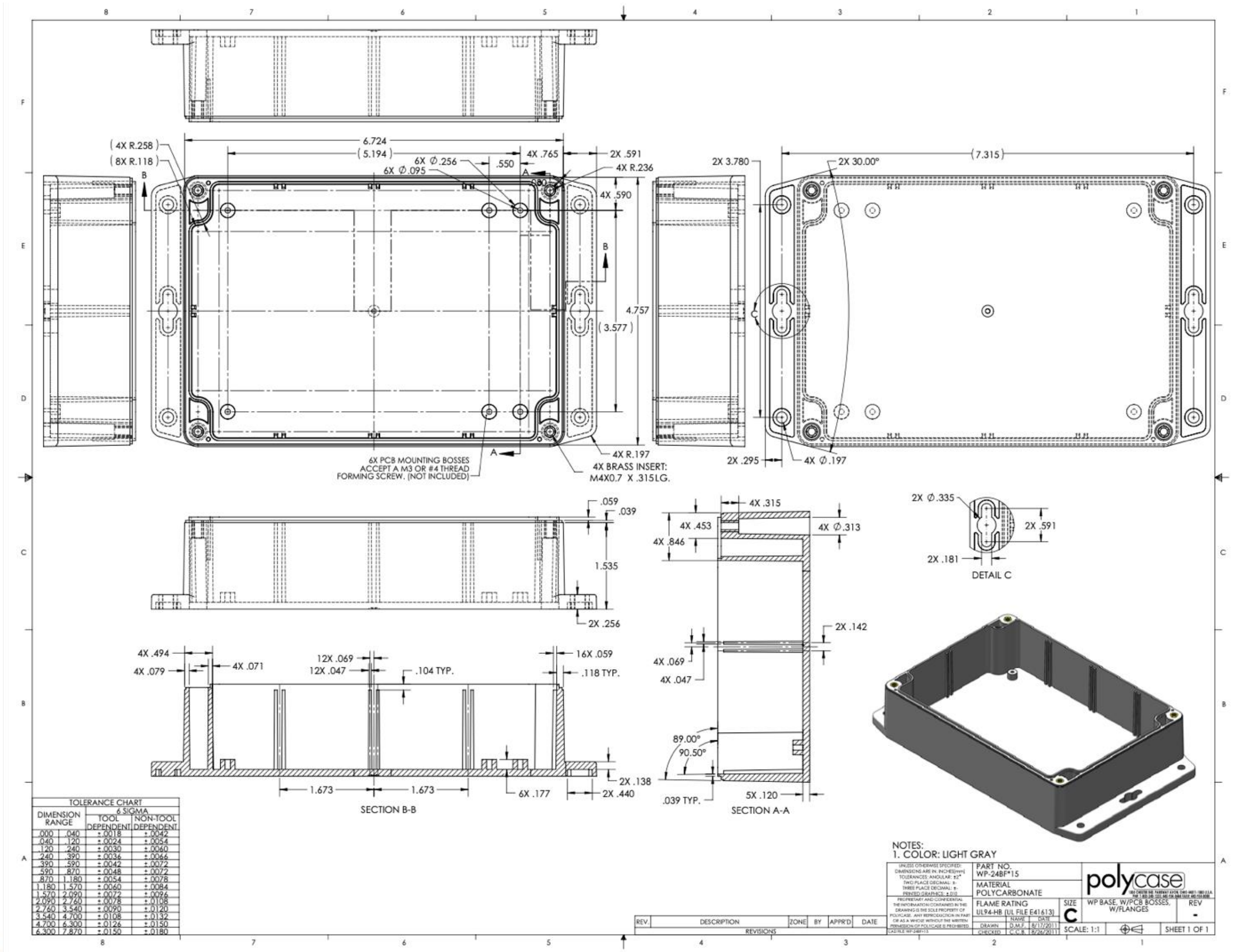
I2C Commands/Key Registers

Key Registers/ Commands	Address	Description
RAM Start Address	0x0400	Holds pixel data (32x24 resolution). Reading from this address retrieves the temperature data for each pixel. Each pixel value is 16 bits.
Status Register	0x8000	This register provides the status of the device, including flags for data availability. **Bit 3**: New data available flag. Indicates when a new frame of data is ready. **Bit 12**: Power mode (0 for normal operation, 1 for sleep). **Bits 4-7**: Subpage selection for interleaved subpage modes
Control Register	0x800D	Used to configure device operation modes like refresh rate. **Refresh Rate Bits (Bits 0-2)**: 0b000: 0.5 Hz 0b001: 1 Hz 0b010: 2 Hz 0b011: 4 Hz 0b100: 8 Hz 0b101: 16 Hz 0b110: 32 Hz 0b111: 64 Hz **Command**: Write to the 0x800D register to set the desired refresh rate.
EEPROM Registers for Calibration Data	0x2400 to 0x273F	Stores the calibration parameters unique to each MLX90640 sensor. These values are needed to convert raw data into accurate temperature readings. **Command**: Read from 0x2400 to 0x273F to obtain the calibration data, which is 832 bytes long.
Device Identification	0x2407 to 0x2408	These registers contain the device ID to identify the specific MLX90640 unit. **Command**: Read from these registers to retrieve the device ID, which may be useful for device validation or troubleshooting.

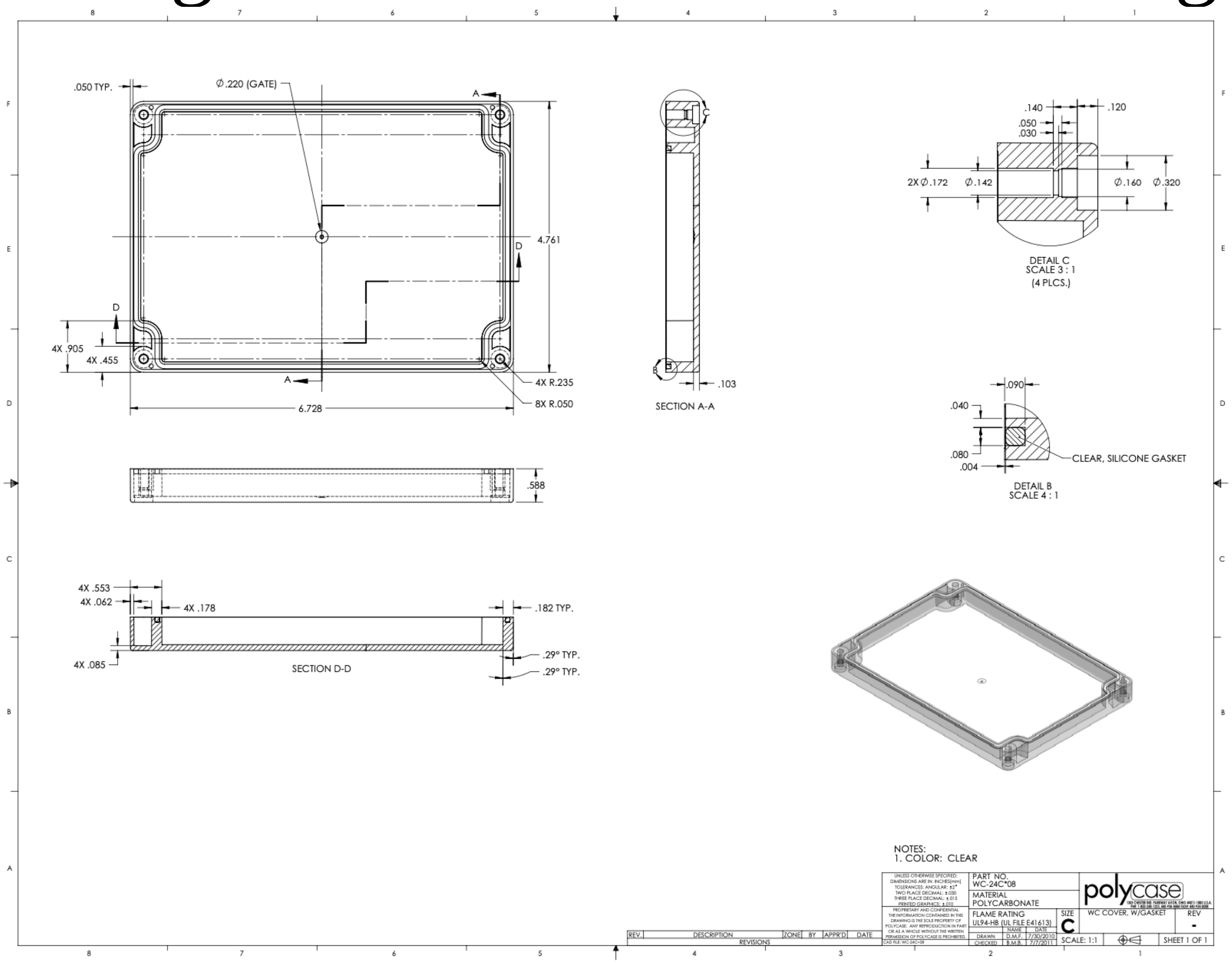
Design Details: Downhill Housing



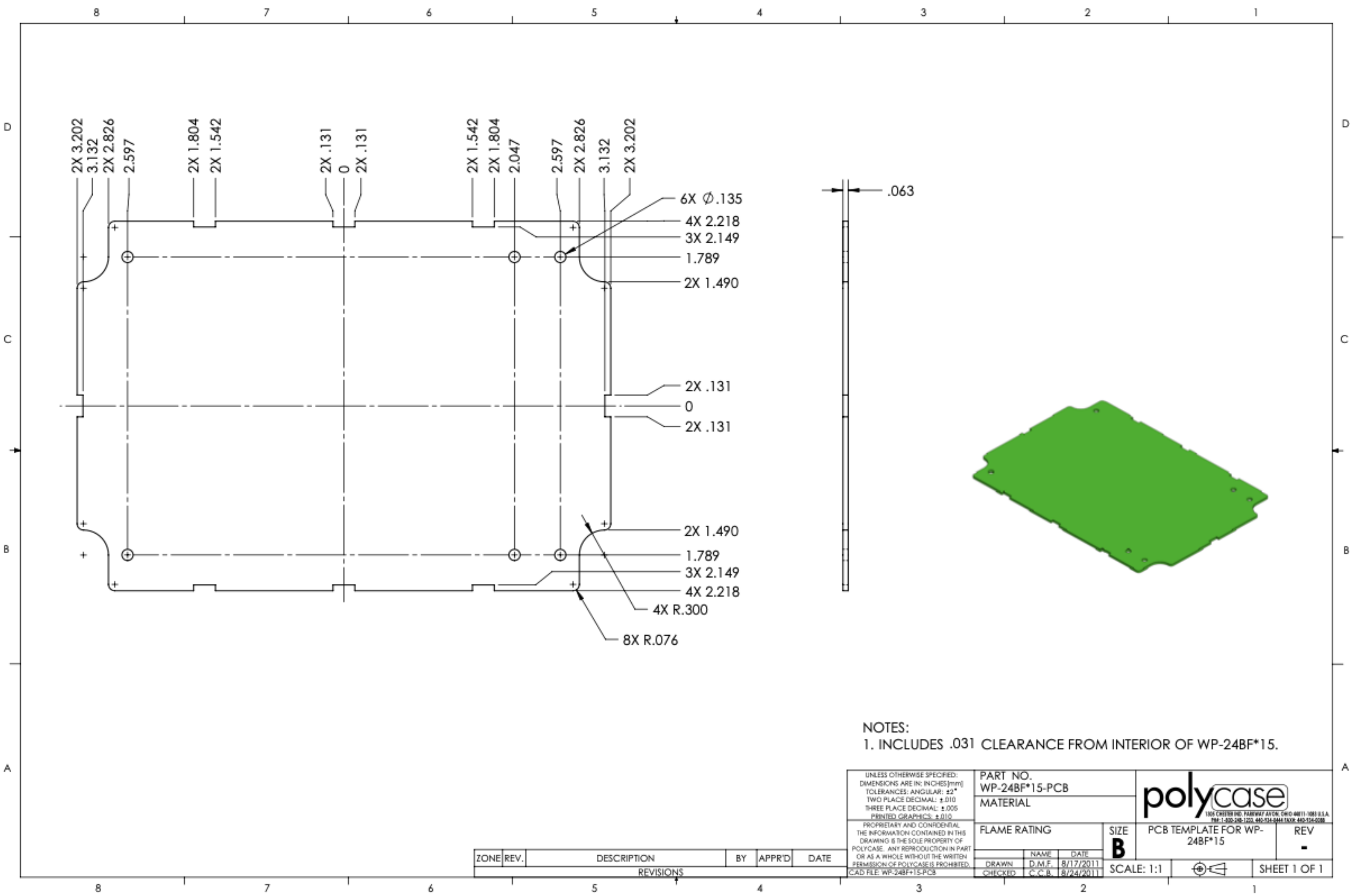
Design Details: Downhill Housing



Design Details: Downhill Housing



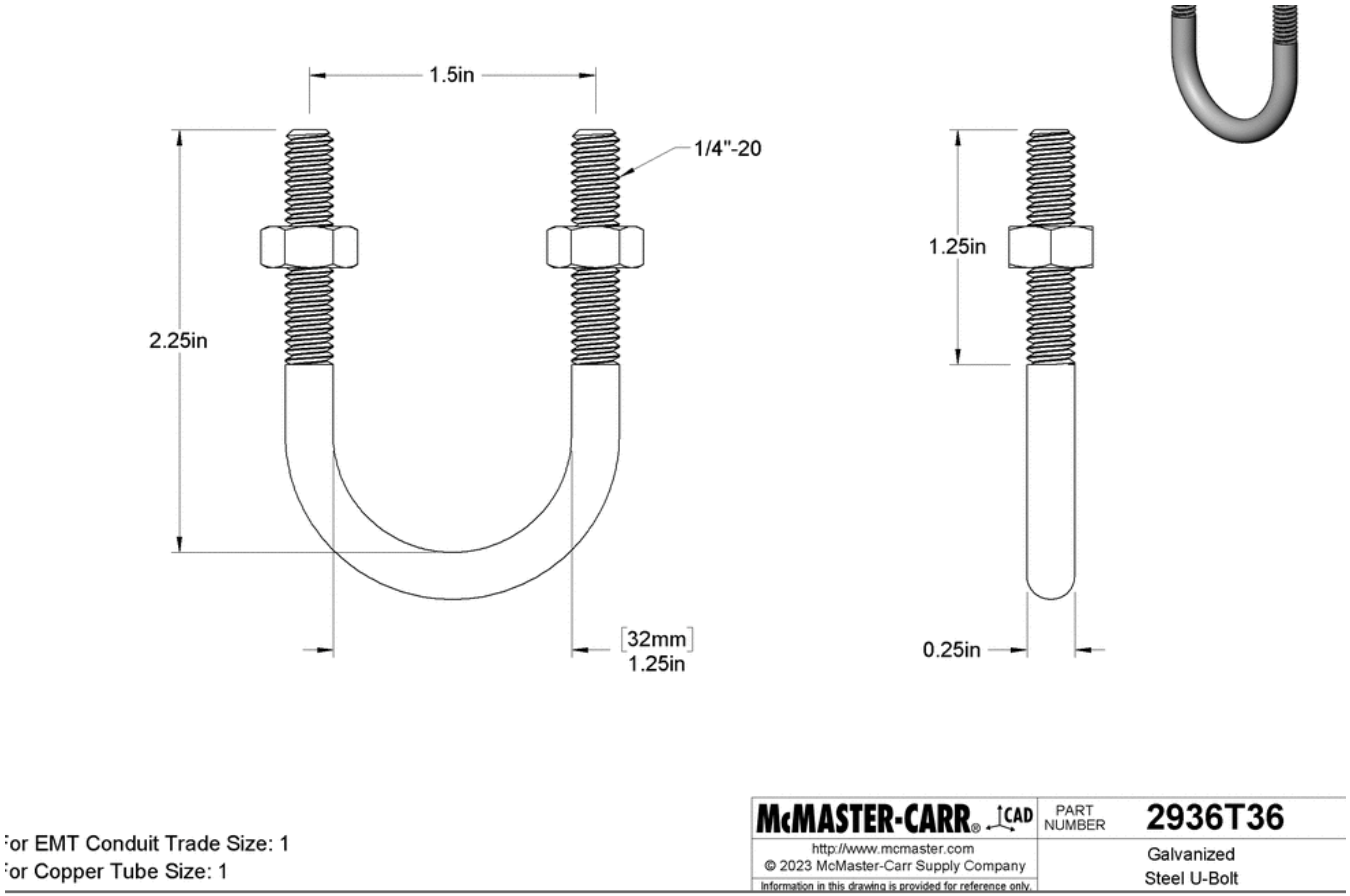
Design Details: Downhill Housing



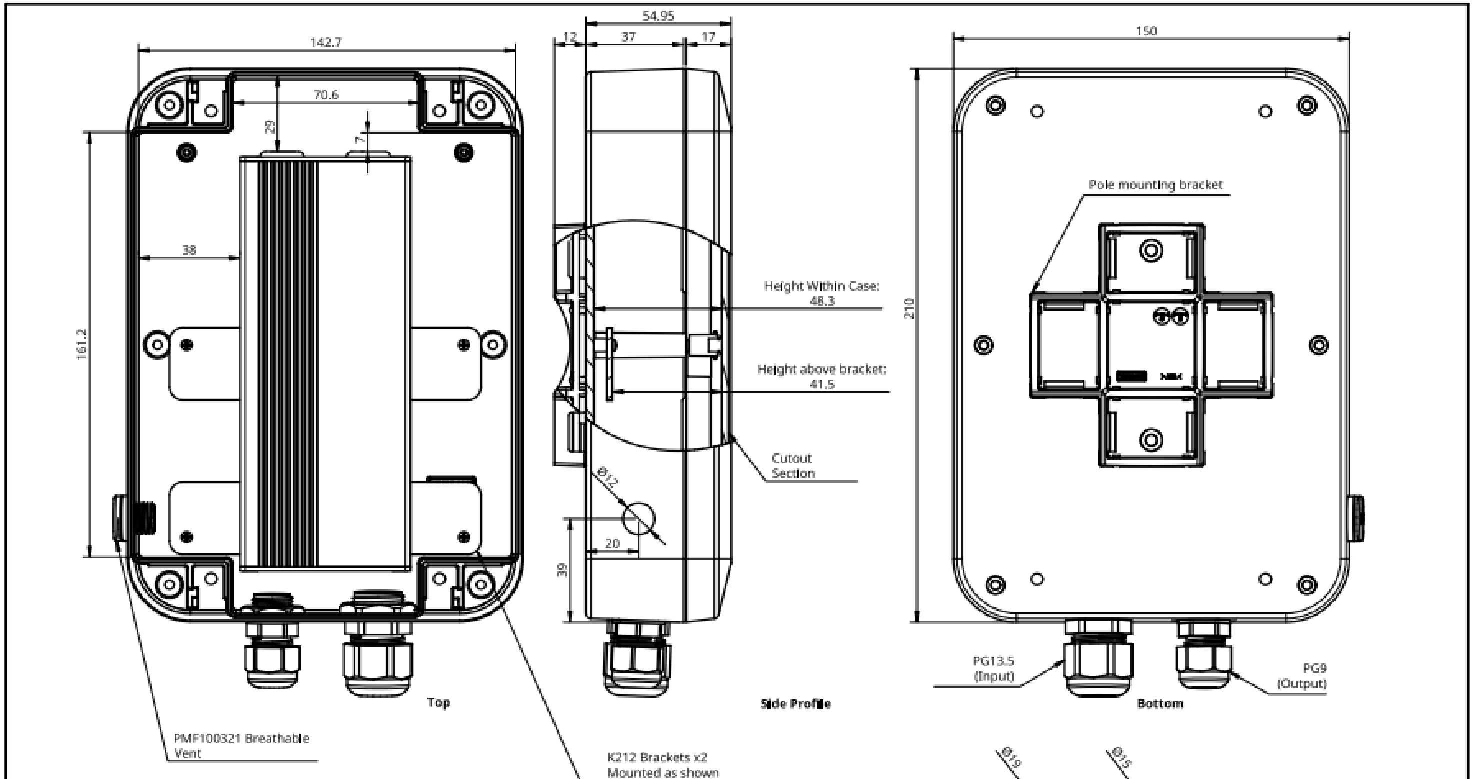
Mounting Critical Component Alternatives Analysis

Characteristics:	Weight	BrushGrip Base	PolyS
Price	2	$16.50	Free
		2	5

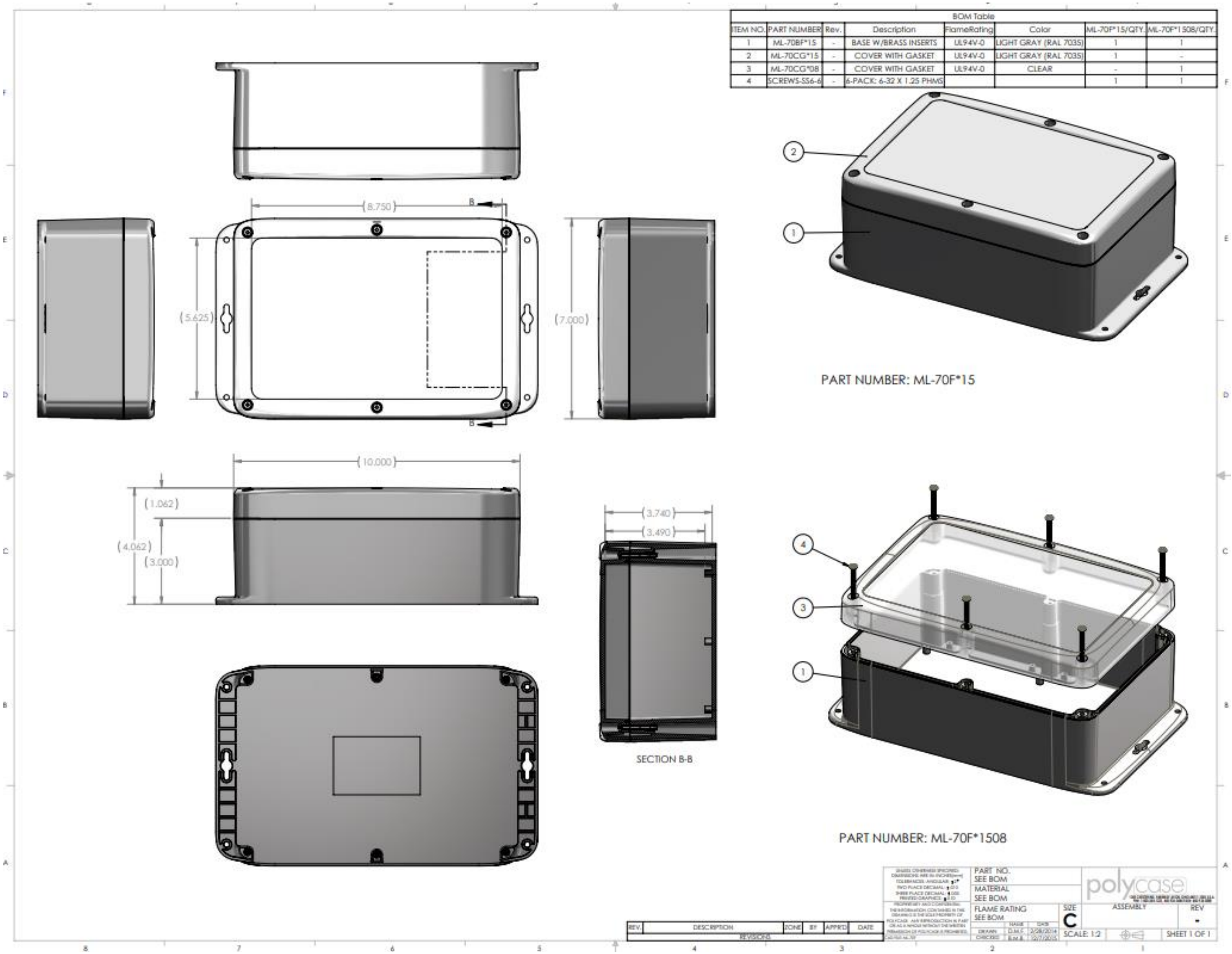
U bolt for mounting components to PolyStake



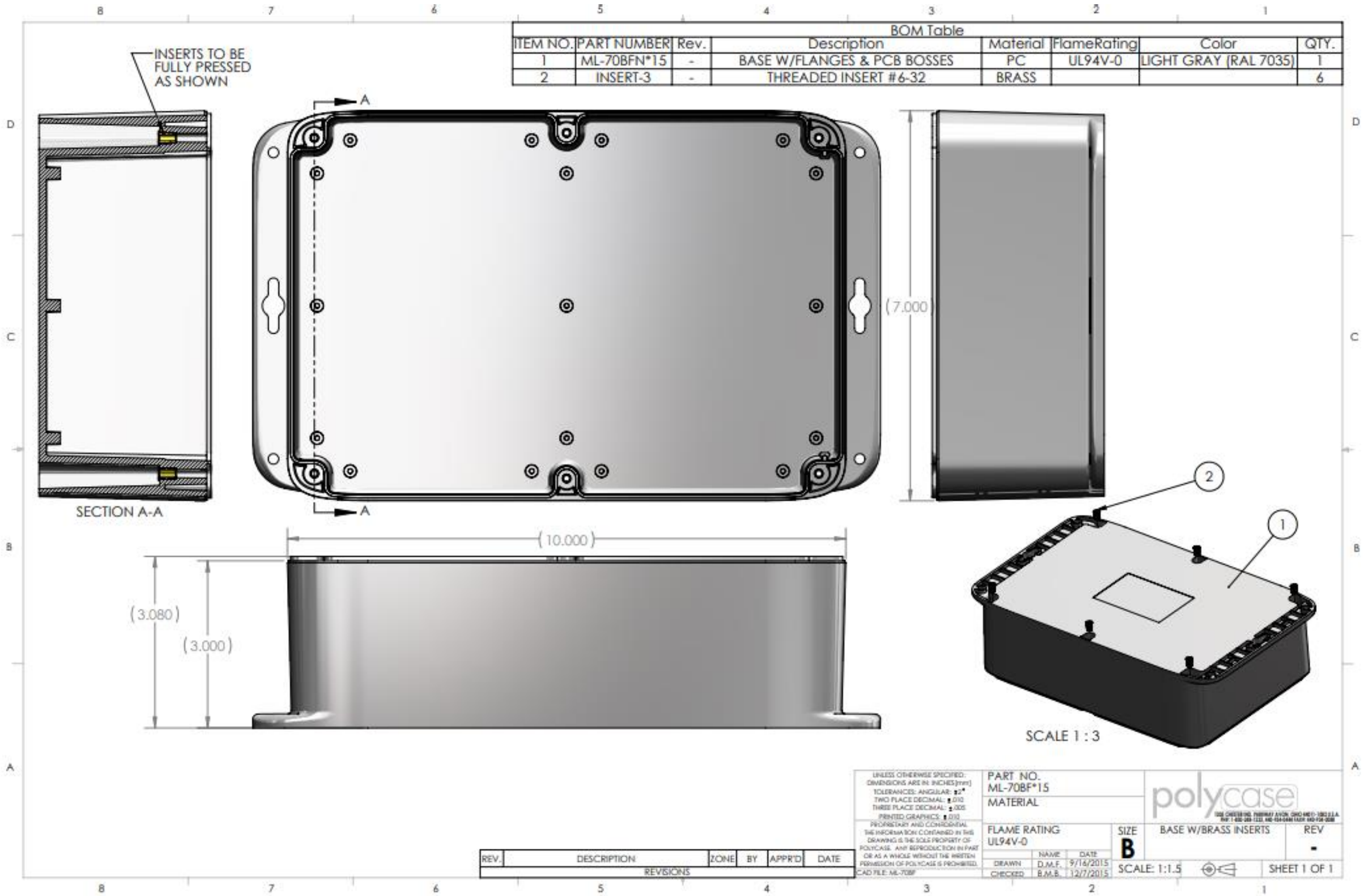
Solar panel battery case Drawing

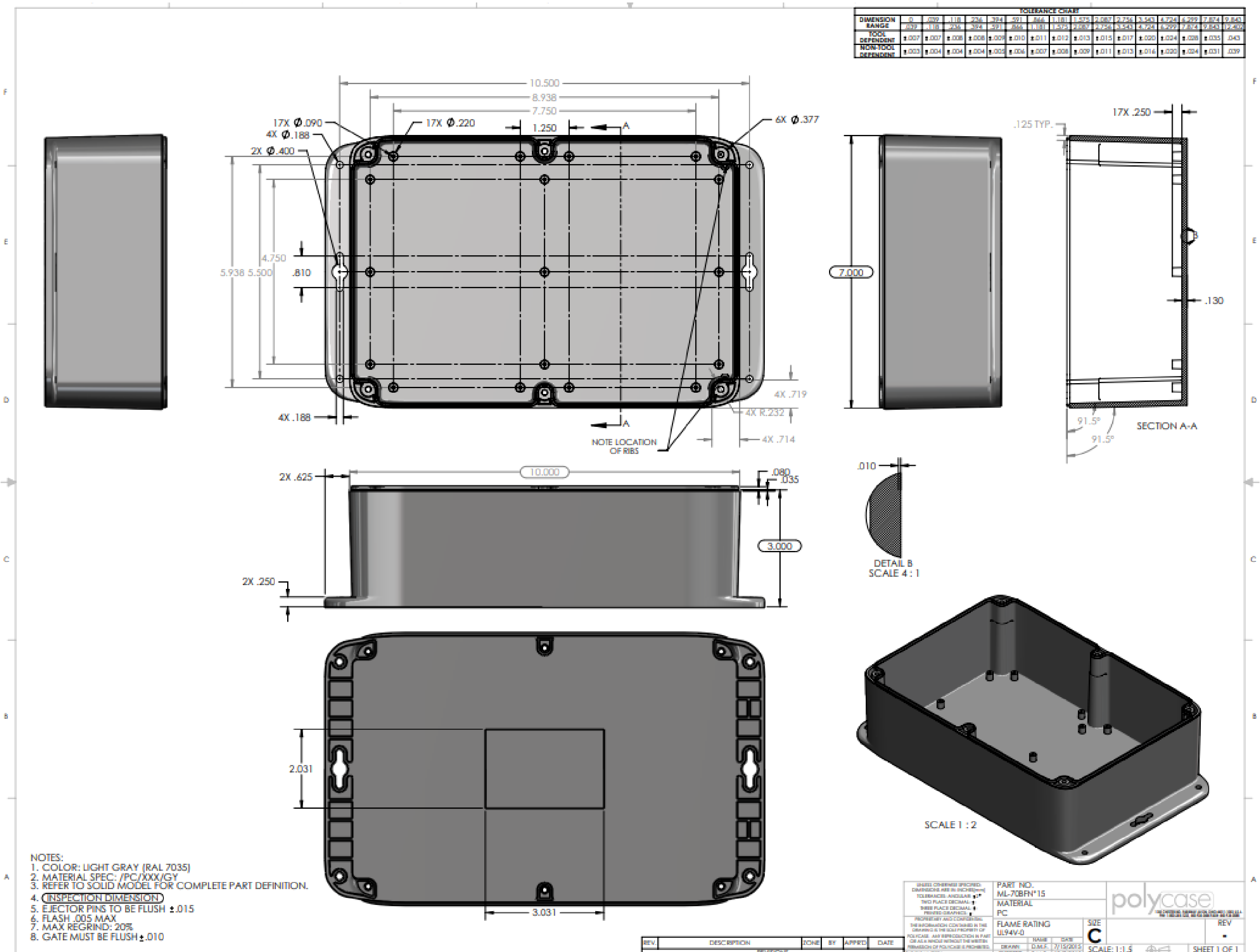


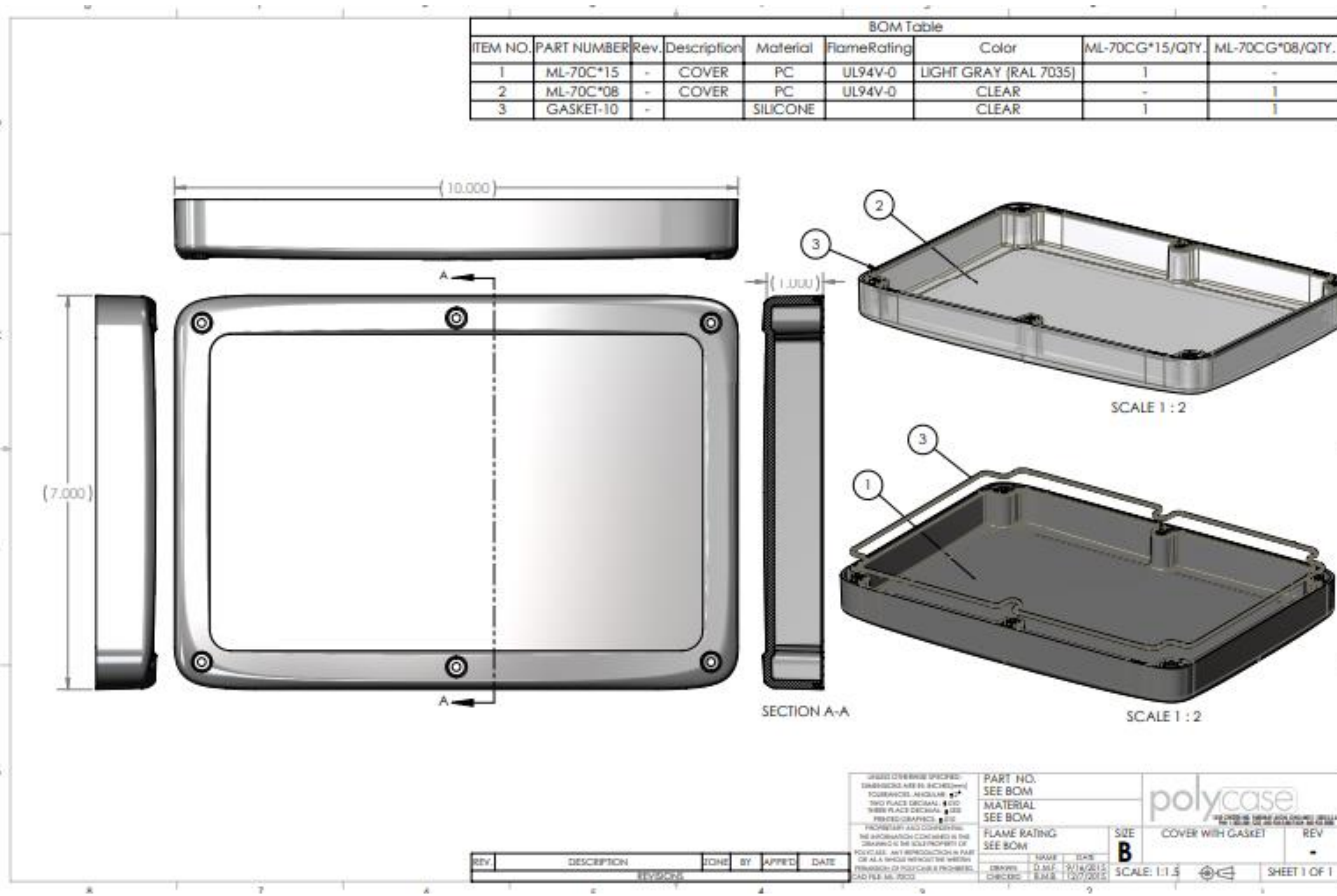
PART DATA			
Voltaic	Part Number	E307 [15X21X6CM] + V70 [12V]	
	Revision	R1A	
	Material	ASA PW957 OFF-WHITE	
This document contains proprietary information and may not be copied or shared without the consent of Voltaic Systems	Date	ME 2021-12-10	
	Approval	SM 2021-12-09	
	Scale: 1:2	Sheet: 4/4	Units: mm



BOM Table							
ITEM NO.	PART NUMBER	Rev.	Description	FlameRating	Color	ML-70F*15/QTY.	ML-70F*1508/QTY.
1	ML-70BF*15	-	BASE W/BRASS INSERTS	UL94V-0	LIGHT GRAY (RAL 7035)	1	1
2	ML-70CG*15	-	COVER WITH GASKET	UL94V-0	LIGHT GRAY (RAL 7035)	1	-
3	ML-70CG*08	-	COVER WITH GASKET	UL94V-0	CLEAR	-	1
4	SCREWS-SS6-6	-	6-PACK: 6-32 X 1.25 PHMS			1	1


BOM Table
ITEM NO. | PART NUMBER | Rev. | Description | Material | FlameRating | Color | QTY.
1 | ML-70BFN*15 | - | BASE W/FLANGES & PCB BOSSES | PC | UL94V-0 | LIGHT GRAY (RAL 7035) | 1
2 | INSERT-3 | - | THREADED INSERT #6-32 | BRASS | | | 6
INSERTS TO BE FULLY PRESSED AS SHOWN
SECTION A-A
A
A
(7.000)
(10.000)
(3.080)
(3.000)
2
1
SCALE 1 : 3
PART NO.
ML-70BF*15
MATERIAL
FLAME RATING
UL94V-0
SIZE
B
BASE W/BRASS INSERTS
REV
-
SCALE: 1:1.5
SHEET 1 OF 1
REV.
DESCRIPTION
ZONE
BY
APPR'D
DATE
REVISIONS
polycase

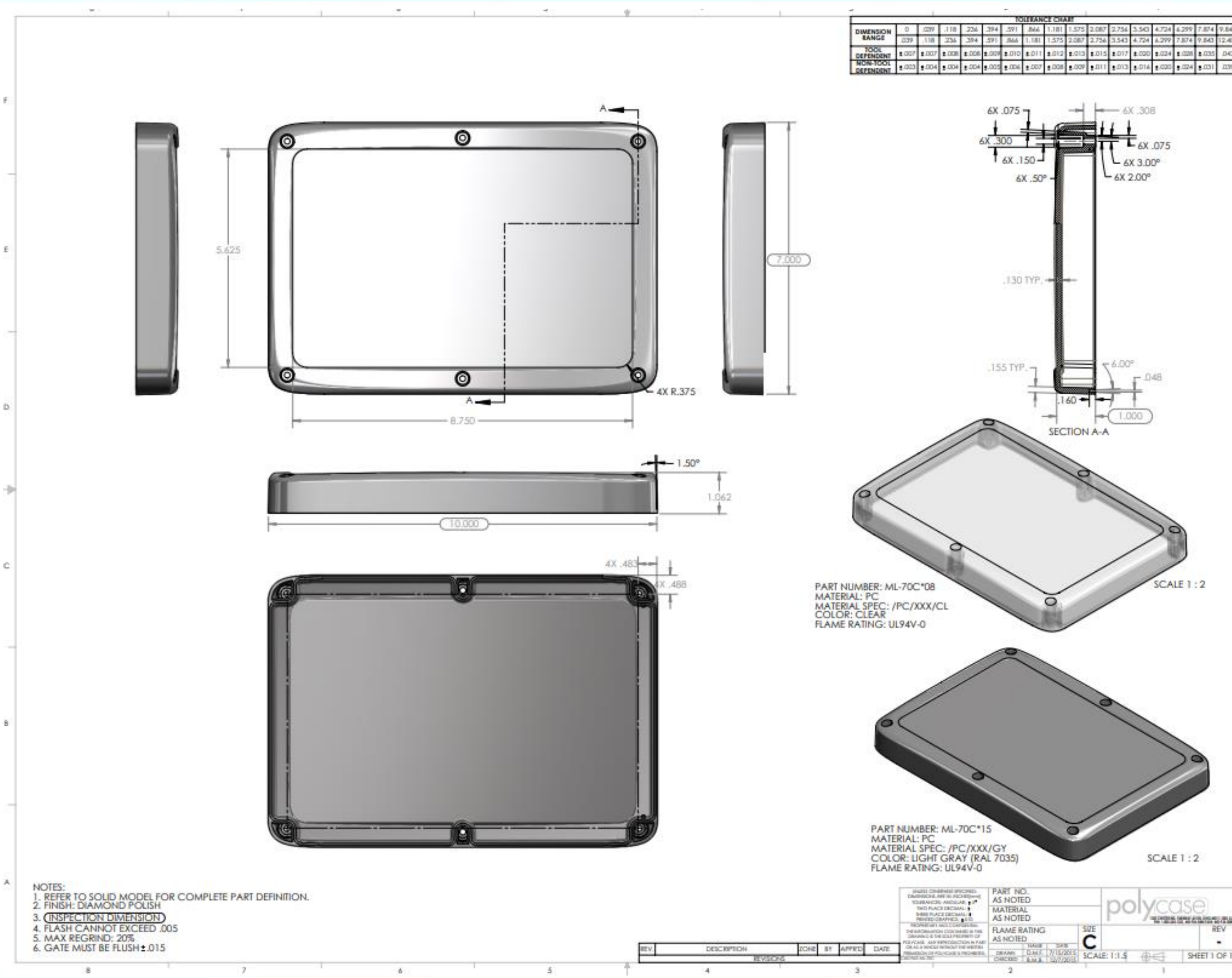

10.500
8.938
7.750
17X Ø.090
4X Ø.188
2X Ø.400
17X Ø.220
1.250
6X Ø.377
4.750
5.938 5.500
.810
4X .188
4X .719
4X R.232
4X .714
NOTE LOCATION OF RIBS
7.000
.125 TYP.
17X .250
.130
91.5°
91.5°
SECTION A-A
2X .625
10.000
.080
.035
3.000
2X .250
.010
DETAIL B
SCALE 4 : 1
2.031
3.031
SCALE 1 : 2
NOTES:
1. COLOR: LIGHT GRAY (RAL 7035)
2. MATERIAL SPEC: /PC/XXX/GY
3. REFER TO SOLID MODEL FOR COMPLETE PART DEFINITION.
4. INSPECTION DIMENSION
5. EJECTOR PINS TO BE FLUSH ±.015
6. FLASH .005 MAX
7. MAX REGRIND: 20%
8. GATE MUST BE FLUSH ±.010
PART NO.
ML-70BFN*15
MATERIAL
PC
FLAME RATING
UL94V-0
SIZE
C
SCALE: 1:1.5
SHEET 1 OF 1
polycase
TOLERANCE CHART



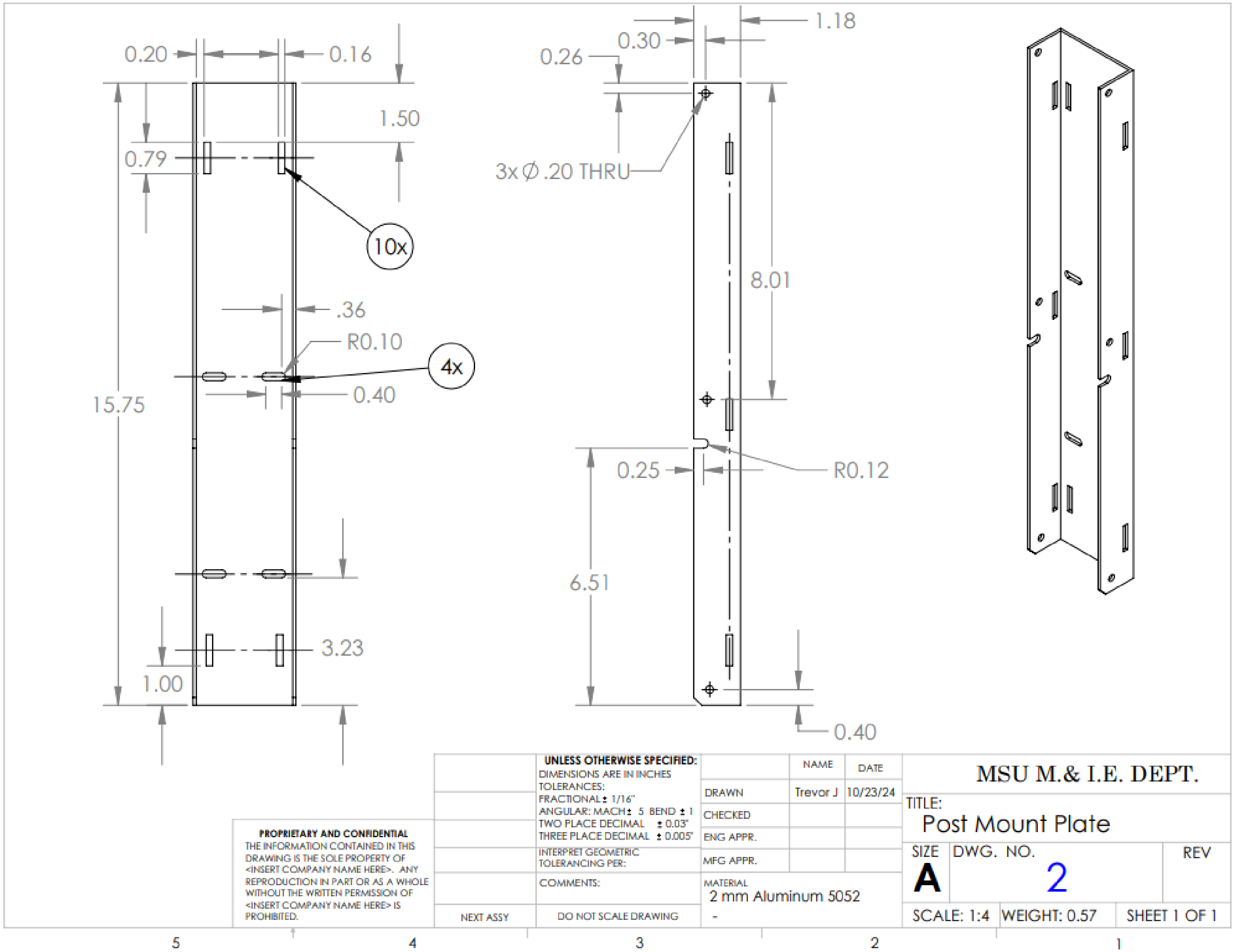
BOM Table								
ITEM NO.	PART NUMBER	Rev.	Description	Material	FlameRating	Color	ML-70CG*15/QTY.	ML-70CG*08/QTY.
1	ML-70C*15	-	COVER	PC	UL94V-0	LIGHT GRAY (RAL 7035)	1	-
2	ML-70C*08	-	COVER	PC	UL94V-0	CLEAR	-	1
3	GASKET-10	-		SILICONE		CLEAR	1	1

MONTANA STATE UNIVERSITY

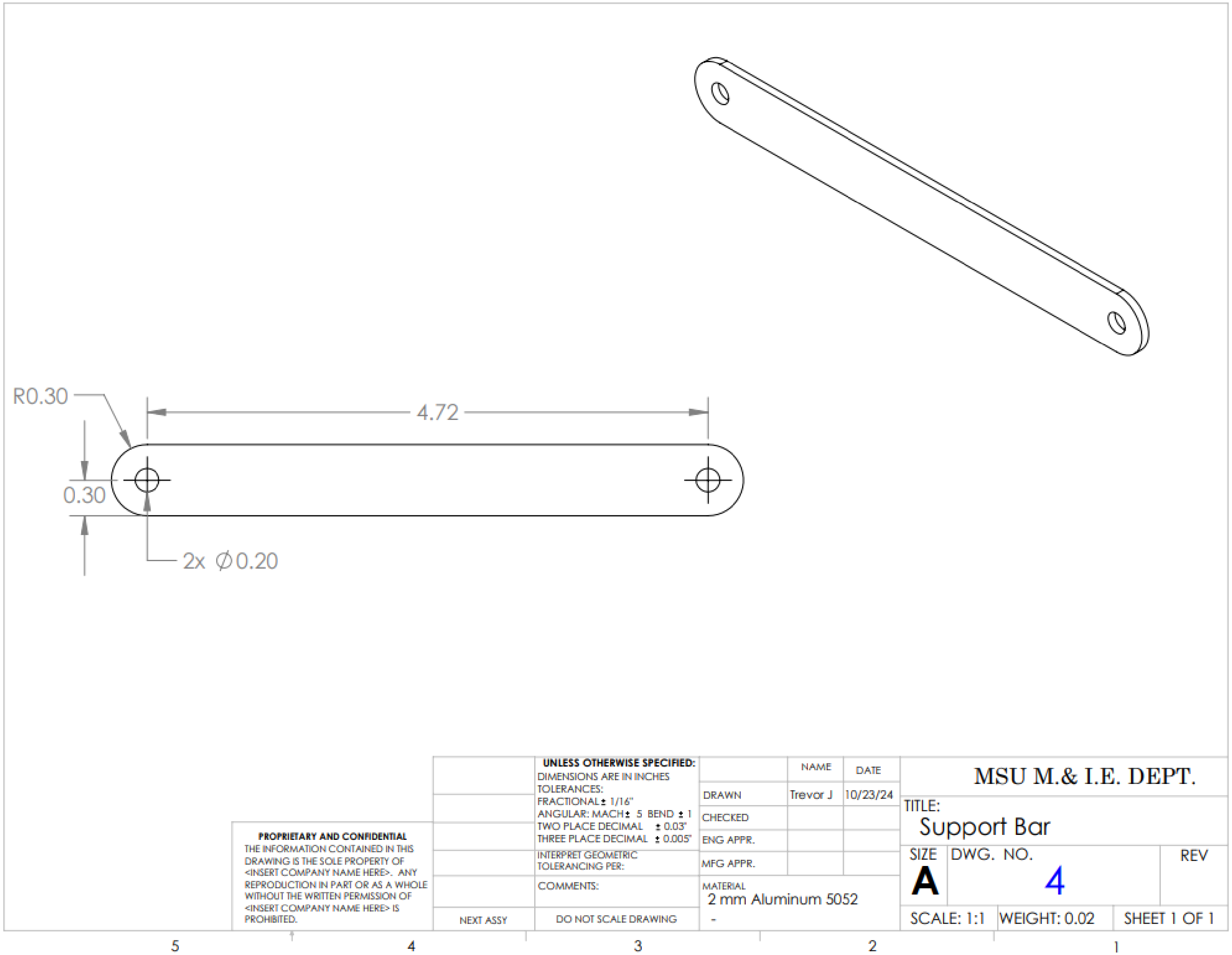
Mountains & Minds



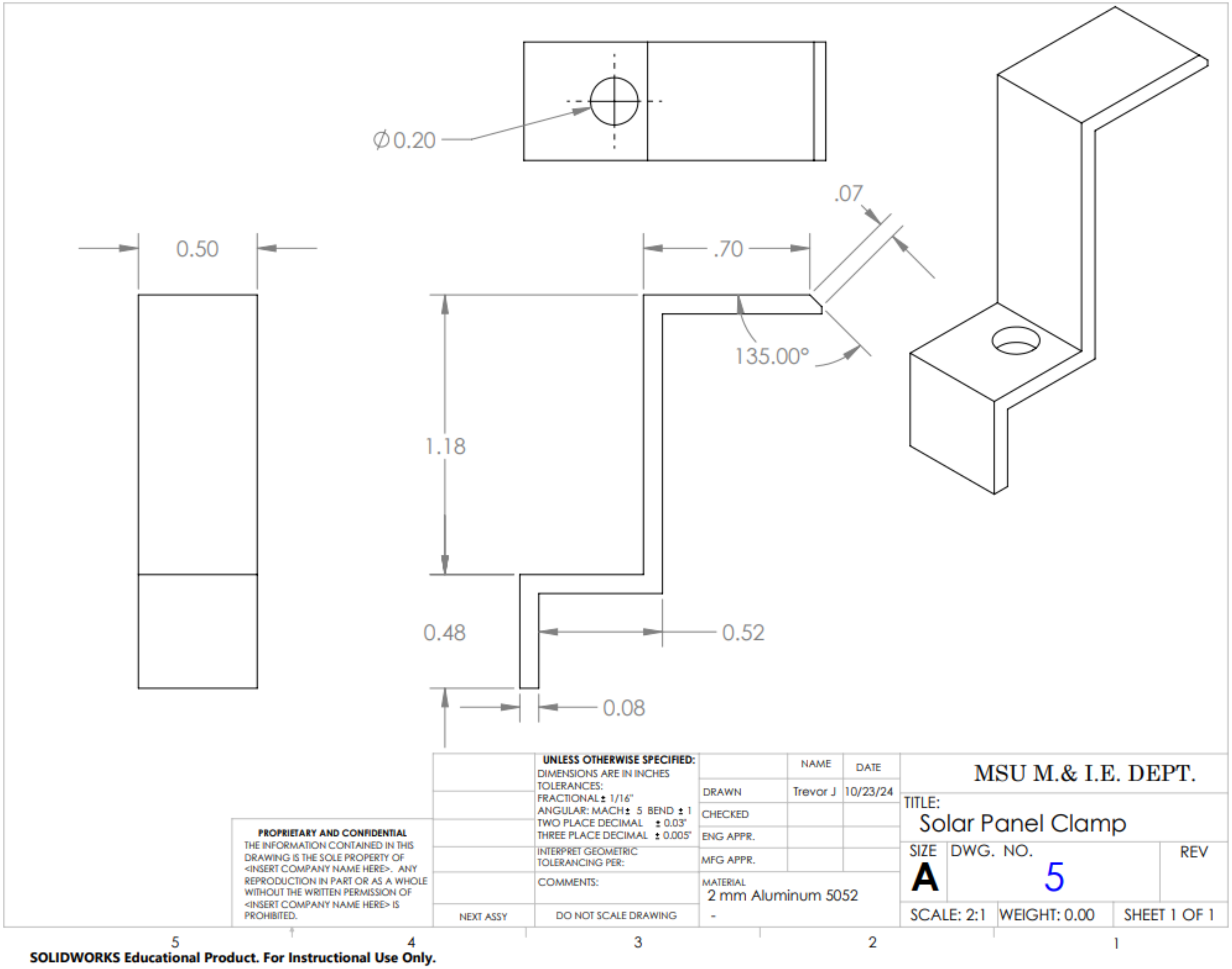
TOLERANCE CHART																
DIMENSION RANGE	0	.039	.118	.236	.394	.591	.866	1.181	1.575	2.087	2.756	3.543	4.724	6.299	7.874	9.843
	.039	.118	.236	.394	.591	.866	1.181	1.575	2.087	2.756	3.543	4.724	6.299	7.874	9.843	12.402
TOOL DEPENDENT	±.007	±.007	±.008	±.008	±.009	±.010	±.011	±.012	±.013	±.015	±.017	±.020	±.024	±.028	±.035	.043
NON-TOOL DEPENDENT	±.003	±.004	±.004	±.004	±.005	±.006	±.007	±.008	±.009	±.011	±.013	±.016	±.020	±.024	±.031	.039



SOLIDWORKS Educational Product. For Instructional Use Only.



SOLIDWORKS Educational Product. For Instructional Use Only.



∅0.20
.07
0.50
.70
135.00°
1.18
0.48
0.52
0.08
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL± 1/16"
ANGULAR: MACH± .5 BEND ± 1
TWO PLACE DECIMAL ± 0.03"
THREE PLACE DECIMAL ± 0.005"
INTERPRET GEOMETRIC TOLERANCING PER:
COMMENTS:
NEXT ASSY
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
Trevor J
10/23/24
CHECKED
ENG APPR.
MFG APPR.
MATERIAL
2 mm Aluminum 5052
-
MSU M.& I.E. DEPT.
TITLE:
Solar Panel Clamp
SIZE
A
DWG. NO.
5
REV
SCALE: 2:1
WEIGHT: 0.00
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
5
4
3
2
1
SOLIDWORKS Educational Product. For Instructional Use Only.

```
% Known parameters
L = 5; % Total height of the stake (ft)
E = 3.68e8; % New Young's modulus (lb/ft^2)
I = 7.75e-6; % Moment of inertia (ft^4)

% Known components:
% Light unit
weight_light = 3.5;
offset_light = 2/12;
height_light = 4;

% Solar panel and battery
weight_solar_battery = 10;
offset_solar_battery = 4/12;
height_solar_battery = 5;

% Unknown battery
offset_battery = 3/12;
height_battery = 4;
weight_unknown_battery = linspace(0, 10, 100);

% Function to calculate displacement at the top of the stake
displacement = zeros(size(weight_unknown_battery));

for i = 1:length(weight_unknown_battery)
    % Calculate moments for each component
    moment_light = weight_light * offset_light * height_light;
    moment_solar_battery = weight_solar_battery * offset_solar_battery * height_solar_battery;
    moment_unknown_battery = weight_unknown_battery(i) * offset_battery * height_battery;

    % Total moment
    total_moment = moment_light + moment_solar_battery + moment_unknown_battery;

    % Deflection at the top of the stake
    displacement(i) = total_moment * L^2 / (2 * E * I);
end
```

```
% Plot the results
figure;
plot(weight_unknown_battery, displacement, 'b-', 'LineWidth', 2);
xlabel('Unknown Battery Weight (lb)');
ylabel('Displacement at Top of Stake (ft)');
title('Load vs. Displacement for Polystake');
xlim([0 10]); % Set x-axis limit to 10 lb
ylim([0.06 0.14]); % Set y-axis limit to 0.06 to 0.14 ft
grid on;

% Adding known displacement from light and solar panel components
known_displacement = (weight_light * offset_light * height_light + weight_solar_battery * offset_solar_battery * height_solar_battery) * L^2 / (2 * E * I);

hold on;
plot([0, 10], [known_displacement, known_displacement], 'r--', 'LineWidth', 2);

% Set displacement limit
displacement_limit = 0.12;
plot([0, 10], [displacement_limit, displacement_limit], 'g--', 'LineWidth', 2);

legend('Displacement with Variable Battery', 'Known Displacement from Components', 'Displacement Limit (0.12 ft)', 'Location', 'NorthWest');
hold off;
```

Communication Alternative Analysis

Characteristics	Weight	Wifi	Bluetooth	LoRa
Costs	4	5	4	2
		$1-5	$10±	$30
Range	4	2	3	5
		150ft	300 ft	10+ miles
Data Transfer Rate	1	5	3	1
		54 Mbps	1 Mbps	.25-22 Kbps
Reliability	5	3	2	5
		*	**	***
Power Consumption	5	2	4	5
		100-300 mA	15-30 mA	10-20 mA
Final		58	65	78

Lights Alternative Analysis

Characteristics	Weight	BBMI 100mm Traffic Light (link)	PAR36 LED DC Light Bulb (link)	QLUXR5010W35LED930 LED Array (link)	G4 LED Light Bulb - Bi-Pin LED Disc (link)	Luxeon C Color LEDs (link)
Visibility	4	1 - 250 lumens	5 - 1280 lumens	5 - 1360 lumens	2 - 350 lumens	2 - G 149 lumens, R 41 lumens
Cost	4	2 - $165.99	3 - $13.99	5 - $3.80	3 - $5.99	3 - $5.11
Power Consumption	5	5 - 2.5W	3 - 12W	3 - 10W	5 - 3W	5 - 14- 3.15W
Weather Resistance	3	5 - IP65	5 - IP65	0 - no rating	0 - no rating	0 - no rating
Size	2	1 - 11.81 x 6.89 x 5.91 inches; 4.41 Pounds	1 - 4.4 inch diameter	5 - 50 mm (1.96 inch) Diameter	5 - 1.36" diameter	5 - 2x2mm
Assembly	3	5 - pre built	2 - needs housing	1 - needs housing	1 - needs housing	1 - needs housing
TOTAL:	null	69	70	68	58	58

Transistor Datasheet Info

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	55	—	—	V	V_{GS} = 0V, I_D = 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.070	—	V/°C	Reference to 25°C, I_D = 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.022	Ω	V_{GS} = 10V, I_D = 25A ④
		—	—	0.025		V_{GS} = 5.0V, I_D = 25A ④
		—	—	0.035		V_{GS} = 4.0V, I_D = 21A ④
$V_{GS(th)}$	Gate Threshold Voltage	1.0	—	2.0	V	V_{DS} = V_{GS}, I_D = 250μA
g_{fs}	Forward Transconductance	21	—	—	S	V_{DS} = 25V, I_D = 25A
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	V_{DS} = 55V, V_{GS} = 0V
		—	—	250		V_{DS} = 44V, V_{GS} = 0V, T_J = 150°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS} = 16V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS} = -16V
Q_g	Total Gate Charge	—	—	48	nC	I_D = 25A
Q_{gs}	Gate-to-Source Charge	—	—	8.6		V_{DS} = 44V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	25		V_{GS} = 5.0V, See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	11	—	ns	V_{DD} = 28V
t_r	Rise Time	—	84	—		I_D = 25A
$t_{d(off)}$	Turn-Off Delay Time	—	26	—		R_G = 3.4Ω, V_{GS} = 5.0V
t_f	Fall Time		15			R_D = 1.1Ω, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.)
L_S	Internal Source Inductance	—	7.5	—		from package and center of die contact 
C_{iss}	Input Capacitance	—	1700	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	400	—		V_{DS} = 25V
C_{rss}	Reverse Transfer Capacitance	—	150	—		f = 1.0MHz, See Fig. 5

Solar Panel Specs

Features

- Waterproof (IP67)
- High efficiency monocrystalline cells: 22.8%
- Compatible with the Extra Large Solar Panel Bracket

Size and Weight

- 58.6 x 50.7 x 3.0 cm
- 3.4 kg

Output

- Open Circuit Voltage: 20.7V
- Peak Voltage: 17.7
- Peak Current: 3.2A
- Peak Power: 56.7W
- Power Tolerance: +/-10%
- For maximum power output, orient the panel towards the sun

Construction

- 3.2mm Glass Laminate
- Anodized Aluminum Frame

Output Cable

- Cable Length: 500 mm
- Cable Color: Black / Red PVC Coated
- Plug: Waterproof MC4

Battery Specs

Size and Weight

- 6.25 x 2.5 x 1.3 in. (16 x 6.4 x 3.3 cm)
- 1 pound 2 ounces (540 g)

V70 IoT Battery

- Capacity: 19,200mAh, 71 Watt Hours
- Output: 60 Watts Maximum, 10-12.6V Unregulated
- Input: 15-23V
- Minimum Charge Current: 5mA
- Maximum Power Point (MPP): 13V
- Input Connector: Molex 43640-0210
- Output Connector: Molex 43645-0200
- Battery Type: Li-Ion LG 18650
- Protection: Short circuit over charge, over discharge, over temperature (45℃ Input Cutoff, 60℃ Output Cutoff), under temperature (0℃ Input Cutoff, -15℃ Output Cutoff)