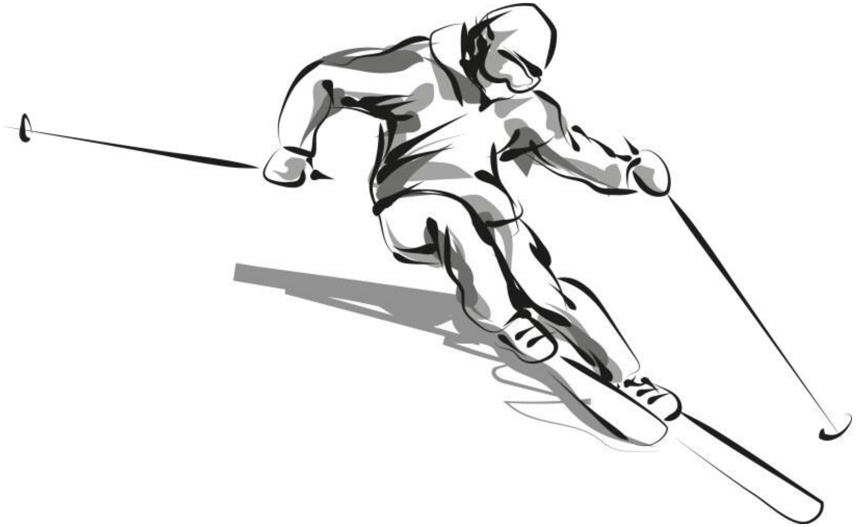
JumpGuard
System Prototype Demo



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Date: 3/11/25

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:

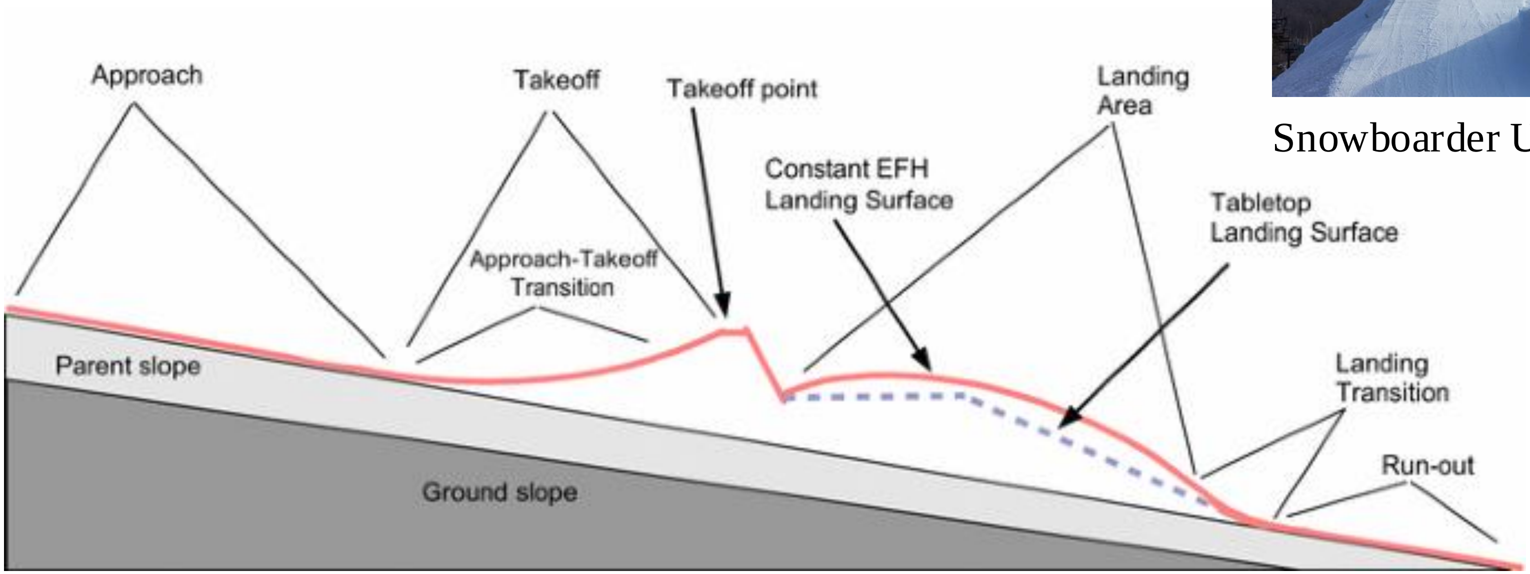
A system will be designed to detect when the landing area is clear before notifying the next athlete that it is safe to proceed from the top of the hill.

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.

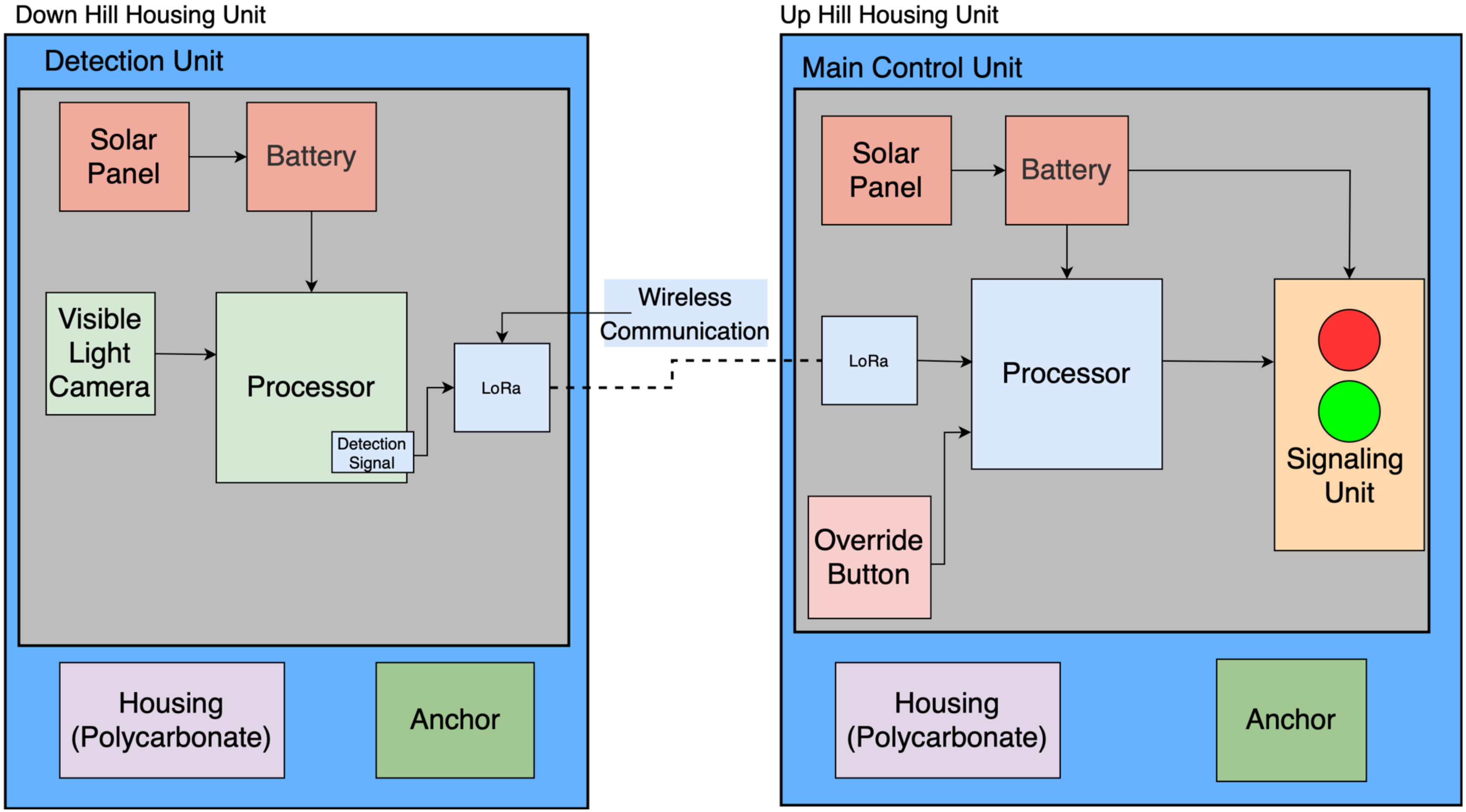
Necessary Background

Snowboarder Using Large Jump



Terrain Park Jump Diagram

Project Design Concept



Conceptual Block Diagram

Objective 1: Sub-Level Testing

Obj 1) 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

- These following slides contain req and spec level testing for the first objective.

Verification: Detection Spec 1.1.2 – Test Plan

Spec 1.1.2: Must have ≥ 95% detection rate

Setup:

- Raspberry pi plugged into display
- Preloaded images on Raspberry pi

Verification: Detection Spec 1.1.2 – Test Plan

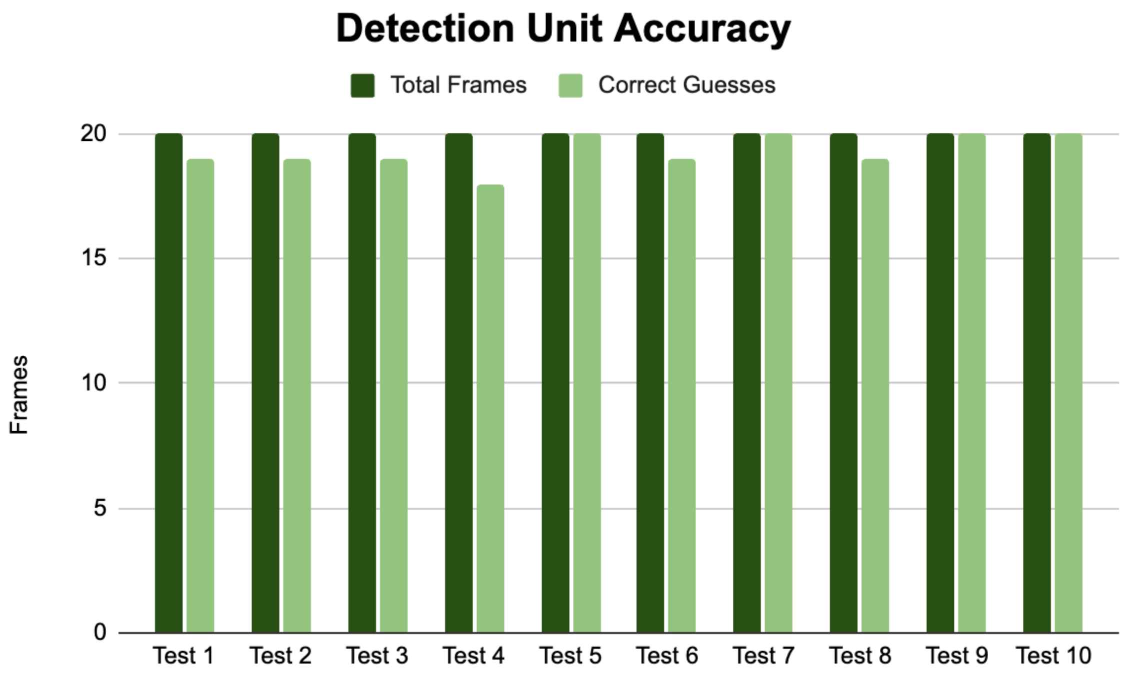
Spec 1.1.2) Must have $\geq$ 95% detection rate

Procedure:

1. Setup the testing system
2. Power on Raspberry Pi
3. Look at the preloaded image set
4. Visually confirm which frames have people present and which do not
5. Write down for that test how many frames have people present
6. Run the preloaded testing code for the first data set, located in frames/frameSet1
7. Write down the number of frames a person was detected
8. Repeat steps 3-7 for the remaining 9 data sets

Verification: Detection
Spec 1.1.2 – Test Results

Spec 1.1.2) Must have ≥ 95% detection rate



- 20 frames per test
- 200 total images
- Images taken every second
- Accuracy across 2 seconds: 100%

Results:

Minimum Accuracy	Actual Accuracy
95%	**96.5%**

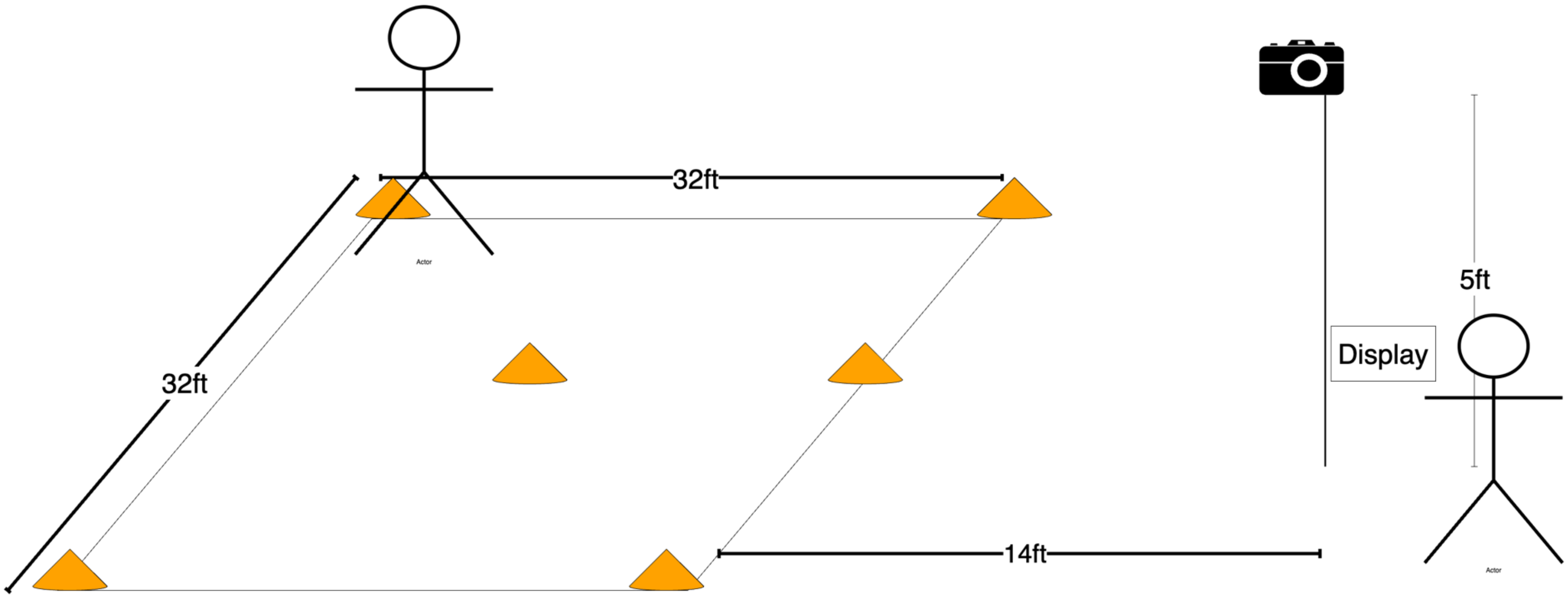
Verification: Detection Spec 1.1.2 – Conclusion

Spec 1.1.2) Must have ≥ 95% detection rate

- The Detection Unit passed the spec
  - Accuracy was greater than 95%
- Since it has been determined that:
  - *Detection is defined as an object being in the frame for more than 2 seconds*
- At an accuracy rate of 2 seconds the current detection rate of the subsystem is 100%
- This is within margins to pass the criteria and move on to the next level of testing

Verification: Detection
Spec 1.1.1 – Test Plan

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



Verification: Detection Spec 1.1.2 – Test Plan

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

Procedure:

1. Setup the testing system
2. Power on the Raspberry Pi
3. Open the terminal on the Raspberry Pi
4. Enter the command, "***rpicam-still –preview —-text ‘Hello’***"
5. Have a participant enter the testing area back corner
6. Ensure the participant is visible in the digital display screen
7. Write down if the participant is visible or not
8. Have the Participant Leave the Testing Area
9. Repeat steps 5-8 for all the testing areas below

Verification: Detection Spec 1.1.1 – Test Results

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

	Orientation in the Area:	Participant's Visibility
Test 1:	Back Right Corner	Yes
Test 2:	Back Left Corner	Yes
Test 3:	Front Right Corner	Yes
Test 4:	Front Left Corner	Yes
Test 5:	Back Middle Edge	Yes
Test 6:	Right Middle Edge	Yes
Test 7:	Left Middle Edge	Yes
Test 8:	Front Middle Edge	Yes
Test 9:	No Participant Present	Yes

- 32ftx32ft tested
- Visible confirmation
- Camera Field of View 110°

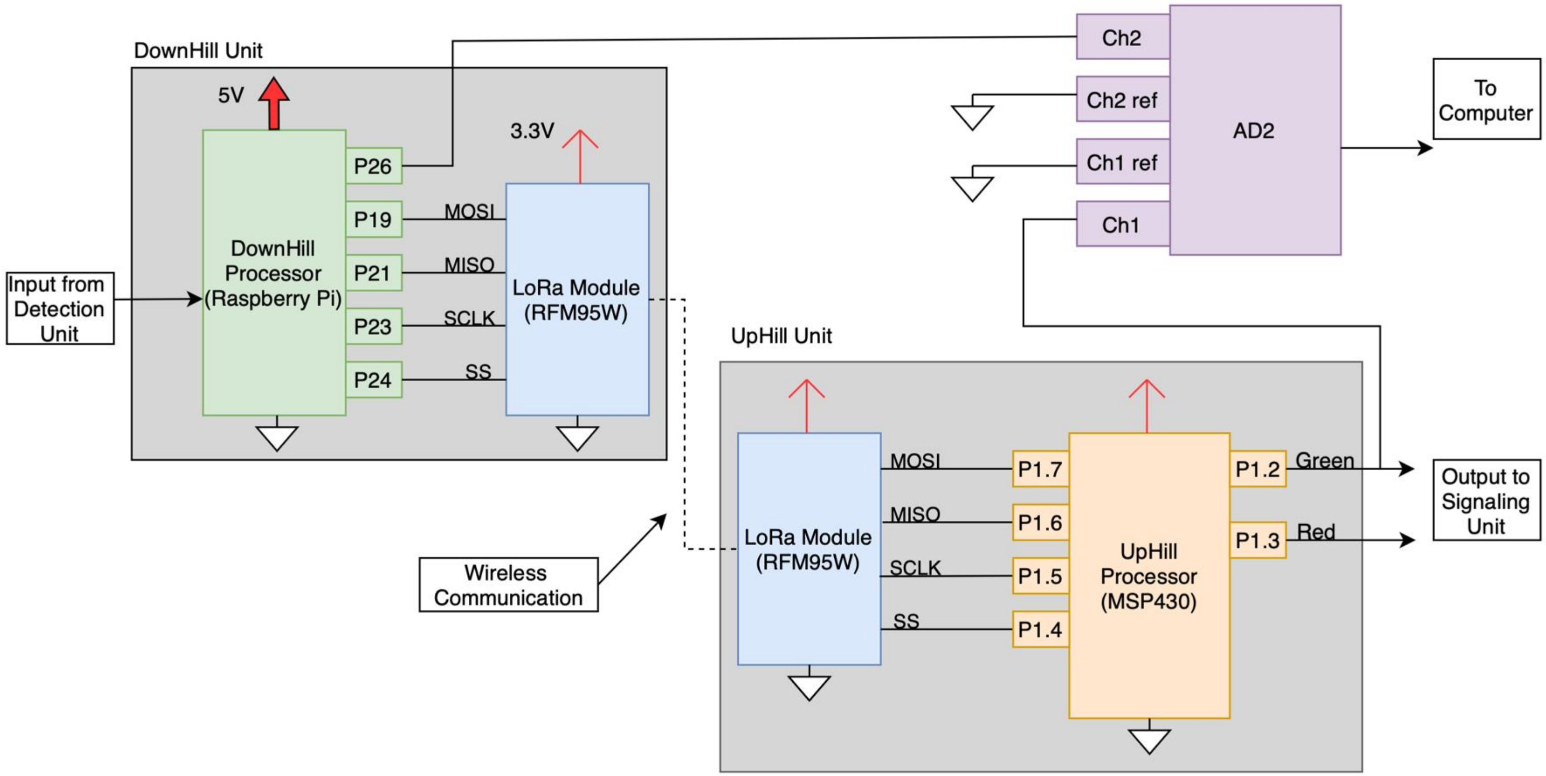
Verification: Detection Spec 1.1.1 – Conclusion

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

- The Detection Unit passed Spec 1.1.1
  - The camera was able to see a person within the frame of 32ft32ft
- This margin of detection is larger than the spec requirements
- This is within margins to pass the criteria and move on to the next level of testing

Verification: Communication Spec 1.2.1 – Test Plan

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



Verification: Communication Spec 1.2.1 – Test Plan

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

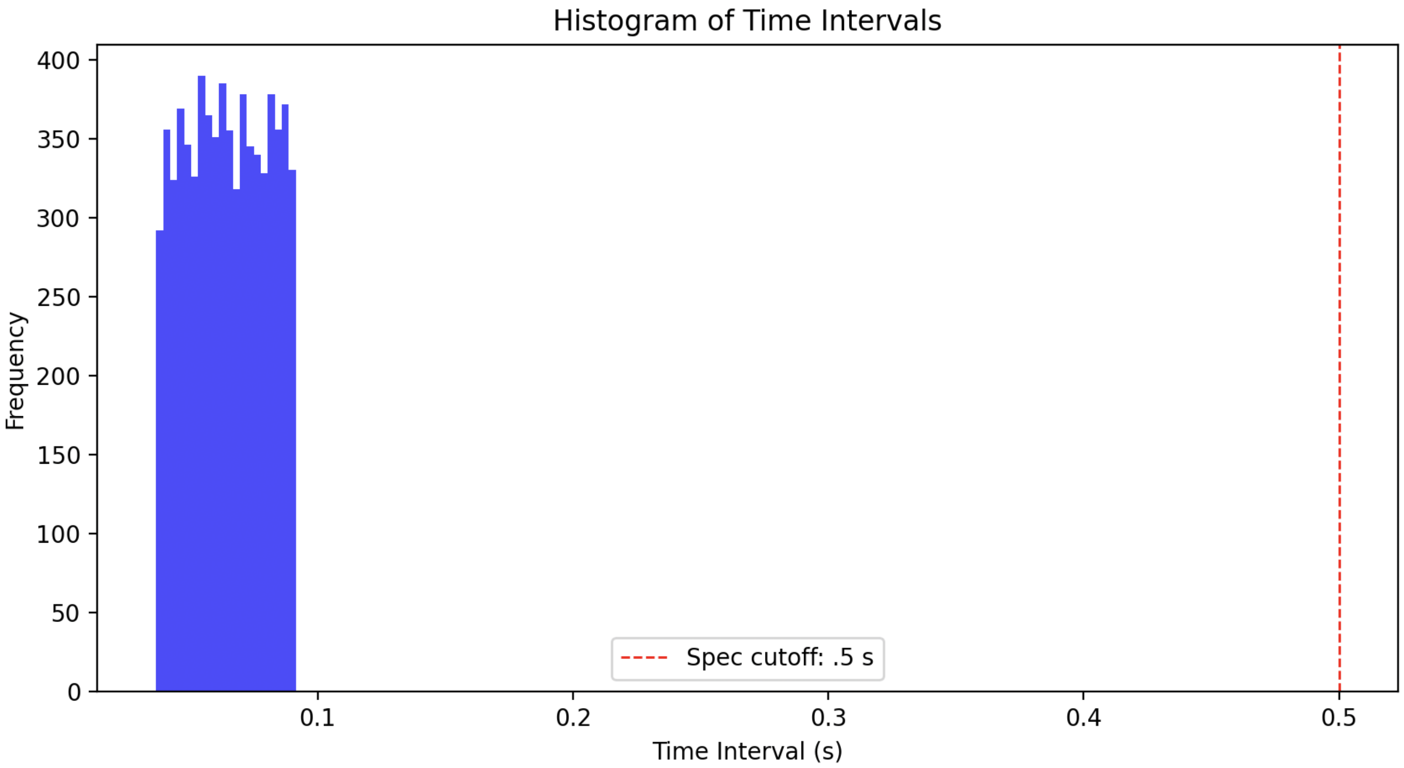
Procedure:

1. Connect ch1 of the AD2 oscilloscope to p1.2 of the MSP430 (the green light). Modify the code to flash the green light when a signal is received.
2. Connect ch2 of the AD2 oscilloscope to pin 26 of the raspberry pi. Modify the Raspberry pi code to flash pin 26 right after a signal is sent.
3. Using the AD2 oscilloscopes trigger and logging features, set the trigger to be on channel 2's rising edge at 2V. Change the logging settings to save a .csv file every time channel 2 is triggered.
4. Modify the Raspberry pi code to send a signal every half second. Have this run for 1 hour. (7200 samples)

Verification: Communication Spec 1.2.1 – Test Results

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

Mean: 64.33 ms
Median: 63.98 ms
Mode: 89.52 ms
Mix: 36.79 ms
Max: 91.40 ms



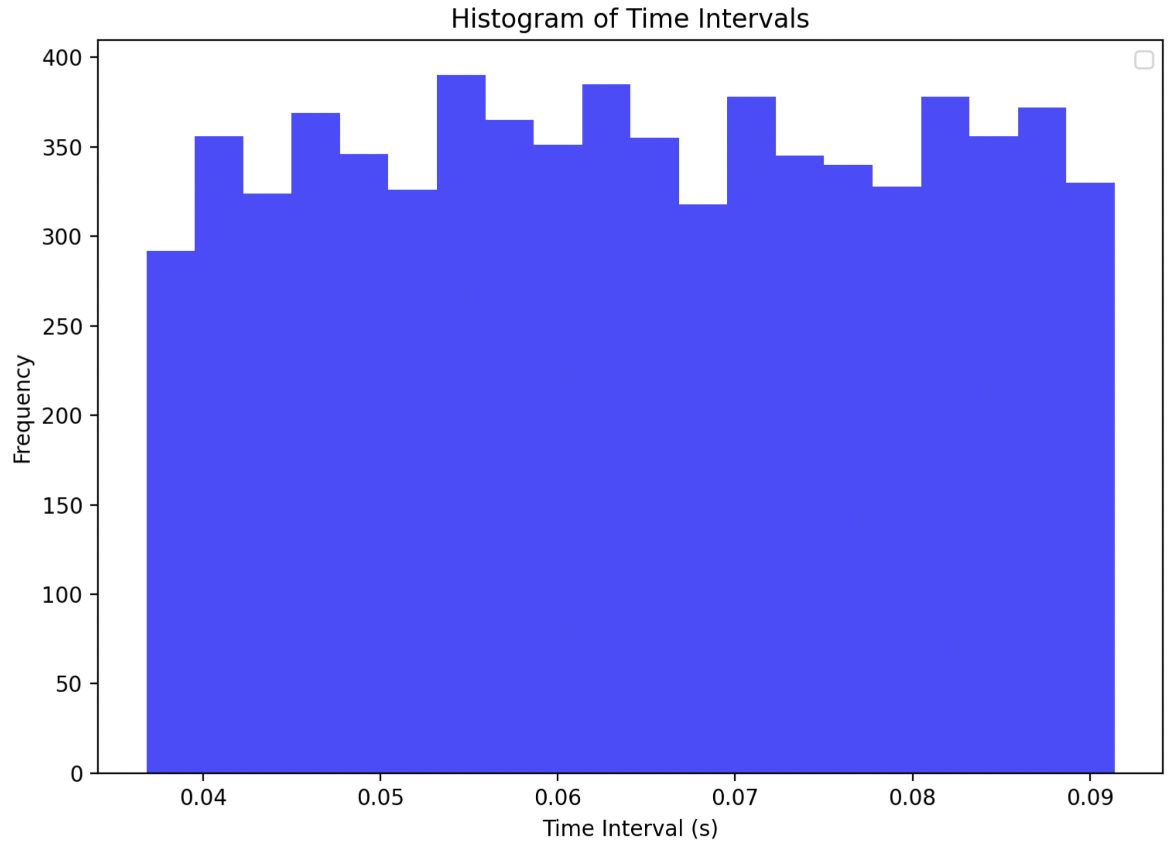
N = 7200 samples

Verification: Communication Spec 1.2.1 – Conclusion

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

Conclusion:

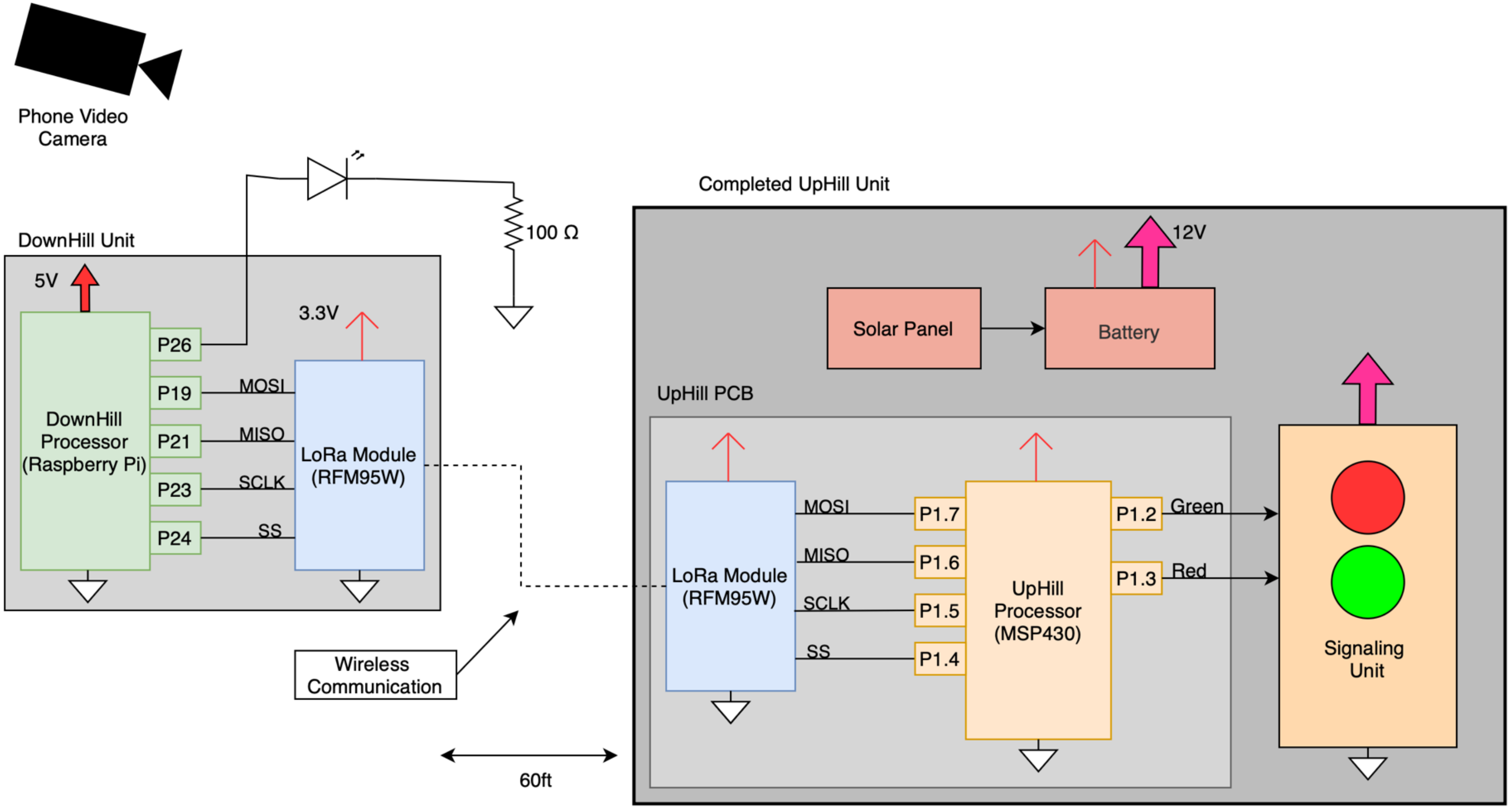
- With a max latency of 91.40 ms, we can conclude the system passes spec
- The system can proceed to the next level of testing



N = 7200 samples

Verification: Communication Req 1.2 – Test Plan

Req 1.2) System must communicate detection results to uphill athletes



Verification: Communication Req 1.2 – Test Plan

Req 1.2) System must communicate detection results to uphill athletes

Procedure:

1. Modify the Raspberry Pi code to send a LoRa signal every second and flicker the led when it sends.
2. When the uphill unit receives the signal, have the green light flicker.
3. Record this with a phone camera. Using the frame timestamps, calculate the latency from when the raspberry pi led turns on, to when the signaling unit turns on.

Verification: Communication Req 1.2 – Test Results

Req 1.2) System must communicate detection results to uphill athletes

Min: 40 ms
Max: 110 ms
Mean: 77 ms

*Unknown accuracy due to camera
**longer results due to signaling unit's LED turning on

Trials	Time of Rasp. Pi LED (s)	Time of signaling unit turning on (s)	Time difference (ms)
1	.21	.29	80
2	1.25	1.33	80
3	2.29	2.38	90
4	3.32	3.42	100
5	4.37	4.40	30
6	5.4	5.47	70
7	6.44	6.54	100
8	7.47	7.57	100
9	8.51	8.62	110
10	9.55	9.60	50
11	10.58	10.65	70
12	11.63	11.70	70
13	12.66	12.76	100
14	13.70	13.81	110
15	14.73	14.77	40
16	15.76	15.83	70
17	16.79	16.88	90
18	17.83	17.94	110
19	18.88	19.00	20
20	19.92	19.97	50

Verification: Communication Req 1.2 – Conclusion

Req 1.2) System must communicate detection results to uphill athletes

Conclusion:

- The system communicates the detection results to the uphill unit, which is displayed with the signaling unit.
- Because our timing is far below 0.5 s, I can conclude the system passes req.

Objective 2: Sub-Level Testing

Obj 2) The system must operate in inclement weather throughout the months of December through April

- These following slides contain spec level testing for the second objective.

Verification: Housing
Spec 2.1.1 - Test Plan

Spec 2.1.1) Must be able to withstand and function in temperatures ≥0° F

- All internal electronics are rated to operate at 0°F (-18°C) and will not fail due to cold temperatures alone.
- The primary concern is moisture buildup affecting electronics, not temperature exposure.
- Excess humidity can lead to corrosion, short circuits, and long-term electronic failure.
- Relative humidity values must remain below 90% within the case to ensure condensation does not form.

Temperature and humidity sensor in case

Verification: Housing
Spec 2.1.1 - Test Plan

Spec 2.1.1) Must be able to withstand and function in temperatures ≥0° F

Procedure:

1. Place temperature and humidity sensor in the housing case and ensure wire glands are plugged for full waterproofness
2. Place case in Freezer set to 0°F
3. Record the humidity and temperature readings for every 10 minutes for a total of 2 hours
4. Remove housing from the freezer and place it in a room-temperature ambient environment ~68°F
5. Record humidity and temperature every 10 minutes for 1 hour, watching for any humidity spikes

Verification: Housing
Spec 2.1.1 - Test Results

Spec 2.1.1) Must be able to withstand and function in temperatures ≥0° F

Data from clear cover detection case which had the highest humidity readings

Max Reading: 79% plateau after 1.5 hours in freezer

Min Reading: 65% initial relative humidity

Time (min)	Temperature (°F)	Humidity (%)
0	68	65
10	60	67
20	50	69
30	35	71
40	20	73
50	10	75
60	0	77
70	0	77
80	0	78
90	0	78
100	0	79
110	0	79
120	0	79
Removed from Freezer		
130	15	78
140	32	77
150	45	75
160	55	73
170	60	71
180	63	70

Verification: Housing
Spec 2.1.1 - Conclusion

Spec 2.1.1) Must be able to withstand and function in temperatures ≥0° F

- Humidity Stayed Below 80% throughout the freezer phase and did not exceed critical levels (90%) where condensation would form.
- No condensation observed inside the enclosure, indicating that the wire glands and seals are effectively preventing moisture ingress.
- Humidity remained stable during the transition back to ambient temperature, showing that the case is properly sealed and that there were no moisture-related issues as the temperature returned to normal.
- The enclosure passed the test, demonstrating it can protect the electronics from humidity buildup in cold environments without affecting functionality.

Verification: Housing
Spec 2.1.2 – Test Plan

Spec 2.1.2) Must operate in winds up to 20 mph*
* Testing done not to ensure operation, as that is system level, but to ensure that we can get there down the road (housing subsystem can survive in said winds)

Verification: Housing
Spec 2.1.2 – Test Plan

Spec 2.1.2) Must operate in winds up to 20 mph*

Procedure:

1. Mount the panels and cases on the Polystakes facing the desired direction
2. Place the equipped Polystake in a bucket of sand
3. Add the batteries to their specific cases
4. Hold the anemometer near the front of the panel
5. Place the level measuring device on the case, and record the measurements throughout the trial
6. Start the leaf blower and stand about 5 feet back, increasing power until the speed reaches over 20mph
7. Repeat 3 times for both the uphill and downhill systems, each from a different side

Verification: Housing
Spec 2.1.2 – Test Results

Pass: <5°, as the Polystake is made of a flexible polymer made to bend without yielding

Downhill Unit

Test Case	Max Wind Speed	Max Angle Change*	P/F
Back	25.6 mph	4.8°	Pass
Side	23.2 mph	1.7°	Pass
Front	24.8 mph	1.1°	Pass

*Some of the angle change comes from the base moving, which would happen much less when mounted deeper and in snow instead of sand

Uphill Unit

Test Case	Max Wind Speed	Max Angle Change*	P/F
Back	20.2 mph	2.4°	Pass
Side	28.4 mph	0.4°	Pass
Front	27.8 mph	0.7°	Pass

Verification: Housing Spec 2.1.2 – Conclusion

Spec 2.1.2) Must operate in winds up to 20 mph*

- The maximum angle of deflection on each test was under 5°, much lower than what would be allowed.
- Maximum deflection was observed when wind came from the back, which was expected.
- This test was passed, proving that once the rest of the system is set up, winds up to spec level should not cause issues with the housings.

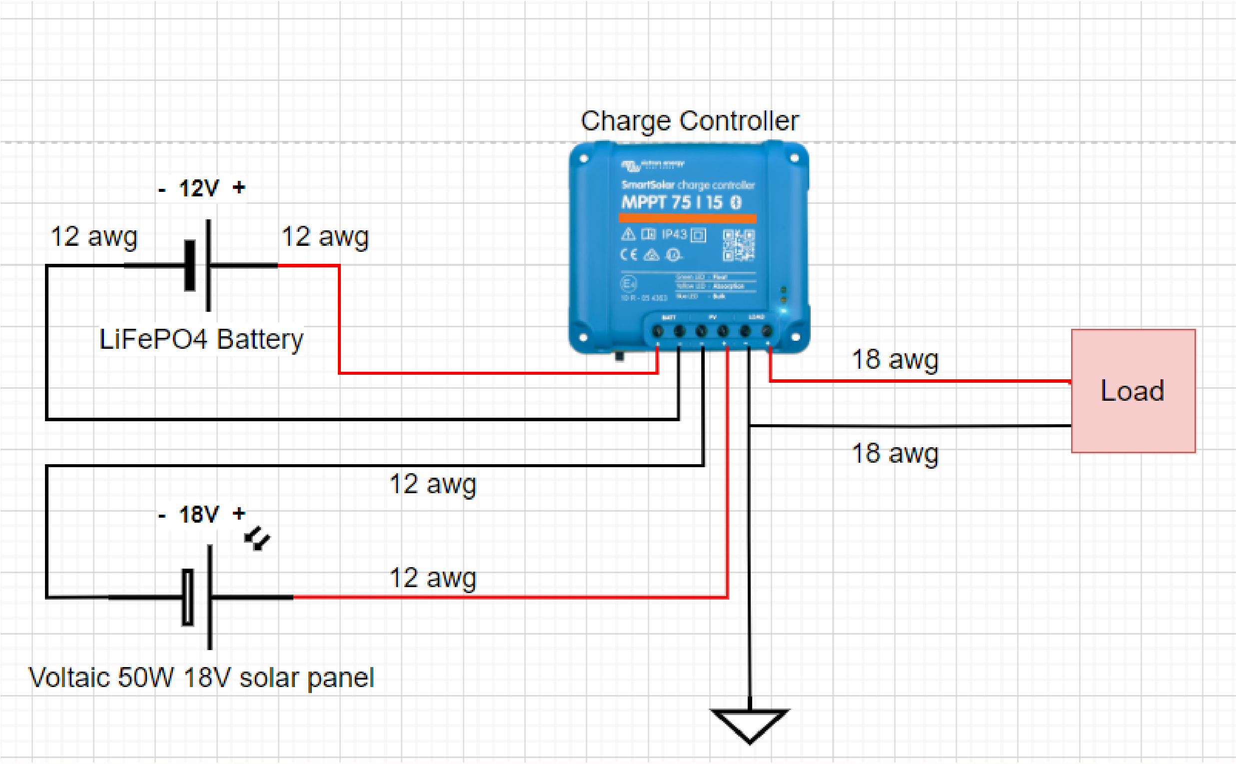
Objective 3: Sub-Level Testing

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

- These following slides contain spec level testing for the third objective

Verification: Power
Spec 3.2.1 – Test Plan

Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight



Verification: Power
Spec 3.2.1 – Background

Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight

- The battery in each respective unit must be able to recharge and operate over a 7.5-hour time interval
- State of charge (SOC) can be estimated using a LiFePo4 SOC chart.
- Going forward with testing, a battery charger will be used to get a more accurate SOC of the batteries

Verification: Power
Spec 3.2.1 – Background

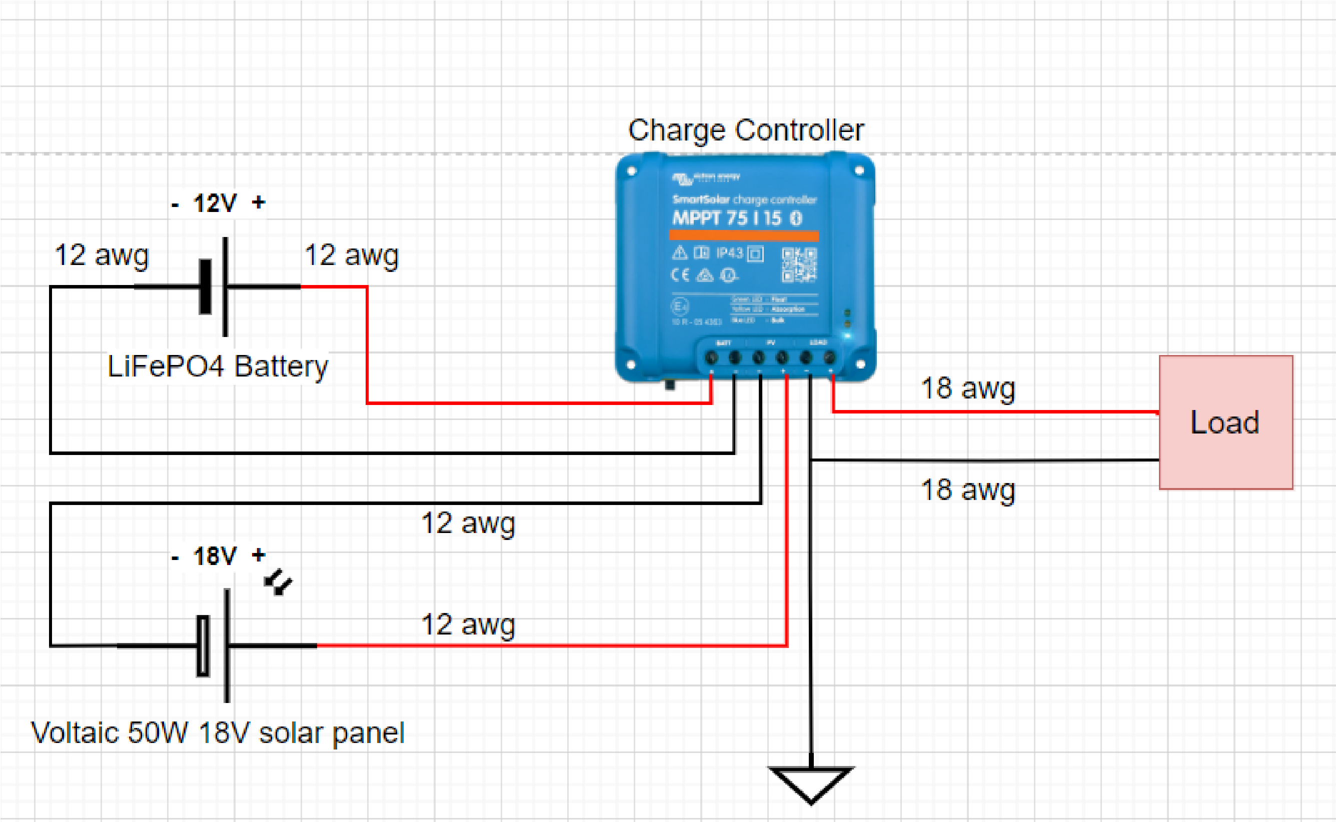
Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight

SOC Chart

Percentage (SOC)	1 Cell	12V	24V	48V
100% Charging	3.65	14.6	29.2	58.4
100% Rest	3.40	13.6	27.2	54.4
90%	3.35	13.4	26.8	53.6
80%	3.32	13.3	26.6	53.1
70%	3.30	13.2	26.4	52.8
60%	3.27	13.1	26.1	52.3
50%	3.26	13.0	26.1	52.2
40%	3.25	13.0	26.0	52.0
30%	3.22	12.9	25.8	51.5
20%	3.20	12.8	25.6	51.2
10%	3.00	12.0	24.0	48.0
0%	2.50	10.0	20.0	40.0

Verification: Power
Spec 3.2.1 – Test Plan

Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight



Verification: Power
Spec 3.2.1 – Test Plan

Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight

Procedure:

1. Record voltage and time when all parts are assembled
2. Wait 7.5 hours
3. Disconnect the solar panel, then battery, then load from the charge controller in that order
4. Record time
5. Wait one hour for battery voltage to stabilize
6. Record measured voltage from the multimeter
7. Compare voltage to SOC chart

Verification: Power
Spec 3.2.1 – Results

Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight

Uphill unit:
Assembled at 9:30am on 3/2, voltage 13.2V
At 5:00pm light was still on
After waiting an hour voltage is 13.6V
Pass

Verification: Power
Spec 3.2.1 – Results

Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight

Downhill unit:
Assembled at 10:30am on 3/4, voltage 13.1V
At 6:00pm light was still on
After waiting an hour voltage is 13.6V
Pass

Verification: Power
Spec 3.2.1 – Results

Spec. 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight

Uphill Voltage: 13.2 V to 13.6 V

Downhill voltage 13.1 V to 13.6 V

Percentage (SOC)	1 Cell	12V	24V	48V
100% Charging	3.65	14.6	29.2	58.4
100% Rest	3.40	13.6	27.2	54.4
90%	3.35	13.4	26.8	53.6
80%	3.32	13.3	26.6	53.1
70%	3.30	13.2	26.4	52.8
60%	3.27	13.1	26.1	52.3
50%	3.26	13.0	26.1	52.2
40%	3.25	13.0	26.0	52.0
30%	3.22	12.9	25.8	51.5
20%	3.20	12.8	25.6	51.2
10%	3.00	12.0	24.0	48.0
0%	2.50	10.0	20.0	40.0

Verification: Power
Spec 3.2.1 – Conclusion

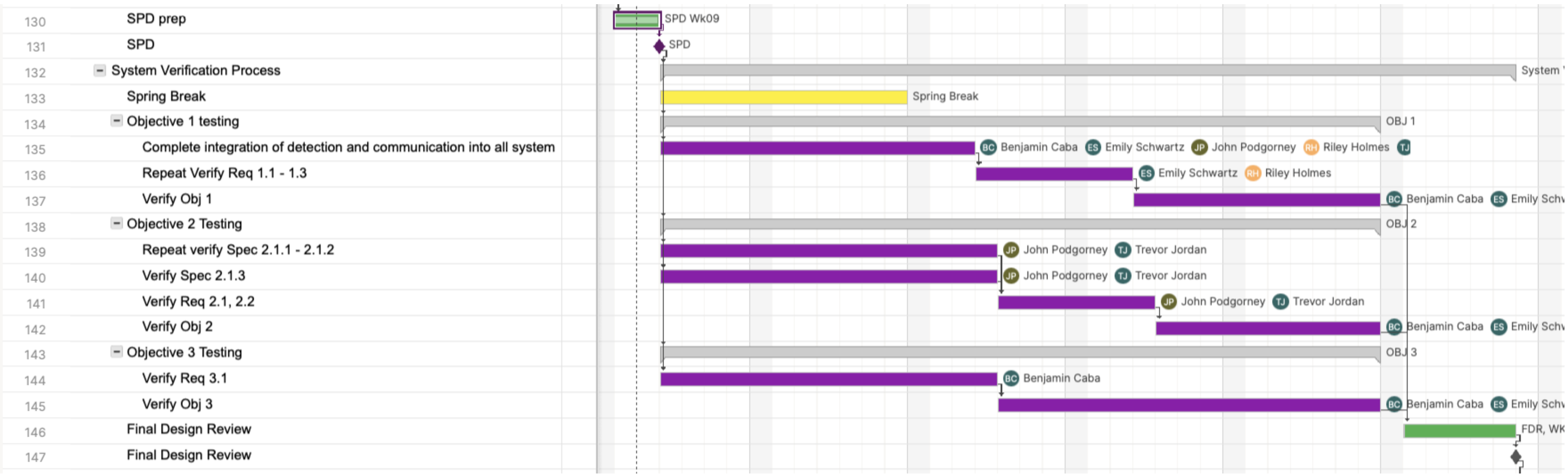
Spec 3.2.1) Can recharge for a 7.5-hour operational day with 3.5 hours of peak sunlight

- Both Uphill and Downhill units proved that they can both operate and charge over a 7.5-hour time interval with 3.5-hours of peak sunlight
- Both batteries fully charged
- The Downhill Unit was set up later in the day and in partially cloudy conditions

Outstanding Concerns

- Current Testing conditions are not the expected conditions for the final product
- Some of the spec/req level testing need the system to be completed to test
- Raspberry Pi malfunction
- Second version of Downhill PCB is in production

System Prototyping Final Schedule



Prototype Demonstration

- We have our two unit with the ability to communicate between each other
- The lights are able to change color based upon the received input

QUESTIONS OR CONCERNS?

SUPPORTING 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

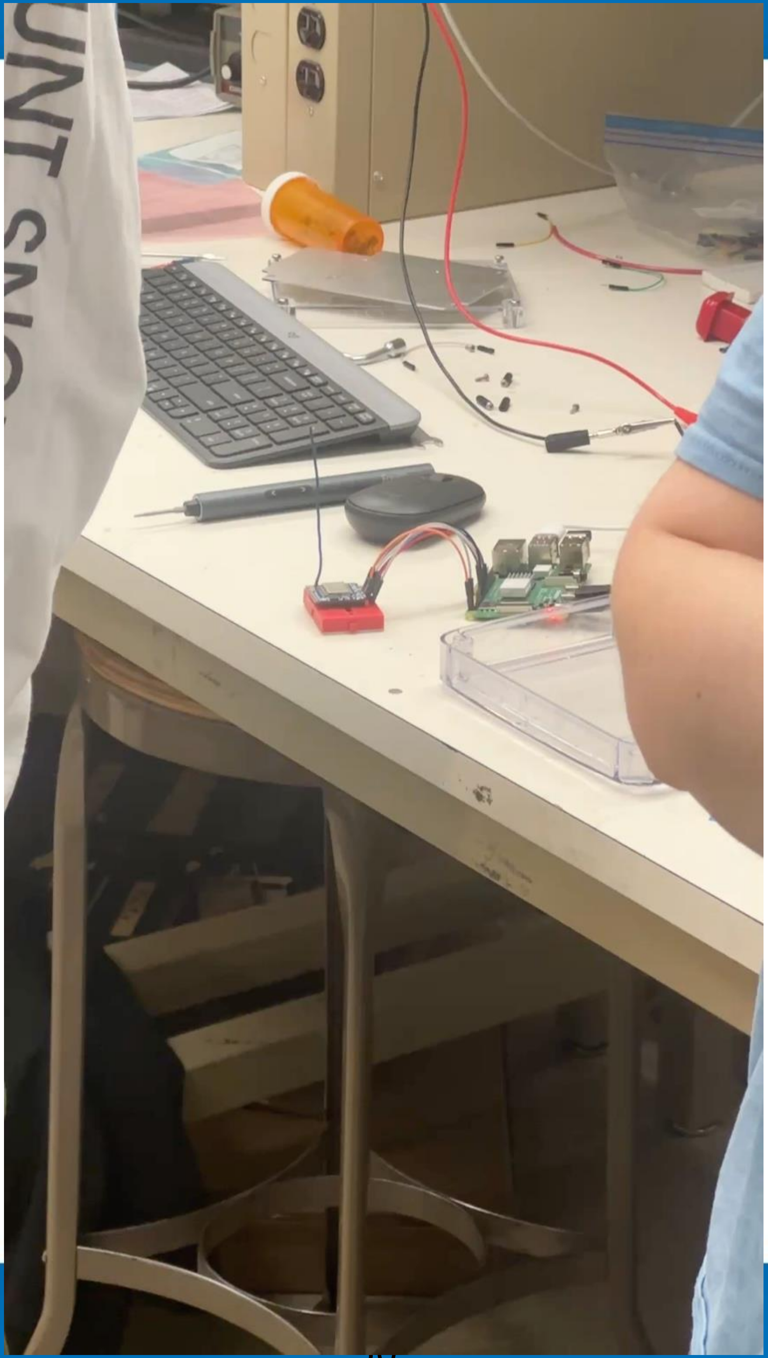
- Spec 2.1.1) Must be able to withstand and function in temperatures ≥ 0°F
- Spec 2.1.2) Must be able to operate in winds up to 20 mph
- Spec 2.1.3) System is not meant to operate in visibility lower than 30 ft or when the terrain park is not operational

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	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	$0.00	Adafruit	1	$25.36	$25.36
3	12.12.2024		Riley	Emergency stop push button(CWI281-	$30.00	$26.51	Digikeey	2	$9.76	$18.26
4	mm.dd.yy			MSP430FR2111	$4.00	$0.00	DigiKey			$0.00
				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
	01.27.2025	02.03.2025	Johnny	ML-92F Weatherproof NEMA Enclosur	$79.00	-$6.34	PolyCase	1	$85.34	$85.34
15	02.02.2025		Johnny	Solar Panel Mounting	$50.00	-$11.08	Voltaic	1	$61.08	$61.08
	02.26.2025		Johnny	Mounting Materials	$20.00	$0.50	Ace Hardware	1	$19.50	$19.50
16				Internal Mounting Plate	$15.00	$0.00	Amazon	1		$0.00
				Downhill Housing						
17	01.23.2025	02.03.2025	Johnny	PolyStakeXL	$21.00	-$39.33	FallLine	1	$60.33	$60.33
18	11.04.2024	12.08.2024	Johnny	WC-24F Outdoor Enclosure with Clear	$35.00	$7.64	PolyCase	1	$27.36	$27.36
	01.27.2025	02.03.2025	Johnny	ZQ-100806 Outdoor Electrical Junction	$63.00	-$9.24	PolyCase	1	$72.24	$72.24
	01.27.2025	02.03.2025	Johnny	WX-22 Panel for WA/WP/WC Series E	$11.00	-$6.15	PolyCase	1	$17.15	$17.15
	02.26.2025		Johnny	Mounting Materials	$20.00	$0.51	Ace Hardware	1	$19.49	$19.49
19	02.02.2025		Johnny	Solar Panel Mounting	$50.00	-$11.07	Voltaic	1	$61.07	$61.07
				Power						
21			Ben	Solar Panel	$89.00	-$89.00	Voltaic	2	$89.00	$178.00
			Ben	Battery 30Ah	$80.00			1	$80.00	$80.00
			Ben	Battery 10Ah	$36.00			1	$36.00	$36.00
				OTHER SYSTEM LEVEL COMPONENTS (these might include bulk wiring, shipping, PCB manufacturing)						
			Trevor	Cable Glands	$15.00	$0.00				$0.00
	03.05.2025		Johnny	Paint and screws for DH	$5.00	-$8.26	Home Depot	1	$13.26	$13.26
	03.10.2025		Johnny	Sand and Bucket (Testing)	$10.00	-$1.11	Home Depot	1	$11.11	$11.11
			Ben	Bulk Wires		$0.00				$0.00
24	01.31.2025	02.03.2025	Emily	Custom PCB for uphill Unit	$100.00	$58.40	Osh Park	1	$41.60	$41.60
25	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:	$489.19	-$41.13			Actual Budget Remaining:	$448.06
				Planned Total Cost:	$1,260.81	-$41.13			Actual Total Cost:	$1,301.94

MONTANA STATE UNIVERSITY

Mountains & Minds

Untested Specs and Reqs

Due to the wording of the following specs and reqs, the system must be fully completed to gather the appropriate data:

- Req 2.1
- Spec 2.1.2*
- Spec 2.1.3

*Partially tested, system withstands but is yet to "operate"

Verification: Detection
Req 1.1 – Test Plan

Requirement 1.1: System must detect when the landing area is clear

Procedure:

1. Setup the Testing System
2. Turn on the raspberry pi
3. Navigate to the place of the preloaded images
4. Write down the orientation of the test and expected detection signals (the amount of times the detection signal should be high) in the table below
5. Using the testing program run the data set determining the actual detected signals
6. Repeat step 3-5 for each of the orientation area and tests (20 total)

Verification: Housing
Spec 2.1.1 - Test Results

Non-clear cover test results

Time (min)	Temperature (°F)	Humidity (%)
0	68	65
10	60	67
20	50	69
30	35	71
40	20	73
50	10	74
60	0	74
70	0	75
80	0	75
90	0	76
100	0	76
110	0	76
120	0	77
Removed from Freezer		
130	15	75
140	32	73
150	45	72
160	55	71
170	60	70
180	63	69