JumpGuard

User Manual

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1. Introduction

The purpose of this product is to improve safety in terrain parks. The JumpGuard system is made up of two units, the uphill unit, and the downhill unit. The downhill unit consists of the detection unit. The uphill unit is meant to communicate if the detection area is safe to proceed. Both units are powered by their own solar panel and battery.

1.1 Overview of System

A system has been designed to detect when the detection area is clear before notifying the next athlete that it is safe to proceed from the top of the hill, JumpGuard. It determines whether the detection area below a jump is clear and then reports the status to athletes uphill from the detection area. JumpGuard operates in inclement weather throughout the ski season and operates on a stand-alone power source to avoid running power lines to it, which would create unnecessary hazards. The JumpGuard system consists of two separate units, a lower detection unit for detecting athletes, and an uphill signaling unit that displays the status of the detection 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 detection area, the lower unit will transmit this information to the signaling unit. Because of the inherent risk of safety, wires between units were not used. Alternatively, the detection unit operates on a standalone power source and transmits data to the signaling unit wirelessly.

The signaling unit's primary purpose is to display either a green or red light, indicating whether the detection area is clear of athletes or not. The signal displays the state of the detection area by processing the wireless information received from the detection unit and then changing the light color based on the status of the detection area. Like the detection unit, to prevent safety concerns, the signaling unit operates on a standalone power system. This power system is not the same as the power system used by the detection unit.

1.2 Key Features

The JumpGuard Ski Jump Traffic Light System is designed to enhance safety and communication on ski jumps by monitoring the landing zone and signaling athletes when it is safe to proceed. Key features include:

- **Automated Detection**
  The downhill unit detects athletes in the landing area using real-time image processing.
- **Wireless Communication**
  Data is transmitted wirelessly to the uphill signaling unit, eliminating the need for cables and reducing hazards.

- **Standalone Power**
  Both units are powered independently, allowing full operation without connection to external power sources.
- **Clear Visual Signals**
  The uphill unit displays a red or green light to indicate whether the landing zone is occupied or clear.
- **Weather-Resistant Design**
  Components are built to operate reliably in snow, wind, and freezing temperatures throughout the ski season.
- **Failsafe Behavior**
  In the event of power loss or communication failure, the system defaults to a red light for maximum safety.
- **Compact and non-intrusive**
  Units are designed to be mounted away from ski paths, minimizing interference with athletes and equipment.

1.3 Package Contents

The JumpGuard system includes the following components. Please verify all items are present before installation:

JumpGuard Detection Unit (Downhill)

- 1 × Detection Unit Enclosure
- 1 × Camera Module (pre-installed)
- 1 × Battery Pack (pre-installed or separate depending on configuration)
- 1 × LoRa Wireless Transmission/Receiver Module (pre-installed)
- 1 × Mounting Hardware Kit (brackets, screws, stakes, etc.)

JumpGuard Signaling Unit (Uphill)

- 1 × Signaling Unit Enclosure with Traffic Light Display
- 1 × LoRa Wireless Transmission/Receiver Module (pre-installed)
- 1 × Battery Pack (pre-installed or separate)
- 1 × Mounting Hardware Kit

Additional Items

- 1 × Full User Manual (this document)

2. Safety Information

2.1 General Safety Warnings

Please read and follow all safety warnings before installing or operating the JumpGuard system. Failure to follow these guidelines may result in equipment damage or injury.

- **Outdoor Use Only**
  JumpGuard is designed for outdoor environments and should not be operated indoors or in enclosed areas.
- **Weather Precautions**
  Do not access or service units during active snowfall, lightning, or extreme wind conditions. Ensure all enclosures remain sealed to protect components from moisture and snow.
- **Electrical Safety**
  Units are powered by standalone battery systems. Do not attempt to connect to external AC power or link units with physical wiring.
- **Battery Handling**
  Use only approved batteries. Do not puncture, short-circuit, expose to flame, or attempt to recharge non-rechargeable battery types.
- **Wireless Operation**
  Do not tamper with antennas or reposition units without consulting system setup guidelines. Signal interference may result in false signaling.
- **Visual Confirmation Required**
  The system is an aid—not a replacement for human judgment. Use best judgement, even when the green light is displayed.
- **Installation Safety**
  Mount units securely and outside ski traffic areas. Do not place units where they could obstruct movement or pose a collision risk.
- **Maintenance Notice**
  Only trained personnel should open or service the units. Always power down units before performing maintenance.
- **Emergency Use**
  In the event of malfunction, communication failure, or system damage, discontinue use immediately and switch to manual clearance protocols.

2.2 Electrical & Handling Precautions

To prevent damage to sensitive electronics and ensure safe maintenance and assembly of the JumpGuard system, follow the handling guidelines below:

- **Electrostatic Discharge (ESD) Protection**
  Many components in the system, including the *MSP430 processor*, *Raspberry Pi*, *LoRa module*, and *camera*, are sensitive to static electricity. If in a lab environment, use an anti-static wrist strap. In field settings, handle PCBs by the

edges with clean, dry gloves on a non-conductive surface. Store electronics in *anti-static bags* when not installed—this includes boards already mounted on PCBs.

- **MSP430 Handling**
  The uphill processor (MSP430) is especially vulnerable to ESD. Avoid direct contact with pins. Always store in an ESD-safe bag when not installed.
- **Raspberry Pi Precautions**
  The Raspberry Pi should be powered off before connecting or disconnecting peripherals (camera, USB devices, power). Avoid flexing or bending the board. Do not operate the board on conductive surfaces.
- **LoRa Module Care**
  The LoRa module contains delicate RF components. Avoid touching the antenna or connector contacts. Do not power the unit without the antenna properly connected, as this can damage the RF circuitry.
- **Camera Handling**
  - Do not touch the camera lens—fingerprints and scratches degrade image quality.
  - Handle the ribbon cable with care; avoid sharp bends or excessive strain.
  - Always power down the system before connecting or disconnecting the camera.
  - Shield the camera from snow, water, and direct impact during installation and use.
- **Battery Safety**
  Only use approved battery packs. Do not short terminals or expose batteries to heat or moisture. Always disconnect power before servicing the system.
- **Moisture & Weather Sealing**
  Ensure all enclosures are *properly sealed* before outdoor deployment. Water ingress can permanently damage sensitive components.
- **Connector Handling**
  Use gentle force when connecting ribbon cables, headers, or plugs. Misalignment can damage pins or sockets.
- **Power Isolation During Service**
  Before servicing any unit, fully disconnect and power down the system. This prevents accidental short circuits and damage to onboard components.

3. System Overview

3.1 Components Description

This section provides an overview of the primary components used in the JumpGuard system, including their function and key characteristics.

Raspberry Pi 4 Model B

The Raspberry Pi 4 serves as the main processing unit for the downhill detection system. It captures images from the camera module, performs image processing, and wirelessly transmits detection data. It features multiple USB ports, GPIO pins, and a CSI camera interface.

MSP430 Microcontroller

The MSP430 is a low-power microcontroller used in the uphill signaling unit. It receives wireless signals from the detection unit and controls the red/green traffic light display based on detection status. It is highly sensitive to static electricity and must be handled with care.

LoRa Modules (RFM95W)

The LoRa module's part number is **RFM95W** from Adafruit. These modules use **LoRa** (Long Range) frequency modulation for communication. Operating at **915 MHz**, they can transmit up to several kilometers in optimal, line-of-sight conditions. These modules enable robust wireless communication between the detection and signaling units.

Camera Module (Sony IMX219)

This visible-light camera connects to the Raspberry Pi via the CSI interface. It captures images of the jump landing area for object detection. The lens must be kept clean and protected from scratches, dust, and moisture to ensure optimal image quality.

Traffic Light Display (Red/Green LED)

The signaling unit contains a simple red-green LED traffic light, visible to athletes from the top of the hill. The light changes based on detection signals to indicate whether the landing zone is clear (green) or occupied (red).

Weatherproof Enclosures

Each unit is housed in a sealed weather-resistant enclosure designed to withstand snow, cold, and moisture during winter conditions. The enclosures protect internal electronics from environmental exposure.

Mounting Hardware

Includes brackets, fasteners, and poles or stakes for securing the detection and signaling units on the ski hill. Designed for quick setup and safe placement away from ski traffic paths.

3.2 System Diagram

The JumpGuard system consists of two primary units: the **Downhill Housing Unit** and the **Uphill Housing Unit** (Figure 1). Each unit operates independently and is powered by a dedicated standalone power system consisting of a **solar panel** and a **battery**, housed separately from the core components to protect them from environmental damage.

Downhill Unit – Detection System

The downhill unit contains the **detection subsystem**, shown in green, which includes a **visible light camera** and a **processor**. This subsystem monitors the jump landing area to determine whether it is clear or occupied. Once detection is completed, the processor sends the status to the **communication subsystem**, shown in blue, which transmits the signal wirelessly using a **LoRa module**.

Uphill Unit – Signaling System

The uphill unit receives the detection signal through its own **communication subsystem**. The **processor** interprets this signal and controls the **signaling unit**, shown in orange, which displays either a red or green light to notify athletes when it is safe to proceed. Additionally, the uphill unit includes an **override button** that allows manual control of the signal in case of an emergency.

Both units are enclosed in durable **polycarbonate housings** and anchored securely to withstand winter conditions and maintain system integrity throughout the ski season.

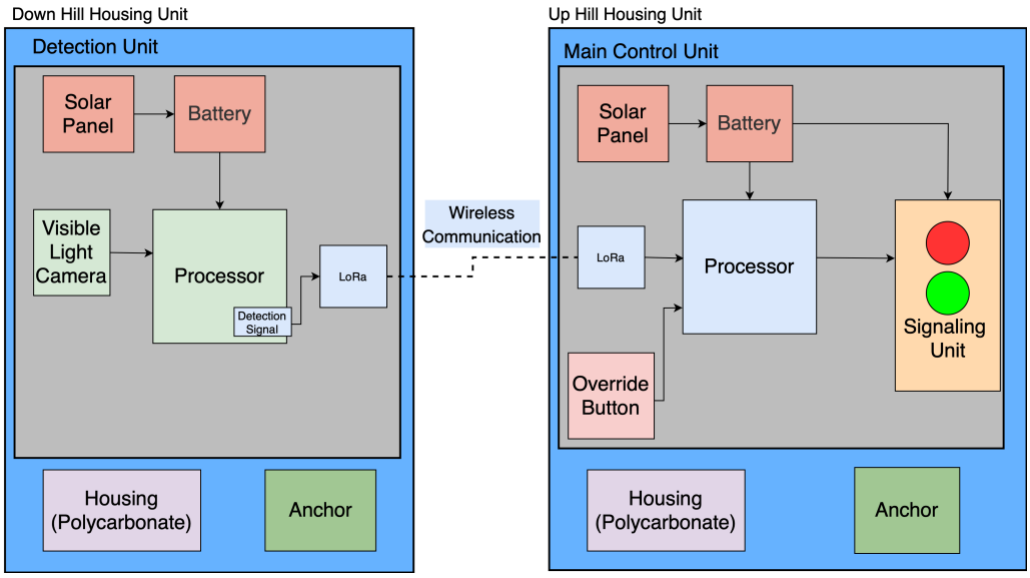

Figure 1: Block Diagram of System

4. Assembly Instructions

4.1 Tools Required

The following tools are recommended for assembling and installing the JumpGuard system in the field:

Table 1: Tools for Installation

Tool	Purpose
Phillips Screwdriver	Securing enclosure covers and mounting brackets
Adjustable Wrench	Tightening bolts on anchors or mounting frames
Drill with Drill Bits	nstalling mounting hardware into the ground or fixed structures
Zip Ties or Cable Clips	Organizing and securing internal wiring
Multimeter	Checking battery voltage and verifying power connections
Clean, Dry Gloves	Handling electronics safely in lieu of ESD tools
Soft Lens Cloth	Cleaning the camera lens before sealing the enclosure

⚠ **Field Note:** While ESD wrist straps may not be practical in the field, always handle PCBs and connectors by the edges and avoid touching component pins directly. Work on a non-conductive surface when possible.

4.2 Step-by-Step Assembly Guide

This section outlines the field assembly process for the **JumpGuard System**, including both the **Uphill Signaling Unit** and the **Downhill Detection Unit**. All PCBs and components are assumed to be fully populated prior to installation.

⚠ **Field Note:** Handle all components with clean, dry gloves. Avoid touching exposed circuitry or connectors. Ensure batteries are disconnected during handling and connected only during final setup.

4.2.1 Uphill Signaling Unit Assembly

This unit controls the red/green light signal seen by athletes at the top of the jump.

Step 1 – Connect the Signaling Lights

- Attach the **red LED light wires** to the labeled **Red Connector** terminal (bottom right of PCB).
- Attach the **green LED light wires** to the labeled **Green Connector** terminal (top right).

- Confirm polarity:
  - **Pos** → Red wire
  - **Neg** → Black wire

Step 2 – Connect the Override Button

- Plug the override button into terminal **J2** on the PCB (center bottom).
- Ensure a secure fit and smooth button action.

Step 3 – Connect the Power Supply

- Connect the **12V battery** leads to the main input terminal (top right corner):
  - **Pos** → Red (positive) wire
  - **Neg** → Black (negative) wire

 The onboard **DC/DC converter** steps 12V down to 3.3V for logic components.

Step 4 – Power Verification

- Use a multimeter to verify:
  - **12V input** is present at the terminal.
  - **3.3V output** is stable at logic components (e.g., MSP430).
- Check for power indicators or correct startup behavior.

Step 5 – Enclosure Assembly

- Place the PCB inside the **polycarbonate housing**.
- Route wires through cable glands or designated openings, ensuring a weatherproof seal.
- Fasten the lid securely with screws.

Step 6 – Mounting

- Mount the enclosure to a fixed, visible location using brackets or anchors.
- Ensure the traffic light is **clearly visible from the top of the hill** and **not obstructing ski paths**.

4.2.2 Downhill Detection Unit Assembly

This unit detects athletes in the landing zone and transmits the detection signal to the uphill unit.

Step 1 – Connect the Camera Module

- Confirm that the **visible light camera** is securely attached to the **Raspberry Pi** using the CSI ribbon cable.
- Avoid bending the ribbon excessively and do not touch the camera lens.

Step 2 – Connect the Power Supply

- Connect the **12V battery** leads to the designated terminal.
  - **Pos** → Red wire
  - **Neg** → Black wire
- The system's **DC/DC converter** steps down 12V to 5V for the Raspberry Pi.

> ⚠ Do not connect a 12V source directly to the Pi without conversion.

Step 3 – Position the Camera

- Secure the camera in a position with a **clear view of the landing zone**.
- Use mounting brackets or fasteners to hold it in place. Confirm the angle is fixed and steady.

Step 4 – Power On and Test

- Power the unit and confirm:
  - The Raspberry Pi boots (indicator LEDs flash or stay lit).
  - The camera is functioning.
  - The LoRa module transmits data (if diagnostics are available).

Step 5 – Enclosure Assembly

- Place the Raspberry Pi, battery, and wiring into the **polycarbonate enclosure**.
- Route all cables through cable glands and ensure a tight seal.
- Secure the housing lid with screws.

Step 6 – Mounting

- Mount the detection unit to a stable location with a **direct line of sight to the landing area**.
- Ensure it is **secure**, **weatherproofed**, and **clear of skier traffic**.

4.3 Final Setup Checklist

Before operating the JumpGuard system, verify that each component is installed and functioning as intended. Use the checklist below during final setup for both units:

Table 2: Final Setup Checklist

Task	Description	Done
1. Enclosures Mounted	Uphill and downhill units are securely mounted and positioned outside of ski traffic zones.	☐
2. Camera Aligned	Downhill unit's camera has a clear, unobstructed view of the landing zone.	☐

3. Lights Positioned	Signal lights are clearly visible from the top of the hill.	☐
4. Battery Connected	Fully charged 12V batteries are securely connected in both units.	☐
5. Power Verified	12V input and DC/DC output voltages are checked (3.3V or 5V where applicable).	☐
6. LoRa Link Active	Wireless communication between detection and signaling units is established.	☐
7. Override Button Tested	Manual override switch triggers signal change on uphill unit.	☐
8. Enclosures Sealed	All housings are fully sealed and weatherproof. Cable glands are tight.	☐
9. System Boot Confirmed	Both processor systems boot and run without error. LEDs or indicators are active.	☐
10. Signal Response Verified	Detection event triggers red light: clear area returns to green. Override works as expected.	☐

⚠ **Note:** If any item above is incomplete or fails during verification, do not proceed with system use until the issue is resolved.

5. Operating Instructions

5.1 Powering On

> ⚠ **Note:** The following instructions assume that **all assembly and setup steps** have been completed successfully. Do not proceed unless the system has been fully mounted, connected, and verified using the Final Setup Checklist (4.3).

To power on the JumpGuard system and begin normal operation, follow the steps below in order:

Step 1 – Turn on the Uphill Signaling Unit

- Locate the **power switch** on the side of the **uphill battery box**.
- Flip the switch to the **ON** position.
- Wait a few seconds to allow the system to initialize. The signal light may briefly flash or display red during startup.

Step 2 – Turn on the Downhill Detection Unit

- Locate the **power switch** on the **downhill unit's battery box**.
- Flip the switch to the **ON** position.
- Once powered, the detection system will begin a **calibration period** lasting approximately **2 minutes**.

Important: During calibration, **no movement, shadows, or objects** should enter the detection area. This includes background motion such as ski lift shadows or people walking nearby. Any movement may affect system performance.

Step 3 – Wait for Calibration to Complete

- When calibration is complete, the **uphill signal light will turn green**.
- This indicates the system is ready to begin detecting real motion.

Step 4 – Perform a Functional Verification

Perform a quick test cycle to ensure the system is operating as expected:

Action	Expected Result
No one in the detection zone	Signal light remains **green** for at least **30 seconds**
Someone enters detection zone	Signal light turns **red**
Person exits detection zone	Signal light returns to **green**

Repeat this process once or twice to ensure consistent behavior before allowing athletes to begin using the jump.

✅ Once this sequence is complete and verified, the system is fully operational.

5.2 Normal Operating Procedure

Once the system has been powered on and properly calibrated (see Section 5.1), the JumpGuard system will automatically begin monitoring and signaling based on the presence of athletes in the detection zone.

System Behavior

Condition	Signal Light Status
Detection area is clear	**Green**
Athlete or movement is detected	**Red**

- The **downhill detection unit** continuously monitors the landing zone using a visible light camera and onboard processing.
- When a person enters the detection area, the **wireless signal** is sent to the **uphill unit**, triggering the light to turn **red**.
- Once the person **exits the area** and no additional motion is detected, the light automatically returns to **green**.

⚠ **Note:** Only movement **within the defined detection area** will trigger a signal change. Shadows, snow drift, or activity outside the detection zone may not affect the light.

No user interaction is required during normal operation. The system runs autonomously until powered down or manually overridden (see Section 0).

5.3 Indicator Lights & Status Descriptions

The JumpGuard system uses two LED indicators, each housed behind a color filter:

- **Red LED** – Indicates the detection area is **occupied** or that the system is in **emergency stop mode**
- **Green LED** – Indicates the detection area is **clear**

Normal Operation Light Behavior

LED Status	Meaning
🔴 Red (Solid)	Person or motion detected in the landing area
🟢 Green (Solid)	Detection area is clear and safe to proceed

Emergency Override Light Behavior

When the **emergency override button** is pressed, the red light will behave as follows:

LED Behavior	Status
🔴 Red Flashes Twice**, then solid**	Emergency override activated. System forces red signal regardless of detection unit status.
🔴 Red Flashes Once**, then solid or green**	Emergency override deactivated. System resumes communication with the downhill unit.

- While in **emergency mode**, the system **disregards signals from the detection unit** and holds the light in the red state.
- Once the emergency button is pressed again, the system returns to **normal detection-based operation**.
- The red light may remain lit briefly until a clear signal is received from the downhill unit.

> ⚠ **Note:** Emergency override should only be used during system failures or urgent safety concerns. Always confirm the system returns to green before allowing athletes to proceed.

5.4 Proper Shutdown

Shutting down the JumpGuard system is straightforward. If the units are remaining installed, follow the **basic power-off procedure** below. If the system is being disassembled for storage or relocation, follow the **extended disassembly shutdown steps** to avoid damaging internal components such as the charge controllers.

Basic Shutdown (Power Off Only)

If the system will remain installed and stationary:

1. **Turn Off the Downhill Unit**
   - Use the switch on the **downhill unit's battery box** to turn the system **OFF**.
2. **Turn Off the Uphill Unit**
   - Use the switch on the **uphill unit's battery box** to turn the system **OFF**.

> ⚠ **Note:** No special shutdown command or software procedure is required. The system can be safely turned off using the hardware switches.

Extended Shutdown (For Disassembly or Storage)

If the system is being removed from the field:

1. **Use Power Switches First**

- Turn **OFF** both the **downhill** and **uphill** units using their respective battery box switches.

2. **Unplug Solar Panels**
   - After both systems are powered off, unplug the **solar panel connectors** from each unit.
3. **Disconnect the Battery**
   - Once the solar panels are unplugged, you may safely disconnect the **battery leads**.

> ⚠ **Important:** Always **disconnect the solar panel before the battery** to avoid damaging the charge controllers. Reversing this order can result in electrical faults or permanent damage.

6. Appendix

6.1 Additional Resources

The following resources provide useful technical reference for key components used in the JumpGuard system. These documents may be helpful for future maintenance, upgrades, or troubleshooting.

Component	Resource
LoRa Module (RFM95W)	Manufacturer datasheet available from Adafruit
MSP430 Microcontroller	Texas Instruments product documentation
Raspberry Pi 4 Model B	Official Raspberry Pi documentation
Camera Module (IMX219)	Manufacturer datasheet (Sony)
DC/DC Converters	Datasheets included with module packaging
LED Traffic Light Module	Basic wiring reference (see internal schematic)
Charge Controller	User instructions on proper battery/solar sequencing

📎 **Note:** Additional datasheets and wiring diagrams can be made available upon request or included in future revisions of this manual.

6.2 Code Repositories

The source code for the JumpGuard system is hosted on GitHub and is publicly accessible for reference, development, and future updates.

Repository	Description
github.com/EmS228/jumpguard	Contains the full software stack for the JumpGuard system, including the Raspberry Pi detection logic, MSP430 signal control, and communication protocols between units. Includes installation scripts, configuration files, and documentation for deployment.

💡 **Note:** For questions or contributions, refer to the README file in the repository or use GitHub's issue tracker.

6.3 Glossary of Terms

Term	Definition
Calibration	A short period after powering on where the system adjusts to lighting and environmental conditions before it begins normal operation.

Detection Area	The zone below the ski jump that the system monitors for people or movement.
DC/DC Converter	An electronic device that converts voltage from one level to another (e.g., 12V to 5V or 3.3V) to power different components.
LoRa	A wireless communication method used in the system to send signals between the downhill and uphill units. Known for its long range and low power use.
MSP430	A low-power microcontroller (tiny onboard computer) used in the uphill unit to process signals and control the traffic light.
Raspberry Pi	A small, general-purpose computer used in the downhill unit to run detection software and manage the camera.
Charge Controller	A device that safely manages the flow of power from the solar panel to the battery to prevent overcharging or damage.
Override Button	A manual emergency button on the uphill unit that forces the system into a red-light (stop) mode regardless of what the detection unit sees.
Signal Light	The red or green light visible to athletes at the top of the jump, showing whether it's safe to proceed.
Gland (Cable Gland)	A weatherproof fitting used to pass cables into an enclosure while keeping out snow and moisture.
Header Pins	Small metal pins on a circuit board used to connect components like buttons, sensors, or modules.
Terminal Block	A small connector on a circuit board where wires are secured by screws for power or signal connections.
Failsafe Behavior	System defaults to red if communication or power fails.
Emergency Override	Button-activated manual red signal for emergencies.

Note: If you encounter a term not listed here, refer to the full user manual context or contact the system developers for clarification.