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June 28, 2025

Dr. Farid Golnaraghi
Professor
The School of Mechatronic Systems Engineering
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250-13450 102 Avenue,
Surrey, BC V3T 0A3

RE: MSE 411 Capstone User and Integration Manual for Bison GPS Tracking Collar

Dear Dr. Golnaraghi,

Attached is the final user and integration manual for the wildlife GPS tracking subsystems developed during our MSE 411 Capstone Project. This document outlines the mechanical, electrical, and software integration requirements for the drop-off mechanism, tracking electronics board, and microcontroller system designed for third-party collar developers.

Unlike a full collar solution, our system is intended to be embedded in externally developed collars used for tracking large animals, such as bison. The hardware provides autonomous GPS logging, ARGOS satellite transmission, battery monitoring, and a load-rated servo drop-off actuator. The manual provides detailed instructions and specifications for integrating our subsystems into a complete wildlife collar design.

Our project is sponsored by Wright Collars Inc., with technical support from wildlife biologist Rob Belanger and mechanical engineer Andrew Williams. Dr. Behraad Bahreyni served as our academic supervisor.

We hope this document will support future development and deployment of advanced wildlife telemetry systems in extreme field environments.

Sincerely,

_____

President, BisonTrack

Wallowing-Resistant and Self-Releasing GPS Collar for Bison Herd Tracking

Spring 2025

Integration Manual

June 28th, 2025

Group 4
BisonTrack

Joel Saunders | 301469793

Submitted to: Farid Golnaraghi

SCHOOL OF MECHATRONIC SYSTEMS ENGINEERING
SIMON FRASER UNIVERSITY

Integration Manual

Drop-Off Mechanism and Tracking Electronics

For Use in Bison GPS Collar Development

About this Manual

This integration manual presents the specifications behind the drop-off mechanism and tracking electronics intended only for use with a GPS collar development for tracking bison. The information presented in this manual is intended for an audience educated in engineering design, mechanical structures, electronic configuration, software integration, and wildlife tracking; education in these fields is essential for comprehension of the design. Information in this manual has not been finalized and is subject to change in the future.

This document introduces the details of the mechanical, electrical, and software subsystems designed for the bison herd tracking collar. The system described in this manual is not a complete collar; it is a system to be mounted on a collar for bison. This manual outlines the integration processes for the drop-off mechanism, tracking board, and battery pack. Safety symbols are defined visually and in text to inform the reader of their meaning, followed by general safety precautions and additional safety information, which will be used throughout this document. The subsystem overview is presented and defines the function of the drop-off mechanism, control board, and battery pack. The mechanical subsystem overview lists the general dimensions and functional operations of the main components; the main components are listed in the following section for the specifications, followed by the integration guidelines, which instruct the user on assembling, testing, and mounting the drop-off. The electrical subsystem overview lists the main components in the working control board design, followed by specifications for the power requirements and physical size of the board. Electronic subsystem lifetime is presented by the power consumption formula, which defines the approximate years of use according to the number of batteries and transmissions per day. The I/O summary section describes each pin connection for all electrical modules used, followed by labelled visuals of the PCB front and rear view to show where to connect the modules. The electronic subsystem integration guidelines are then defined. The software subsystem for the GPS communication states the firmware overview, with the customizable options listed at their default values. The flashing and software updates subsection highlights flashing and software updating procedures, as well as the lines of code to be changed for altering the transmission schedule and drop-off timing. The subsystem section ends with the custom requirement procedures. This integration manual finishes by providing a summarized integration checklist, a technical support contact information page, instructions for disposal and sustainability for the drop-off and electronics design, and a glossary for acronyms and technical terms used throughout this manual.

Introduction

This integration manual provides the necessary specifications, mechanical details, and electrical interface documentation for embedding our modular hardware subsystems into a third-party wildlife tracking collar. These subsystems include:

- A **servo-actuated drop-off mechanism** designed to release reliably under high tension
- A **compact electronics board** housing the GPS, ARGOS satellite communication module, and power circuitry
- A **low-power microcontroller system** responsible for data acquisition, communication, actuation, and power management
- **Firmware** to support autonomous field deployment and scheduled data logging

This system is **not a complete collar**. It is intended for integration into externally developed collar enclosures by third-party engineers and manufacturers. It is particularly suited for applications involving large, rugged animals such as bison, where mechanical durability and energy efficiency are critical.

The components have been developed as part of a capstone design project sponsored by **Wright Collars Inc.**, with technical support from wildlife biologists and engineers. The system is optimized for long-term autonomous field operation in extreme environmental conditions.

This manual outlines everything required to physically mount, power, communicate with, and program the integrated hardware, allowing collaborators to focus on developing their own enclosure, strap system, and form factor around our proven internals.

Purpose

This document provides integration guidelines for third-party teams building a GPS-enabled wildlife collar around our provided subsystems:

- **Drop-off mechanism** (servo-actuated, sealed, load-rated)
- **Tracking Board** (Includes satellite transmitter, GPS module, and microcontroller)
- **Power Management** (lithium power support with deep sleep capabilities)

The system enables:

- Scheduled GPS sampling and data logging
- Satellite uplink using ARGOS protocol
- Remote or timed-triggered collar drop-off
- Energy-efficient autonomous operation
- Drop-off reliability under 1000kg of force
- Drop off actuation under 200kg of pulling load

This hardware set is designed for field-deployable wildlife tracking applications with minimal external I/O and a fully autonomous operating profile. It is designed to be simple to integrate mechanically and electrically into enclosures developed by third-party engineers.

Safety

Safety Symbol Definitions

The DANGER symbol is used in the following contexts:

- Indicates a hazardous situation, if not avoided, **will** result in serious injury or death.
- Indicates a procedure, step, or guidance that if now followed correctly, **will** result in serious injury or death.

The WARNING symbol is used in the following contexts:

- Indicates a hazardous situation, if not avoided, **could** result in serious injury or death.
- Indicates a procedure, step, or guidance that if now followed correctly, **could** result in serious injury or death.

The CAUTION symbol is used in the following contexts:

- Indicates a hazardous situation, if not avoided, **could** result in equipment or property damage.
- Indicates a procedure, step, or guidance that if now followed correctly, **could** result in equipment or property damage.

The NOTICE symbol highlights information that may be useful or require special attention

General Safety Precautions

Pinch Hazard
The drop-off subsystem contains pinch points with enough force to seriously injure.

Battery Shorting
The electrical subsystem contains batteries that can burn or explode if heated, punctured, or short-circuited.

Operation Voltage
Operating any subsystems outside of the intended voltage ranges could lead to system damage and failure; the systems may misbehave and act unpredictably.

Water Exposure
The electrical subsystem needs protection from water and shock. If not adequately protected, the system can be damaged.

Dust and FOD Exposure
The drop-off subsystem needs protection from excessive dust and foreign debris. If not adequately protected, the mechanism may clog and fail to actuate.

Subsystem Overview

The wildlife collar tracking collar breaks down into three main subsystems: the drop-off mechanism, the control board, and the battery pack. Each can be used as a stand-alone system and does not need to be integrated with the other.

Subsystem	Function
Drop-Off Mechanism	Mechanically separated collar ends; servo-driven ● Withstands static forces greater than 1000kg ● Releases under up to 200kg of tensile force ● Straight-insert steel piece with locking tab supported by rack and pinion design to ensure robust and secure connection ● The assembly process is simplified to require minimal building procedures to ensure mechanical success
Control Board	50 x 40mm PCB ● Gathers GPS coordinates ● Sends data to the ARGOS network ● Monitors battery voltage ● Activates the drop-off on a timer or by customer request
Battery Pack	Customizable battery pack solution/ ● Triple LSH20 lithium battery configuration (13Ah each) enables a 4-year battery lifespan, uploading 16 location points every 6 hours.

Mechanical Subsystem

Overview

The drop-off mechanism is a compact, sealed assembly that allows the collar to disengage from the animal on a timer or remote command. It is engineered for high axial loads and designed to operate reliably in rugged outdoor environments.

Main Components	
Overall Dimensions	112.5mm x 84.6mm x 44mm
Main Unit Dimensions (without mounting tabs)	70mm x 84.6 x 44mm
Mounting	6x 7.5mm holes for rivets. 3 on housing, 3 on tongue
Actuation	Rack-and-pinion servo drive
Force Tolerance	Rated to 990kg axial tension
Enclosure	Fully Sealed; dust/debris/water resistant

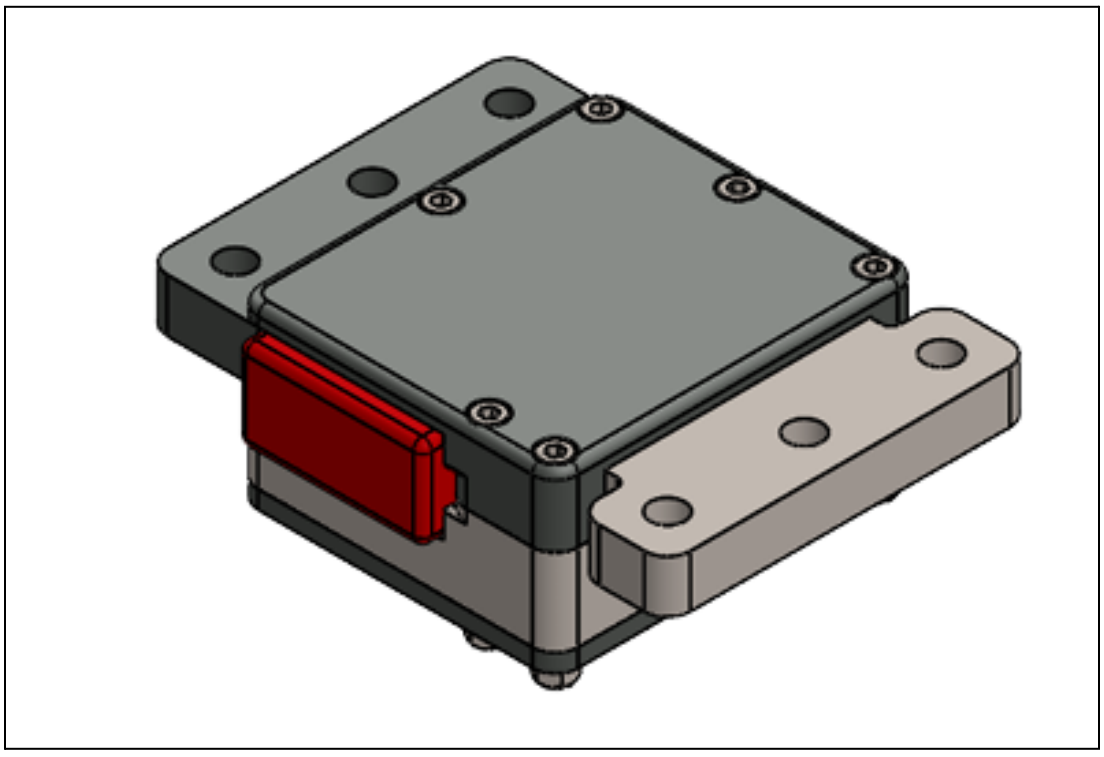


Figure 1: Drop-Off Assembly

Specifications

The drop-off assembly is comprised of the components shown in figure 2 and listed below:

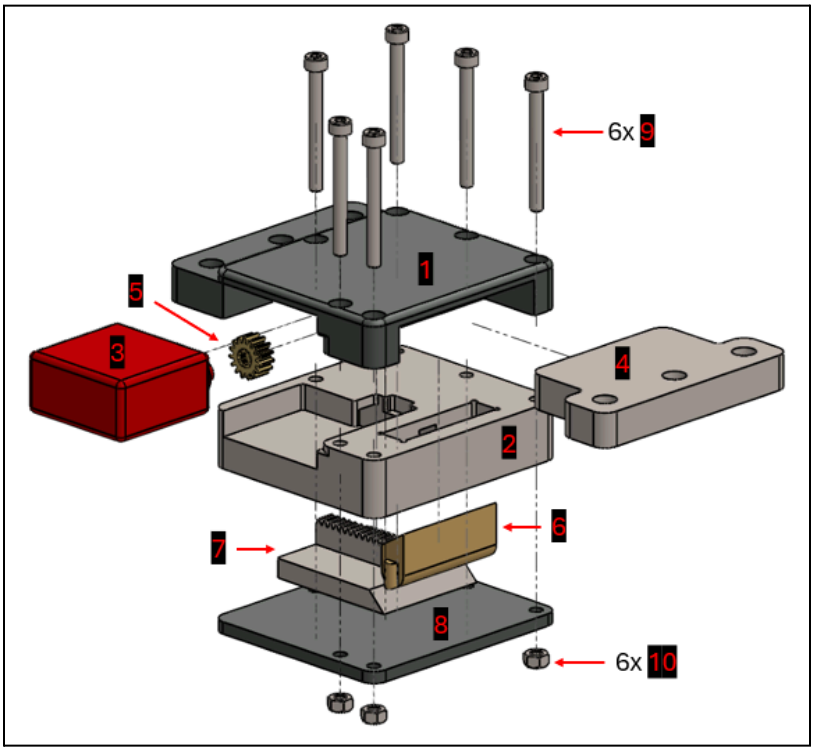


Figure 2: Labeled Drop-Off Exploded View

Part #	Quantity	Description
1	**1**	Top Plate - 6061 Aluminum
2	**1**	Main Body and Servo Housing - 6061 Aluminum
3	**1**	Miuzei 20kg Digital Servo - DS3218
4	**1**	Locking Tongue - 304 Stainless Steel
5	**1**	Pinion Gear - Brass
6	**1**	Locking Tab - 304 Stainless Steel
7	**1**	Rack Release Tab - 304 Stainless Steel
8	**1**	Bottom Plate - 6061 Aluminum
9	**6**	40mm Hex Head M4 Bolt - 304 Stainless
10	**6**	M4 Nylock Locking Nut

Integration

For testing and mounting, refer to the tables labeled “Drop-Off Testing” and “Mounting Guidelines”.
The drop-off is designed to be assembled according to the following assembly guidelines:

Step #	Drop-Off Assembly Steps
1	Apply grease to all sides of the slanted tab, then insert the slanted tab into the keyed front hole of the main body. The high side of the slanted tab must face outward.
2	Apply grease to all sides of the rack tab, in place the rack tab in the grooved bottom opening of the main body. Ensure the angled portion of the rack tab faces forward. Slide the rack tab to its rearmost position.
3	Attach the pinion gear to the servo shaft using the included M3 bolt. Torque bolt to 2.2 Nm (≈ 19.5 in-lbs)
4	Apply epoxy resin to the mating faces of the servo. Then place the servo into the main body.
5	Confirm pinion alignment with rack teeth before the enclosure is sealed. manual drop-off function, ensure drop-off has been released after the manual release function is complete. (Figure 3)
6	Place the top plate over the servo. Ensure proper epoxy distribution
7	Align the holes of the bottom plate with the underside of the main body.
8	Install 6x 40mm hex head M4 bolts from the top plate to the bottom plate. The hex head of the bolts must be on the top plate side. Torque bolts to 4.5Nm (≈ 40 in-lbs)
9	Apply medium-strength (blue) thread locker on the exposed tip of M4 bolts.
10	Install 6x M4 Nylock locking nuts on the bottom plate side of the drop-off.
11	Apply epoxy coat to the exterior of the drop-off assembly (Do not apply any epoxy coat to the locking tongue or the tongue entrance).

NOTICE

For further clarification, see the exploded view below (Figure 4)

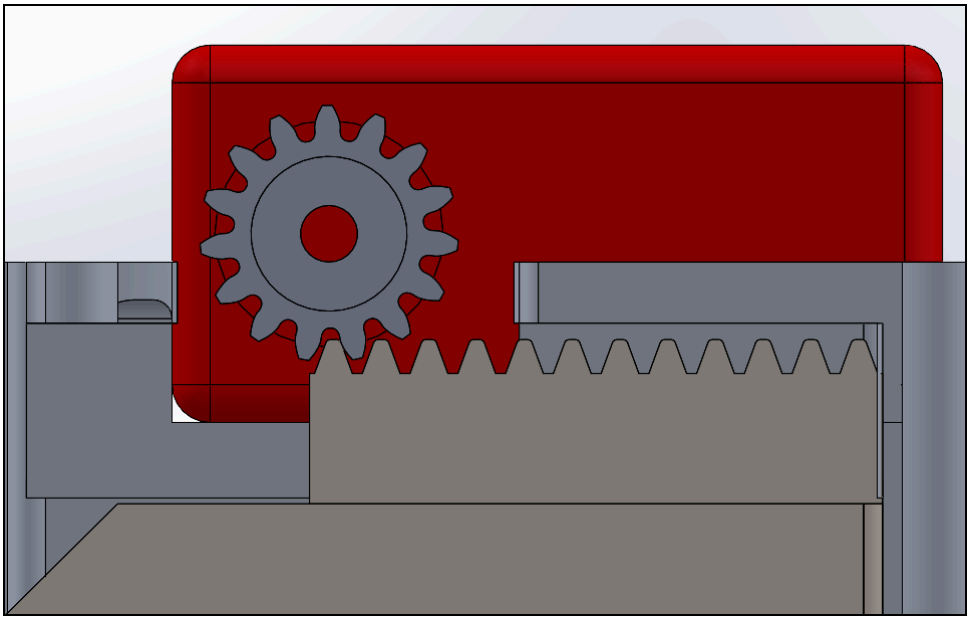


Figure 3: Drop-Off Rack and Pinion Tooth Alignment

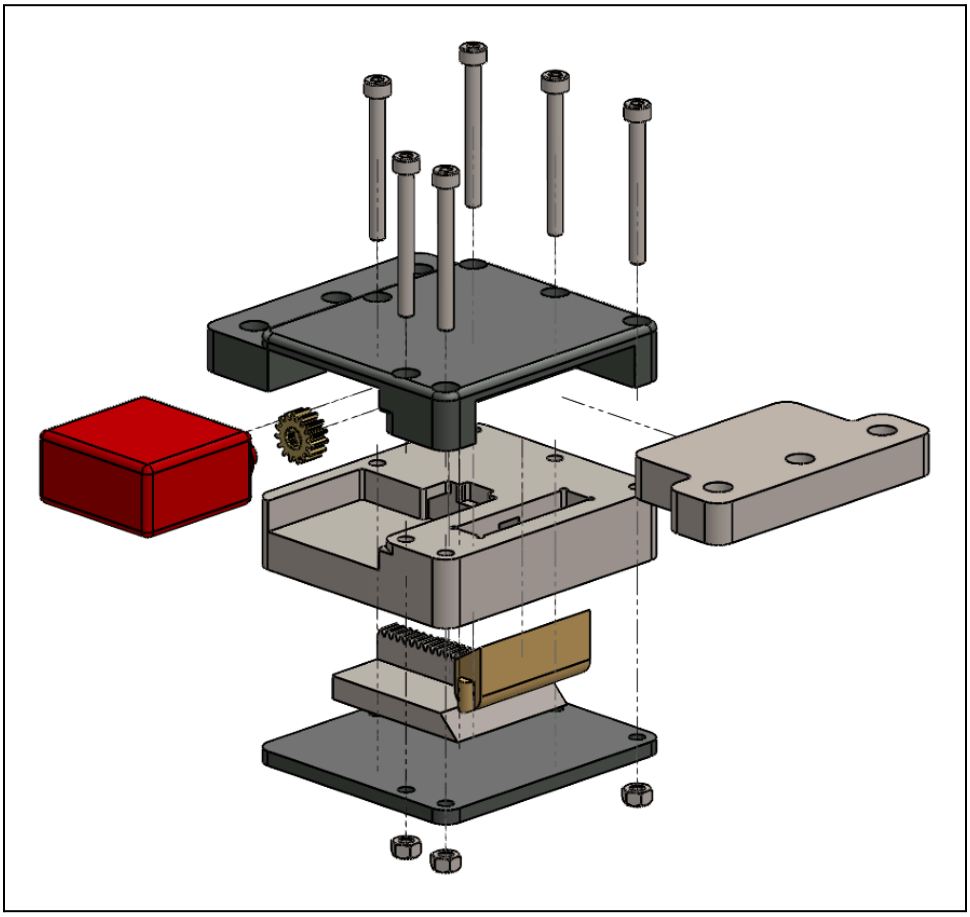


Figure 4: Drop-Off Assembly Exploded View

CAUTION

Motor Stalling
The rack must be placed in the rear position, and the pinion gear must mesh its teeth with the rack properly. If positioned incorrectly, the servo motor will stall, and the release system will fail.

Step #	Drop-Off Testing
1	Ensure that the servo is connected to GND, Signal, and Power pins.
2	Apply 3V to the PCB.
3	Flash the “Drop-off_Test” program onto the PCB.
4	Ensure that the pin actuates up and that you can push the pin back down after the motor retracts. **WARNING** **Do not insert fingers or any other body part into the drop-off when operational. Use a flathead screwdriver to push the pin down.** See figure 6 for pinch point clarification.

Mounting Guidelines
Ensure drop-off is **contained within the central collar housing** for protected wiring
Allow 5 mm minimum clearance on all sides for vibration isolation or overmolding.
Route servo wiring (PWM signal, GND, V+) through collar halves.

It is recommended that 2 pieces of collar material be used on the top and bottom of the drop-off connection points. Both faces of the mounting holes on the drop-off should be covered by collar material.

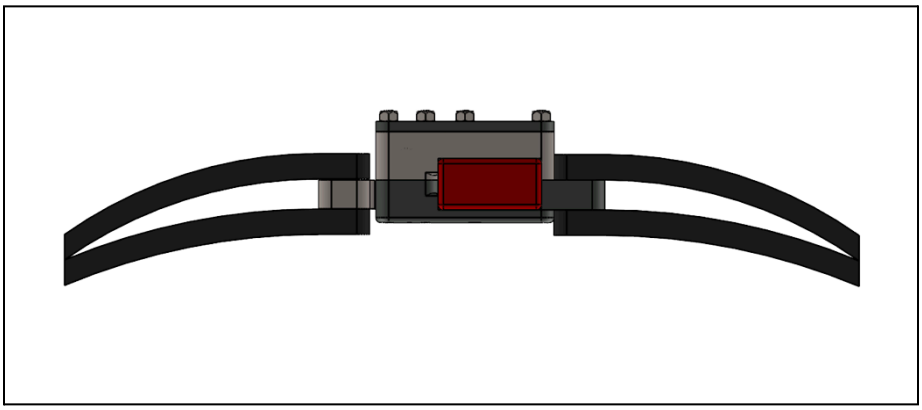


Figure 5: Recommended Drop-Off Configuration

NOTICE

Correct drop-off orientation in the recommended double-belted configuration. The top plate with a filleted edge must face the neck of the animal.

⚠WARNING

Pinch points are indicated below. Pinch points become hazardous when the locking tongue is removed.

- **Do not insert any body part at any time. Disregarding this warning may result in bodily harm.**
- If a free movement test needs to be performed, use a thin flathead screwdriver or a thin spatula.

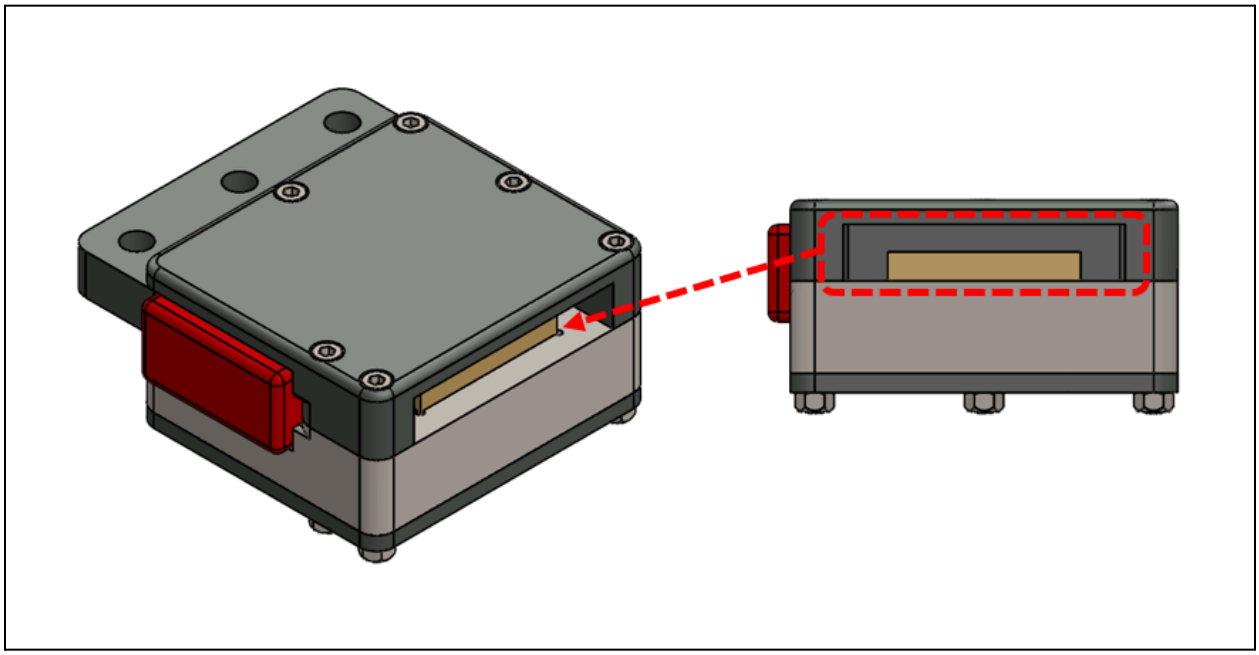


Figure 6: Labeled Drop-Off Pinch Points

⚠WARNING

When testing the drop-off mechanism under load, ensure proper restraints are in place.

The system may respond with unexpected force or pushback and cause damage if improperly handled.

Electrical Subsystem Overview

The electrical subsystem is a board that controls the collar. GPS, satellite communication, battery monitoring, and drop-off activation are all controlled on board.

Main Components	
Microcontroller	LPC802M001JDH20FP
Satellite Transmission Module	KIM2
GPS	SAM-M10Q
DC-DC	TPS63021DSJT
MOSFET	FDN339AN

Specifications

The board is intended to be powered using batteries within the collar. These batteries must be within the specs below.

Power Requirements	
Input Voltage	2.0 - 5.0 VDC
Peak Input Current	<2 A
Idle Current Draw	<100 µA

Physical Size	
Board Footprint	40x50 mm
Height	10 mm

Power Consumption Formula

The control board stays in a low-power mode until woken up at preset times to collect GPS data. After the GPS data has been collected, the board transmits the data to the ARGOS network. Due to this unique transmission process, a formula is required to calculate the approximate power consumption and the required batteries.

$$\text{Years of Use} = \frac{(\#\text{ of batteries}) * (\text{mAh per battery})}{(\text{Flat Power Consumption per Year}) + (\text{Transmission Power Consumption per Year}) * (\#\text{ of Transmissions per day})}$$

# of batteries and mAh per battery are set according to the layout of the battery pack, # of transmissions per day can be configured in software. Note that "# of transmission per day" relates to how many batches of eight GPS coordinates are sent.

Power Consumption Constants	
Flat Power Consumption per Year	152.5 mAh
Transmission Power Consumption per Year	2286.0 mAh

I/O Summary

The I/O of the board includes the flashing connectors of the microcontroller and KIM2, the battery connection, the antenna port, and the servo connection.

I/O Summary	
Eight-Pin Connection	Microcontroller and KIM2 communication ports.
Antenna port	Vertical jack labelled AE1.
Battery Connection	The batteries are connected to the control board via pads on the PCB labeled Vcc and GND.
Servo Connection	The servo is connected by pads from the "Power" pad to Vcc and from the "Signal" pad to the servo signal.
UART Debug Port	Pin for external debug device.

The **eight-pin** is a SWD interface for firmware flashing and debugging for both the microcontroller and KIM2. An external J-link probe is intended to connect to either the microcontroller or the KIM2.
The **antenna port** is the antenna for KIM2/ARGOS communication. An antenna is supplied, but the user can use their own antenna. Performance is not guaranteed, and additional development may be needed for a different antenna configuration.
The **battery connection** connects the batteries to the board. A power supply can also be connected for debugging.
The **servo connection** connects the servo power and signal to the board. When the servo is not latching or unlatching the dropoff the servo is not connected to power to save energy.
The **UART debug** port is used to debug the microcontroller. It can be connected to a UART-to-USB bridge.

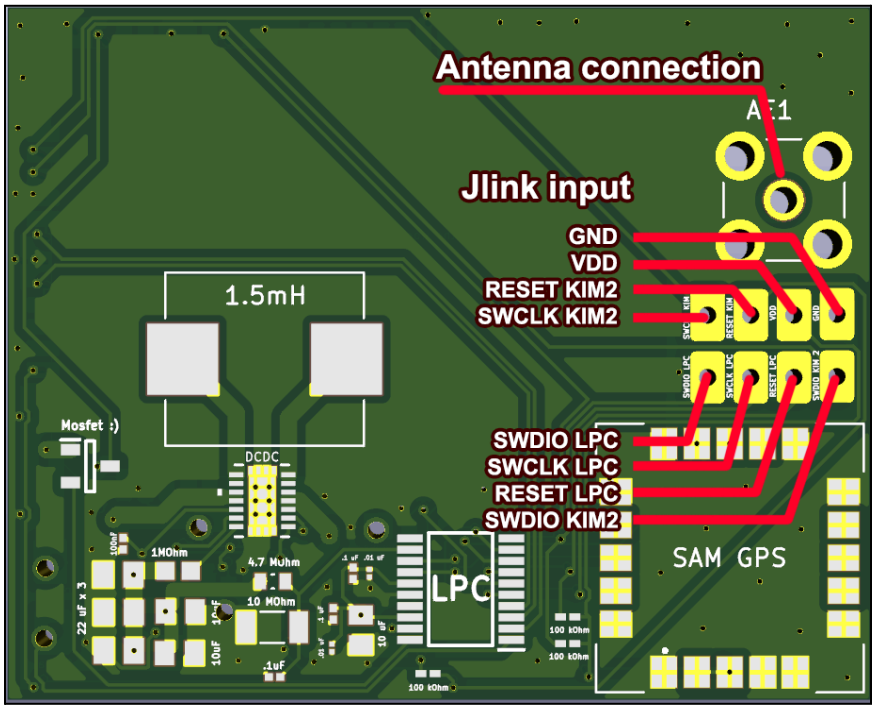


Figure 7: PCB Front View

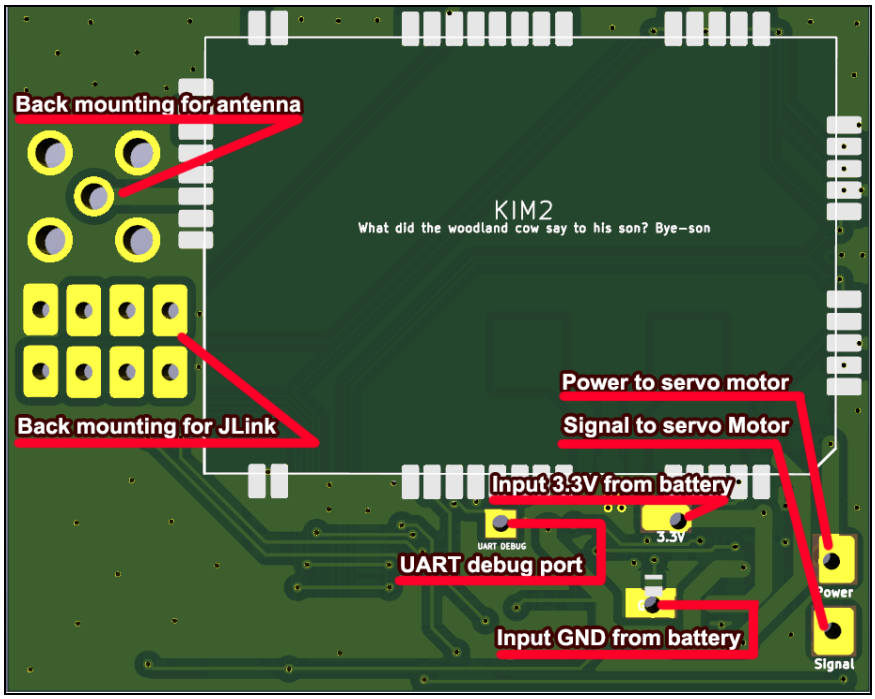


Figure 8: PCB Rear View

Integration

Failure to follow ESD-safe handling procedures may result in damage to components
Always use grounded wrist straps, ESD mats, or other protective measures when working with or installing PCB.

The board is designed to be cast into an epoxy or polyurethane casing and connected to the I/O described in the I/O section of the manual.
The antenna port is intended to work with the antenna supplied. If a different antenna layout is used, additional development may be needed to impedance match the system.
The eight-pin connection must be accessible to activate the device. We recommend the “Buccaneer for data” series of ports for IP6/8 protection.

The electrical subsystem is designed to be coated in epoxy or polyurethane.
Coating the system in a layer of nonconductive adhesive decreases the possibility of failure due to water/moisture, physical impacts, vibrations, shifting of internal components, and short circuits.
Offering a longer and more reliable product life and transmission quality.

If epoxy or polyurethane coating is not possible, the following risks are present.

Water Exposure
The electrical subsystem needs protection from water and shock. If not adequately protected, the system can be damaged.

Impact Sensitivity
The electrical subsystem needs protection from large physical impacts and prolonged weak impacts. If not adequately protected, the system can be damaged.

Vibration Sensitivity
The electrical subsystem needs protection from vibrations. If not adequately protected, system components may disconnect or fail to transmit signals reliably, and the system can be damaged.

Software Subsystem

Firmware Overview

The firmware in this device is configurable according to customer needs. The firmware can be set before the device is encased in epoxy, or a port can be left open for future configuration. We recommend leaving the port open as it allows the device to be activated closer to the time it is on an animal.

Customizable Options	
Transmission Schedule	Select a Transmission Period. (Default 15 minutes)
Drop-off Timing	Select a drop-off timing. (Default 4 years)

Flashing and Software Updates

The microcontroller and the satellite transmission module can both be flashed for firmware updates and configuration changes.

The microcontroller and the satellite communication module are flashed by connecting the J-Link device to the eight-pin port, and Keil uVision is recommended to flash the firmware

Using Keil uVision, in the Main.h file, the following parameters can be changed.

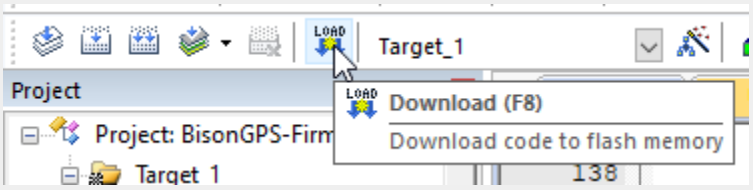
```
26
27  #define DROP_OFF_TIME           48 //Months before dropoff
28  #define TRANSMISSION_PERIOD     15 //Mins between transmission
29
```

Figure 9: Customizable Options

NOTICE

Always verify that flashing was successful before operating or testing products.

Flashing Instructions

Step #	Microcontroller Flashing Instructions
1	Ensure Keil uVision is installed on the computer.
2	Open the desired firmware's project file in Keil uVision.
3	Build the target files by clicking the build button or by pressing F7 
4	Connect a J-link probe to the SWDIO LPC, SWCLK LPC, RESET LPC, GND, and VCC pads.
5	Apply 3V to the PCB.
6	Download the program to the microcontroller by clicking the download button or by pressing F8. 

Custom Requirements

If custom firmware requirements are needed, please contact BisonTrack Solutions, and we can help you with your specific use case.

Technical Support

For troubleshooting, firmware updates, required firmware changes, or technical support, contact:

BisonTrack Solutions Inc.
Email: support@bisontrack.ca
Phone: +1-800-BISON-GPS
Website: www.bisontracksolutions.ca

Disposal and Sustainability

Please return used collars to BisonTrack for safe disposal, further testing, and additional development support. The aluminum and stainless steel housing can be recycled, and electronics may be recovered under certified e-waste procedures.

Glossary

Term	Definition
DC-DC	A power converter that controls the voltage to an appropriate level.
ESD	Electrostatic Discharge: A burst of electricity that can damage electronics.
FOD	Foreign Object Debris: material (e.g., dust, dirt, loose hardware) that can interfere with system performance.
I/O	Input/Output: electrical connections used to communicate with or control devices.
J-Link	A debugging tool used to flash and debug microcontroller firmware.
PCB	Printed Circuit Board – the physical board that connects electrical components.
PWM	Pulse Width Modulation – a method to control analog devices (like servos) with signals.
UART	Universal Asynchronous Receiver-Transmitter – a protocol for communication between electronic components.
SWD	Serial Wire Debug – a protocol for debugging and flashing ARM microcontrollers.