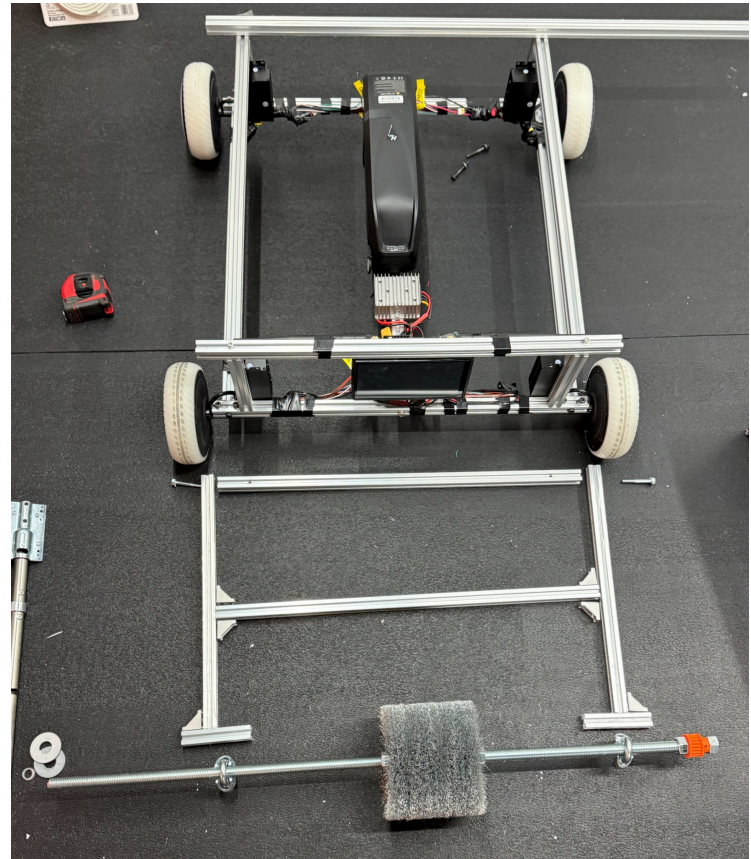


Technical Manual

BVR0

Base Vectoring Rover



Revision 0.1 December 2025

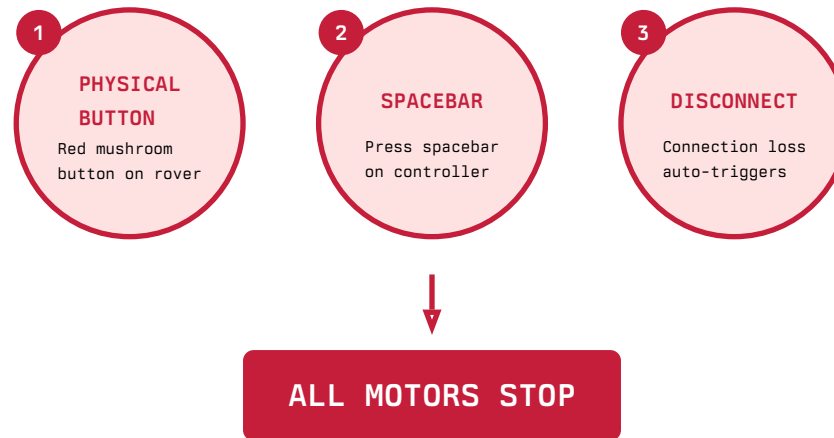
Municipal Robotics
Cleveland, Ohio
muni.works

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Emergency Stop



⚠ DANGER Know this page. If anything goes wrong, use one of these three methods immediately.

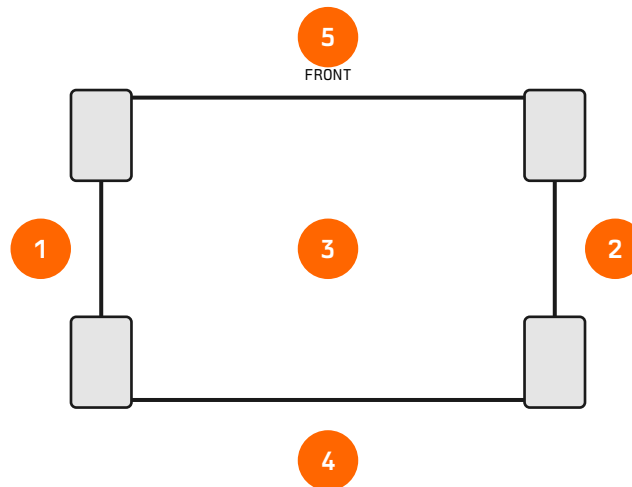
When to E-Stop:

- Person in path of rover
- Unexpected movement
- Smoke, sparks, or fire
- Loss of control
- Any doubt about safety

To resume after E-Stop:

1. Resolve the cause
2. Release physical button (if used)
3. Reconnect controller
4. Verify telemetry on dashboard
5. Resume operation

Pre-Flight Checklist

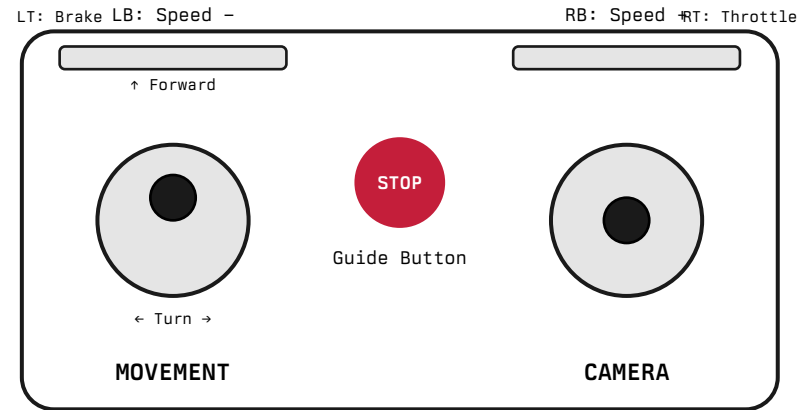


Use this checklist before every operation session.

- | | |
|---|--|
| <input type="checkbox"/> 1 Wheels spin freely, no debris | <input type="checkbox"/> 4 Battery voltage > 40V |
| <input type="checkbox"/> 2 All wheel bolts tight | <input type="checkbox"/> 5 Camera and LiDAR clean |
| <input type="checkbox"/> 3 E-Stop button not stuck | <input type="checkbox"/> 6 All connectors secure |

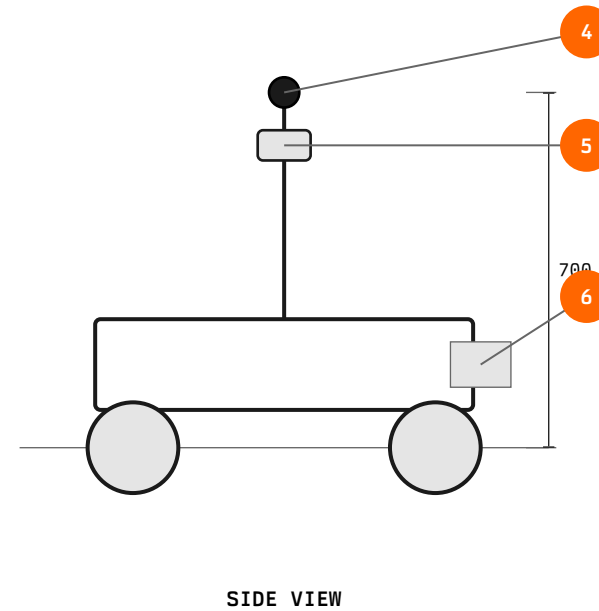
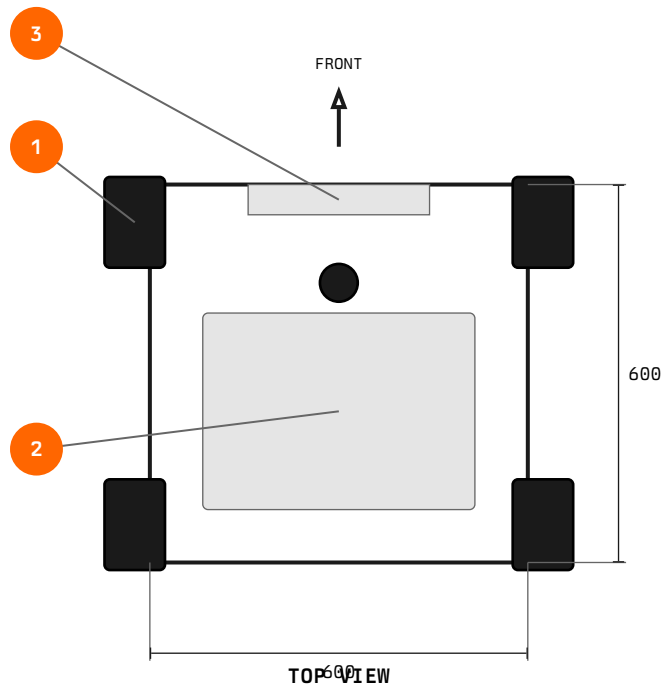
i NOTE If any check fails, do not operate. Resolve the issue first.

Controls



| Input | Action |
|-----------------------|----------------------------|
| Left Stick Up/Down | Forward / Reverse |
| Left Stick Left/Right | Turn left / right |
| Right Stick | Pan camera view |
| Left Bumper (LB) | Decrease max speed |
| Right Bumper (RB) | Increase max speed |
| Left Trigger (LT) | Brake / slow down |
| Right Trigger (RT) | Throttle (overrides stick) |
| Guide Button (center) | Emergency Stop |
| Spacebar (keyboard) | Emergency Stop |

Overview



Components

- 1 Hub motor wheels (×4)
- 2 Electronics bay
- 3 Tool mount
- 4 360° camera
- 5 LiDAR sensor
- 6 Tool attachment

Key Specifications

| | |
|------------|--------------------|
| Dimensions | 600 × 600 × 700 mm |
| Weight | 30 kg with battery |
| Speed | 1.0–2.5 m/s |
| Runtime | 4 hours |
| Temp range | –20°C to +40°C |

Specifications

Mechanical

| | |
|------------------|-------------------------|
| Footprint | 600 × 600 mm |
| Height | 700 mm (with mast) |
| Weight | 30 kg |
| Ground clearance | 50 mm |
| Wheel diameter | 160 mm |
| Frame | 2020 aluminum extrusion |

Electrical

| | |
|----------------|-------------------|
| Main battery | 48V 20Ah (960 Wh) |
| Chemistry | 13S LiPo |
| Voltage range | 39-54.6V |
| Accessory rail | 12V 10A |
| Main fuse | 100A |

Drivetrain

| | |
|--------------|--------------------|
| Motors | 4× 350W hub motors |
| Controllers | 4× VESC 6.7 |
| Drive type | Skid-steer |
| Max speed | 2.5 m/s |
| Cruise speed | 1.0 m/s |

Perception

| | |
|--------|------------------------|
| LiDAR | Livox Mid-360 |
| Camera | Insta360 X4 (360°) |
| GPS | RTK-capable (optional) |

Compute

| | |
|---------------|---------------------|
| Main computer | Jetson Orin NX 16GB |
| Connectivity | LTE + WiFi |
| CAN bus | 500K baud |

Required Tools



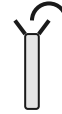
Hex Keys

2.5, 3, 4, 5 mm



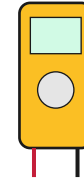
Screwdriver

Phillips 2



Wrenches

8, 10, 13 mm



Multimeter

V / Ω / Continuity

Required

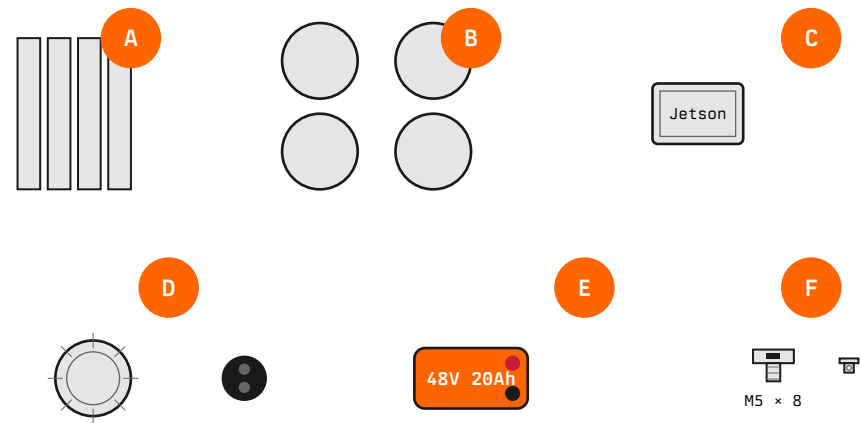
- Hex key set (metric: 2.5, 3, 4, 5 mm)
- Phillips screwdriver (2)
- Adjustable wrench or socket set (8, 10, 13 mm)
- Multimeter (voltage, resistance, continuity)
- Wire strippers (20-12 AWG)
- Soldering iron (40W+) and solder
- Heat shrink assortment
- Miter saw or hacksaw (for extrusions)

Recommended

- Torque wrench (4 Nm for M5)
- Drill and drill bits (3.2, 4.2, 5 mm)
- Tap set (M4×0.7, M5×0.8)
- Deburring tool
- Cable ties (assorted sizes)
- Label maker
- Work mat
- Helping hands / PCB holder

i NOTE All M5 bolts should be torqued to 4 Nm. Over-tightening can strip aluminum threads.

Parts List



| Parts | |
|---|---------|
| A Chassis: extrusions, brackets, plate | \$150 |
| B Drivetrain: motors, VESCs, mounts | \$800 |
| C Electronics: Jetson, CAN, LTE | \$900 |
| D Perception: LiDAR, camera, pole | \$1,800 |
| E Power: battery, DC-DC, fuse, E-stop | \$400 |
| F Hardware: bolts, T-nuts, wire | \$100 |

| Cost Summary | |
|--------------|----------------|
| Chassis | \$150 |
| Drivetrain | \$800 |
| Electronics | \$900 |
| Perception | \$1,800 |
| Power | \$400 |
| Hardware | \$100 |
| Total | \$4,150 |

All parts commercially available.

Hardware Reference

Standard fasteners and hardware used throughout the build.

Bolts

| Size | Use |
|-------|------------------------|
| M3×8 | Electronics mounting |
| M4×8 | Motor to bracket |
| M5×8 | T-nut, light duty |
| M5×10 | T-nut, standard |
| M5×16 | T-nut, through plate |
| M6×12 | Motor bracket to frame |

T-Nuts

Connectors

| Type | Rating |
|------------------|----------------|
| Use | XT90 |
| 90A | Battery main |
| XT60 | 60A |
| Motor phase | XT30 |
| 30A | 12V power |
| JST-PH | 3A |
| CAN bus, signals | DT 4-pin |
| 25A | Tool connector |

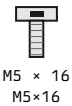
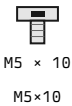
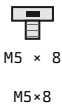
Wire Gauge

| AWG | Use |
|-----|-----|
|-----|-----|

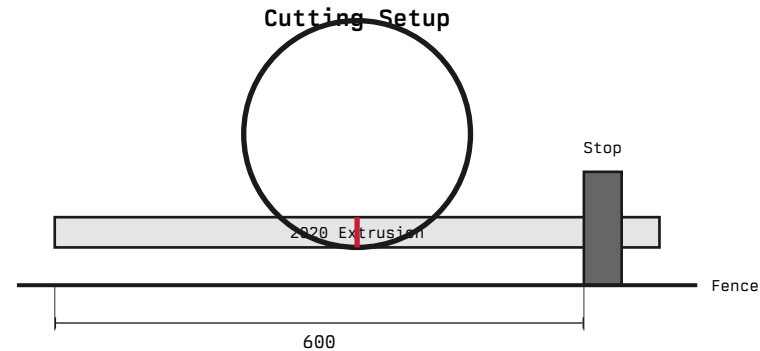
| Type | Use |
|-------------|-------------------------|
| M5 drop-in | Post-assembly insertion |
| M5 slide-in | Pre-assembly (easier) |
| M6 drop-in | Heavy-duty mounts |

| | |
|--------|------------------|
| 8 AWG | Battery to bus |
| 10 AWG | Bus to VESCs |
| 14 AWG | 12V power |
| 22 AWG | CAN bus, signals |

Common Hardware (actual size)



Cutting Extrusions



Cut 8 pieces of 2020 aluminum extrusion to 600mm length.

Procedure:

1. Clamp stop block at 600mm from blade
2. Place extrusion against fence and stop
3. Cut slowly to prevent burrs
4. Rotate 90° and re-cut if needed for square ends
5. Deburr all cut edges with file or deburring tool

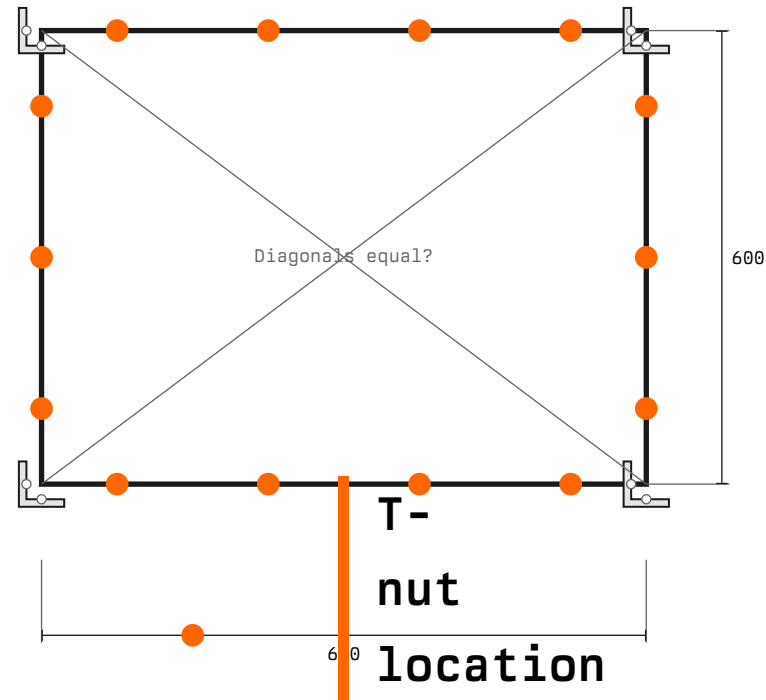
Cut List:

| Qty | Length |
|----------------|------------|
| Purpose | 4 |
| 600mm | Base frame |
| 4 | 600mm |
| Top frame | |

Optional: cut 4× 200mm for vertical posts if using shorter design.

⚠ WARNING Aluminum chips are sharp. Wear safety glasses. Clean chips from T-slots before assembly.

Base Frame Assembly



Assemble the 4-sided base frame using corner brackets.

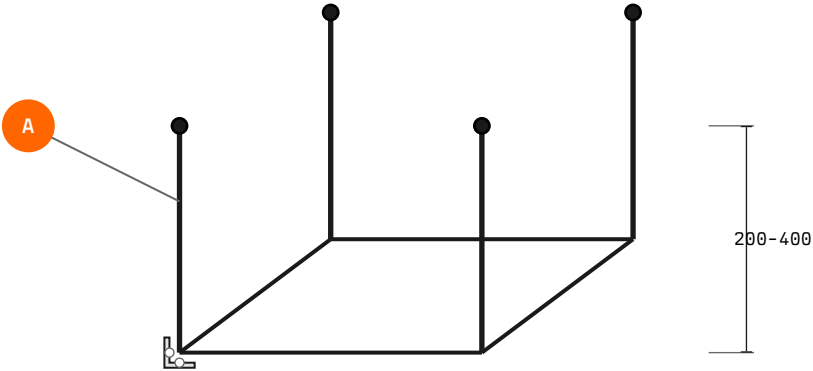
Assembly Steps:

1. **Pre-insert T-nuts** into all extrusion channels (8 per extrusion, 32 total for base)
2. **Dry-fit** all four extrusions in a square, corners aligned
3. **Attach corner brackets** loosely (finger-tight M5×10 bolts)
4. **Check squareness:** measure both diagonals. They must be equal ($\pm 1\text{mm}$).

5. **If not square:** tap the long diagonal corner with a mallet to adjust
6. **Tighten all bolts** to 4 Nm in a star pattern

i NOTE Leave extra T-nuts in channels for later mounting. Easier now than adding drop-in nuts later.

Vertical Posts



Add 4 vertical posts at the corners to create the frame height.

| | |
|------------------|------------------|
| Standard outdoor | 400mm |
| 600mm | Tall sensor mast |

Mounting Method A: Corner Bracket

- Use 90° corner brackets at each post base.
- 2× M5×10 bolts per bracket
 - Insert T-nuts in both base and post
 - Tighten to 4 Nm

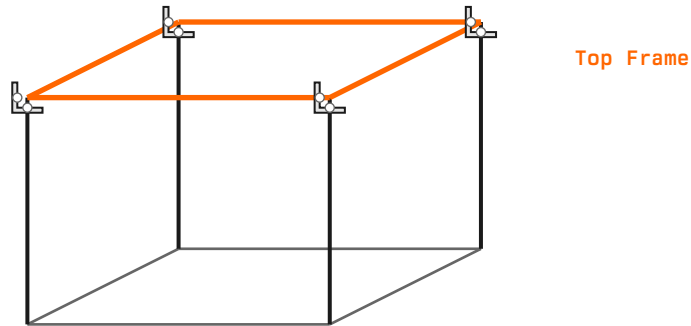
Mounting Method B: Blind Joint

- Use blind joint connectors for cleaner look.
- Drill 5mm access hole in base extrusion
 - Thread M5×25 bolt through into post
 - Hidden hardware, harder to adjust

Height Options:

| Post Length | Total Height |
|-------------|---------------------|
| Use Case | 200mm |
| 400mm | Low profile, indoor |
| 300mm | 500mm |

Top Frame



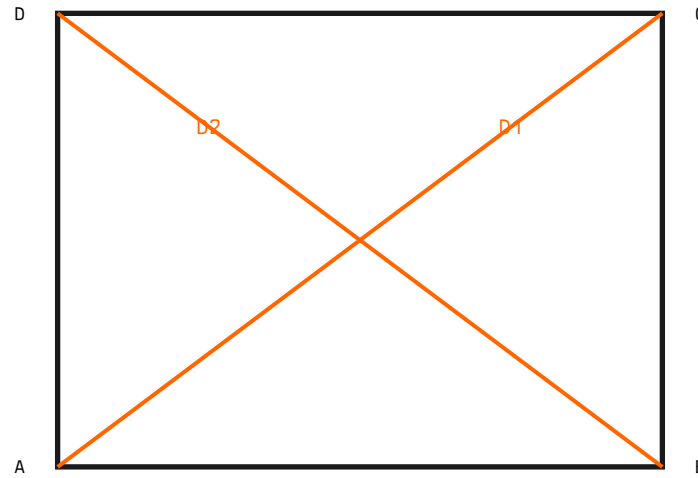
Complete the box structure with the top frame.

Assembly:

1. Attach corner brackets to top of each vertical post (loosely)
2. Place top frame extrusions onto brackets
3. Align extrusions flush with vertical posts
4. Check that top frame is level (use spirit level)
5. Tighten all connections to 4 Nm

i NOTE The top frame provides mounting points for the electronics plate, sensor mast, and protective covers.

Squareness Check



$$D1 = D2 \pm 1\text{mm}$$

Verify the completed frame is square and rigid.

Squareness Test:

1. Measure diagonal A→C (D1)
2. Measure diagonal B→D (D2)
3. Compare: D1 should equal D2 within 1mm
4. If not equal: loosen corners, tap long diagonal, re-tighten

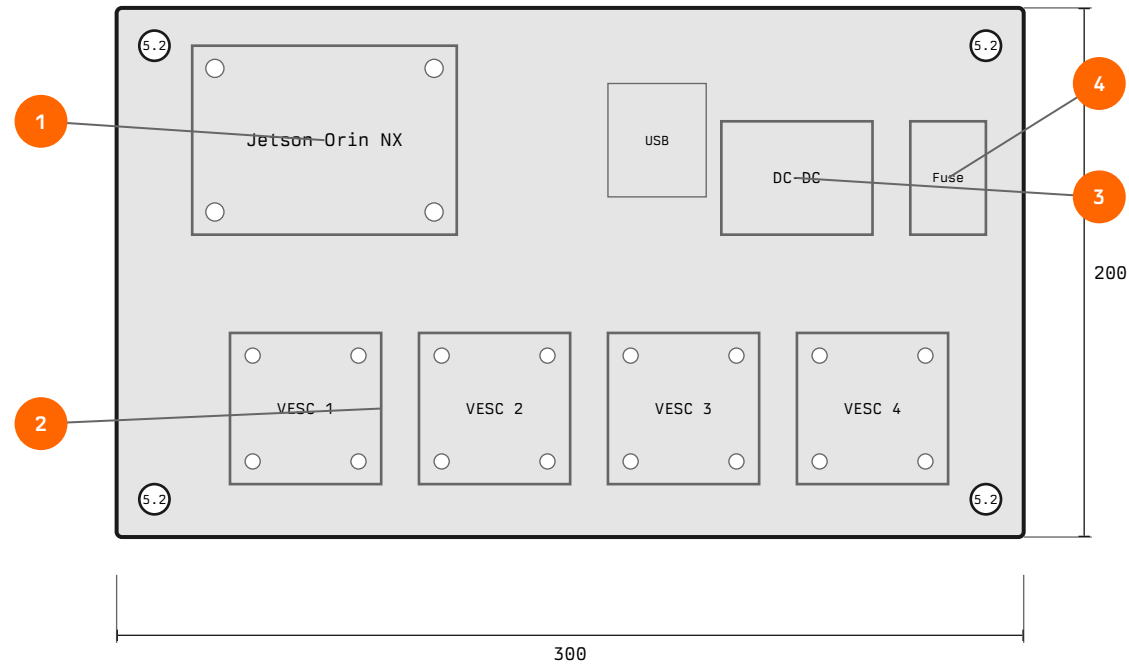
Rigidity Test:

1. Grip opposite corners
2. Try to twist the frame
3. Frame should not flex or rack
4. If loose: check all bolt torque, add corner braces if needed

Final Checklist:

- ☐ All corners have brackets installed
- ☐ All bolts torqued to 4 Nm
- ☐ Diagonals equal within 1mm
- ☐ Frame does not rack or twist
- ☐ All T-slots clear of debris
- ☐ Extra T-nuts in channels for later use

Electronics Plate Layout



The electronics plate holds the Jetson, VESCs, DC-DC converter, and fuse.

Components:

- 1 Jetson Orin NX (69×45mm)
- 2 VESC 6.7 ×4 (60×40mm each)
- 3 DC-DC 48V→12V
- 4 100A fuse holder

Plate Material:

- 3mm aluminum sheet (recommended)
- Or: 5mm acrylic (lighter, less heat dissipation)
- Or: 3mm FR4/G10 (good insulator)

Drilling Guide

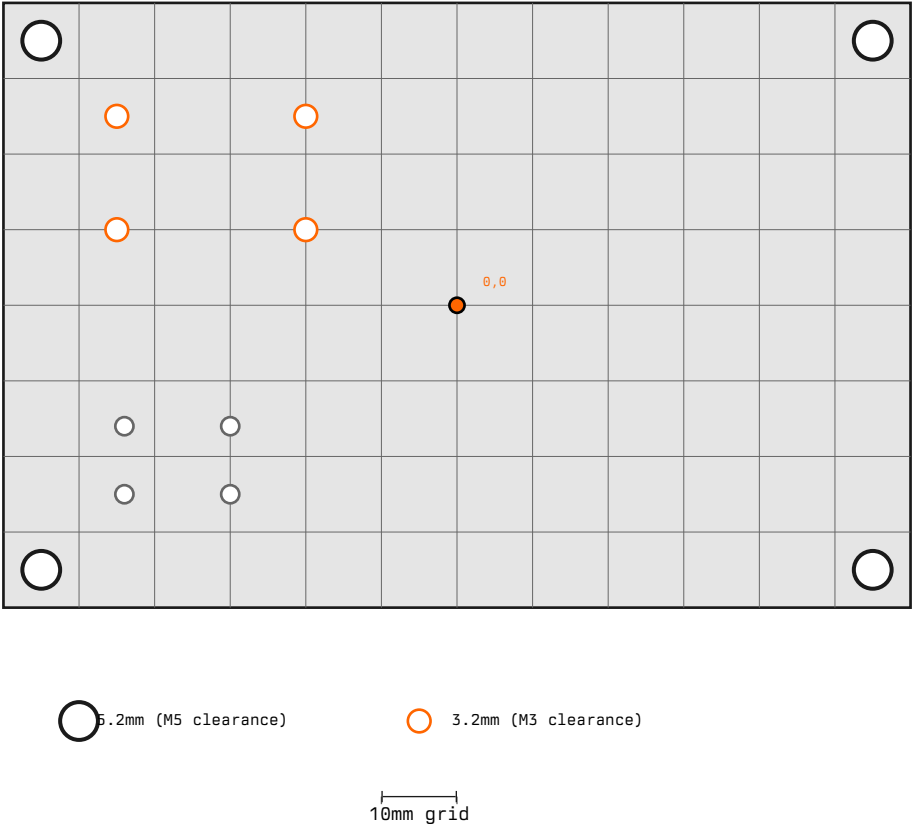


Figure 14: Hole positions. Grid squares = 10mm. Origin at plate center.

Hole positions for mounting electronics to the plate.

Drill Sizes:

| Hole Type | Drill Size |
|-----------|-------------------------|
| Purpose | M5 clearance |
| 5.2mm | Plate mounting to frame |

| | |
|----------------------|-----------------------|
| M3 clearance | 3.2mm |
| Electronics mounting | M3 tap |
| 2.5mm | If threading aluminum |
| M4 clearance | 4.2mm |
| Larger components | |

Plate Mounting

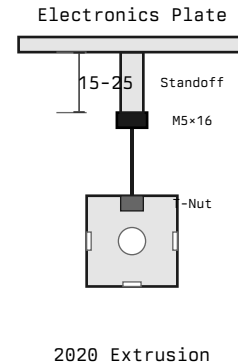


Figure 15: Cross-section: standoff mounting provides airflow under plate.

Attach the electronics plate to the chassis frame.

i NOTE Leave plate loose until all electronics are mounted. Easier access.

Mounting Hardware (per corner):

- 1× M5×16 or M5×20 bolt
- 1× M5 T-nut (drop-in or slide-in)
- 1× M5 standoff (15-25mm height)
- 1× M5 nut or second standoff

Standoff Height:

- 15mm: Minimal, tight fit
 - 20mm: Recommended (good airflow)
 - 25mm: Maximum cable clearance
- Use same height at all 4 corners.

Installation:

1. Insert T-nuts into top extrusion slots
2. Thread M5 bolts through standoffs
3. Position plate on standoffs
4. Align with T-nuts
5. Tighten to 4 Nm

Motor Bracket Design



Figure 16: Motor bracket with slotted holes for alignment adjustment.

Each hub motor requires a mounting bracket to attach to the chassis frame.

Bracket Specifications:

- Material: 3mm aluminum or steel
- Frame holes: M5, slotted 10mm for adjustment
- Motor holes: M4, match motor bolt pattern
- L-bracket design for rigidity

Sourcing Options:

- Custom CNC cut (recommended)
- 3D printed (PLA not recommended, use PETG/ABS)
- Off-the-shelf motor mounts (verify hole pattern)

Motor Bracket Mounting

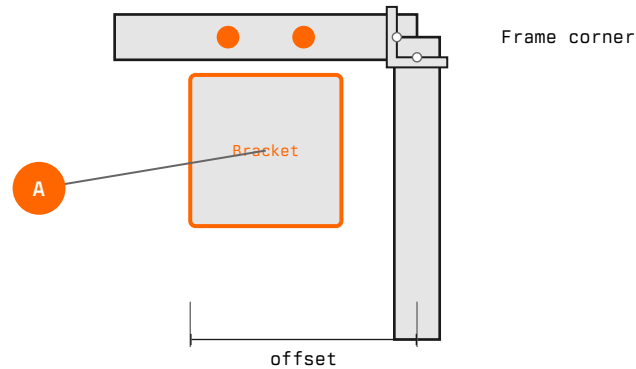


Figure 17: Motor bracket position at frame corner. All 4 corners mirror this layout.

Attach motor brackets to the chassis at each corner.

Mounting Procedure:

1. Slide T-nuts into bottom extrusion channel
2. Position bracket with motor axle aligned to wheel position
3. Insert M5×10 bolts through bracket slots into T-nuts
4. Leave bolts finger-tight for adjustment
5. Verify bracket is perpendicular to extrusion
6. Tighten to 4 Nm

Bracket Positions:

| Corner | Offset from corner |
|-------------|--------------------|
| Front Left | 50mm |
| Front Right | 50mm |
| Rear Left | 50mm |
| Rear Right | 50mm |

Alignment Check:

- Motor axles should be parallel
- Equal distance from frame edges
- Perpendicular to travel direction

Hub Motor Installation

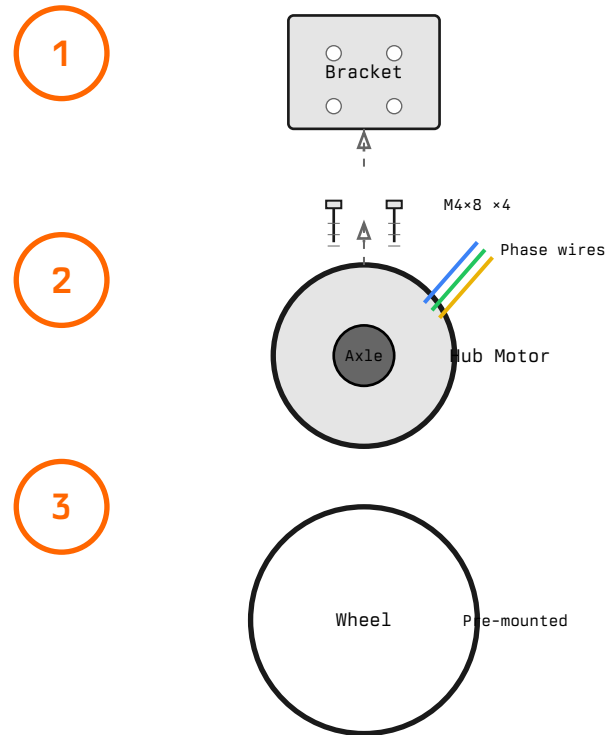


Figure 18: Motor installation sequence. Wheels typically come pre-mounted on hub motors.

Mount hub motors to the brackets and connect phase wires.

⚠ WARNING Do not pinch phase wires between motor and bracket. This can cause shorts.

Installation Steps:

1. Align motor mounting holes with bracket holes
2. Insert M4x8 bolts through bracket into motor
3. Tighten in cross pattern to 2 Nm
4. Route phase wires toward electronics bay
5. Secure wires with cable ties (leave slack for wheel movement)

Wheel Alignment

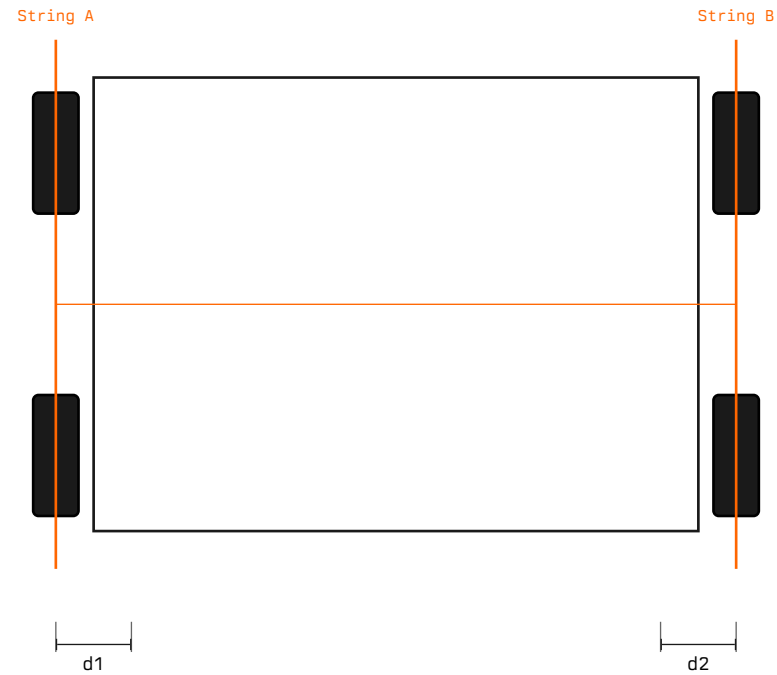


Figure 19: String alignment method. Stretch strings parallel to frame sides.

Verify all wheels are parallel and the rover tracks straight.

Alignment Procedure:

1. Stretch two parallel strings along frame sides
2. Measure gap from string to front wheel edge
3. Measure gap from string to rear wheel edge
4. Gaps should be equal ($\pm 2\text{mm}$) on each side
5. If not equal: loosen bracket, adjust, re-tighten

Common Issues:

| Symptom | Cause |
|-----------------------|-------------------------------|
| Fix | |
| Right wheels toe-in | Rover pulls left |
| Rover pulls right | Adjust right brackets outward |
| Left wheels toe-in | Adjust left brackets outward |
| Wheels not parallel | Excessive tire wear |
| Vibration at speed | Realign all brackets |
| Replace tire or motor | Wheel out of round |

Battery Tray

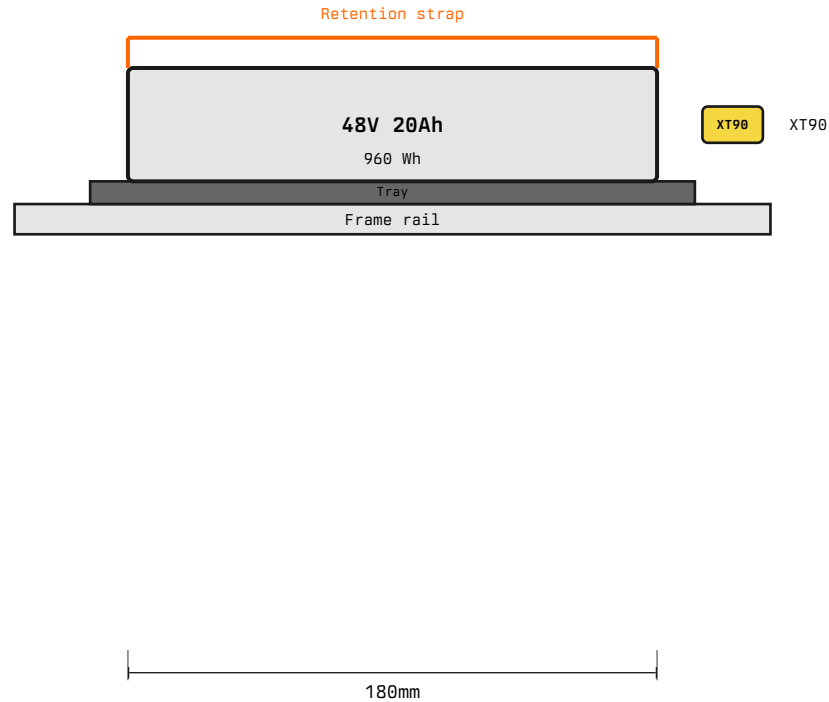


Figure 20: Battery mounted on tray with retention strap. XT90 connector for quick disconnect.

Secure mounting for the 48V battery pack.

⚠ WARNING Battery must not shift during operation. Loose batteries can short on frame, causing fire.

Tray Construction:

- 3mm aluminum sheet
- Bent edges for rigidity
- Foam padding underneath battery
- Holes for cable routing

Retention Requirements:

- Secure in all axes
- Quick-release for service
- Must hold during tip-over
- Vibration dampening (foam/rubber)

Fuse and E-Stop

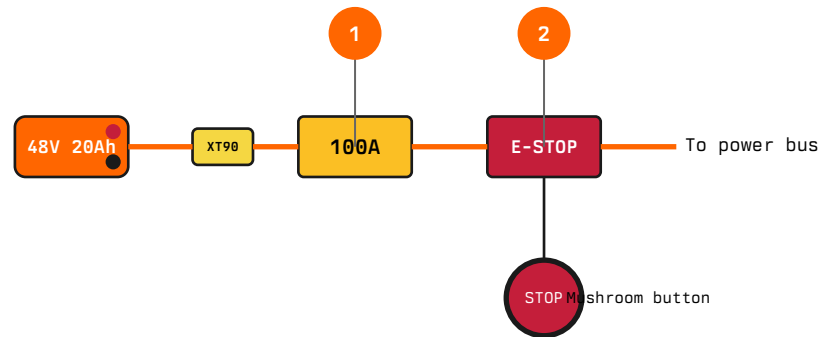


Figure 21: Power flows: Battery → XT90 → Fuse → E-Stop relay → Power bus

Install overcurrent protection and emergency disconnect.

1 Fuse (100A):

- ANL or MIDI style fuse
- Inline fuse holder with ring terminals
- Mount accessible for replacement
- Size: protects wiring, not electronics

2 E-Stop Relay:

- Normally-open contactor (closes when safe)
- 12V coil, controlled by Jetson GPIO
- 100A+ contact rating
- Fails safe: power loss = stop

Wiring:

- Use 8 AWG wire for main power path
- Ring terminals with heat shrink
- Keep runs short between fuse and relay

DC-DC Converter

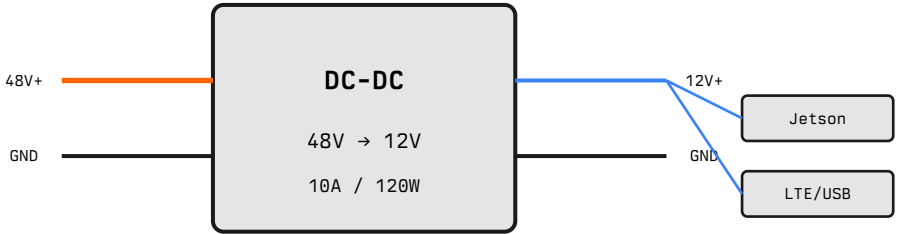


Figure 22: DC-DC powers all 12V devices from the 48V main bus.

Total

6A typical, 10A max

Step down 48V main power to 12V for electronics.

Specifications:

| Parameter | Value |
|----------------|------------------------------|
| Input voltage | 36-60V (fits 13S LiPo range) |
| Output voltage | 12V regulated |
| Output current | 10A continuous |
| Efficiency | >90% |
| Mounting | M3 holes, heatsink on bottom |

12V Load Budget:

| Device | Current |
|----------------|---------------------|
| Jetson Orin NX | 5A peak, 3A average |
| LTE modem | 1A |
| USB hub | 0.5A |
| Accessories | 1A reserve |

Power Distribution

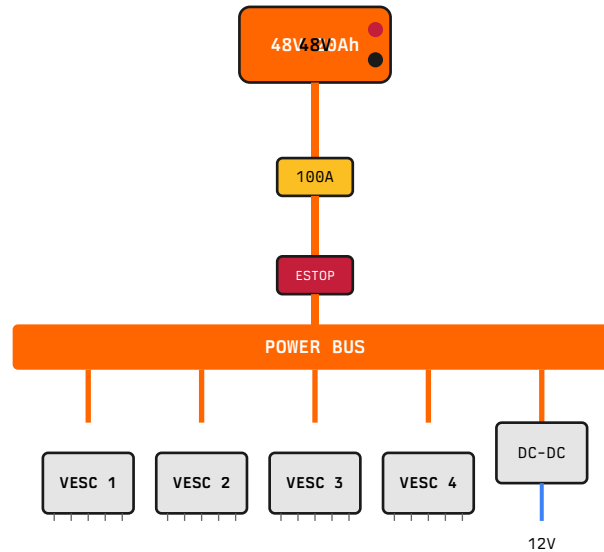


Figure 23: Power distribution topology. All 48V loads connect to central bus.

Main power bus connects battery to all high-current loads.

Bus Options:

Bus Bar (recommended):

- Solid copper bar with tapped holes
- Clean, low resistance
- Easy inspection

Splitter Cable:

- XT90 to 4× XT60
- Simpler for prototypes
- Higher resistance

VESC Mounting

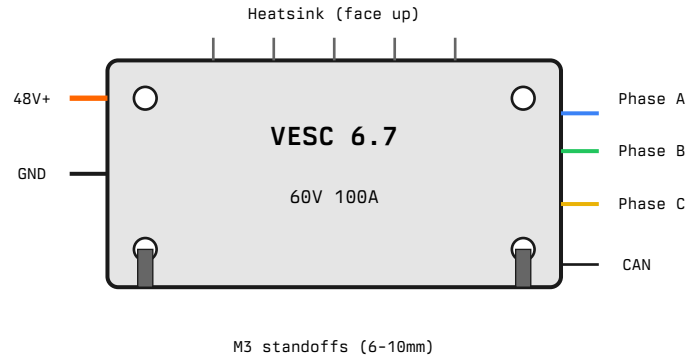


Figure 24: VESC mounted on standoffs for airflow. Heatsink faces up.

Mount the four VESC motor controllers on the electronics plate.

Mounting:

- M3×6 standoffs at all 4 corners
- M3×8 bolts through plate into standoffs
- Thermal pad between VESC and plate (optional, for heat transfer)

Power Connections:

- 10 AWG wire for 48V input
- XT60 connectors recommended
- Keep power wires short

VESC Configuration

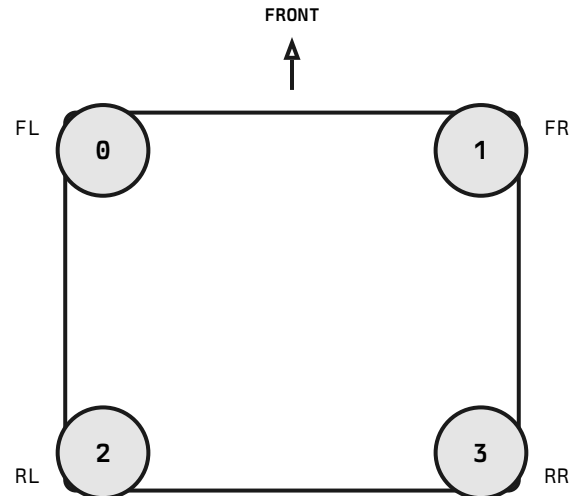


Figure 25: CAN ID assignment. ID 0-3 for wheels, ID 10+ for tools.

Configure each VESC with unique CAN ID and motor parameters.

VESC Tool Configuration:

| Parameter | Value |
|-----------------|--------------------------------|
| Controller ID | 0, 1, 2, 3 (unique per VESC) |
| CAN Mode | VESC |
| CAN Baud Rate | CAN_500K |
| Send CAN Status | Enabled |
| CAN Status Rate | 50 Hz |
| Motor Type | BLDC or FOC (depends on motor) |
| Current Limit | 30A (per motor) |

Motor Detection:

1. Connect VESC to computer via USB
2. Open VESC Tool
3. Run Motor Detection wizard
4. Save configuration to VESC
5. Disconnect USB, connect CAN

Jetson Mounting

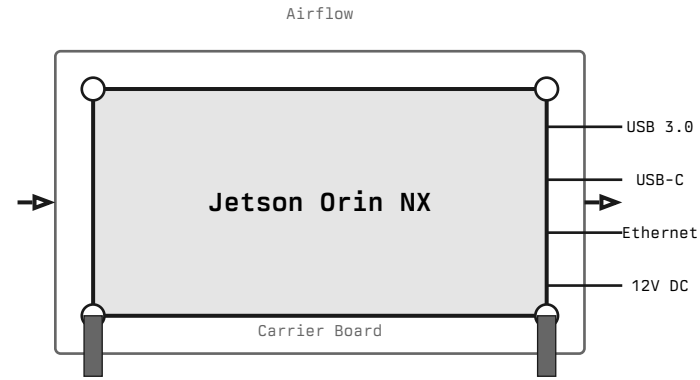


Figure 26: Jetson mounted on standoffs. Ensure airflow around heatsink.

Mount the Jetson Orin NX compute module.

Connections:

| Port | Connection |
|-----------|-----------------------|
| USB 3.0 1 | USB-CAN adapter |
| USB 3.0 2 | USB hub (camera, LTE) |
| 12V DC | From DC-DC converter |
| GPIO | E-Stop relay control |

Software:

- JetPack 6.0 or later
- bvr daemon (auto-start on boot)
- Insta360 SDK for camera

USB-CAN Adapter

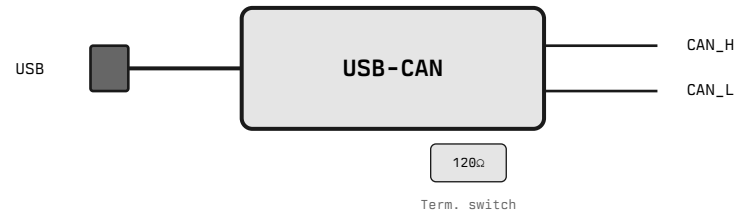


Figure 27: USB-CAN adapter provides CAN bus access from Jetson.

Connect the Jetson to the CAN bus network.

Recommended Adapters:

- Canable Pro (open source)
- PEAK PCAN-USB
- Innomaker USB-CAN

Configuration:

```
# Set up CAN interface
sudo ip link set can0 type can bitrate 500000
sudo ip link set can0 up

# Test with candump
candump can0
```

Termination:

- If adapter is at end of CAN bus: enable 120Ω termination
- If adapter is in middle of chain: disable termination
- Total bus should have exactly 2 termination resistors

Sensor Mast Assembly

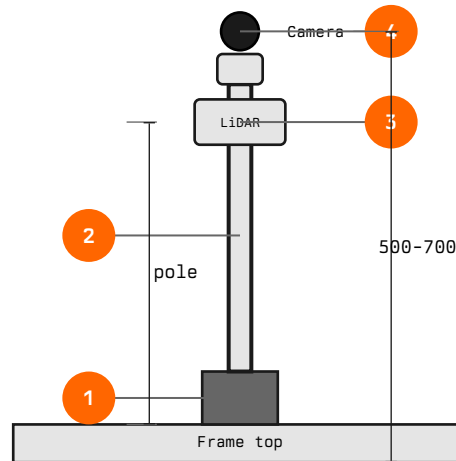


Figure 28: Sensor mast with LiDAR below camera for unobstructed 360° view.

The sensor mast elevates LiDAR and camera for optimal field of view.

Components:

- 1 Pole mount bracket
- 2 Carbon fiber or aluminum tube
- 3 LiDAR mount plate
- 4 Camera mount (1/4-20)

Pole Specifications:

- Diameter: 25-30mm OD
- Material: Carbon fiber (light) or 6061-T6 aluminum
- Length: 400-600mm depending on design
- Wall thickness: 2mm minimum

LiDAR Mounting

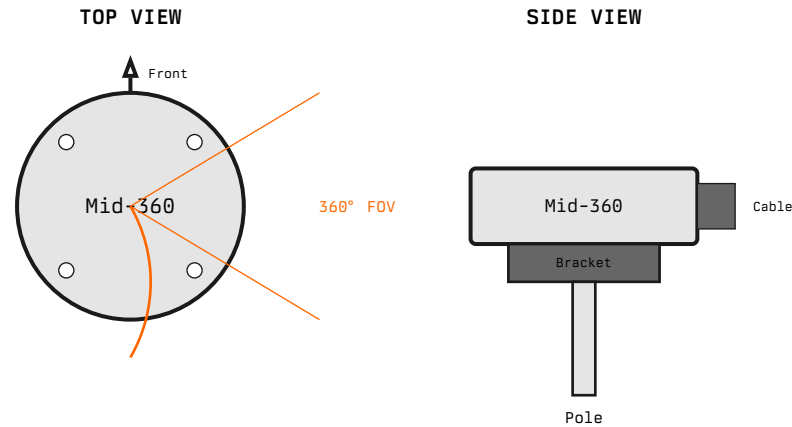


Figure 29: LiDAR mounted level with 360° horizontal FOV. Cable routes down pole.

Mount the Livox Mid-360 LiDAR on the sensor mast.

Installation:

1. Attach LiDAR to mount plate with M3 bolts
2. Level the mount plate (use spirit level)
3. Secure mount plate to pole with hose clamps or bolts
4. Route cable inside pole or along outside with ties
5. Connect to Jetson via Ethernet

Orientation:

- LiDAR "front" should face rover front
- Ensure level within $\pm 1^\circ$
- No obstructions in 360° view

Camera Mounting

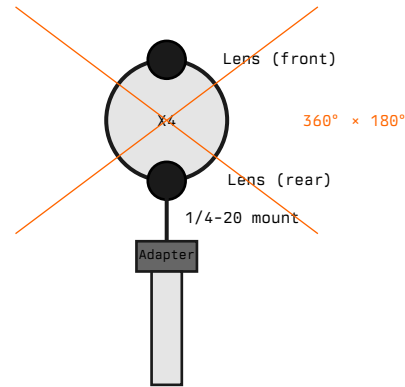


Figure 30: Camera at mast top. Dual lenses capture full spherical view.

Stabilization

FlowState (on)

Mount the Insta360 X4 camera at the top of the sensor mast.

Mount Options:

- 1/4-20 threaded insert in pole top cap
- GoPro-style mount adapter
- Custom 3D-printed adapter

Cable Routing:

- USB-C cable to Jetson
- Route inside pole if possible
- Secure with cable ties
- Leave strain relief loop at camera

Camera Settings:

| Setting | Value |
|------------|------------------------|
| Mode | Live streaming (H.265) |
| Resolution | 4K or 5.7K |
| Frame rate | 30 fps |

CAN Bus Wiring

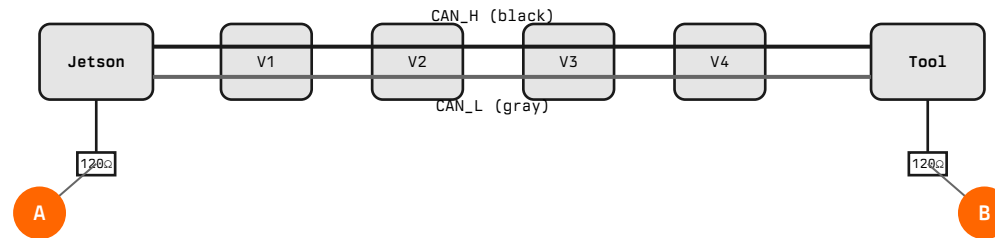


Figure 31: CAN bus with 120Ω termination at each end (A and B).

Daisy-chain all CAN devices together.

Wiring Rules:

- Use twisted pair wire (22 AWG)
- CAN_H to CAN_H, CAN_L to CAN_L at each device
- Maximum total bus length: 40m at 500K baud
- Exactly 2 termination resistors (one at each end)
- Keep CAN wires away from motor phase wires

JST Connector Pinout:

| Pin | Signal |
|-----------------|------------------|
| Color (typical) | 1 |
| GND | Black |
| 2 | CAN_L |
| Gray or White | 3 |
| CAN_H | Orange or Yellow |
| 4 | +5V (optional) |
| Red | |

Motor Phase Wiring

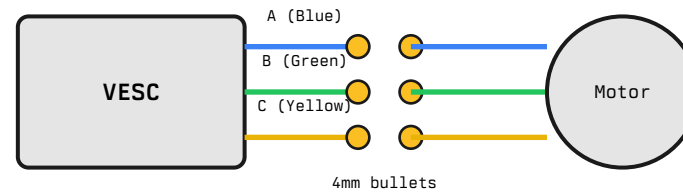


Figure 32: Phase wires connect VESC to motor via bullet connectors.

Connect VESC outputs to hub motor phase wires.

Connection Notes:

- Motor wire colors may not match VESC colors
- If motor spins wrong direction: swap any two phase wires
- Use 4mm gold bullet connectors (60A rated)
- Solder connections, use heat shrink
- Keep phase wires away from signal wires (EMI)

Wire Lengths:

| Motor Position | Approx. Length |
|----------------|----------------|
| Front Left | 400mm |
| Front Right | 500mm |
| Rear Left | 300mm |
| Rear Right | 400mm |

i NOTE Add 50mm extra for service loops. Too tight = strain on connectors.

Signal Wiring

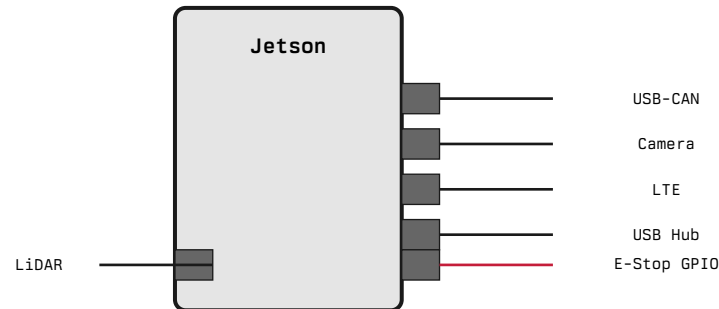


Figure 33: Jetson connections. USB for peripherals, GPIO for E-Stop, Ethernet for LiDAR.

Connect low-voltage signals: USB, GPIO, sensors.

USB Allocation:

| Port | Device |
|-----------------|------------------|
| Cable | USB 3.0 1 |
| USB-CAN adapter | USB-A to adapter |
| USB 3.0 2 | USB Hub |
| USB-A to hub | Hub Port 1 |
| Insta360 X4 | USB-C |
| Hub Port 2 | LTE modem |
| USB-A | |

GPIO:

- Pin for E-Stop relay control
- Active-high: GPIO high = relay closed = power on
- On Jetson startup: default low = safe state

Cable Management

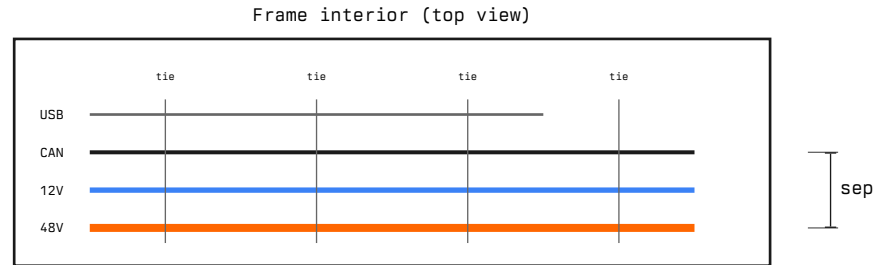


Figure 34: Route power and signal cables separately. Secure every 150mm.

Organize and secure all wiring for reliability and serviceability.

☐ Labels on power cables

Routing Rules:

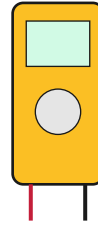
- Separate power (48V) from signals by at least 25mm
- CAN bus twisted pair reduces interference
- Use cable ties every 100-150mm
- Leave service loops at connectors
- Label both ends of each cable

Cable Tie Points:

- Frame corners
- Near each connector
- Before/after bends
- At entry to electronics bay

- ☐ No cables in wheel path
- ☐ No cables near hot components (VESC's)
- ☐ All connectors accessible
- ☐ Service loops at key points

Pre-Power Checks



Multimeter Tests

Before applying power, verify all connections are correct.

Continuity Tests (power OFF):

| Test | Probe Points |
|---------------------------------|----------------------------|
| Expected | 48V+ to GND |
| Battery connector pins | Open (no beep) |
| 12V+ to GND | DC-DC output |
| Open (no beep) | CAN_H to CAN_L |
| CAN connector | 60Ω (two 120Ω in parallel) |
| Phase A to B | Motor connector |
| Low resistance (motor windings) | |

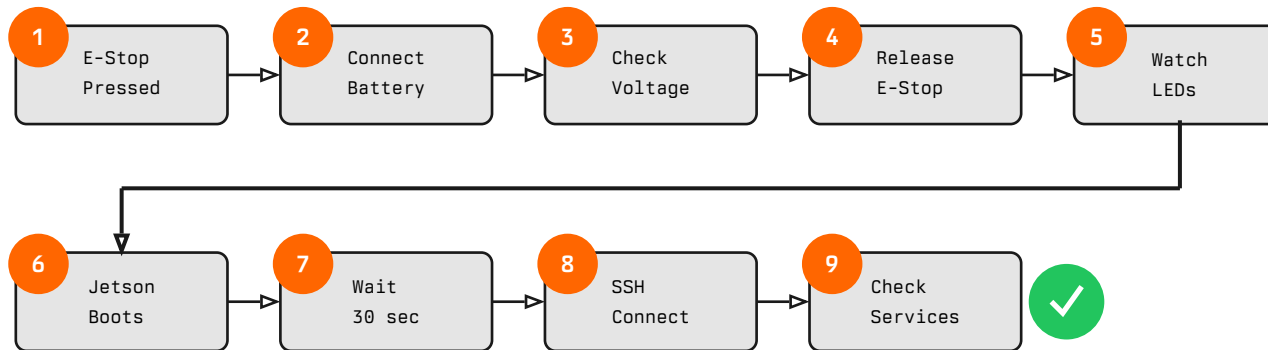
Visual Inspection:

- ☐ No exposed wire or bare conductors

- ☐ All connectors fully seated
- ☐ Polarity correct (red to +, black to -)
- ☐ No pinched wires
- ☐ Fuse installed and correct rating
- ☐ E-Stop button in pressed (safe) position

⚠ DANGER If any continuity test shows a short (beep) between power and ground, DO NOT APPLY POWER. Find and fix the short first.

First Power-Up



Initial power-on sequence with safety precautions.

What to Watch:

| Indicator | Normal |
|-------------------------------|------------------------------|
| Problem | VESC LEDs |
| Solid green | Red = fault, none = no power |
| Jetson LED | Solid then blinking |
| None = power issue | DC-DC LED |
| Green (if equipped) | None = input voltage issue |
| Smell | None |
| Burning = immediate power off | Sound |
| Quiet hum | Buzzing = loose connection |

VESC Configuration

Configure motor controllers using VESC Tool.

Connection:

1. Connect laptop to VESC via USB
2. Open VESC Tool
3. Select serial port, click Connect

Motor Wizard:

1. Navigate to Motor → Motor Wizard
2. Select motor type (usually “Large outrunner”)
3. Run detection: VESC will spin motor briefly
4. Review detected parameters
5. Write configuration to VESC

CAN Configuration:

1. Navigate to App → CAN Status
2. Set unique Controller ID (0, 1, 2, 3)
3. Set CAN Baud to 500K
4. Enable “Send CAN Status”
5. Write configuration

Per-VESC Settings:

| VESC | ID |
|-----------------|---------------|
| Motor Direction | Front Left |
| 0 | Forward = CCW |
| Front Right | 1 |
| Forward = CW | Rear Left |
| 2 | Forward = CCW |
| Rear Right | 3 |

Forward = CW

i NOTE Left and right motors spin opposite directions for forward motion in skid-steer.

Motor Testing

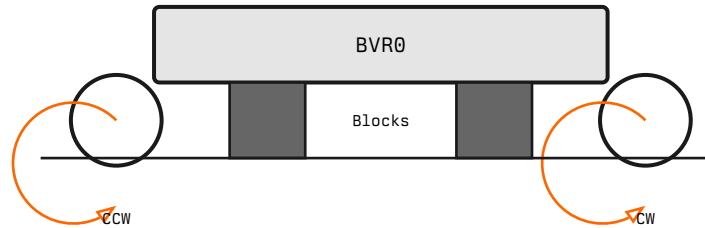


Figure 37: Test with wheels elevated. Verify each motor spins correct direction.

Verify all motors respond correctly before road testing.

⚠ WARNING Elevate rover so all wheels are off the ground before motor testing.

- ☐ No unusual sounds or vibration
- ☐ VESCs not overheating

Test Procedure:

1. Elevate rover on blocks (all wheels free)
2. Power on, release E-Stop
3. Connect controller
4. Command forward slowly: all wheels should spin "forward"
5. Command reverse: all wheels should spin "backward"
6. Command left turn: right wheels forward, left wheels backward
7. Test E-Stop: press button, verify immediate stop

Direction Fix: If a motor spins wrong direction, swap any two phase wires on that motor.

- ☐ All 4 motors respond to commands
- ☐ Direction correct for each motor
- ☐ E-Stop stops all motors immediately

Startup Procedure

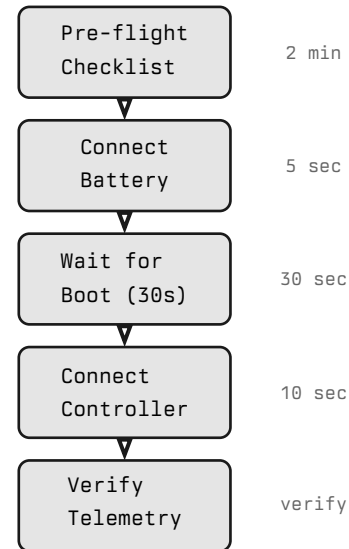


Figure 38: Startup takes approximately 3 minutes.

Standard startup sequence for daily operation.

Detailed Steps:

1. **Pre-flight:** Complete checklist on page 2
2. **Battery:** Connect XT90 (hear click). E-Stop should be pressed.
3. **Boot:** Release E-Stop. Wait for Jetson to boot (30s). VESC LEDs turn green.
4. **Controller:** Power on controller. Connect to operator station.
5. **Telemetry:** Verify video feed, voltage reading, and mode indicator.

i NOTE Do not operate if telemetry shows errors or video feed is absent.

Shutdown Procedure

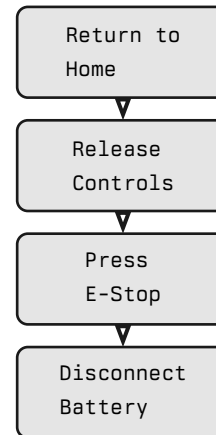


Figure 39: Always press E-Stop before disconnecting battery.

Safe shutdown sequence after operation.

⚠ WARNING Never disconnect battery while Jetson is running. This can corrupt the filesystem.

Shutdown Checklist:

- ☐ Rover parked in designated area
- ☐ Controller set down / powered off
- ☐ E-Stop button pressed (red button down)
- ☐ Wait 5 seconds for Jetson to save state
- ☐ Disconnect battery (pull XT90)
- ☐ Store battery properly (50-60% charge for long storage)

Tool Attachment

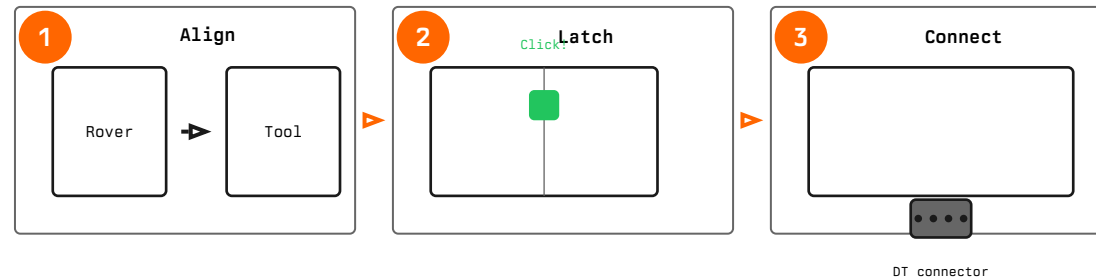


Figure 40: Tool attachment: align rails, latch, then connect electrical.

Attach and detach modular tool attachments.

Attachment Procedure:

1. Power OFF rover (E-Stop pressed)
2. Align tool mounting rails with rover interface
3. Slide tool forward until latch clicks (audible)
4. Verify latch indicator shows green/locked
5. Connect DT electrical connector (power + CAN)
6. Power ON rover
7. Tool announces itself automatically on CAN bus
8. Operator UI shows tool status

Detachment:

1. Power OFF rover
2. Disconnect DT electrical connector first
3. Release latch lever
4. Slide tool rearward to remove

i NOTE Always disconnect electrical before unlatching mechanical. Prevents arcing.

Hazard Zones

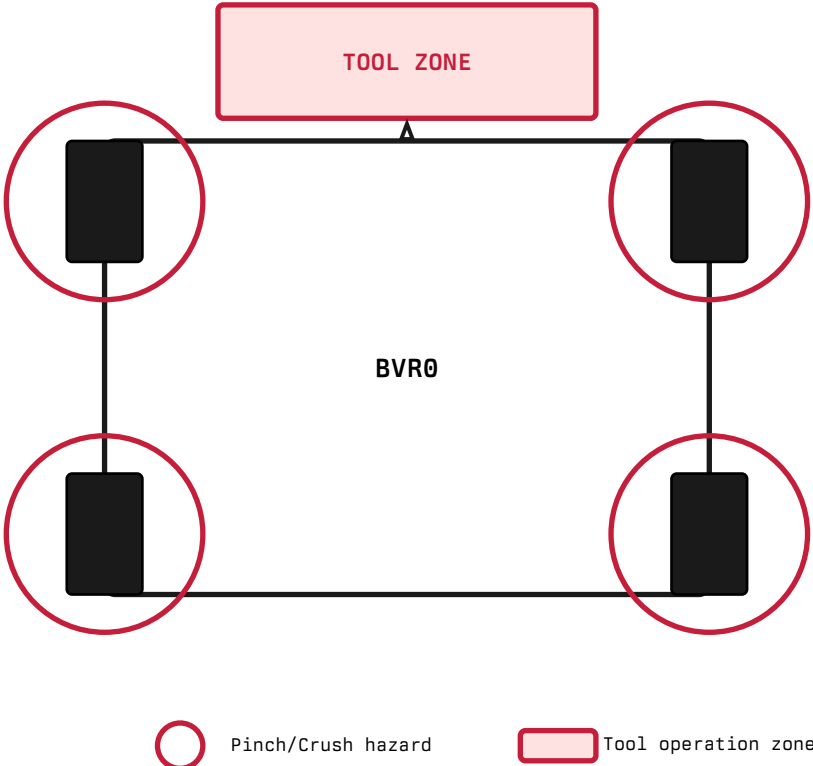


Figure 41: Keep hands, feet, and loose clothing clear of marked zones.

Areas requiring clearance during operation.

⚠ DANGER Stay clear of marked zones during operation. Serious injury possible.

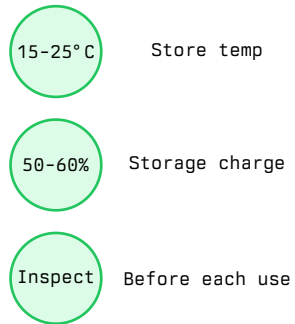
Hazard Types:

| Zone | Hazard |
|------|--------|
|------|--------|

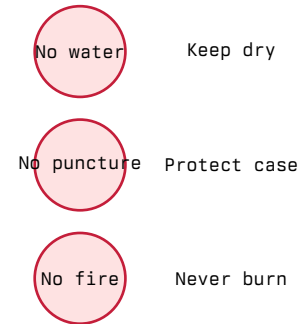
| Injury Type | Wheel areas |
|-------------------------------|-----------------------------|
| Rotating wheels, motor torque | Crush, pinch, friction burn |
| Tool zone | Rotating auger/blade |
| Laceration, amputation | Underside |
| 50mm ground clearance | Crush if rover tips |
| Battery area | Electrical, thermal |
| Shock, burns | |

Battery Safety

DO



DON'T



Lithium battery handling and emergency procedures.

⚠ WARNING Li-ion batteries can catch fire if damaged, punctured, or short-circuited.

⚠ DANGER Never attempt to charge a damaged battery. Dispose at authorized recycling facility.

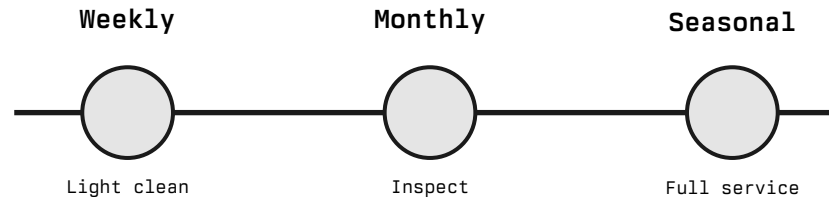
Signs of Battery Damage:

- Swelling or bulging
- Unusual heat
- Hissing or venting
- Visible damage to case
- Reduced capacity

In Case of Battery Fire:

1. **Evacuate** the immediate area
2. **Do not** use water to extinguish
3. Use **Class D fire extinguisher** or **dry sand**
4. Call fire department: **911**
5. Ventilate area (toxic fumes)

Maintenance Schedule



Preventive maintenance keeps the rover reliable.

Weekly

- Clean wheels and chassis
- Wipe camera lens
- Wipe LiDAR lens
- Check connector seating
- Verify wheel spin
- Test E-Stop function

Monthly

- Inspect all wiring
- Check bolt torque
- Clean electrical contacts
- Check battery health
- Update firmware
- Review error logs

Seasonal

- Full electrical inspection
- Check wheel bearings
- Replace worn tires
- Deep clean chassis
- Calibrate sensors
- Battery capacity test

Troubleshooting

Common issues and solutions.

| Symptom | Likely Cause |
|---------------------------------------|---------------------------------------|
| Solution | Won't power on |
| Battery disconnect | Check XT90 connection, verify fuse |
| No video feed | Camera USB |
| Reconnect camera, check USB hub power | Motor not responding |
| CAN wiring | Check CAN connections, verify VESC ID |
| Erratic movement | VESC ID mismatch |
| Verify IDs match wheel positions | E-Stop won't release |
| Button stuck | Check relay wiring, verify mechanism |
| Overheating | Ventilation blocked |
| Clean vents, reduce load | Poor LTE signal |
| Antenna position | Reposition antenna, check SIM |
| Battery dies quickly | Battery age |
| Check cell balance, replace if needed | Jerky motion |
| Motor calibration | Re-run VESC motor detection |

| | |
|-------------------------|-----------------|
| Drift to one side | Wheel alignment |
| Re-align motor brackets | |

Diagnostic Commands:

```
# Check system status
bvr status

# List CAN devices
bvr can scan

# Test individual motor
bvr motor test <id>

# View recent logs
journalctl -u bvr -n 100
```

Storage

50-60%

Battery charge

Disconnect

Unplug battery

15-25° C

Temperature

Proper storage extends component life.

2. Charge battery fully
3. Run pre-flight checklist
4. Test all functions before field use

Short-Term Storage (< 1 week):

- ☐ Press E-Stop
- ☐ Disconnect battery
- ☐ Cover if stored outdoors

Long-Term Storage (> 1 week):

- ☐ Charge battery to 50-60%
- ☐ Disconnect battery completely
- ☐ Clean chassis and wheels
- ☐ Cover camera and LiDAR lenses
- ☐ Store in dry location (15-25°C)
- ☐ Check battery monthly (recharge if < 40%)

Returning from Storage:

1. Inspect for moisture, corrosion, pest damage

Municipal Robotics
Cleveland, Ohio
muni.works