JumpGuard
Final Design Review

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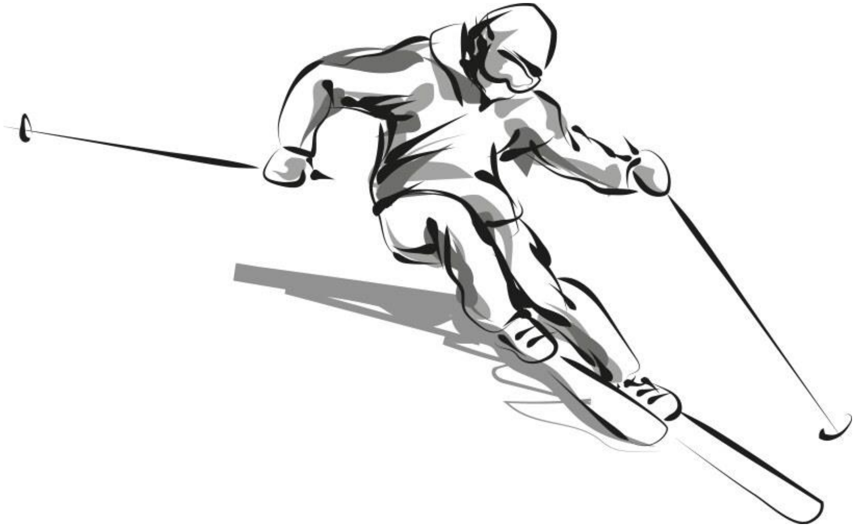


Clients: Nick Hekker, Kade Borson, Tate Ellinwood, Tristan Tober

Advisor: Dr. Kevin Repasky

Date: 4/15/2025

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.

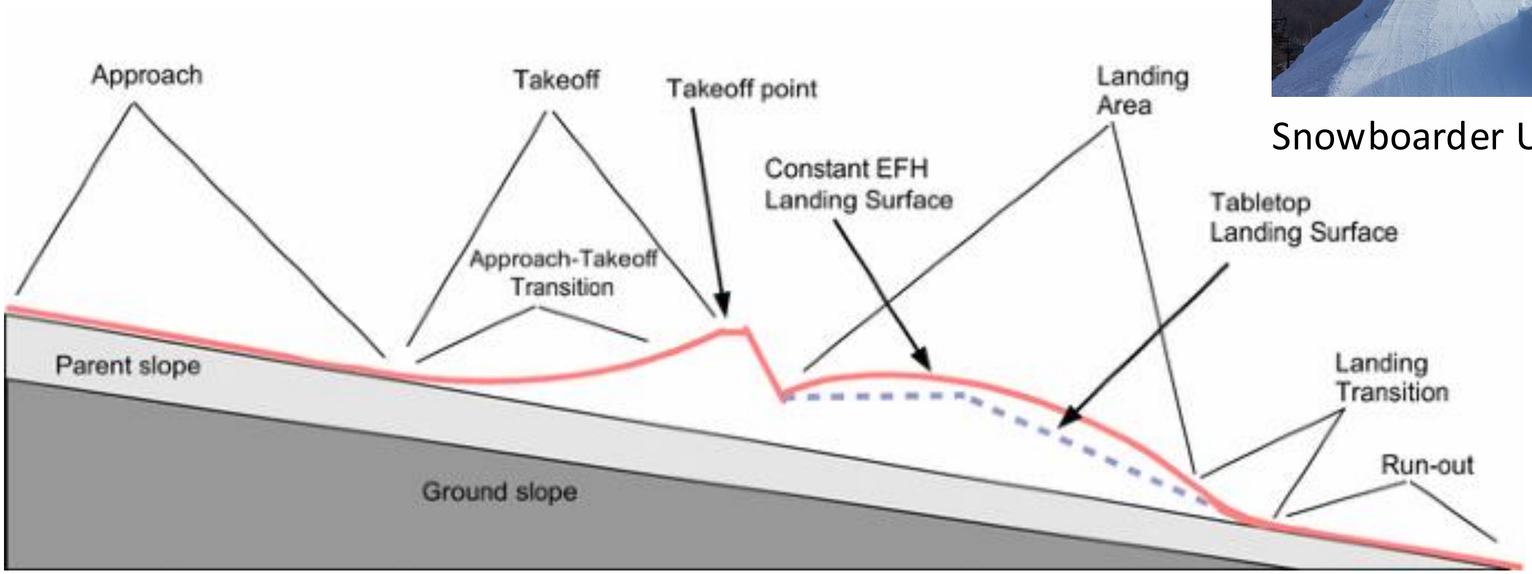
Project Description:

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.

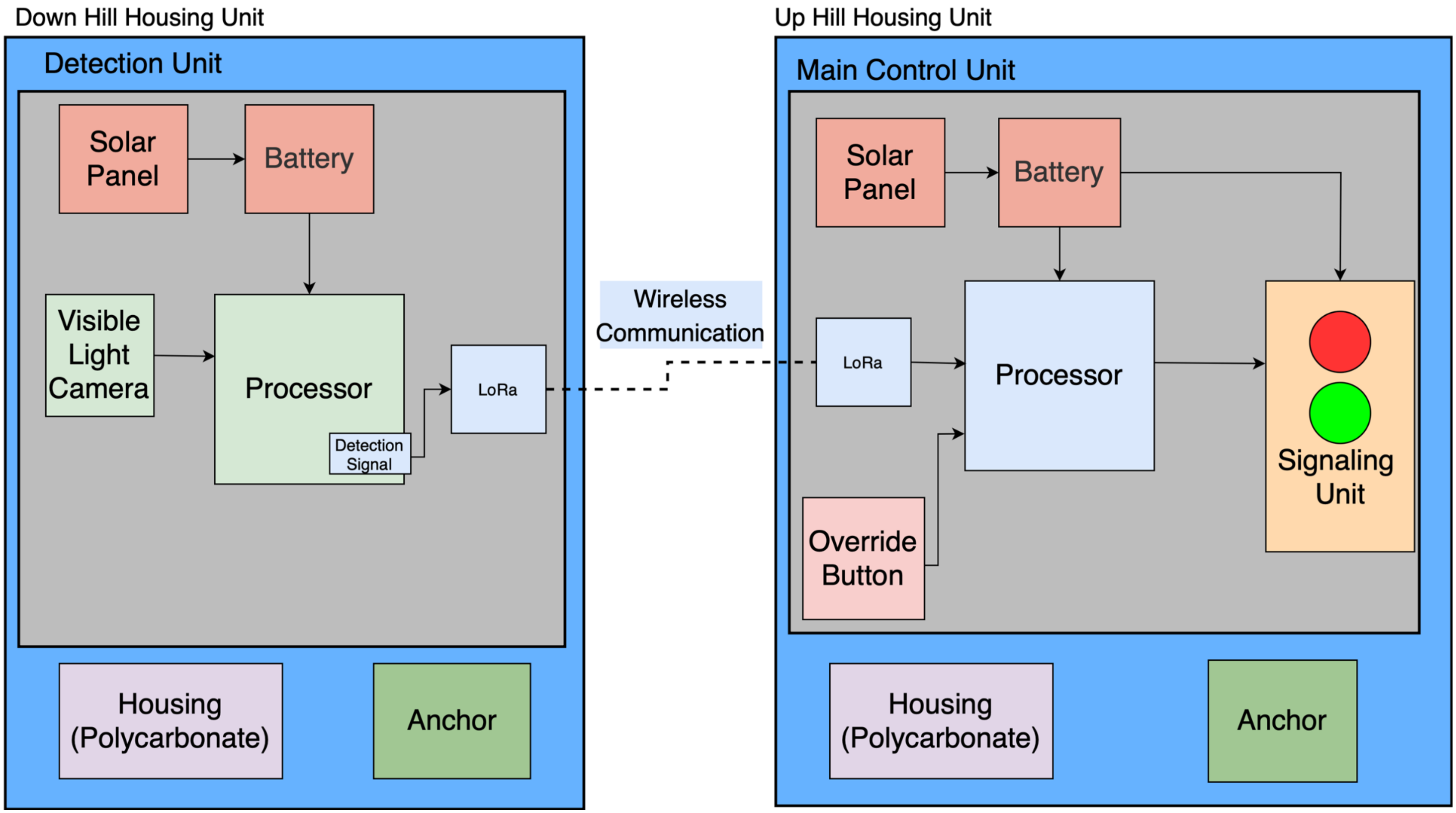
Necessary Background



Terrain Park Jump Diagram

Snowboarder Using Large Jump

Project Design Concept



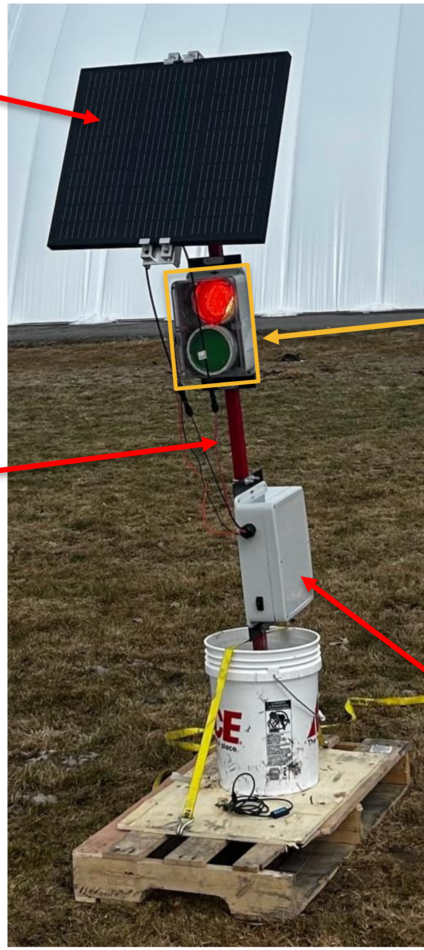
Conceptual Block Diagram

System Design Solution

Uphill Solution

Solar Panel

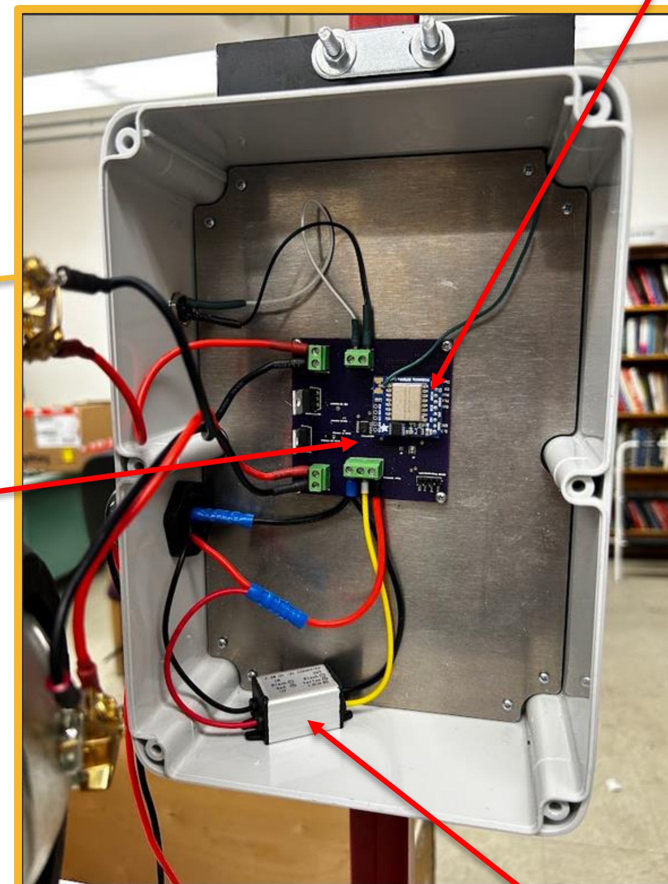
PolyStake



Battery and
Charge Controller

MSP430

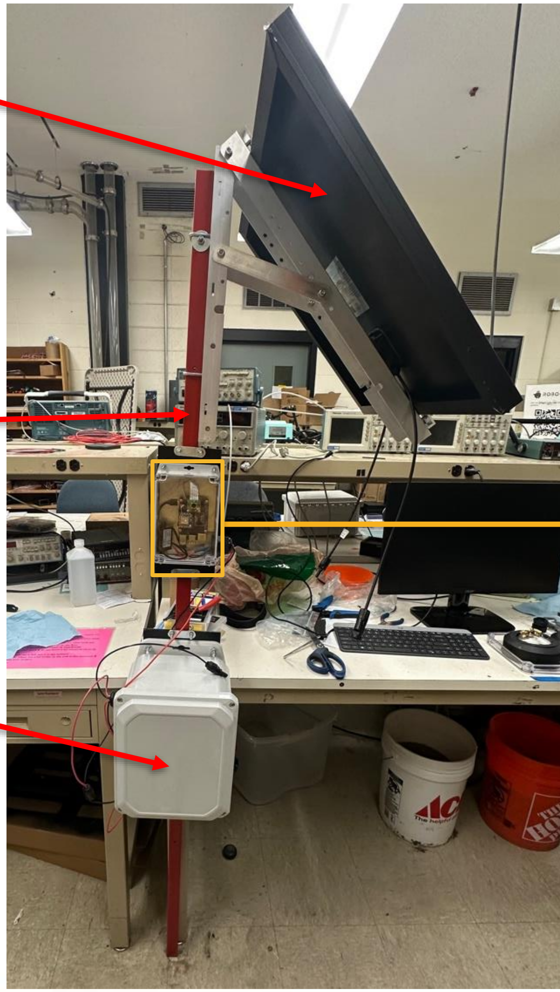
LoRa

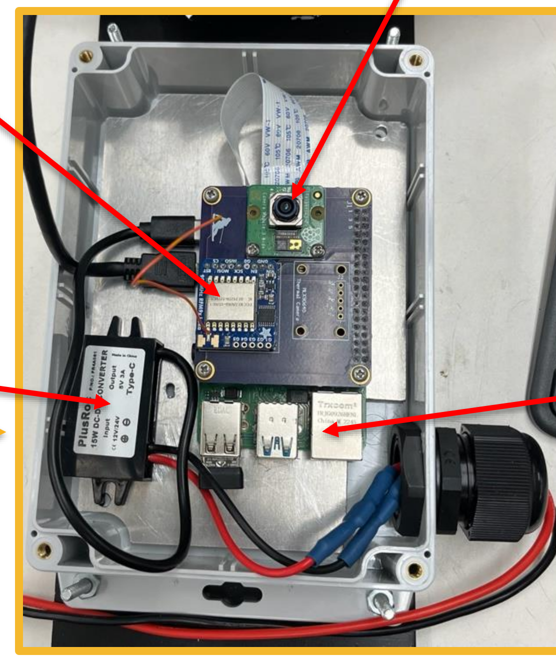


DC/DC Converter

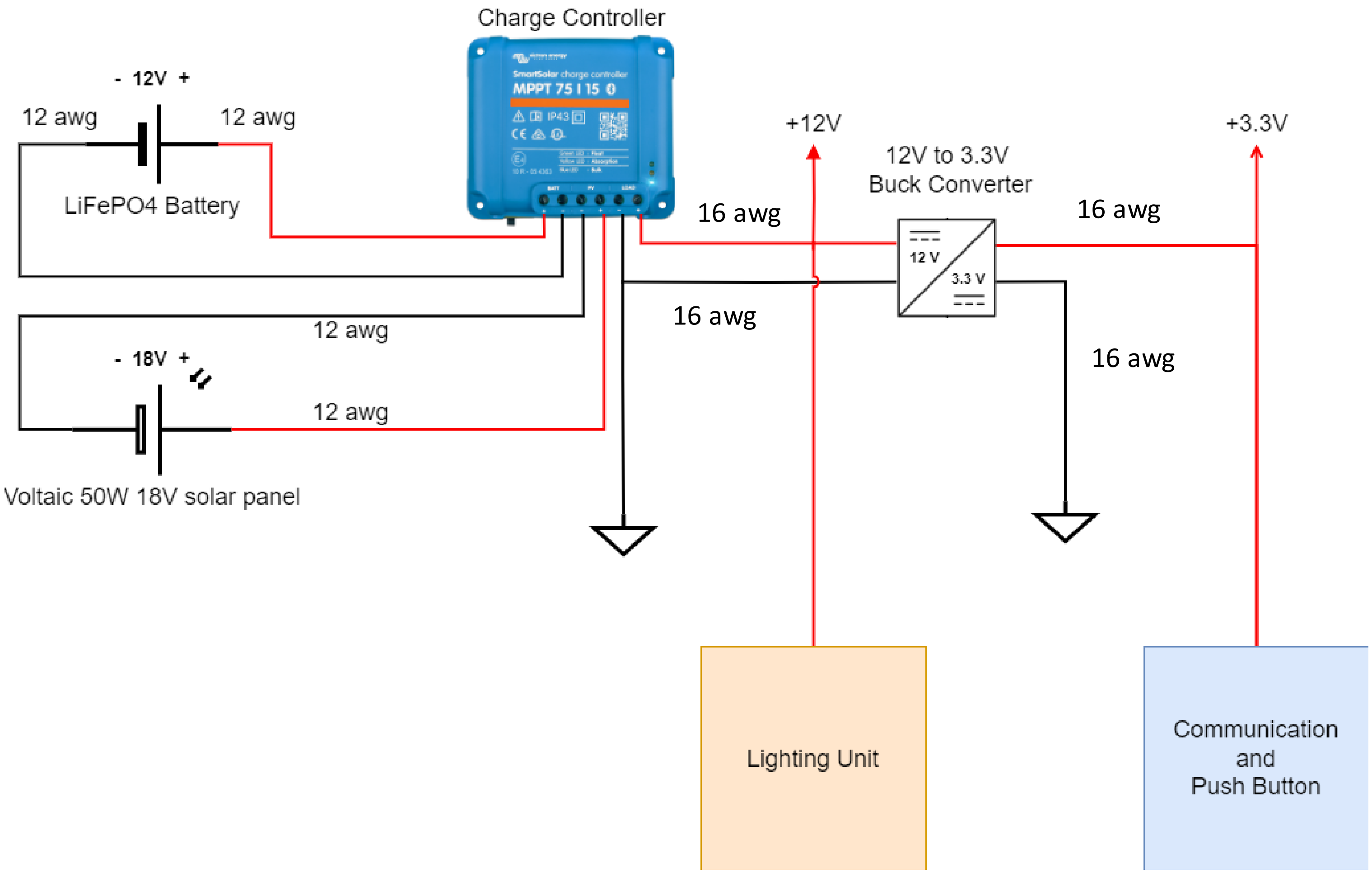
System Design Solution

Downhill Solution





Design Solution: Uphill Power



Design Solution: Uphill Power

PV

Battery

Load

Communication/Lighting

Light Connections

DC/DC Converter

Load

System Verification: Power (Spec 3.2.1 – test description)

Spec 3.2.1) Can recharge for a 7-hour operational day with 3.5 hours of peak sunlight

- Full system assembled
- Run off backup power for one day
- Run with solar panels for one day
- Run off backup power for one day

System Verification: Power (Spec 3.2.1 – test results)

Spec 3.2.1) Can recharge for a 7-hour operational day with 3.5 hours of peak sunlight

Uphill test results (04/09 – 04/11)

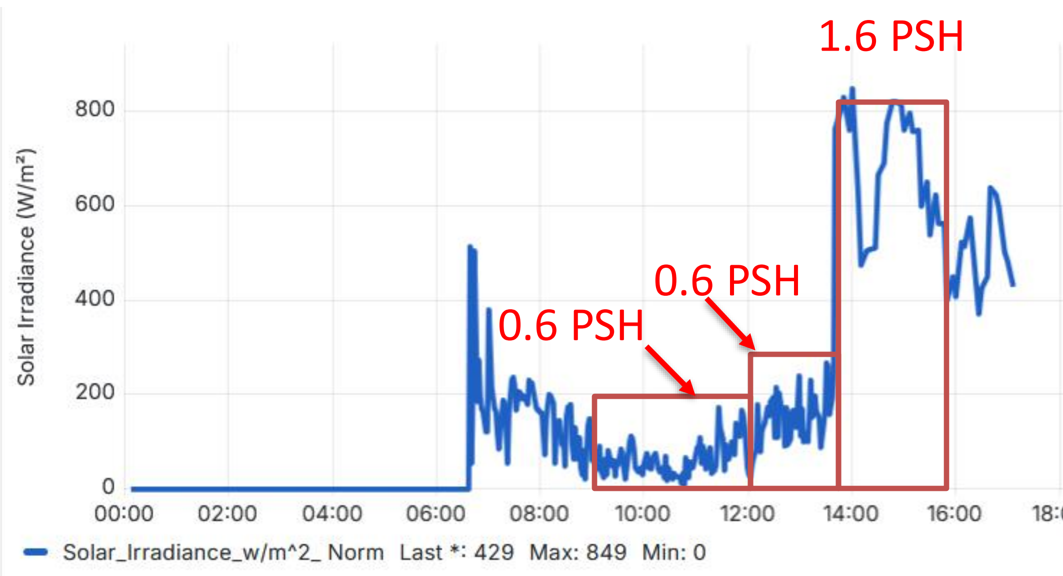
Date (mm/dd/yyyy)	Consumption (Wh)	Yield (Wh)	Initial Voltage (V)	Final Voltage (V)
04/09/2024	80	0	13.27	13.12
04/10/2024	70	160	13.14	13.42
04/11/2024	80	0	13.29*	13.00

*system was used for additional testing after the 7 hour testing window

System Verification: Power (Spec 3.2.1 – test results)

Spec 3.2.1) Can recharge for a 7-hour operational day with 3.5 hours of peak sunlight

Solar irradiance data for 04/10/2024 [1]



Testing window: 8:56am-4:00pm

PSH for 4/10/2025 =
0.6 + 0.6 + 1.6 = ~2.8 PSH

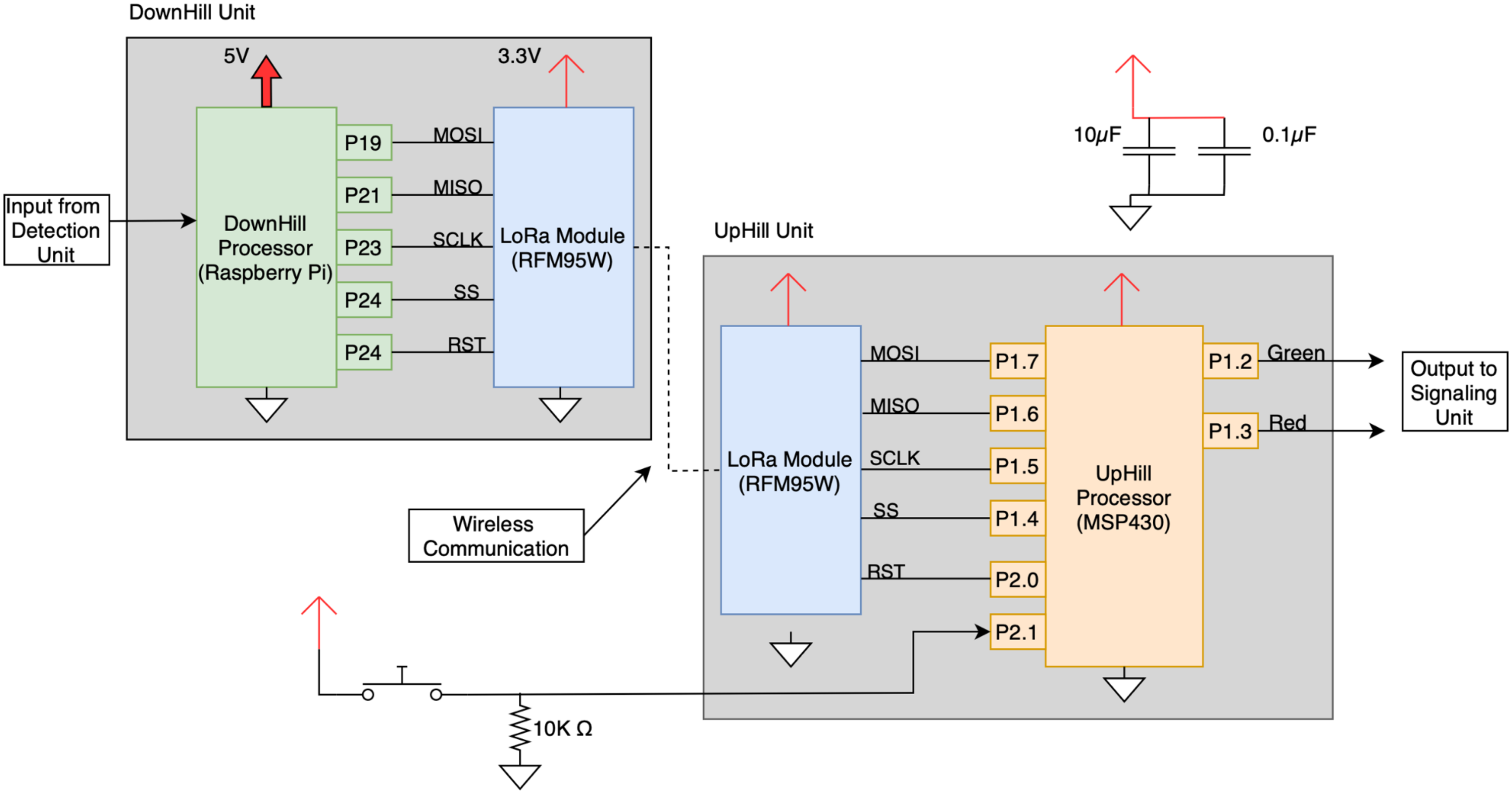
[1] Montana State ORSL Weather Station

Local Montana Time

System Verification: Power (summary)

Req Doc Item	Result	Pass/Fail
Req 3.1	System operated continuously for 7 operational days	Pass
Spec 3.1.1	System operated continuously for a 7-hour operational day	Pass
Spec 3.1.2	Backup power operated for 7 hours	Pass
Req 3.2	Solar and battery charger both charged the system	Pass
Spec 3.2.1	Recharged with under 2.8 PSH	Pass
Spec 3.2.2	Battery charger charged battery under 8 hours	Pass

Design Solution: Communication



System Verification: Communication Setup

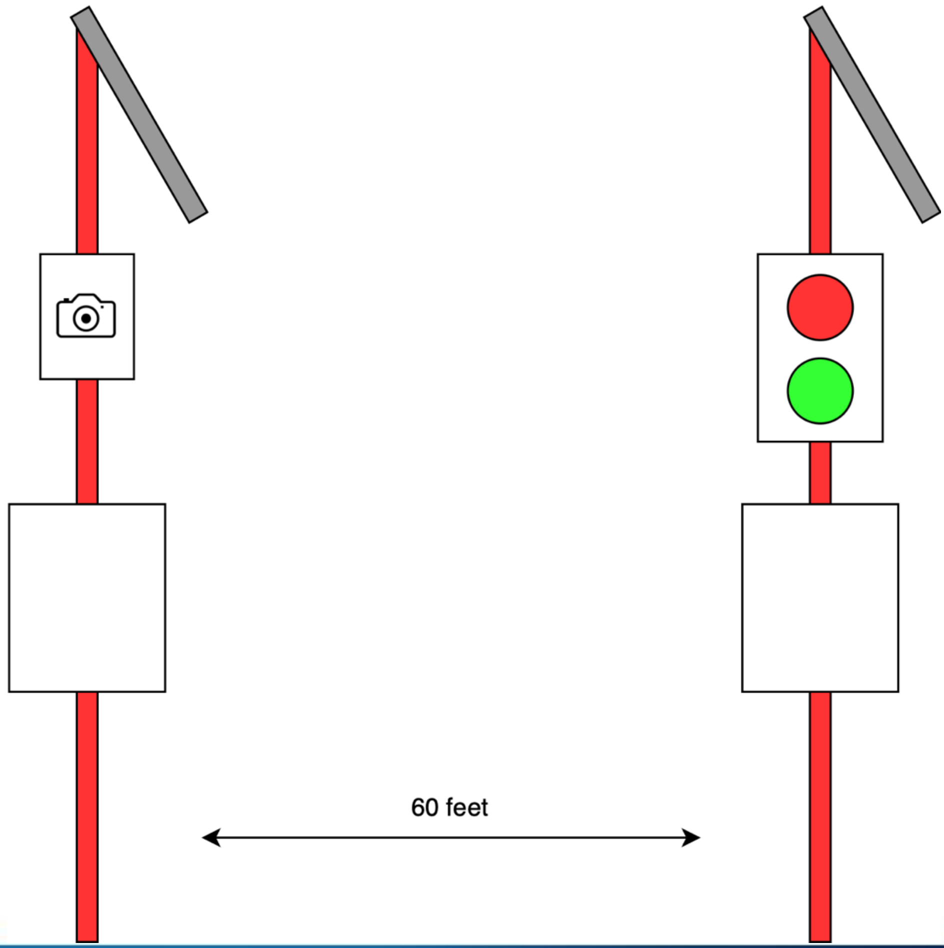
Req 1.2) System must communicate detection results to uphill athletes.

Spec 1.2.2) Dropout rate of information must be ≤ 2.0%

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

Testing Procedures:

- Tested 20 times throughout a 7-hour period
- Tested for 5 days total
- Camera was covered with paper; green light is expected. When camera is uncovered, red light is expected



System Verification: Communication Results

Testing day 1 – April 6th

	Expected Detection Signals	Actual Detection Signals
Test 1:	1	1
Test 2:	1	1
Test 3:	1	1
Test 4:	1	1
Test 5:	1	1*
Test 6:	1	1
Test 7:	1	1
Test 8:	1	1*
Test 9:	1	1
Test 10:	1	1
Test 11:	1	1*
Test 12:	1	1
Test 13:	1	1
Test 14:	1	1
Test 15:	1	1
Test 16:	1	1*
Test 17:	1	1
Test 18:	1	1
Test 19:	1	1
Test 20:	1	1

Req 1.2) System must communicate detection results to uphill athletes.

Spec 1.2.2) Dropout rate of information must be ≤ 2.0%

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

0 = lights did not operate as expected
1 = lights operated as expected (changed from green to red when camera was uncovered, then back to green once covered)

Results for day 1:

- 100% communication rate
- 0% dropout rate

Results for all days:

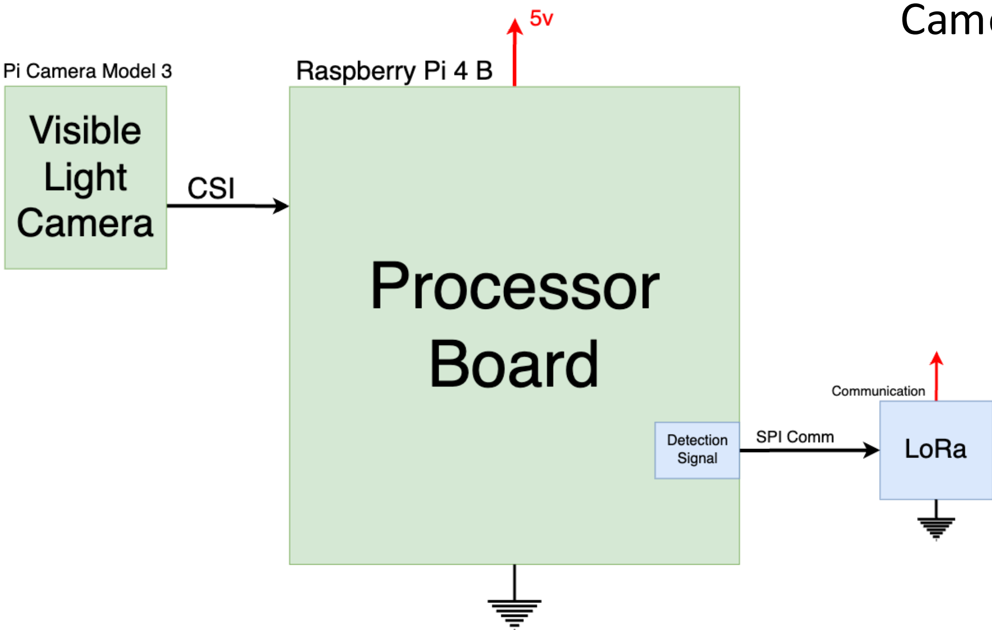
- 100% communication rate
- 0% dropout rate

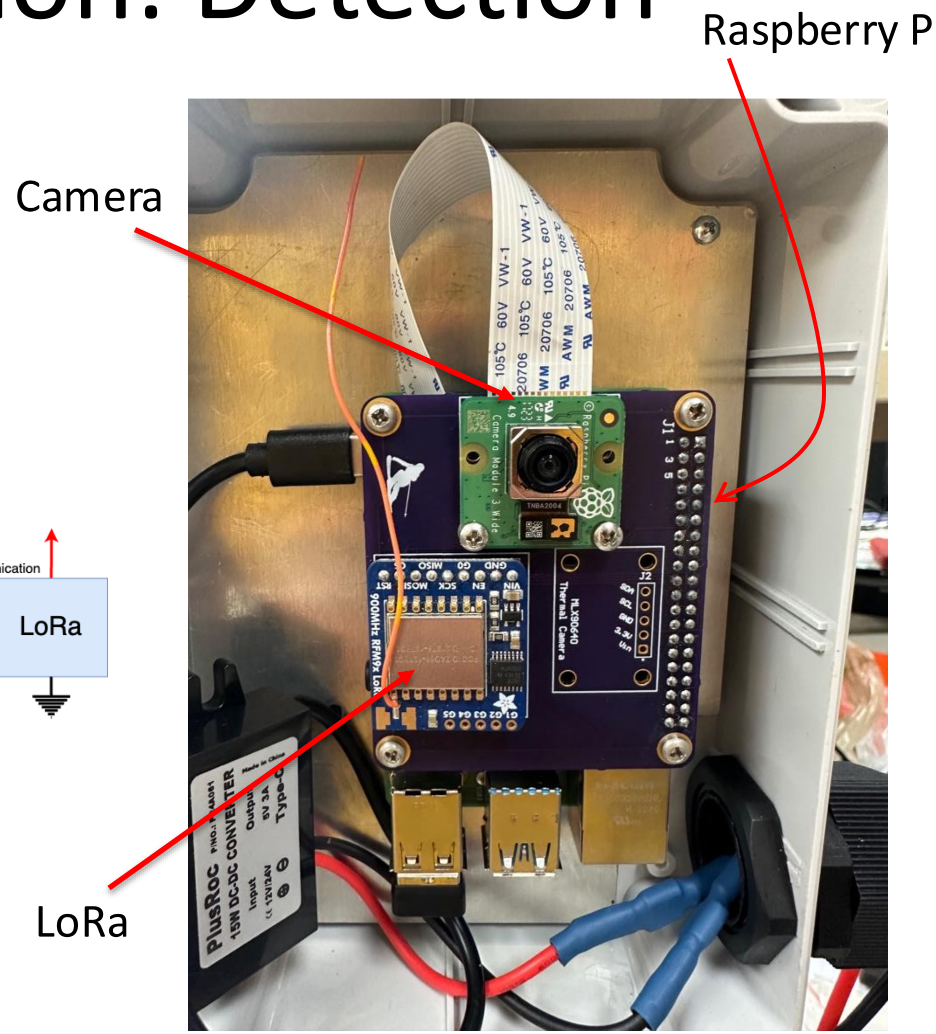
*Camera timed out, after a reboot the system operated as expected

Verification: Communication (Summary)

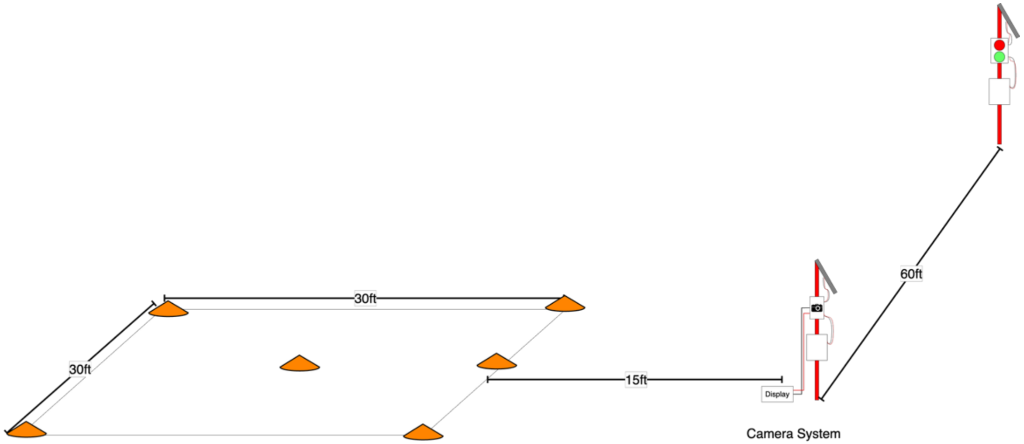
Req Doc Item	Results	Pass
Spec 1.2.1 – Latency from when the sensor triggers, to when the signaling unit triggers, must be ≤ 0.5s	Maximum Latency of 110 ms	Pass
Spec 1.3.3 – Latency of the lights changing states after a signal is received must be ≤ 0.5s	Refer to spec 1.2.1 results	Pass
Spec 1.3.4 – Must have a manual override to send the system to the "stop" state in case of emergencies	Entered "Stop" mode 20/20 times	Pass

Design Solution: Detection





System Verification: Detection Setup

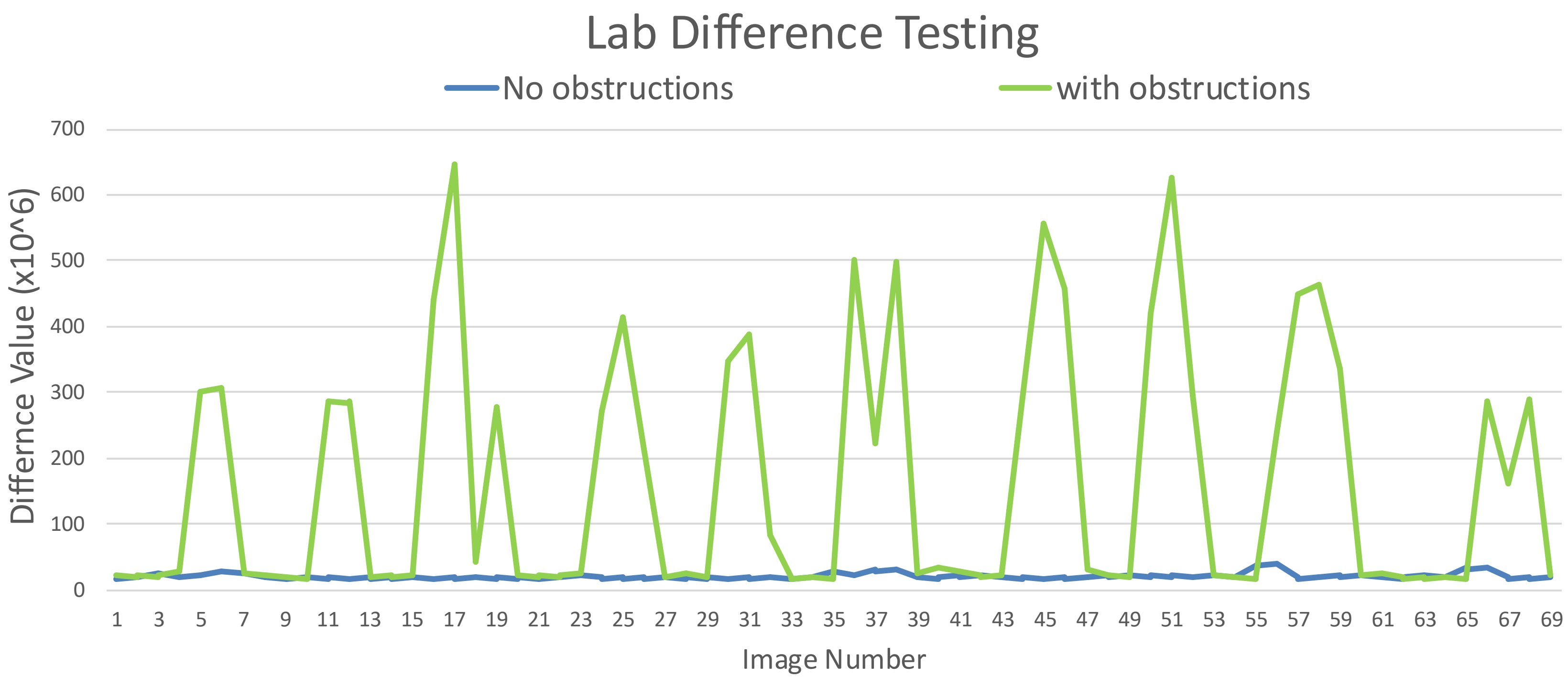


Controlled Environment Testing Area

- Difference detection algorithm initialized using average of 10 static images + 10% margin
- Reference image updated dynamically (based on test type)
- Tested in small (2–3 ft) lab and larger intended deployment areas (indoors & outdoors)
- Data logged: difference values, CPU temp, usage, processing time, capture time

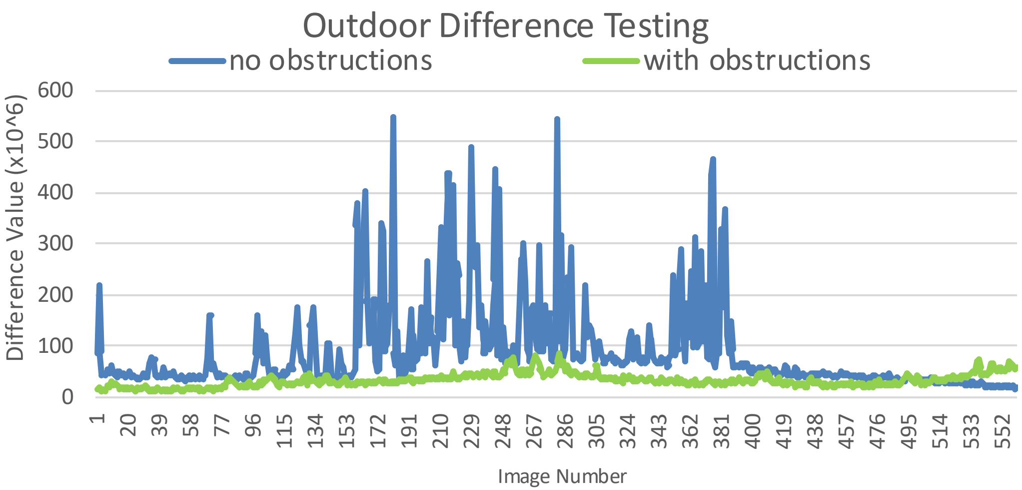
Outdoor Environment Testing Area

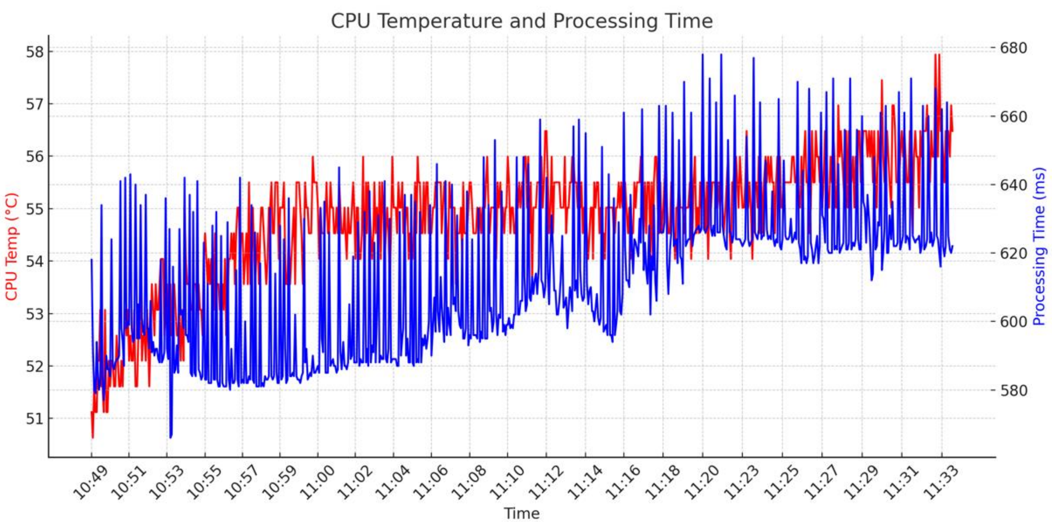
System Verification: Detection Results (Controlled Test)



- Detection was 100% accurate in limited space (~2–3 ft)
- Threshold logic performed consistently
- Difference values remained consistent: **~20-30M**
- System remained responsive and CPU/memory usage stable
- Confirms **algorithmic viability** in stable, small-scale settings

System Verification: Detection Results (Outdoor Test)





- Initial 2–3 frames post-threshold were green → quickly turned red and stayed
- False triggers likely from shadows, light shifts, environmental motion
- CPU temp peaked ~58°C, but not dangerously high
- Camera stopped responding ~1 hour in (timeout)
- Increasing CPU temperature and rising processing time likely contributed to camera timeouts

System Verification: Detection Summary & Lessons Learned

Metric	Small-Scale Lab	Full-Area Setup	Outdoor
Accuracy	100%	Inconsistent	**Unusable**
Threshold Stability	High	Low	**Very Low**
CPU/Temp	Stable	Stable	**High Load**
Behavior	Reliable	Detection Drift	**Crashes/Freezes**

Lessons + Next Steps

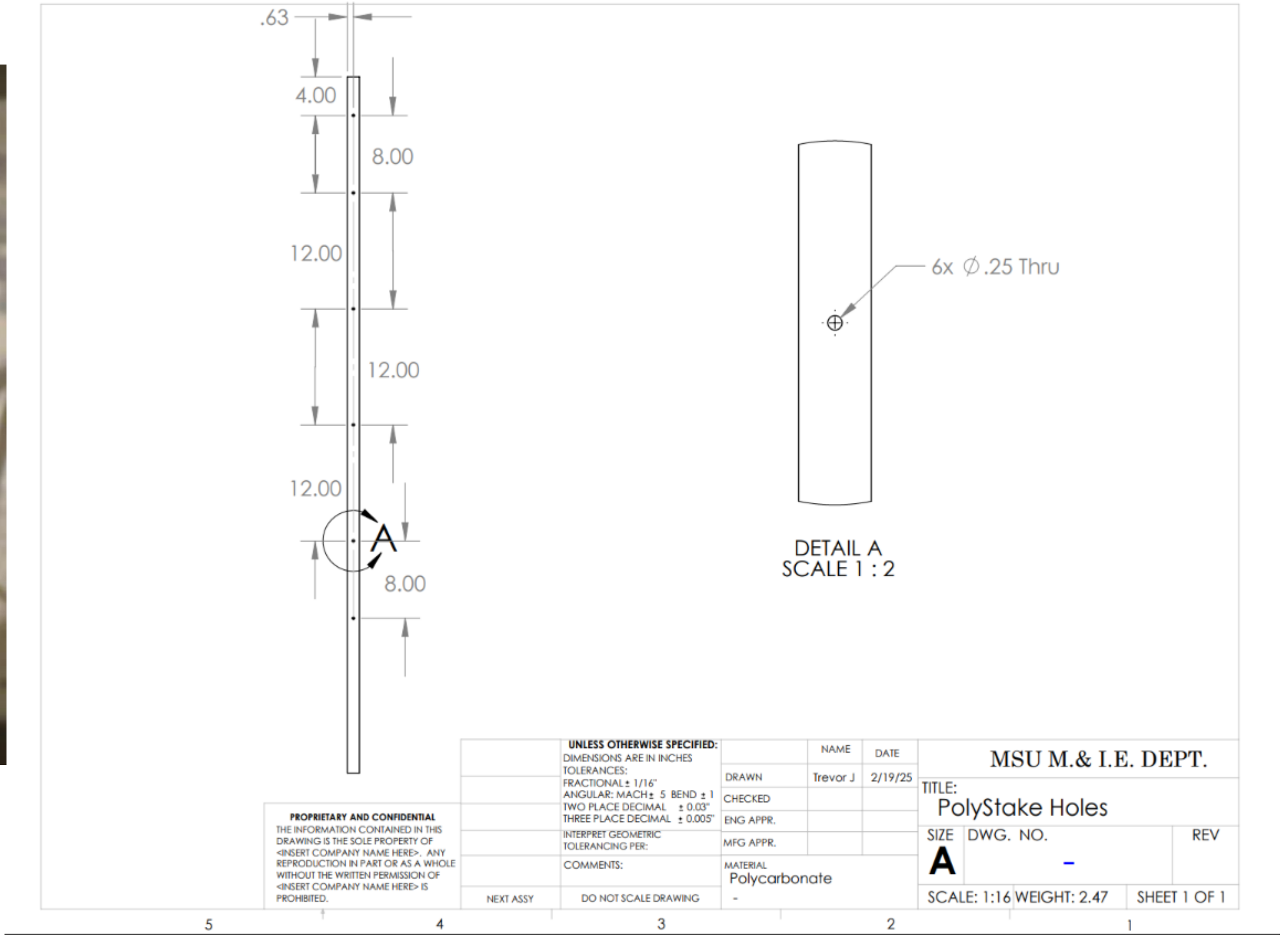
- **What Worked:** Algorithm logic, adaptive thresholding, thermal performance
- **What didn’t Work:** Environmental adaptation, reference handling, long-term stability
- **To be added in the Future:** Add thermal camera, region filtering, watchdog for camera recovery

System Verification: Detection Summary

Req Doc Item	Results	Pass
Req 1.1: System must detect when the landing area is clear	In controlled smaller environments the system can detect a clear detection area	Fail at system level
Spec 1.1.1: Detection system must be able to detect athletes within a 30x30 ft area within the landing area	Environmental noise prevents detection over larger areas	Pass at Spec level, fail at system level
Spec 1.1.2: Must have ≥ 95% detection rate	In controlled environments the system can detect a clear landing area.	Pass at Spec level, fail at system level

*Based on image difference noise behavior shown in Slide 3

Design Solution: Mounting and Anchoring



System Verification: Mounting and Anchoring Setup

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

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

Testing Procedure:

- System fully set up outdoors daily for 6 days with 20 random checks for functionality
- Wind speed, temperature, and overall conditions were recorded during each detection test
- Sand Bucket used to simulate mounting in snow

System Verification: Mounting and Anchoring Results

Key Points of data from Thursday, April 10

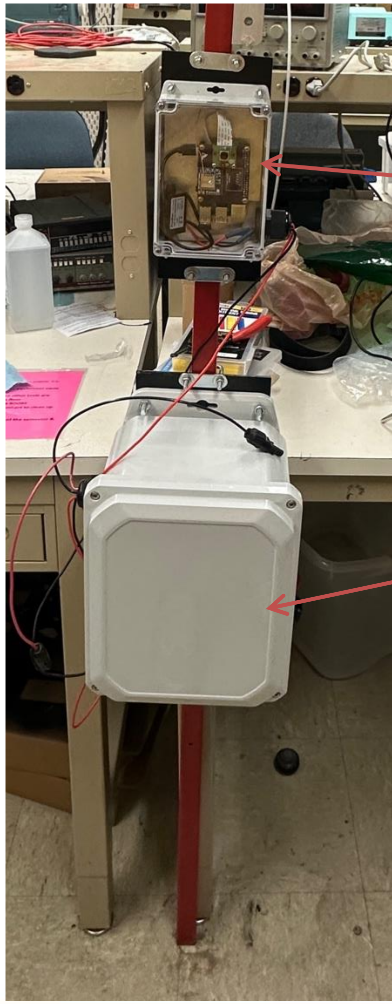
Test #	Expected Signal	Actual Signal	Time	Weather	Light Visible?	Wind	Temp
6	1	1	10:50 AM	Light Hail	Yes	1.21 mph	46.8°F
7	1	1	11:05 AM	Light Hail	Yes	1.13 mph	47°F
18	1	1	3:15 PM	Sunny/ Cloudy	Yes	23 mph	54°F
19	1	1	3:30 PM	Sunny/ Cloudy	Yes	24	54°F

System Verification: Anchoring and Mounting

- **Spec 2.1.2 Verified**
  The system was exposed to wind conditions up to and above 20 mph. All components remained fully functional, meeting the design specification.
- **Weather Resistance Demonstrated**
  During testing, the system withstood not only wind but also rain and hail. No damage or performance issues were observed, confirming durability under various weather conditions.
- **0°F Temperature Specification Partially Verified**
  Full-system cold testing at 0°F was not possible due to the lack of a controlled environment and spring weather. However, the housings were tested separately and passed under low-temperature conditions.

Design Solution: Housing

Detection Unit

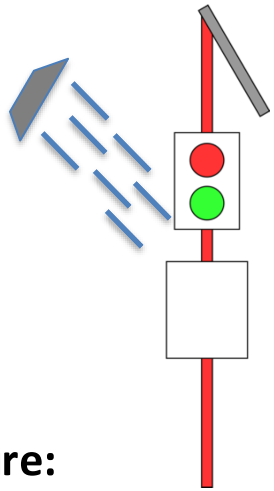


Detection Housing

Battery Housing

System Verification: Housing Setup

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



Test Method Summary:
Water was sprayed on the housings for 4 minutes from all sides using a hose / similar source, then internal elements were inspected for moisture and electronics functionality.

Testing Procedure:

1. Absorbent paper was placed in all housing at seams and cable entries
2. Housings were sprayed at medium pressure from the top, front, left, and right for 1 minute each
3. Housings were dried off, opened and inspected for water ingress

System Verification: Housing Results

Housing Unit	Water Present?	Paper Damp?	Leak Location?	Electronics Functional?
Signaling	N	Y	Cable Gland	Y
Uphill Battery	N	N	N/A	Y
Detection	N	Y	Cable Gland	Y
Downhill Battery	N	N	N/A	Y

Pass/Fail Criteria:
PASS: No visible internal water, dry paper/sensors, electronics working normally.

FAIL: Any sign of internal water, malfunctioning components, or wet absorbent indicators.

- Since slight water ingress was present, the system cannot confidently pass Req 2.1
- Moving forward, a simple fix can be made by getting some larger rubber plugs or silicon-based sealant for the unused spots in the cable glands

System Verification: Objective 2

Req Doc item	Result	Pass
Spec 2.1.1	Humidity remained below 80% at 0°	Spec passes, System N/A
Spec 2.1.2	System operated in wind over 20mph	Pass
Spec 2.1.3	Unable to test	N/A
Req 2.1	Slight water ingress, electronics protected	Fail – Can be fixed with some quick changes to sealing
Spec 2.2.1	Light visible from 180ft	Pass
Spec 2.2.2	Green: 1317 Lumens Red: 1626 Lumens	Pass
Spec 2.2.3	Housings fully adjustable along stake up to 5ft individually	Spec pass, System fail – Can be fixed with a longer stake/extension
Req 2.2	Lights produce bright and visible light from 30ft away	Pass

Spec 2.1.1) Must be able to withstand and function in temperatures ≥ 0°F
Spec 2.1.3) System is not meant to operate in visibility lower than 30 ft or when the terrain park is not operational
Spec 2.2.3) Adjustable between 0 - 5 feet with height increments by ± 6” for every adjustment

Project Status

- Working to complete Final Project Report, and create User's manual for Sponsors
- Communicating with the Sponsors for Project Handoff
- Design Fair Poster is nearly complete
- Preparing System to display during Design Fair
- Req 2.1 will be tested again before Design Fair with improved sealing in the upper units' glands

Project Budget

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	10.31.2024	12.08.2024	Riley	LoRa Module (RMF95W)	$75.00	$23.68	Adafruit	2	$25.66	$51.32
2	10.14.2024	12.08.2024	Riley	MSP430 launchpad	$25.00	-$0.36	Adafruit	1	$25.36	$25.36
3	12.12.2024	02.03.2025	Riley	Emergency stop push button(CWI2	$30.00	$11.74	Digikeey	2	$9.76	$18.26
4	10.17.2024	12.08.2024	Riley	MSP430FR2111	$4.00	$0.00	DigiKey	1	$4.00	$4.00
Detection System										
5	11.03.2024	12.08.2024	Emily	Thermal Camera (Adafruit MLX90640 24x32 IR Thermal Camera Breakout - 110 Degree FoV)	$74.95	-$3.81	Adafruit	1	$78.76	$78.76
6	11.03.2024	12.08.2024	Emily	Visible Light Camera (Raspberry Pi Camera Module 3 Standard - 12MP Autofocus)	$35.00	-$3.81	Adafruit	1	$38.81	$38.81
8	11.03.2024	12.08.2024	Emily	Processor (Raspberry Pi 4 Model B)	$75.00	-$3.81	Adafruit	1	$78.81	$78.81
9	02.02.2025	02.03.2025	Emily	Downhill Detection Unit PCB components	$13.81	$0.00	Digikey	1	$13.81	$13.81
Stoplight System										
10	11.05.2024	12.08.2024	Ben	Lights	$27.98	$0.00	Amazon	2	$13.99	$27.98
11	11.05.2024	12.08.2024	Ben	Transistors	$18.10	-$8.80	DigiKey	10	$2.69	$26.90
12	11.19.2024	12.08.2024	Ben	Color filters (Red and Green)	$16.97	$0.00	Amazon	2	$8.99	$16.97
Uphill Housing										
13	01.23.2025	02.03.2025	Johnny	PolyStakeXL	$21.00	-$39.33	FallLine	1	$60.33	$60.33
14	11.04.2024	12.08.2024	Johnny	ML-70F Plastic NEMA Enclosure	$45.00	-$4.20	PolyCase	1	$49.20	$49.20
15	01.27.2025	02.03.2025	Johnny	ML-92F Weatherproof NEMA Enclo	$79.00	-$6.34	PolyCase	1	$85.34	$85.34
16	02.02.2025	03.15.2025	Johnny	Solar Panel Mounting	$50.00	-$11.08	Voltaic	1	$61.08	$61.08
17	02.26.2025		Johnny	Mounting Materials	$20.00	$0.50	Ace Hardware	1	$19.50	$19.50
18	02.10.2025	03.15.2025	Trevor	Internal Mounting Plate	$15.00	$0.00	PolyCase	1		$0.00
Downhill Housing										
19	01.23.2025	02.03.2025	Johnny	PolyStakeXL	$21.00	-$39.33	FallLine	1	$60.33	$60.33
20	11.04.2024	12.08.2024	Johnny	WC-24F Outdoor Enclosure with C	$35.00	$7.64	PolyCase	1	$27.36	$27.36
21	01.27.2025	02.03.2025	Johnny	ZQ-100806 Outdoor Electrical Jun	$63.00	-$9.24	PolyCase	1	$72.24	$72.24
22	01.27.2025	02.03.2025	Johnny	WX-22 Panel for WA/WP/WC Serie	$11.00	-$6.15	PolyCase	1	$17.15	$17.15
23	02.26.2025		Johnny	Mounting Materials	$20.00	$0.51	Ace Hardware	1	$19.49	$19.49
24	02.02.2025	03.15.2025	Johnny	Solar Panel Mounting	$50.00	-$11.07	Voltaic	1	$61.07	$61.07
Power										
25	01.29.2022		Ben	Solar Panel	$89.00	-$89.00	Voltaic	2	$89.00	$178.00
26	01.29.2023		Ben	Battery 30Ah	$80.00	$0.00	Eco-Worthy	1	$80.00	$80.00
27	01.29.2024		Ben	Battery Charger	$49.99	$0.00	Eco-Worthy	1	$49.99	$49.99
28	01.29.2025		Ben	Charge controller	$50.15	-$50.15	Blue Marine	2	$50.15	$100.30
29	01.29.2026		Ben	Battery 10Ah	$36.00	$0.00	Eco-Worthy	1	$36.00	$36.00
OTHER SYSTEM LEVEL COMPONENTS (these might include bulk wiring, shipping, PCB manufacturing)										
30	03.30.2025		Riley	Sand and Bucket (Testing)	$14.18	$0.00	Ace Hardware	1	$14.18	14.18
31	02.10.2025		Trevor	Cable Glands	$15.00	$0.00				$0.00
32	03.05.2025		Johnny	Paint and screws for DH	$5.00	-$8.26	Home Depot	1	$13.26	$13.26
33	03.10.2025		Johnny	Sand and Bucket (Testing)	$10.00	-$1.11	Home Depot	1	$11.11	$11.11
34	01.28.2025		Ben	Bulk Wires	$35.00	$0.00	Home Depot	1	$35.00	$35.00
35	03.10.2025	03.15.2025	Emily	Second Rev Downhill PCB	$37.45	$0.00	Osh Park	1	$37.45	$37.45
36	01.31.2025	02.03.2025	Emily	Custom PCB for uphill Unit	$100.00	$58.40	Osh Park	1	$41.60	$41.60
37	01.31.2026	02.03.2025	Emily	Custom PCB for downhill Unit	$100.00	$68.10	Osh Park	1	$31.90	$31.90
Summary				Planned Budget Remaining:	$302.42	-$95.28			Actual Budget Remaining:	$207.14
				Planned Total Cost:	$1,447.58	-$95.28			Actual Total Cost:	$1,542.86

Bill of Materials

Bill of Materials				
Item #	Description	Quantity	Total Cost	Link
Housing				
1	ML-92F Weatherproof NEMA Enclosure	1	$79	Polycase
2	Clear Red Acrylic Color Filter	1	$9.98	Amazon
3	Clear Green Acrylic Color Filter	1	$9.98	Amazon
4	WX-22 Panel	1	$65.89	Polycase
5	WC-24F Outdoor Enclosure with Clear Cover	1	$27.36	Polycase
6	ML-70F*1508 Plastic NEMA Enclosure	1	$49.20	Polycase
7	ML-70K ML Mounting Plate	1	$15.26	Polycase
8	Wire Glands	4	$4.18	CableGlandsDirect
Detection				
9	Raspberry Pi Camera Module 3 Wide Angle Camera	1	$35	Adafruit
10	Raspberry Pi 4 Model B	1	$75	Adafruit
11	Detection PCB (Pi Sheild)	1	$38	Custom (Oshpark)
12	9 Pin header 2.54MM	1	$0.12	Digikey
13	2.5M Mounting Screws	8	$1.06	Digikey
14	Plastic Spacer	4	$1.21	Digikey
15	Nylon Washer 2.5M	16	$1.60	Digikey
16	Nylon Washer 2M	4	$0.40	Digikey
17	2M Mounting Screws	2	$1.48	Digikey
18	2M Nut	2	$0.20	Digikey
Communication				
19	MSP430FR2111	1	$1.13	Digikey
20	RFM95W (LoRa)2	2	$49.90	Adafruit
21	Push Button	1	$9.99	Digikey
22	Transistors	2	$2.50	Digikey
23	10 UF capactor	1	$0.58	Digikey
24	0.1 UF capactor	1	$0.10	Digikey
25	2 pin screw terminal	3	$1.08	Digikey
26	3 pin screw terminal	1	$0.59	Digikey
27	Custom Uphill PCB	1	$28.25	Oshpark (N/A)
28	2.5mm mounting screws	4	$4.24	Digikey
29	2.5Mm mnuts	4	$0.40	Digikey
30	2.5mm nylon washer	8	$0.80	Digikey
Power				
31	Voltaic 50W panel	2	$178	Voltaic
32	LiFePo4 10Ah battery	1	$36	Eco-Worthy
33	LiFePo4 30Ah battery	1	$80	Eco-Worthy
34	12V/3.3V DC/DC converter	1	$9	Amazon
35	On/Off Switch	1	$10	Amazon
36	Bulk Wires	20ft	$35	Homedepot
Mounting				
37	Polystake XL	2	$42.00	Fallline
38	Square U Bolts	1	$21.59	Amazon
39	M5-0.8x16mm Zinc Machine Screw	12	$10.50	Home Depot
40	M5-0.8 Stainless Steel Lock Nut	12	$13.50	Home Depot
41	Solar Panel Bracket	2	$98	Voltaic
42	Mounting Brackets	8	$40	Custom (Aluminum 8x2x8)
43	5/16in-18 x 1-1/2in Round Head Machine Screws	2	$2.97	Home Depot
44	#8-32x1-1/2in Round Head Machine Screws	1	$1.47	Home Depot
		Total Cost:	$1,092	

MONTANA STATE UNIVERSITY

Mountains & Minds

Summary

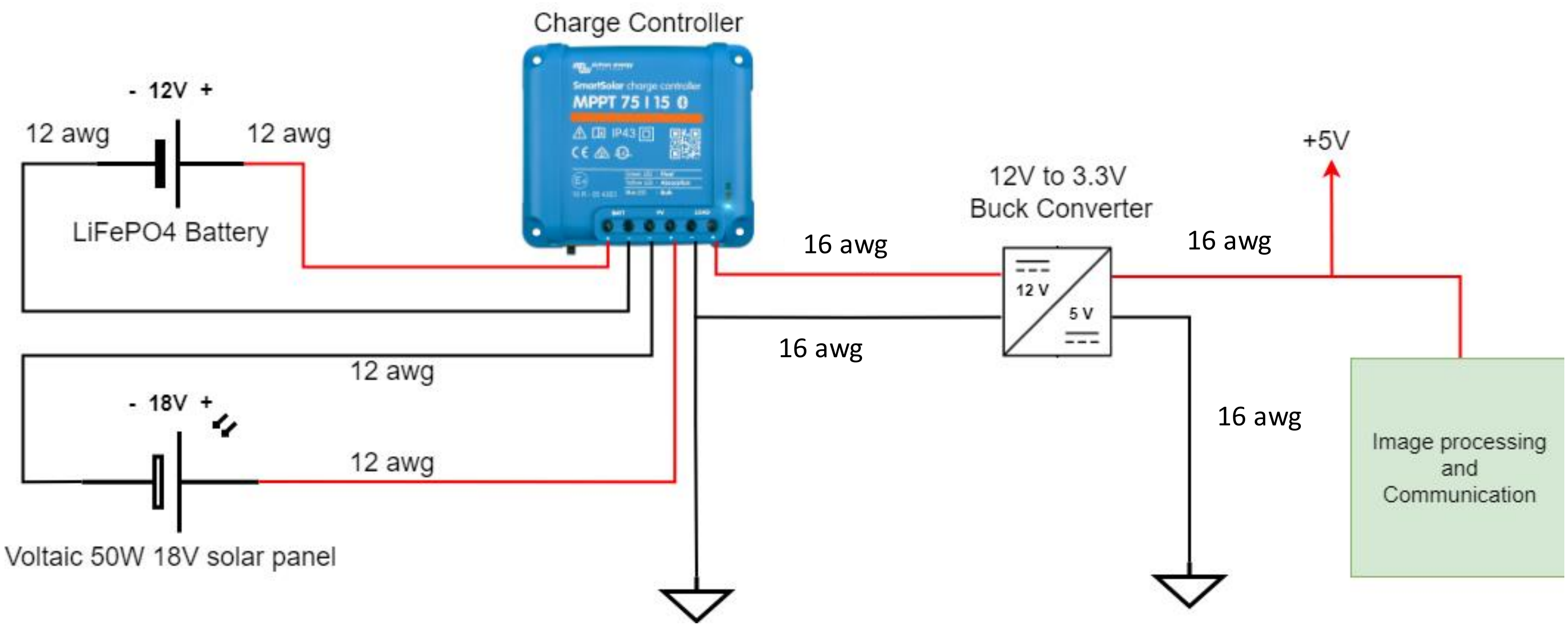
- This project integrated electrical, computer, and mechanical subsystems into a unified object detection system. While the system worked reliably in a controlled lab setting, real-world testing revealed challenges with environmental variability and system stability.

- We gained valuable experience in applying the full engineering design process—designing, testing, analyzing results, and iterating based on performance. Each team member contributed to this effort:
  - Electrical Engineer: Power and lighting subsystem
  - Computer Engineers: Image processing and LoRa communication
  - Mechanical Engineers: Stake and protective hardware design

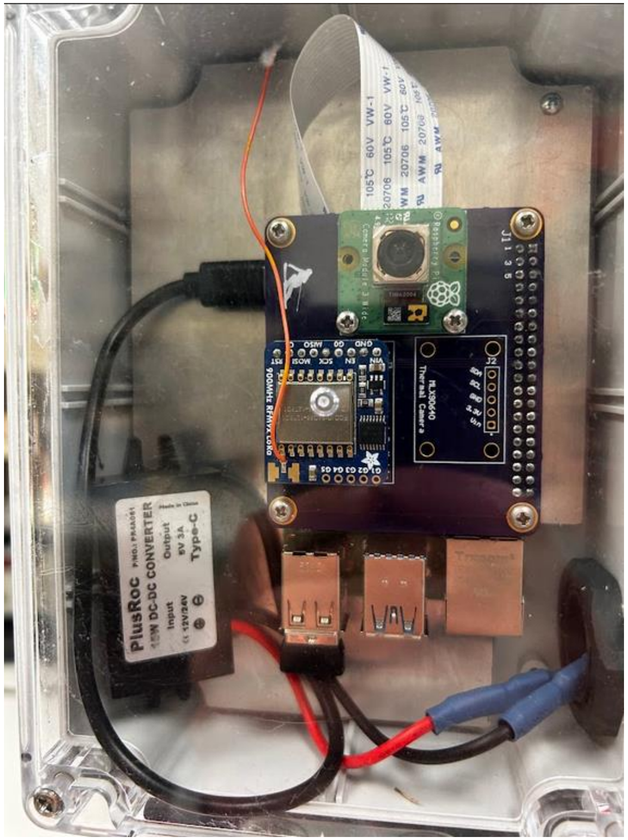
- Although not all detection goals were met in the field, the project gave us meaningful hands-on experience in cross-disciplinary collaboration and real-world system design, and a successful proof of concept and prototype was designed for the sponsors to move into the next stage of the design process.

QUESTIONS?

Design Solution: Downhill Power System



Design Solution: Downhill Power System



System Verification: Power system test results (uphill)

Date	Yield(Wh)	Consumption (Wh)	Max. PV power(W)	Max. PV voltage(V)	Min. battery voltage(V)	Max. battery voltage(V)
4/11/2025	0	80	0	0.01	12.87	13.43
4/10/2025	160	70	54	19.62	13.15	14.21
4/9/2025	0	80	0	0	13.12	13.27
4/8/2025	50	80	50	19.01	12.71	13.35
4/7/2025	60	70	35	20.72	13.19	14.23
4/6/2025	0	70	0	0.01	12.97	13.8

System Verification: Power system test results (downhill)

Date	Yield(Wh)	Consumption (Wh)	Max. PV power(W)	Max. PV voltage(V)	Min. battery voltage(V)	Max. battery voltage(V)
4/11/2025	0	40	0	0.01	13.24	13.39
4/10/2025	70	40	38	19.74	13.25	14.22
4/9/2025	0	30	0	0.01	13.24	13.39
4/8/2025	40	30	57	20.59	13.26	14.22
4/7/2025	50	30	36	18.19	13.28	13.49
4/6/2025	0	30	0	0.01	13.25	13.31

System Verification: Mounting and Anchoring

- Spec 2.2.3: Adjustable between 0 - 5 feet with height increments by ± 6” for every adjustment

Lighting Case:

Target Height (ft)	Measured Height	Pass/Fail
0	0.00	Pass
0.5	0.51	Pass
1	1.03	Pass
1.5	1.48	Pass
2	2.08	Pass
2.5	2.57	Pass
3	3.04	Pass
3.5	3.46	Pass
4	4.03	Pass
4.5	4.51	Pass
5	5.00	Pass

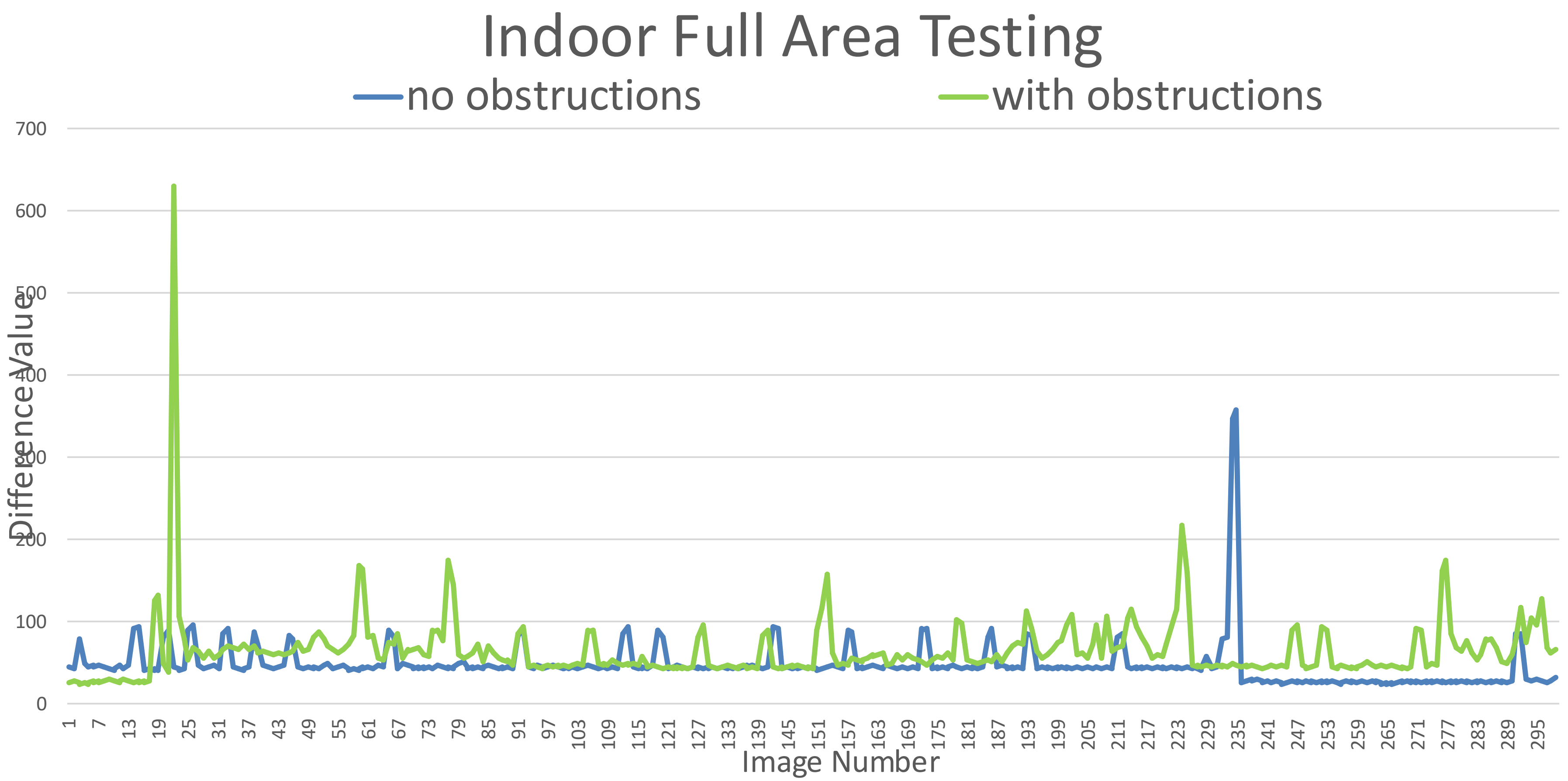
Battery Case:

Target Height (ft)	Measured Height	Pass/Fail
0	0.00	Pass
0.5	0.51	Pass
1	1.03	Pass
1.5	1.48	Pass
2	2.08	Pass
2.5	2.57	Pass
3	3.04	Pass
3.5	3.46	Pass
4	4.03	Pass
4.5	4.51	Pass
5	5.00	Pass

Solar Panel:

Target Height (ft)	Measured Height	Pass/Fail
0	0.02	Pass
0.5	0.52	Pass
1	1.02	Pass
1.5	1.53	Pass
2	2.05	Pass
2.5	2.56	Pass
3	3.08	Pass
3.5	3.53	Pass
4	4.09	Pass
4.5	4.53	Pass
5	4.98	Pass

System Verification: Detection Data



Day 1 System Testing Data

Table 2: Data Collection of Objective 1 Day 1

	Expected Detection Signals	Actual Detection Signals	Time
Test 1:	1	1	10:00am
Test 2:	1	1	10:55am
Test 3:	1	1	11:29am
Test 4:	1	1	11:35am
Test 5:	1	1	11:44am
Test 6:	1	1	12:29pm
Test 7:	1	1	12:53pm
Test 8:	1	1	1:44pm

Day 2 System Testing Data

Sunday April 6th:

	Expected Detection Signals	Actual Detection Signals	Time	Weather	Light Visible?
Test 1:	1	1	9:27 AM	Sunny / warm	Y
Test 2:	1	1	10:01 AM	Sunny / warm	Y
Test 3:	1	1	10:49 AM	Sunny / warm	Y
Test 4:	1	1	11:27 AM	Sunny / warm	Y
Test 5:	1	1*	11:57 AM	Sunny / warm	Y
Test 6:	1	1	12:25 PM	Sunny / warm	Y
Test 7:	1	1	12:46 PM	Sunny / warm	Y
Test 8:	1	1*	1:00 PM	Sunny / warm	Y
Test 9:	1	1	1:05 PM	Sunny / warm	Y
Test 10:	1	1	1:25 PM	Sunny / warm	Y
Test 11:	1	1*	1:55 PM	Sunny / warm	Y
Test 12:	1	1	1:57 PM	Sunny / warm	Y
Test 13:	1	1	2:23 PM	Sunny / warm	Y
Test 14:	1	1	3:07 PM	Sunny / warm	Y
Test 15:	1	1	3:25 PM	Sunny / warm	Y
Test 16:	1	1*	3:42 PM	Sunny / warm	Y
Test 17:	1	1	3:57 PM	Sunny / warm	Y
Test 18:	1	1	4:09 PM	Sunny / warm	Y
Test 19:	1	1	4:18 PM	Sunny / warm	Y
Test 20:	1	1	4:28 PM	Sunny / warm	Y

Day 3 System Testing Data

Monday April 7th:

	Expected Detection Signals	Actual Detection Signals	Time	Weather	Light Visible?
Test 1:	1	1*	9:19 AM	Sunny / warm	Y
Test 2:	1	1	9:43 AM	Sunny / warm	Y
Test 3:	1	1	9:56 AM	Sunny / warm	Y
Test 4:	1	1	10:21 AM	Sunny / warm	Y
Test 5:	1	1	10:35 AM	Sunny / warm	Y
Test 6:	1	1*	10:47 AM	Sunny / warm	Y
Test 7:	1	1	11:03 AM	Sunny / warm	Y
Test 8:	1	1	11:17 AM	Sunny / warm	Y
Test 9:	1	1	11:20 AM	Sunny / warm	Y
Test 10:	1	1	11:44 AM	Cloudy / warm	Y
Test 11:	1	1	12:11 PM	Cloudy / warm	Y
Test 12:	1	1	12:33 PM	Cloudy / warm	Y
Test 13:	1	1	1:16 PM	Cloudy / warm	Y
Test 14:	1	1	1:39 PM	Cloudy / warm	Y
Test 15:	1	1	2:02 PM	Cloudy / warm	Y
Test 16:	1	1*	2:32 PM	Cloudy / warm	Y
Test 17:	1	1	2:50 PM	Cloudy / warm	Y
Test 18:	1	1	3:00 PM	Cloudy / warm	Y
Test 19:	1	1	3:33 PM	Cloudy / warm	Y
Test 20:	1	1	3:58 PM	Cloudy / warm	Y

ra timed out, after a reboot the system operated fine and like normal

Day 4 System Testing Data

	Expected Detection Signals	Actual Detection Signals	Time	Weather	Light Visible?	Wind	Temperature
Test 1:	1	1	9:07 AM	Cloudy/cool	Y	0.6 mph	39 F
Test 2:	1	1	9:34 AM	Cloudy/cool	Y	1.8 mph	41 F
Test 3:	1	1*	10:05 AM	Cloudy/cool	Y	3.5 mph	41 F
Test 4:	1	1	10:30 AM	Cloudy/cool	Y	1.7 mph	41 F
Test 5:	1	1*	10:55 AM	Sunny/cool	Y	2.1 mph	46 F
Test 6:	1	1	11:12 AM	Sunny/cool	Y	0.8 mph	49.6 F
Test 7:	1	1	11:36 AM	Cloudy/cool	Y	0.7 mph	49.4 F
Test 8:	1	1*	12:02PM	Cloudy/cool	Y	1.7mph	49.8 F
Test 9:	1	1	12:26 PM	Cloudy/cool	Y	1,5 mph	50.1 F
Test 10:	1	1	12:49 PM	Cloudy/cool	Y	1.6 mph	48.8 F
Test 11:	1	1*	1:05 PM	Cloudy/cool	Y	1.3 mph	51.0 F
Test 12:	1	1	1:26 PM	Cloudy/breeze	Y	1.2 mph	51.7 F
Test 13:	1	1	1:45 PM	Cloudy/wind	Y	6.4 mph	53.7 F
Test 14:	1	1*	2:03 PM	Cloudy/wind	Y	2.2 mph	52.3 F
Test 15:	1	1	2:52 PM	Cloudy/breeze	Y	2.2 mph	52.5 F
Test 16:	1	1*	3:13 PM	Cloudy/breeze	Y	2.4 mph	52.0F
Test 17:	1	1	3:30 PM	Sunny/ wind	Y	2.7 mph	52.8 F
Test 18:	1	1	3:40 PM	Sunny/ wind	Y	2.3 mph	54.2 F
Test 19:	1	1	3:50 PM	Sunny/ wind	Y	2.2 mph	56.0 F
Test 20:	1	1	3:59 PM	Sunny/ wind	Y	2.1 mph	57.3 F

Day 5 System Testing Data

	Expected Detection Signals	Actual Detection Signals	Time	Weather	Light Visible?	Wind	Temperature
Test 1:	1	1	9:00 AM	cloudy	Y		
Test 2:	1	1	9:17 AM	cloudy	Y		
Test 3:	1	1	9:40 AM	cloudy	Y		
Test 4:	1	1*	10:20 AM	Cloudy/breeze	Y	1.54 mph	48.0 F
Test 5:	1	1	10:30 AM	Cloudy/breeze	Y	2.09 mph	47.8 F
Test 6:	1	1	10:50 AM	Soft hail	Y	1.21 mph	46.8 F
Test 7:	1	1	11:05 AM	Light hail	Y	1.13 mph	47 F
Test 8:	1	1*	11:28 AM	Cloudy	Y	0.5 mph	48 F
Test 9:	1	1	11:35 AM	Cloudy/slight breeze	Y	1.1 mph	48 F
Test 10:	1	1	11:54 AM	cloudy	Y	2.2 mph	48 F
Test 11:	1	1	12:10 PM	cloudy	Y	2.6 mph	49 F
Test 12:	1	1*	12:33 PM	Partially sunny	Y	4.1 mph	51 F
Test 13:	1	1	12:50 PM	p.sunny and wind gusts	Y	3.0	51 F
Test 14:	1	1	1:00 PM	Partly cloudy/breeze	Y	3.3 mph	52 F
Test 15:	1	1*	1:30 PM	Mostly sunny	Y	1.5 mph	53 F
Test 16:	1	1	2:00 PM	Mostly sunny/ gusty winds	Y	5.2 mph	54 F
Test 17:	1	1*	2:30 PM	Sunny	Y	1.8 mph	56 F
Test 18:	1	1	3:15 PM	Sunny/Cloudy	Y	23 mph	54 F
Test 19:	1	1	3:30 PM	Sunny/Cloudy	Y	24 - 40 mph	54 F
Test 20:	1	1	3:40 PM	sunny	Y	10 mph	52 F

*Camera timed out, after a reboot the system operated fine and like normal

Day 6 System Testing Data

	Expected Detection Signals	Actual Detection Signals	Time	Weather	Light Visible?	Wind	Temperature
Test 1:	1	1	9:04	sunny	yes	2.2	44.4 F
Test 2:	1	1	9:35	partially cloudy	yes	0.8	48.4
Test 3:	1	1*	10:25 am	Cloudy	Y	5	48
Test 4:	1	1	10:45 am	Cloudy	Y	4	50
Test 5:	1	1	11:14 am	Cloudy	Y	4	50
Test 6:	1	1	11:38 am	Cloudy	Y	7	54
Test 7:	1	1*	12:45 PM	Sunny/cloudy	Y	5mph	60
Test 8:	1	1	1:00 PM	Sunny/cloudy	Y	5mph	61
Test 9:	1	1	1:15 PM	sunny	Y	6mph	61
Test 10:	1	1*	1:44 PM	sunny	Y	6mph	60
Test 11:	1	1	2:14 PM	cloudy	Y	6mph	64
Test 12:	1	1	2:24 PM	cloudy	Y	6mph	64
Test 13:	1	1	2:40 PM	cloudy	Y	6mph	65
Test 14:	1	1	2:50 PM	sunny	Y	6mph	65
Test 15:	1	1	3;18 PM	Sunny	Y	1.1	68 F
Test 16:	1	1*	3:42 PM	Sunny	Y	1.5	69
Test 17:	1	1	3:47 PM	`sunny	Y	2.8	68
Test 18:	1	1	3:50 PM	sunny	Y	3	68
Test 19:	1	1	3:55PM	sunny	Y	3	68
Test 20:	1	1	4:00 PM	sunny	Y	1.3	69

*Camera timed out, after a reboot the system operated fine and like normal

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 $\geq 0°F$
- 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 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 hours
- Spec 3.1.2) Must have sufficient backup power to operate normally for 7 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 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 7 operational hours