# Electrical and Computer Engineering
# Montana State University

**EELE488R -- Electrical Engineering Design I**
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**Senior Capstone Project Charter**

## *JumpGuard: Making the Terrain Park Safer One Jump at a Time*


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# 1. Introduction

## 1.1 Project 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 is present at 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. This could lead to serious injury and potential trips to the hospital for the athletes involved in an incident. It has been reported that features in a terrain park that promote aerial maneuvers account for 83% of total terrain park injuries [1]. Due to the popularity of terrain parks in ski resorts, the risk and occurrence of injury to athletes will persist unless preventative actions are taken.

## 1.2 Project Description

Because of the obstructed view created by the large jumps in a terrain park, it is crucial to provide a way for athletes uphill to know whether the landing area is clear in order to prevent potential collisions and injury. Therefore, 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. 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. The system will consist of two separate units, a lower detection unit for detecting athletes, and an uphill signaling unit that will display the status of the landing area to uphill athletes.

The function of the lower unit is to detect athletes in the landing area of a jump. When an athlete is detected in the landing area, the lower unit will transmit this information to the signaling unit. Because of the inherent risk of safety, wires to a power source and between units will not be used. Alternatively, the detection unit will operate on a standalone power source and transmit data to the signaling unit wirelessly.

The signaling unit's primary purpose is to display either a green or red light, indicating whether the landing area is clear of athletes or not. The signal will display the state of the landing area by processing the wireless information received from the detection unit and then changing the light color based on the status of the landing area.

Similar to the detection unit, to prevent safety concerns the signaling unit will operate on a standalone power system. This power system will not be the same as the power system used by the detection unit.

## 1.3 Project Background

This background section provides a detailed exploration of the key topics and subsystems relevant to the design of the stoplight system for ski terrain park jumps. It includes a comprehensive discussion of the current state of terrain park safety, the technologies and systems used to mitigate risks, and any related information deemed necessary.

### 1.3.1 Project History

The first terrain park was opened in Bear Valley Ski Area (California) during the 1989/90 season [2]. Since the creation of the first terrain park, they have generated a lot of popularity amongst ski resort athletes all over the world. With the surge in popularity, the features have now advanced into larger scale versions of previous iterations. One of the most common and popular features that can be found in a terrain park are jumps. Terrain Park jumps are designed to utilize athletes' downhill momentum to propel them into the air over a ranging distance called a "gap". After clearing the gap, athletes will land in the landing area and proceed to the bottom of the run.

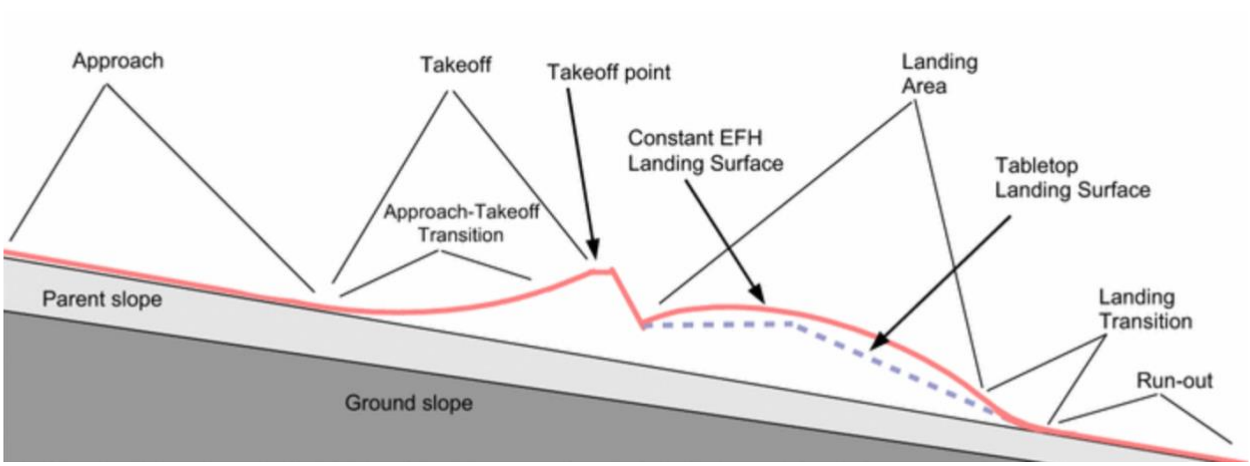


**Figure 1: Terrain Park Jump Diagram [3]**

A typical terrain park jump, Figure 1, consists of several important features. The approach and takeoff sections are where the athlete builds speed before launching into the air at the takeoff point. This is followed by the constant EFH (equivalent fall height)

Landing Surface, which is a measure to ensure that the slope of the landing zone reduces the impact of landings. Athletes attempt to land their jumps on this flat landing surface, but often overshoot or undershoot the landing area. Due to the height of the takeoff point, the landing zone is not always within a clear line of sight for an athlete coming down from the approach.

Around the jump, visibility is crucial for riders to assess whether the landing area is clear or occupied. There have been multiple instances where the "blind spot" on terrain park jumps have led to serious collisions. One notable case occurred at Mammoth Mountain, where a snowboarder landed directly on a girl who was in the blind landing zone of a jump. This incident, captured on video, highlighted the danger of not being able to see the landing surface before taking off. The snowboarder had no idea someone was in the landing area, which is a common risk when the jump obscures the view of the landing area. [4]

Ski resorts have long recognized the inherent risks involved in terrain parks, especially since they cater to athletes of varying skill levels. Traditionally, safety in terrain parks has been maintained through basic traffic flow measures such as signage and resort personnel acting as spotters [3]. These methods, while helpful, have several shortcomings, particularly in high-traffic or low-visibility conditions, such as fog or snowstorms. For example, signage can be obscured, and human spotters cannot be present in every key location. This can lead to miscommunication and reduce the effectiveness of risk reduction. Furthermore, these methods only address the risks after they become apparent, which leaves room for dangerous situations to arise.

The desired stoplight system will be designed to operate autonomously and integrate seamlessly with the larger infrastructure of a ski resort. Powered by solar energy, the system will be self-sustaining, reducing the need for regular battery changes. Also, the system incorporates sensors to detect when an athlete is in the landing zone, allowing it to automatically switch between proceed and do not proceed signals without the need for human intervention. Additionally, the stoplight will be designed to be highly visible in a variety of weather conditions to cut through fog, snow, and low light, which are common conditions at ski resorts.

### *1.3.2 Technology Review*

This technology review explores past systems, projects, and technologies that are relevant to developing a stoplight system for terrain park jumps. This report aims to provide a comprehensive understanding of how modern advancements in safety technology, communication, and sensors can be integrated into a terrain park stoplight system to improve athlete safety.

<u>SmartPatrol System:</u>

Many ski resorts implement various safety measures to reduce the risk of accidents in terrain parks. Some examples of these safety measures are the Park Smart program, special signage, or employing human spotters. There are very few systems designed to detect the presence of others in landing zones. Research led to the discovery of only one system that accomplishes this, SmartPatrol [5].

**Figure 2: SmartPatrol System in Use [6]**

The SmartPatrol system, Figure 2Figure 2: SmartPatrol System in Use [6], is similar to the desired to-be-designed system, detecting the real-time status of the landing area of jumps and relaying that information to those uphill. This system achieves its task by using a camera fed into computer vision algorithms to determine if the area is clear [6]. While highly innovative, being the first of its kind in the field allows room for improved development.

Unlike the SmartPatrol system, the JumpGuard system will use solar energy as its primary power source, instead of batteries. This reduces the need for battery recharging and aligns with the net-zero goals of many ski resorts [6]. JumpGuard will also utilize a detection unit that is separate from the signaling unit. The separation of the two units will provide a method that is more versatile between different sizes and designs of terrain park jumps.

Communication:

There are a variety of ways wireless communication can be achieved across a terrain park. Factors such as interference, range limits, and environmental factors like weather are all things that need consideration.

WIFI is one possible method of wireless communication. As one of the fastest and most used methods of data transmission, it has potential within the system due to the components and help available. Using WIFI in an outdoor setting with obstacles, such as in a terrain park, would lead to a range of roughly 50-100 feet, which is on the cusp of what we need [7]. Additionally, WIFI has a very high data transfer rate, which could be overkill and lead to unnecessary power consumption.

Bluetooth is also a popular method of data transmission, mostly used in headphone and sound applications. Standard Bluetooth modules, commonly found in most Bluetooth devices, are of class 2, which usually has a range of roughly 33 ft [8]. Class 1 Bluetooth modules, used in industrial applications, have the ability to reach up to 300 ft, though a significant increase in power is required [8]. Due to this higher power consumption and our system having a stand-alone power system, class 1 Bluetooth modules don't seem like a compelling option. Class 2 Bluetooth modules may be a viable option, if there is a way to increase range.

LoRa is a form of communication that utilizes a wireless modulation technique known as chirp modulations. In this method, the frequency of a LoRa chirp radio wave increases or decreases with time. By altering different characteristics of the chirp wave, data can be transmitted effectively [9]. This technique allows for the radio waves to communicate over 5 miles in an open outdoor setting. LoRa is also known for having ultra-low power consumptions, which would fit our system perfectly with the limited power supply we have. A downside to LoRa is the data transfer rate, which we can overlook due to the low amount of data needing to be transmitted.

Sensors:

The sensors for the project will be a critical component of the system. Without the sensors to detect the athletes at the bottom of the hill, there will be no way to transmit to the top of the hill that the jump is clear. In order to accomplish this task several technologies were researched to decide what type of sensor would be best suited for this project. The characteristics of a good sensor for this project are, low cost, reliable, sensitivity that suites the system, good resolution, able to withstand cold temperatures, and a far enough range to detect a 30-foot by 30-foot square. Many sensors, like passive IR sensors are used all around the world today. [11] The types of sensors researched for this project include motion, LiDAR, pressure, and thermal.

Motion detection is another technology that was researched. This sensor classification was quickly determined to be too broad. There are many different types of motion sensors.[13] The types of motion sensors can include, Area reflective sensors, Ultrasonic motion sensors, Vibration motion sensors, and contact sensors. The main role of motion sensors is to detect a person preset. This is the goal of our system; so different types of motion sensors were researched further.

One of the technologies researched was the LiDAR detection sensor. This technology is a remote sensing system. It can be used to measure landscape and altitude.[13] It is used to map structure including vegetation height, and density of vegetation on the ground.

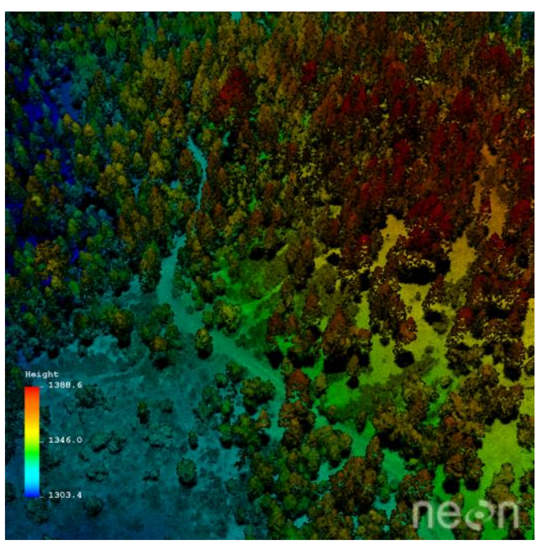


**Figure 3: LiDAR Altitude Detection Processing [13]**

LiDAR sends a strobing light down towards the ground and then reflects off the ground and once it returns to the sensor and that provides a measurement of depth,

Figure 3Figure 3: LiDAR Altitude Detection Processing [13]. Unfortunately, as the temperature drops the sensor's performance also drops. LiDAR tends to be more expensive compared to other sensor types. LiDAR can be accurate as large as 600 feet away. LiDAR is typically used for Aerial surveillance. In order to implement this into our system we would need a large processor with the capabilities of image analysis. However, this is meant to be used for long distances and might prove to be difficult for smaller areas.

The next technology researched was a pressure sensor. “A pressure sensor detects a force and converts that into an output signal that is relative to the strength of the pressure being exerted. A pressure transducer converts the detected force into a continuous voltage output (V)”. [14]

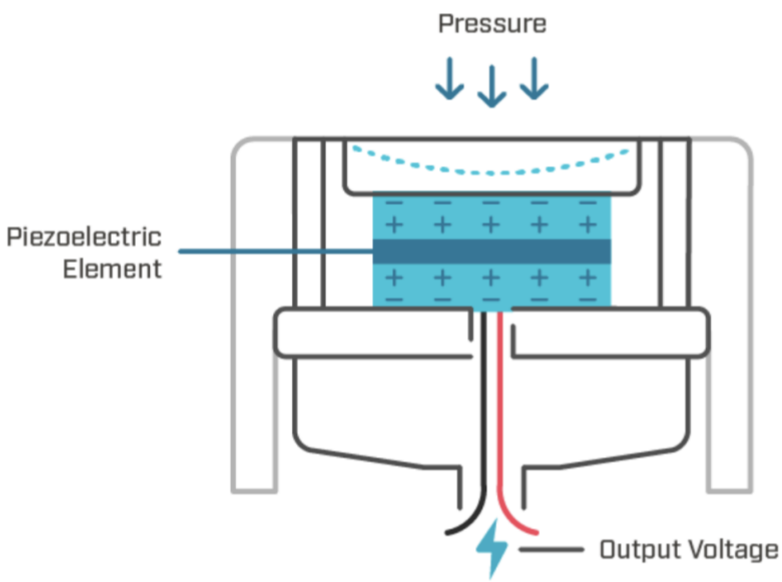


**Figure 4: Basic working principle of a pressure sensor using a piezoelectric diaphragm [14]**

This sensor was taken out of the idea pool quickly due to its difficulty of installation within this system. The design of the sensor, Figure 4 Figure 4: Basic working principle of a pressure sensor using a piezoelectric diaphragm [14], would require it to be placed underneath the snow, and a lot of physical labor would be needed to evaluate the pressure pads. A test or research would need to be done to determine whether the snow falling would affect the results. A lot of this system would be implemented under the ground or as a trip wire, that could result in various hazards. The reliability of this would be difficult to gauge as the system would depend on a lot of moving parts. Additionally, if the system were to need to be taken down at the end of the night this system would prove difficult to execute that need. In the case of this system sensitivity of small changes may pose more of an issue than alternative solutions. If the sensitivity is too great, then the snow falling or shifting of snow with the sensor could cause unfortunate results. The smallest degree of pressure change is the resolution of the sensor. Pressure sensors additionally do not react well to cold weather. A good example of this is the tire pressure gauge in a car. When it gets colder outside it tends to think that the tires are flat. Most pressure sensors have the ability to measure between 0-100 psi. This may pose another issue due to the pressure from the snow build up on top of the system.

The final sensor type researched was thermal sensors. Thermal sensors measure physical parameters based on the heat or flux change. These sensors have a high sensitivity to change in temperature. Depending on the resolution of the sensor the price can range from $200-$8,000. These types of sensors are normally cheaper than RTDs. This sensor is typically more accurate in registering different temperatures reliably than other sensors. The ability of this sensor to act at lower temperatures is greater than most other sensor's due to its ability to read temperature. This sensor can detect differences in temperature up to 0.02ºC. Depending on the price and resolution of the sensor this value could be greater or worse. The reliability of the thermal sensor can depend on various inputs. For example, the temperature drift, ambient temperature, and the distance that is being measured. The range of this sensor is from a few centimeters to several hundred meters.

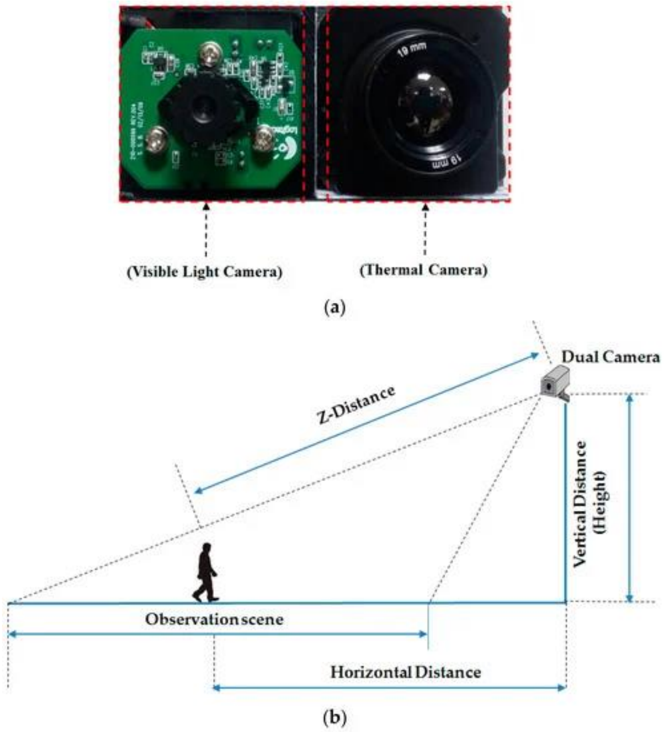

**Figure 5: Imaging Setup to Detect People Using Light Camera and Thermal Camera [15]**

A dual camera system could be used to detect the athlete present. This system would use a visible light camera in conjunction with a thermal camera, Figure 5, to have better accuracy. An experiment has been done that uses a thermal camera and visible light camera to detect when a person is present in front of the camera. [15] This test is relevant to the system, because the product being implemented is very similar and needs to detect when an athlete is present. The difference in this system is the addition of more intense weather conditions, like snow or fog. These conditions will provide a more difficult path to a solution. However, the findings in this test can be used to drive the progress of this project towards an affordable and affective solution.

Additionally, another set of testing was done to detect the presence of a person with a low-resolution thermal sensor.

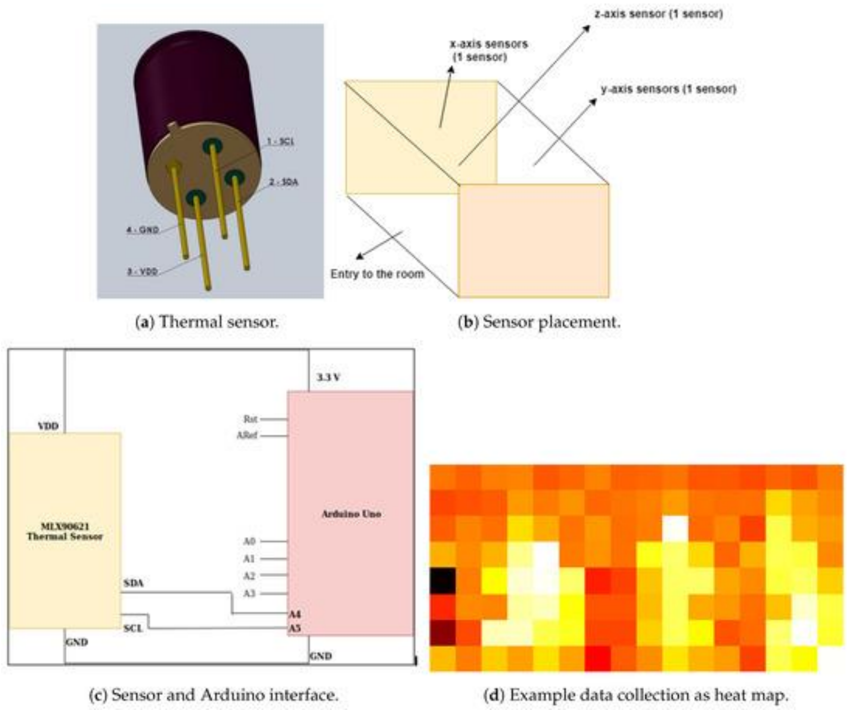


**Figure 6: Hardware Setup and Data Collection for Low-Resolution Thermal Image Testing [16]**

In this experiment there was data collected and processed, Figure 6, to determine when a person was present. A test or set of tests was done to determine the number of people in a particular area from a low-resolution thermal sensor. [16] This test is related to the system being developed by this team, because due to constraints on the budget of the project a lower resolution detector may be necessary to produce a product within budget. However, the system would still need to detect when there was a presence in front of it. The findings of this test may not be applicable to all aspects of the test but can still be used to drive the project towards the solution.

The technology that was decided on was the thermal sensor due to its effectiveness in detecting the athlete, and its ability to withstand lower temperatures. Additionally, it costs less than LiDAR and is more affective in close range detection. Thermal sensing had a higher reliability than pressure and motion sensors, along with the best sensitivity of all the sensors researched.

### *1.3.3 Applicable Standards*

With the development of a new product, it is important to take into consideration regulations and standards that relate to the project. Some areas related to the project are prohibited radio frequencies, power regulations, Montana traffic light laws, and communication standards. These standards ensure that the system will be able to operate safe and successfully.

With the use of wireless data transmission between the signaling unit and detection unit, a potential solution could be that of radio communication. Radio transmission is not prohibited, although there are multiple prohibited frequency bands [17]. These prohibited frequencies, Table 1, are important to consider if radio transmission is used.

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090-0.110 | 16.42-16.423 | 399.9-410 | 4.5-5.15 |
| [1] 0.495-0.505 | 16.69475-16.69525 | 608-614 | 5.35-5.46 |
| 2.1735-2.1905 | 16.80425-16.80475 | 960-1240 | 7.25-7.75 |
| 4.125-4.128 | 25.5-25.67 | 1300-1427 | 8.025-8.5 |
| 4.17725-4.17775 | 37.5-38.25 | 1435-1626.5 | 9.0-9.2 |
| 4.20725-4.20775 | 73-74.6 | 1645.5-1646.5 | 9.3-9.5 |
| 6.215-6.218 | 74.8-75.2 | 1660-1710 | 10.6-12.7 |
| 6.26775-6.26825 | 108-121.94 | 1718.8-1722.2 | 13.25-13.4 |
| 6.31175-6.31225 | 123-138 | 2200-2300 | 14.47-14.5 |
| 8.291-8.294 | 149.9-150.05 | 2310-2390 | 15.35-16.2 |
| 8.362-8.366 | 156.52475-156.52525 | 2483.5-2500 | 17.7-21.4 |
| 8.37625-8.38675 | 156.7-156.9 | 2690-2900 | 22.01-23.12 |
| 8.41425-8.41475 | 162.0125-167.17 | 3260-3267 | 23.6-24.0 |
| 12.29-12.293 | 167.72-173.2 | 3332-3339 | 31.2-31.8 |
| 12.51975-12.52025 | 240-285 | 3345.8-3358 | 36.43-36.5 |
| 12.57675-12.57725 | 322-335.4 | 3600-4400 | ([2]) |
| 13.36-13.41 | | | |

**Table 1: Prohibited Frequencies [18]**

If other wireless communication methods are used, there are other applicable standards, including but not limited to IEEE 802.11, IEEE 802.15.1, and IEEE 802.15.4. These are the IEEE standards for local wireless transmission, Bluetooth, and LoRa.

A solution for the signaling unit could involve the use of a traffic light feature to indicate when the landing area is clear. To ensure the signaling unit is easily understood by athletes uphill, the displayed colors must follow Montana Code 61-8-207 using green to signal go, and red to signal stop [19].

When designing a power system which includes solar panels and batteries, the standards must be obeyed in order to allow for safe day to day operations. Standards applicable could be IEEE 1562-2007, IEEE 307-1969, and IEEE 519. These are the IEEE Standards for battery sizing in a PV(Photovoltaic) system, adding solar cells to a power system, and for loads in electrical systems.

# 2. Project Requirements

## *2.1 Objectives*

This project has three major objectives that must be achieved in order to be successful. The first objective is to design a system that will determine whether the landing area below a jump is clear, then report the status to the uphill signaling system to inform athletes. This is to provide the athlete uphill with knowledge of the landing area status to reduce the risk of collision.

The second objective is to design a system so that it can operate successfully in inclement weather throughout the months of December through April. This period is the peak of the skiing season, which is when the system will be in full use. The system must be able to work in cold snowy conditions, so the system must be durable.

The third objective is to design a system such that it will operate on a standalone power system. Being on a ski resort mountain, access to traditional powering methods will be limited. This induces the need for a standalone system that must be self-sufficient and have reliable energy storage.

## *2.2 Product Requirements Outline*

To achieve these objectives, the following requirements have been selected and will need to be met:

**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**

- 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

**Obj 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

**Obj 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

## 2.3 Design Constraints

While achieving these requirements, there are four primary constraints the design process must follow:

- The system must use solar power as the primary power source.
- The system must provide a light signaling unit in order to give athletes indication on whether it is safe to proceed or not.
- The system must communicate among units with wireless transmission, in order to ensure there are no hazards added to the terrain park like wires.
- The system must have manual height adjustment to account for changes in the snow base and to save power.

## 2.4 Additional Project Concerns or Deliverables

Along with meeting the above requirements, there are some additional deliverables that will be produced with the system. These are as follows:

- Detailed user manual / instruction set
- All Circuit schematics, structural drawings, and PCB artwork

## 2.5 Team Member Responsibilities

To accomplish the goals and requirements of this project, the responsibilities of certain systems were split up between group members. While being in open communication with each other about the project, each member was assigned a slight focus by area of expertise, Table 2.

**Table 2: Percent responsibility for each team member on project**

| Name | Detection | Power | Data Processing* | Mechanical Structures | Documentation | Team Management |
|---|---|---|---|---|---|---|
| Riley Holmes | 20% | 15% | 50% | 0% | 20% | 18% |
| John Podgorney | 5% | 5% | 0% | 45% | 20% | 18% |
| Ben Caba | 10% | 60% | 0% | 10% | 20% | 18% |
| Emily Schwartz | 60% | 15% | 50% | 0% | 20% | 28% |
| Trevor Jordan | 5% | 5% | 0% | 45% | 20% | 18% |
| Total | 100% | 100% | 100% | 100% | 100% | 100% |

**Data Processing being defined as the wireless communication between the uphill and downhill units, and the changing of the Signal Light.*

The responsibilities of each member are explained below:

*Holmes:*

[9] Riley Holmes' responsibilities include detection, power, data processing, documentation and team management, with a focus in data processing. Wireless transmission and processing are also included in included in the data processing category. Wireless transmission and processing are critical to the project's success, as it's the driver behind the main functionality of our system. He will also have a significate part in the PCB design, where collaboration will prove key to accurately design a PCB and to ensure its fit in the housing. As with everyone else in the group, he will play a role in documentation and overall team management.

*Podgorney:*

John Podgorney's primary responsibility is the mechanical structure of the system, with a focus on the materials used to create the system. Additionally, he is also responsible for working with the other members to ensure the fitting of all components in the housing. His duties include designing the structure of the system, determining the best material to use, determining the best method to build the system, making sure the components don't get too cold, and documenting all findings and progress [9].

*Caba:*

Ben Caba's responsibilities in relation to the project are split between, the power system, detection, documentation, team management, and mechanical structures. The primary focus of his contributions will be with the design and implementation of the system's power unit. Power is essential for operation of all components within the system. It will be critical for him to understand the power required by all subsystems, such as, the detection unit, signaling unit, microcontrollers, etc. All research and developments will be documented and shared with the group, collaboration between members will allow for a more seamless implementation of detection and fitment into mechanical structures.

*Schwartz:*

Emily Schwartz's responsibilities for this project are detection, power, data processing, documentation, and team management. The focus of the effort contributed will be due to the detection. This will include software development, and signal analysis. Additionally, as team leader a larger portion of team management has been attributed to her. It will be critical to create a positive work environment with solid communication amongst team members to allow for proper flow and integration of various subsystems. To promote this work environment proper documentation will need to be completed in order to maintain a consistent perception of the project among all team members.

*Jordan:*

Trevor Jordan's responsibility to contribute to the project mostly includes the mechanical structures of the system. This includes the development of an anchoring system and mounting capable of withstanding varying surface conditions. There will also be a focus on ensuring that the system is durable, easy to install and maintain, and perform consistently in harsh environments. His duties also include full documentation of findings and progress, team management, and a responsibility to assist teammates working on detection and power.

# 3. Technical Description

## *3.1 Conceptual Block Diagram*

[9]To represent the key components and relationships within the system, a conceptual block diagram was created. The goal of the diagram was to illustrate how all the different inputs, outputs, and processes are interconnected. By presenting a clear overview of the interactions between these components, the block diagram provides a valuable aid to the design of the system.

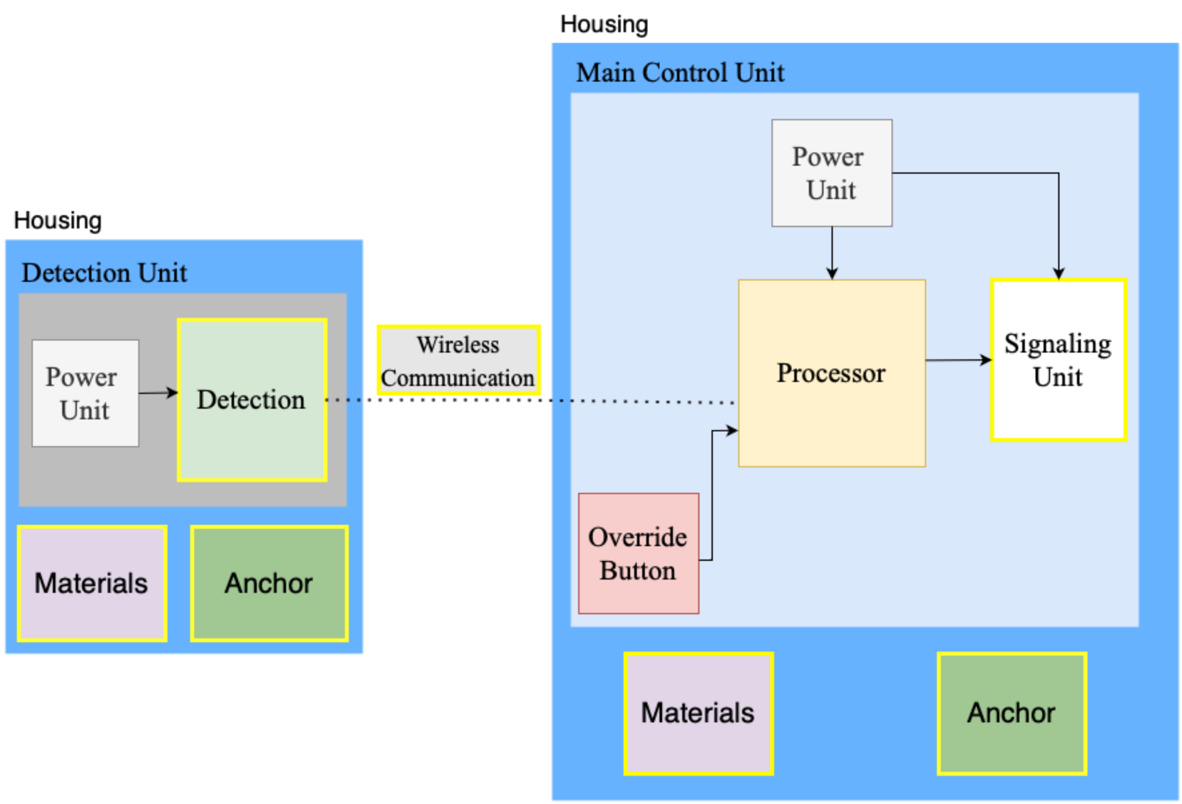


**Figure 7: Block Diagram**

The system consists of two primary components: a detection unit and a main control unit, both housed separately. The detection unit, powered by a dedicated power unit, will detect when the landing area is clear through video processing. This data will be wirelessly transmitted to the main control unit. The main control unit is responsible for receiving this detection data and controlling the signaling unit to display the appropriate traffic light signal [9]. Additionally, the override button provides manual control over the system, allowing for emergency interventions or special circumstances [9]. The highlighted blocks show our critical components. These components have been selected to be the most critical to our project. See 3.2 Critical Component Selections below.

### 3.2 Critical Component Selections

***Communication Electronics: Holmes***

The communication electronics are vital to the overall usability, reliability, and function of the system. As required by our sponsors, the system must be wireless to avoid dealing with wires during setup and takedown, as well as to eliminate the hazard that wires would pose in a terrain park. The wireless communication and its associated electronics must be robust enough to withstand outdoor conditions, including snow, wind, and variable temperatures. Any failure in the communication system would result in a failure of the entire system, directly compromising safety in the terrain park [9].

***Signaling Unit: Caba***

The signaling unit is a crucial aspect for the development of the project. The signaling unit will receive data from the detection unit and then utilize the received data to report the status of the landing area to athletes uphill. The signaling unit will display either a red or green light depending on the status of the landing area. The signaling unit is a critical component because understanding of the structure, electronics, and power draw for the signaling unit will be necessary in the high-level design and assembly of the complete system. Without a functioning signaling unit, the goal of increased terrain park safety will result in failure.

***Detection Unit: Schwartz***

The detection unit is a critical component of the design. This aspect of the design will dictate how a lot of the other components of the project are formed. This component is the key component in determining when the jump area is clear. This system could be brought about in various different ways. The specifications that need to be met by this component are the detection area of 30ft by 30ft, a 95% detection rate and the system must be able to detect the jump being clear in various weather conditions. To do this the detection unit must be able to accommodate snow, fog, and wind. If this component were to fault at any point the result could lead to injuries within the terrain park.

***Material Selection: Podgorney***

The housing of the system is a key factor in the success of the project. All the other components rely on the housing materials to keep them protected from the elements and other extreme conditions. The housing must be able to withstand cold temperatures, high moisture levels, high wind, and be adjustable for changes in snow base, all of which have an impact from the chosen material. Making the housing out of the right material is crucial, as anything insufficient will likely fail, and housing failure will lead to catastrophic system failure. [9]

***Anchoring / Mounting: Jordan***

Given the harsh conditions of a ski resort, including high winds, heavy snowfall, and temperature fluctuations, the system must be securely fastened to withstand these elements. A poorly designed anchoring unit could lead to misalignment of the sensors and even failure of the stoplight. Also, the anchoring unit must account for the ease of installation and maintenance done by resort staff. During the winter season, the system will be mounted on snow and ice, which can shift or settle over time. To address this, the anchors may need to be adjustable or extendable to maintain stability as the snowpack changes. Thus, the design of the anchoring system is essential for operational stability and the long-term reliability of the system. [9]

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# Appendix A (List of Figures and Tables)

## List of Figures



## List of Tables