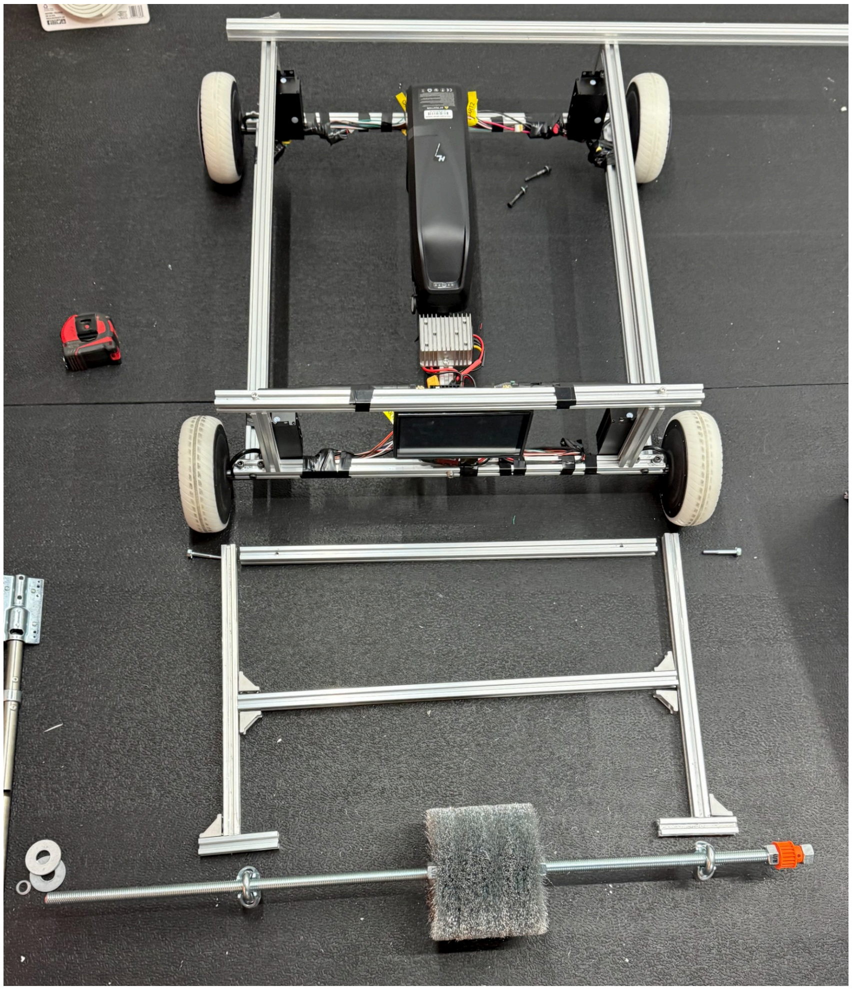
Technical Manual

BVR0

Base Vectoring Rover



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Contents

1 Specifications

1.1 Overview

The BVR0 (Base Vectoring Rover, Revision 0) is a compact sidewalk-scale robotic platform designed for snow clearing and grounds maintenance. The rover measures 600mm square and stands 400mm tall, sized to navigate standard sidewalks while remaining small enough for a single person to lift.

Four independently-driven hub motors provide omnidirectional control without mechanical steering. A modular tool interface at the front accepts snow augers, brine sprayers, and sweeper attachments. The operator controls the rover remotely via LTE teleoperation, viewing a 360° video feed from the onboard camera.

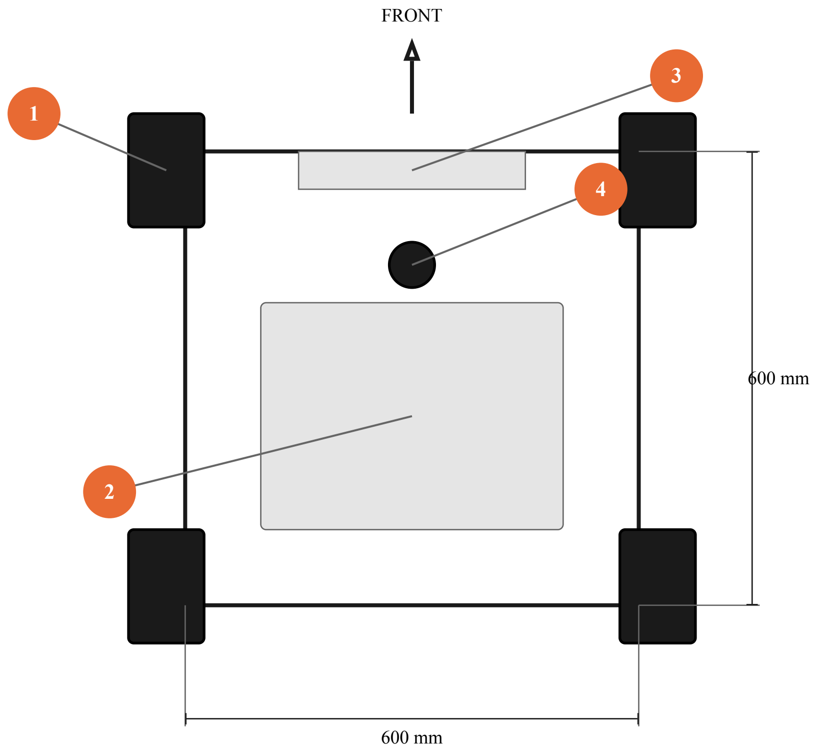

Figure 1: BVR0 top view: (1) Hub motor wheels, (2) Electronics bay, (3) Tool mount, (4) Sensor mast

1.2 Physical Specifications

The chassis is constructed from 2020 aluminum extrusion, providing a rigid yet lightweight frame. The electronics plate mounts centrally, keeping the center of gravity low. Hub motors integrate directly into the wheels, eliminating drivetrain complexity.

Dimension	Value
Length	600 mm
Width	600 mm

Height	400 mm (without sensor mast)
Weight	25 kg (without battery)
Ground Clearance	50 mm
Wheel Diameter	165 mm (6.5″)

1.3 Electrical Specifications

The rover operates on a 48V nominal battery pack, providing sufficient voltage for efficient motor operation while remaining within safe handling limits. A DC-DC converter steps voltage down to 12V for the compute module and accessories.

Parameter	**Value**
Battery	13S4P Li-ion, 48V nominal, 20Ah
Voltage Range	39V - 54.6V
Motor Power	4× 350W hub motors (1.4 kW total)
Continuous Current	60A per motor controller
Control Voltage	12V (via DC-DC converter)
Communication	CAN bus 500 kbps

1.4 Performance

Operating speed is intentionally limited to human walking pace. This enables safe sidewalk operation, reduces stopping distance, and improves operator situational awareness. The 4-hour runtime covers typical snow clearing shifts.

Metric	**Value**
Max Speed	2.5 m/s (5.6 mph)
Operating Speed	1.0 - 1.5 m/s
Runtime	4 hours at working speed
Max Grade	15%
Operating Temperature	−20°C to 40°C

1.5 Sensors

The sensor suite prioritizes situational awareness for teleoperation. The 360° camera provides immersive video for the operator. LiDAR enables future autonomous capabilities and provides depth information for obstacle detection.

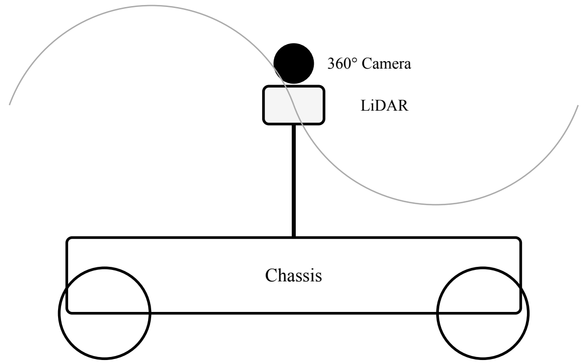

Figure 2: Sensor mast carries LiDAR and 360° camera above obstacle height

Sensor	Purpose
Livox Mid-360 LiDAR	3D mapping, obstacle detection
Insta360 X4	360° video for teleoperation
IMU (integrated)	Orientation, motion estimation
GPS (optional)	Georeferenced positioning

2 Bill of Materials

The BVR0 is designed for approximately $4,000 in components, prioritizing availability and replaceability over optimization. All parts are commercially available; custom fabrication is limited to simple cut-and-drill operations on aluminum plate and extrusion.

2.1 Cost Summary

Category	Est. Cost
Chassis	$150
Drivetrain	$800
Electronics	$900
Perception	$1,800
Power	$400
Wiring/Misc	$100
Total	**$4,150**

2.2 Chassis

The chassis uses 2020 aluminum extrusion for its balance of strength, weight, and ease of modification. T-slot construction allows components to be repositioned without drilling.

Part	Qty	Unit	Total
2020 extrusion 600mm	8	$5	$40
2020 corner bracket	16	$2	$32
M5×10 BHCS	100	$0.10	$10
M5 T-nut	100	$0.15	$15
Electronics plate (1/4″ AL)	1	$50	$50
Subtotal			**$147**

2.3 Drivetrain

Hub motors eliminate chains, belts, and gearboxes. Each motor contains a brushless DC motor, planetary gearbox, and wheel tire in a single unit. VESC motor controllers provide precise torque control and regenerative braking.

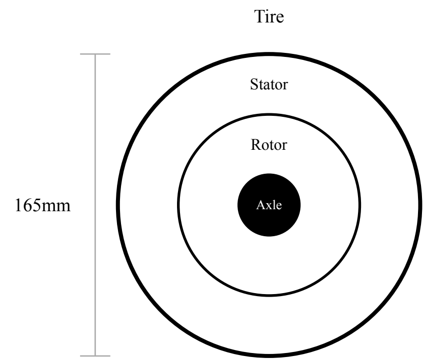

Figure 3: Hub motor integrates motor, gearbox, and wheel in one unit

Part	Qty	Unit	Total
Hoverboard hub motor 350W	4	$50	$200
VESC 6.6	4	$120	$480
Motor mount (custom)	4	$20	$80
Wheel spacer (custom)	4	$10	$40
Subtotal			**$800**

2.4 Electronics

The Jetson Orin NX provides GPU-accelerated compute for video encoding, sensor processing, and future autonomy features. The Sierra MC7455 LTE modem enables reliable cellular connectivity for teleoperation.

Part	Qty	Unit	Total
Jetson Orin NX 16GB	1	$600	$600
Jetson carrier board	1	$100	$100
USB CAN adapter	1	$30	$30
LTE modem (Sierra MC7455)	1	$80	$80
7″ HDMI display	1	$50	$50
GPS module (optional)	1	$30	$30
Subtotal			**$890**

2.5 Perception

The Livox Mid-360 provides 360° LiDAR coverage in a compact, solid-state package. The Insta360 X4 captures 360° video that the operator can pan and tilt virtually, providing natural situational awareness.

Part	Qty	Unit	Total
Livox Mid-360 LiDAR	1	$1,500	$1,500
Insta360 X4	1	$300	$300
Sensor mount pole (1″ AL)	1	$20	$20
Subtotal			**$1,820**

2.6 Power System

The 13S4P battery pack provides 960Wh of capacity. At typical operating loads of 200-300W, this yields 3-4 hours of runtime. The pack includes a battery management system (BMS) for cell balancing and protection.

Part	Qty	Unit	Total
13S4P battery pack 20Ah	1	$300	$300
48V→12V DCDC 20A	1	$40	$40
100A ANL fuse + holder	1	$15	$15
E-Stop relay 100A	1	$25	$25
E-Stop button	1	$15	$15
Subtotal			**$395**

2.7 Wiring & Connectors

Silicone wire handles the temperature extremes of outdoor operation. XT90 connectors are rated for the high currents of the main battery circuit. Deutsch DT connectors provide weatherproof connections for the tool interface.

Part	Qty	Unit	Total
8 AWG silicone wire (red)	2m	$3/m	$6
8 AWG silicone wire (black)	2m	$3/m	$6
14 AWG wire assortment	1	$15	$15
22 AWG twisted pair	5m	$1/m	$5
XT90 connectors (5 pair)	1	$12	$12
XT30 connectors (10 pair)	1	$8	$8
Deutsch DT connector kit	1	$25	$25
Heat shrink kit	1	$12	$12

Cable management	1	$10	$10
Subtotal			**$99**

3 Assembly

Assembly proceeds in five phases: chassis frame, motor mounting, electronics installation, wiring, and testing. Each phase should be completed and verified before proceeding to the next.

3.1 Required Tools

A basic set of hand tools is sufficient for assembly. No specialized equipment is required.

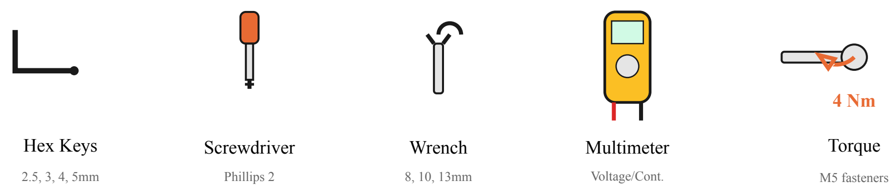

Figure 4: Required tools: hex keys, screwdriver, wrenches, multimeter. M5 bolts torque to 4 Nm.

3.2 Phase 1: Chassis Frame

The chassis forms a 600mm square base with vertical supports for the electronics plate. Corner brackets provide rigidity without welding.

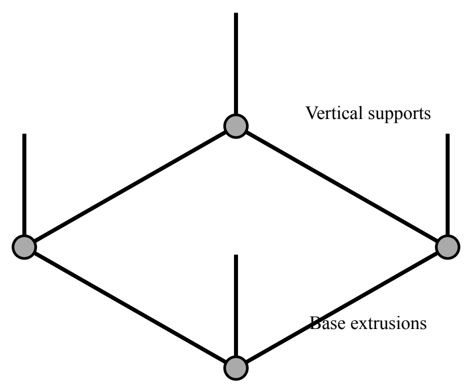

Figure 5: Chassis frame assembly sequence

Assembly steps:

1. Cut extrusions to length if not pre-cut. Deburr all cuts with a file.
2. Assemble the base rectangle (600×600mm) using corner brackets.
3. Verify the frame is square by measuring diagonals (should be equal).
4. Add corner gussets at each joint for additional rigidity.
5. Mount the four vertical supports at the corners.

3.3 Phase 2: Motor Mounting

Each hub motor mounts to a custom bracket that bolts to the extrusion. The bracket positions the wheel axis at the correct height for ground clearance.

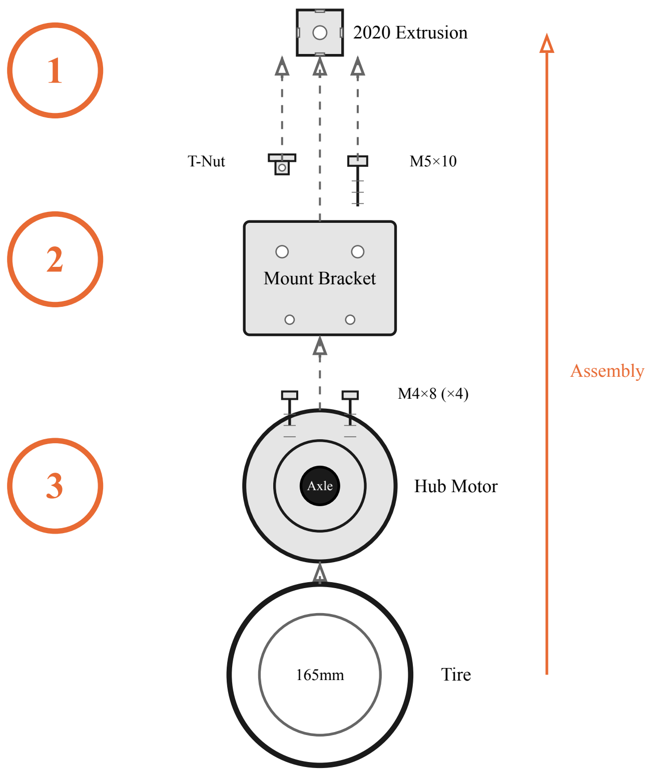

Figure 6: Exploded view: (1) Insert T-nuts into extrusion, (2) Bolt bracket to frame, (3) Attach motor and tire

Assembly steps:

1. Slide M5 T-nuts into the extrusion slot at each motor position.
2. Align the motor bracket holes with the T-nuts and secure with M5×10 bolts. Torque to 4 Nm.
3. Mount the hub motor to the bracket using four M4×8 bolts. Ensure the axle is centered.
4. Press the tire onto the hub motor rim. Spin by hand to verify free rotation.

3.4 Phase 3: Electronics Mounting

The electronics plate serves as both a mounting surface and heat sink. VESCs mount with thermal pads to conduct heat into the aluminum plate.

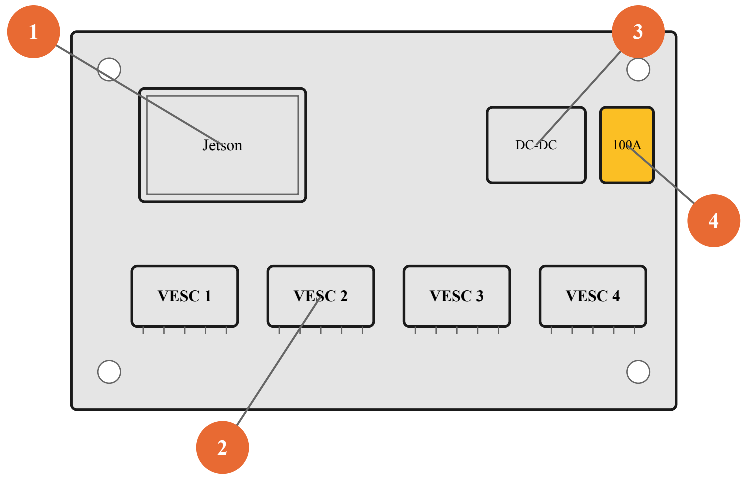

Figure 7: Electronics plate: (1) Jetson Orin NX, (2) VESC motor controllers, (3) DC-DC converter, (4) Main fuse

Assembly steps:

1. Mount the electronics plate to the vertical chassis supports.
2. Install the Jetson module using M3 standoffs.
3. Mount VESCs with thermal pads between the VESC and plate.
4. Install the DC-DC converter and main fuse holder.
5. Route all power wiring before securing with cable ties.

3.5 Phase 4: Wiring

Wiring divides into two domains: high-current power wiring and low-current signal wiring. Keep these separated to reduce electrical noise.

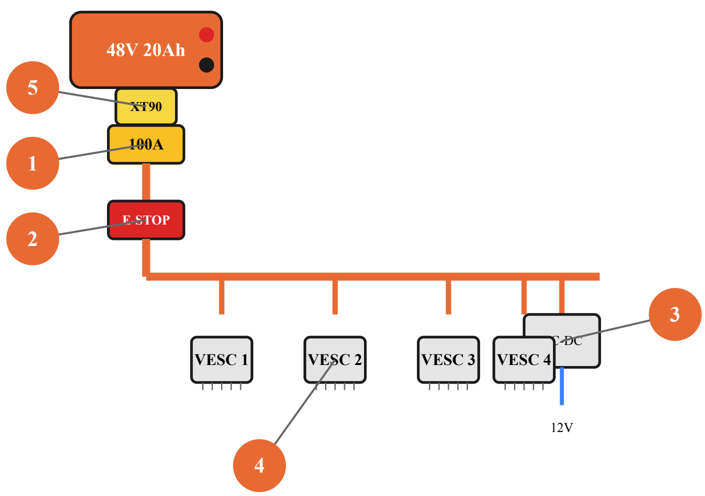

Figure 8: Power distribution: (1) Main fuse, (2) E-Stop relay, (3) DC-DC converter, (4) VESCs, (5) XT90 disconnect

Power wiring:

1. Connect the battery positive to the main fuse.
2. Wire from fuse output to E-Stop relay input.
3. Connect E-Stop relay output to all four VESCs in parallel.
4. Wire battery to DC-DC input; DC-DC output to Jetson and accessories.
5. Install XT90 connector inline for battery disconnect.

Signal wiring:

1. Connect CAN bus in a daisy chain: Jetson → VESC1 → VESC2 → VESC3 → VESC4.
2. Install 120Ω termination resistors at each end of the CAN bus.
3. Wire the E-Stop button in series with the relay coil.
4. Connect the LTE modem to Jetson via USB.

3.6 Phase 5: Testing

Testing proceeds from basic power verification to full system operation. Never skip steps; catching problems early prevents damage.

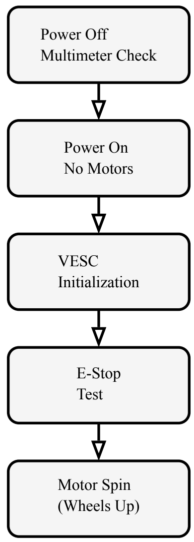

Figure 9: Testing sequence from power-off checks to motor operation

Testing steps:

1. **Power off:** Use a multimeter to verify no shorts between battery terminals.
2. **Power on (no motors):** Connect battery, verify Jetson boots, check 12V rail.
3. **VESC initialization:** Confirm all four VESCs show green status LEDs.
4. **E-Stop test:** Press E-Stop, verify power to VESCs is cut.
5. **Motor spin:** With wheels off the ground, command each motor individually.

3.7 Quality Checklist

Before considering the build complete, verify each item on this checklist.

- [ ] All bolts torqued to specification
- [ ] No exposed wiring or bare conductors
- [ ] CAN bus termination verified with oscilloscope or by VESC status
- [ ] E-Stop cuts power within 100ms
- [ ] All wheels spin freely without rubbing

- [ ] Battery is secure and protected from impact
- [ ] All connectors fully seated with positive click
- [ ] Thermal management verified under load

4 Electrical System

The electrical system distributes power from the 48V battery to motors and electronics. This section details the power topology, CAN bus network, and connector pinouts.

4.1 Power Distribution

Power flows from the battery through a single 100A fuse, then splits to three subsystems: motor controllers (VESCs), emergency stop circuit, and DC-DC converter. The E-Stop relay can cut power to the VESCs while leaving the Jetson powered for diagnostics.

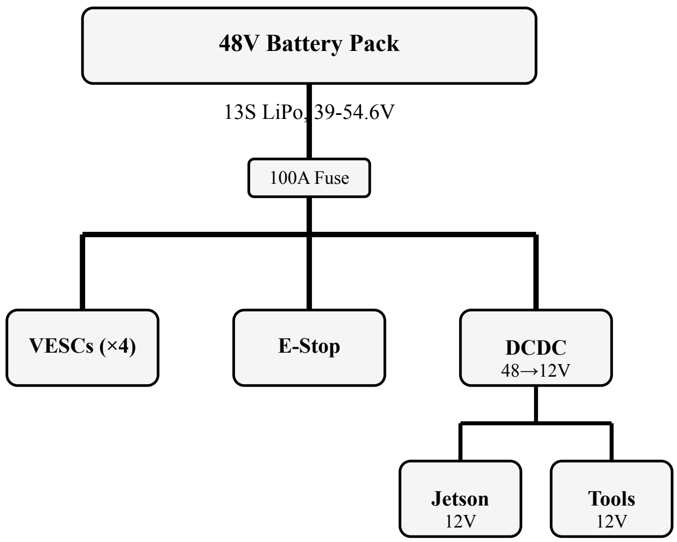

Figure 10: Power distribution from 48V battery to all subsystems

4.2 Main Components

Each component in the power system serves a specific protective or conversion function.

Component	Specification
Battery	13S4P Li-ion, 48V 20Ah with BMS
Main Fuse	100A ANL at battery positive
E-Stop	Normally closed contactor, cuts 48V to VESCs
DCDC	48V→12V, 20A for Jetson + accessories
VESCs	4× VESC 6, 60A continuous each

4.3 CAN Bus Topology

The CAN bus connects all motor controllers and the tool interface in a daisy chain. Each end of the bus requires a 120Ω termination resistor to prevent signal reflections.

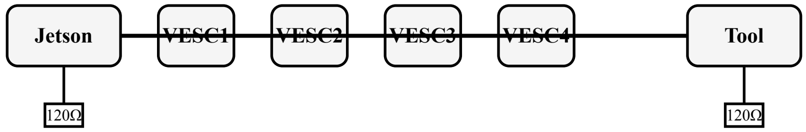

Figure 11: CAN bus daisy chain with 120Ω termination at each end

The CAN bus operates at 500 kbps using twisted pair wiring (CANH and CANL). Termination resistors are essential: without them, signal reflections cause communication errors.

4.4 Connectors

Standardized connectors enable quick assembly and field replacement.

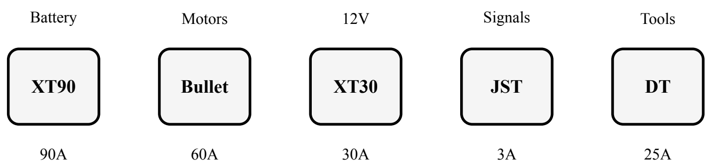

Figure 12: Connector types used throughout the rover

Connector	Use
XT90	Main battery power (90A rated)
5.5mm bullet	Motor phase wires (60A rated)
XT30	12V accessories (30A rated)
JST-XH	Sensors and buttons (signal level)
Deutsch DT06-6S	Tool interface (weatherproof)

4.5 VESC Configuration

Each VESC requires configuration via the VESC Tool software before first use. The CAN ID must be unique for each motor controller.

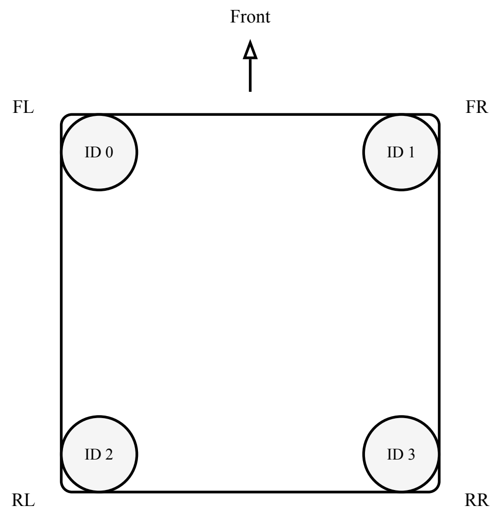

Figure 13: CAN ID assignment by wheel position

Setting	Value
Controller ID	0-3 (unique per VESC)
CAN Mode	VESC
CAN Baud Rate	CAN_500K
Send CAN Status	Enabled
CAN Status Rate	50 Hz

5 Operation

Operating the BVR0 requires completing startup procedures, understanding teleoperation controls, and following shutdown protocols. This section covers each phase of operation.

5.1 Startup Procedure

Startup follows a consistent sequence that verifies system health before enabling motor control.

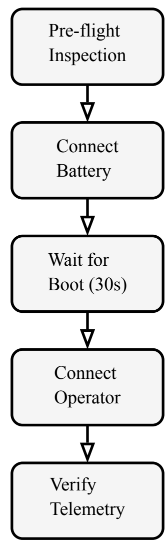

Figure 14: Startup sequence from inspection to operation

Pre-flight check: Before connecting power, verify the battery is charged (>40V), the E-Stop is not engaged, wheels are clear of obstructions, and the LTE antenna is connected.

Power on: Connect the battery via the XT90 connector. The Jetson will boot automatically, which takes approximately 30 seconds. The onboard display will show the dashboard when ready.

Connect operator station: Open the operator interface in a web browser and navigate to the rover's IP address. Verify the video feed is active and telemetry readings are nominal before commanding movement.

5.2 Teleoperation

The operator controls the rover through a web interface that displays video, telemetry, and control inputs.

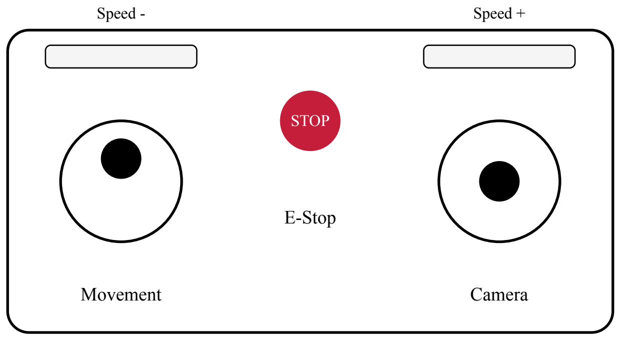

Figure 15: Gamepad control layout for teleoperation

The rover accepts input from keyboard (WASD), gamepad, or touchscreen. Movement commands map the left stick to forward/backward and rotation. The right stick pans the 360° camera view. Speed is adjusted with bumpers or scroll wheel.

5.2.1 Control Modes

Three control modes provide different levels of automation.

Mode	Description
Direct	1:1 joystick to motor control, no assistance
Assisted	Obstacle avoidance prevents collisions
Waypoint	Autonomous path following between points

5.3 Shutdown Procedure

Proper shutdown protects the electronics and battery.

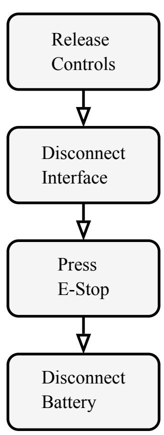

Figure 16: Shutdown sequence

Release all controls so the rover comes to a stop. Disconnect from the operator interface. Press the physical E-Stop button. Finally, disconnect the battery using the XT90 connector and store the rover in a dry location.

5.4 Tool Attachment

Tools connect via a quick-release mechanical mount and a Deutsch DT electrical connector.

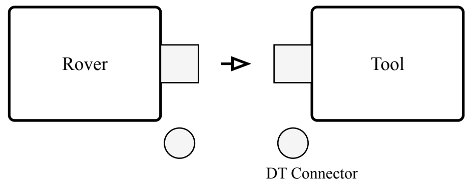

Figure 17: Tool attachment via quick-release mount and DT connector

Power off the rover before attaching tools. Align the tool mount with the front bracket and engage the quick-release latch. Connect the Deutsch DT connector for power and CAN communication. Power on and verify the tool appears in the dashboard.

6 Safety

The BVR0 is a powered machine capable of causing injury. This section covers safety protocols, hazard awareness, and emergency procedures.

> ⚠️ **DANGER** This is a heavy, powered machine. It can cause serious injury if mishandled. Always maintain situational awareness when operating.

6.1 Hazard Awareness

Understanding potential hazards enables safe operation.

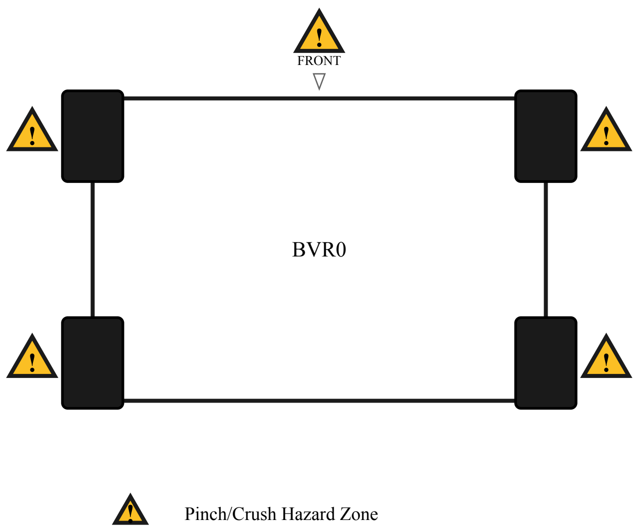

Figure 18: Hazard zones: wheel areas and tool mount require clearance during operation

Keep hands and feet clear of wheels and moving parts at all times. The hub motors can generate significant torque instantly. Never reach under the rover while it is powered.

6.2 Battery Safety

Lithium-ion batteries require careful handling to prevent fire or explosion.

> ⚠️ **WARNING** Lithium-ion batteries can catch fire if damaged, overcharged, or short-circuited. Handle with care.

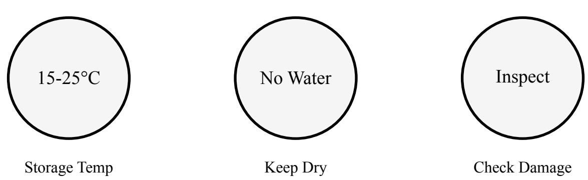

Figure 19: Battery handling requirements

Store batteries at room temperature (15-25°C). Never charge batteries unattended. Inspect for physical damage before each use. Do not expose to water or extreme temperatures. Use only the provided charger. Dispose of damaged batteries through proper recycling channels.

6.3 Emergency Stop

Multiple E-Stop mechanisms provide redundant safety.

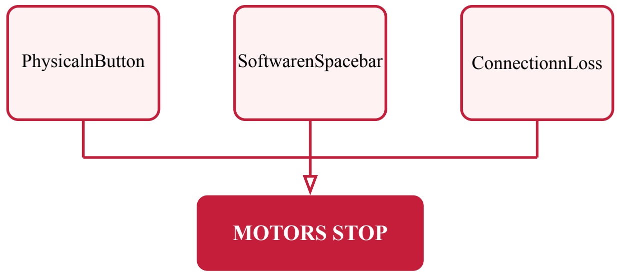

Figure 20: Three independent paths to emergency stop

The physical E-Stop button on the rover chassis immediately cuts power to all motors. The software E-Stop (spacebar in operator interface) sends a stop command over the network. If the network connection is lost for more than 2 seconds, the rover automatically stops.

> i **NOTE** To reset after E-Stop: identify and resolve the cause, twist or pull the physical button to release, reconnect the operator interface, and confirm the rover is ready in the dashboard.

6.4 Operating Conditions

Environmental limits ensure safe operation.

Condition	Limit
Temperature	−20°C to 40°C
Precipitation	Light rain/snow only
Wind	< 40 km/h
Visibility	Operator must see rover or camera feed

Do not operate on slopes exceeding 15%. Do not operate in standing water deeper than 50mm. Always maintain a clear line of sight or reliable video feed.

7 Maintenance

Regular maintenance ensures reliable operation and extends the life of components. This section covers inspection schedules, maintenance procedures, and troubleshooting.

7.1 Regular Inspection

Perform these checks before each operation.

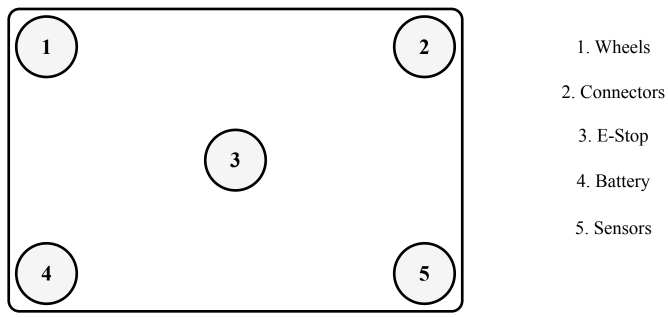

Figure 21: Pre-operation inspection points

- [ ] Battery voltage > 40V
- [ ] No visible damage to chassis or wheels
- [ ] All connectors secure
- [ ] Wheels spin freely
- [ ] E-Stop button functions
- [ ] Sensors clean and unobstructed

7.2 Periodic Maintenance

Scheduled maintenance prevents failures and catches wear before it becomes critical.

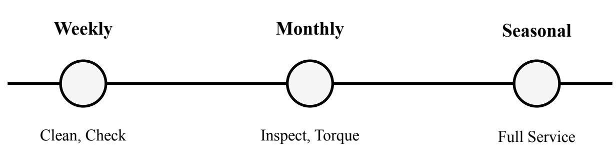

Figure 22: Maintenance schedule intervals

Weekly: Clean debris from wheels and chassis. Wipe camera lenses. Check CAN bus connections. Verify LTE signal strength at operating locations.

Monthly: Inspect wiring for chafing or wear. Check bolt torque on motor mounts. Clean battery contacts. Update firmware if available.

Seasonal: Perform full electrical inspection. Check bearings on hub motors. Replace worn cables or connectors. Calibrate sensors if needed.

7.3 Storage

Proper storage protects the battery and electronics during periods of non-use.

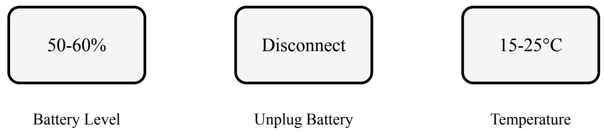

Figure 23: Storage preparation requirements

For extended storage (>2 weeks): charge the battery to 50-60% (storage charge), disconnect the battery from the rover, store in a dry location at 15-25°C, cover to protect from dust, and check battery monthly to top up if below 40%.

7.4 Troubleshooting

Common issues and their solutions.

Symptom	Solution
Rover won't power on	Check battery connection, verify fuse
No video feed	Check LTE connection, verify camera USB
Motor not responding	Check CAN wiring, verify VESC ID
E-Stop won't release	Check relay wiring, verify button not stuck
Poor LTE signal	Relocate antenna, check SIM data plan
Erratic movement	Verify VESC IDs match wheel positions

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