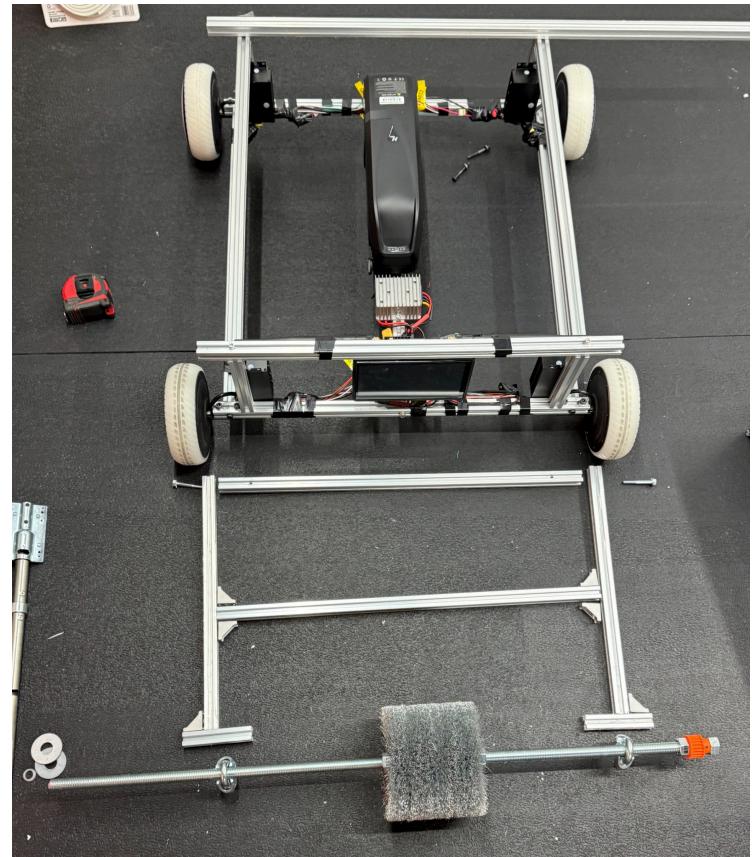


Technical Manual

BVR0

Base Vectoring Rover



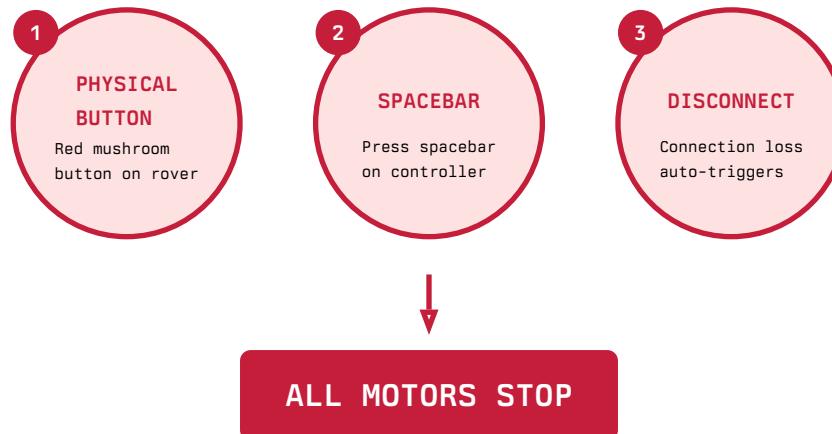
Revision 0.1 December 2025

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.

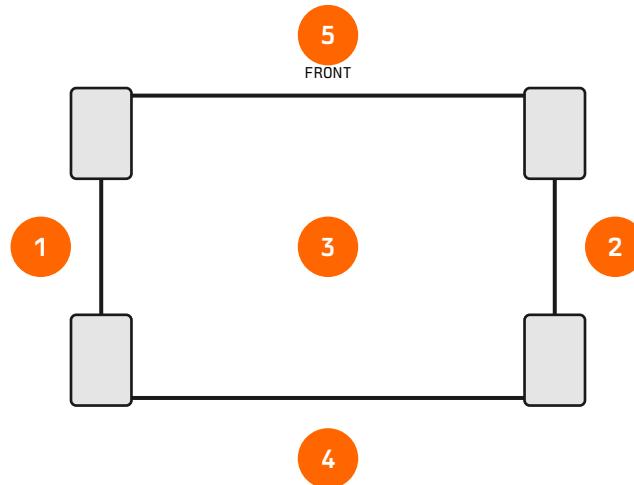
When to E-Stop:

- 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



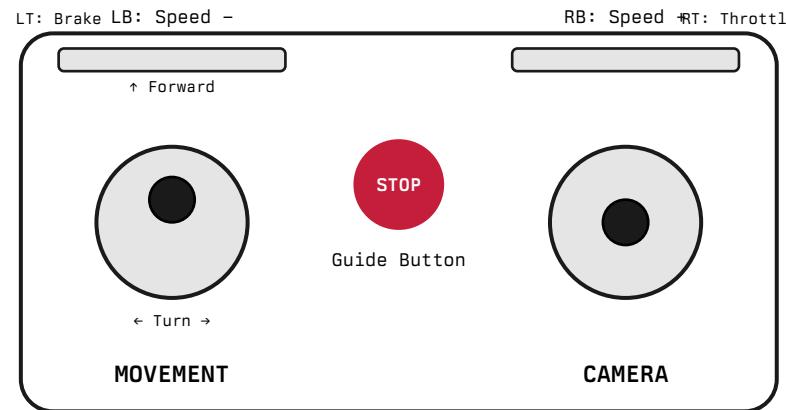
Use this checklist before every operation session.

- 1 Wheels spin freely,
no debris
- 2 All wheel bolts
tight
- 3 E-Stop button not
stuck

- 4 Battery voltage >
40V
- 5 Camera and LiDAR
clean
- 6 All connectors
secure

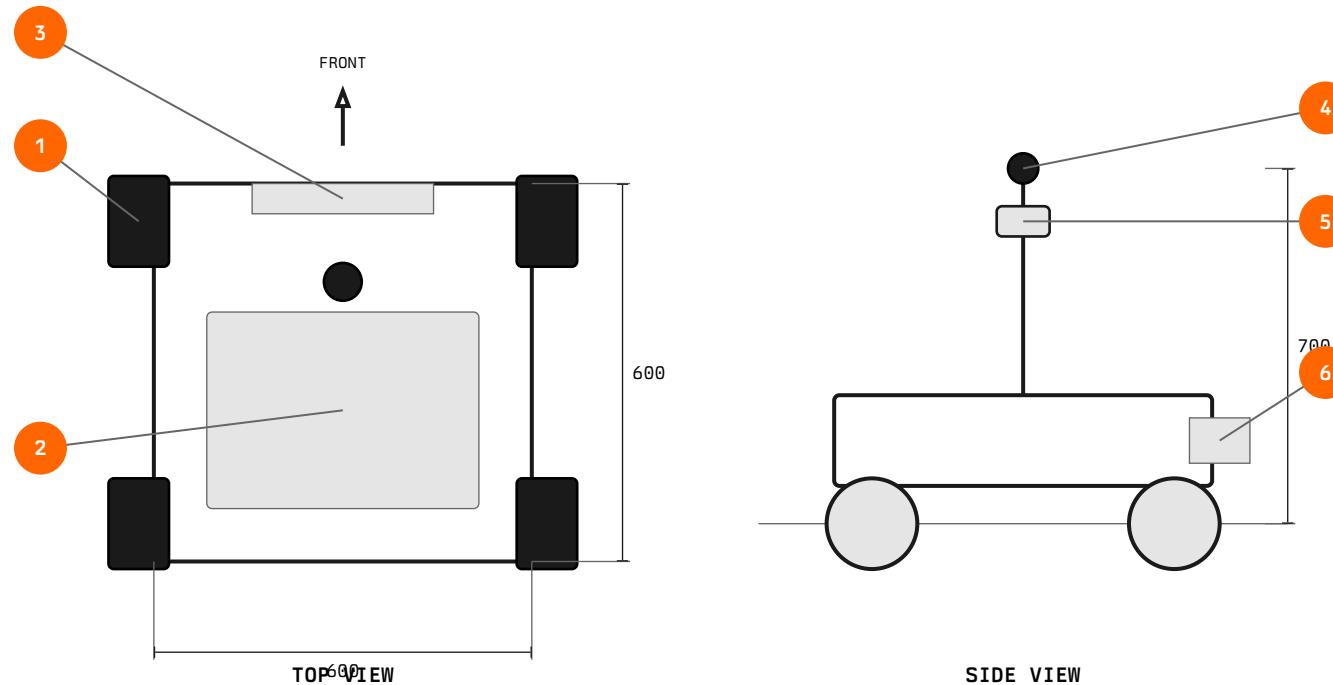
i NOTE If any check fails, do not operate. Resolve the issue first.

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

Component	Description
1	Hub motor wheels ($\times 4$)
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)

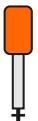
Compute

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

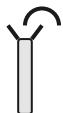
Required Tools

**Hex Keys**

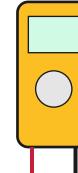
2.5, 3, 4, 5 mm

**Screwdriver**

Phillips 2

**Wrenches**

8, 10, 13 mm

**Multimeter**

V / Ω / Continuity

Required

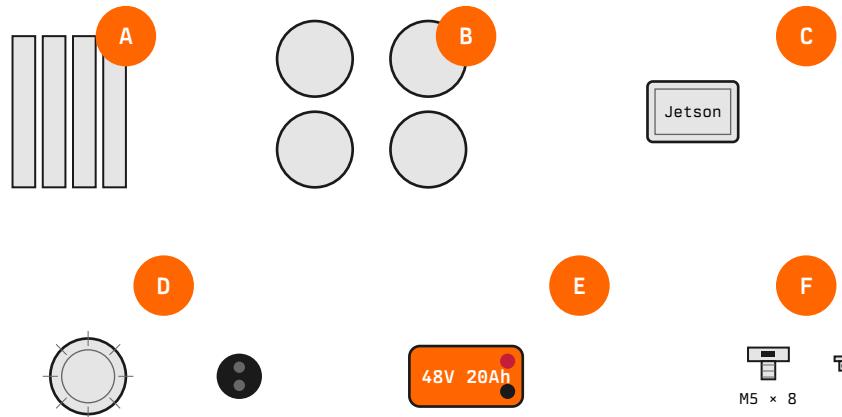
- Hex key set (metric: 2.5, 3, 4, 5 mm)
- Phillips screwdriver (2)
- Adjustable wrench or socket set (8, 10, 13 mm)
- Multimeter (voltage, resistance, continuity)
- Wire strippers (20-12 AWG)
- Soldering iron (40W+) and solder
- Heat shrink assortment
- Miter saw or hacksaw (for extrusions)

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	Cost
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

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

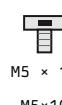
AWG	Use
8 AWG	Battery to bus

T-Nuts

Common Hardware (actual size)



M5 × 8
M5×8



M5 × 10
M5×10



M5 × 16
M5×16



M5 T-Nut

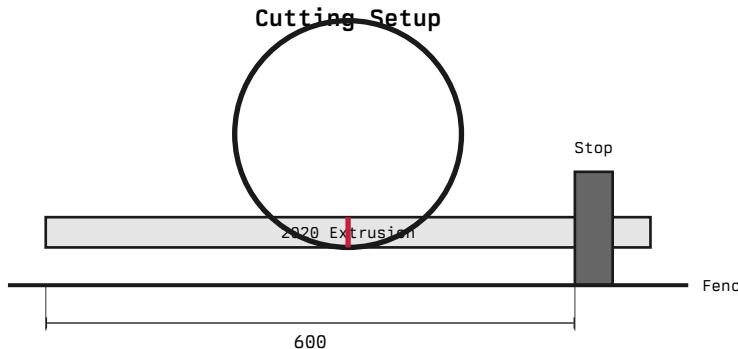


Corner

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 VSCs
14 AWG	12V power
22 AWG	CAN bus, signals

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:

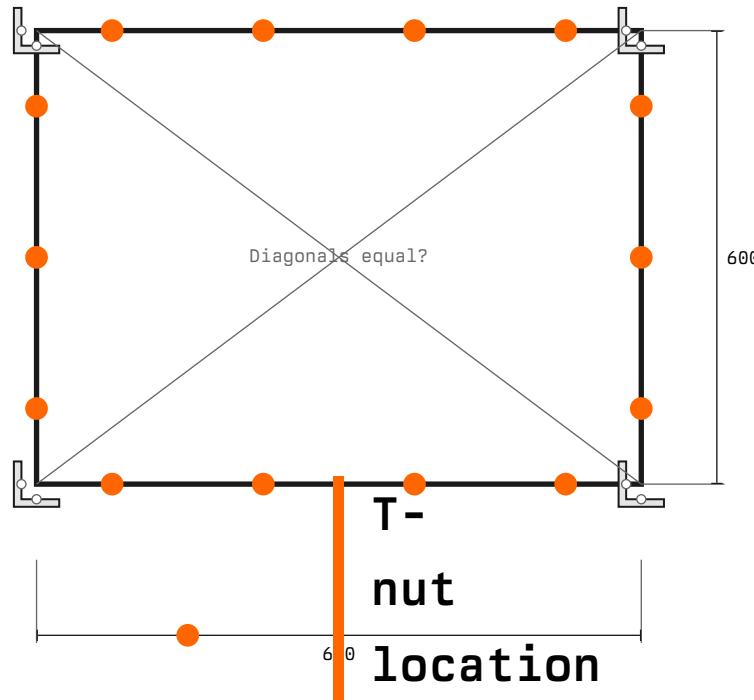
Qty	Length
Purpose	4
600mm	Base frame
4	600mm
Top frame	

Optional: cut 4x 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.

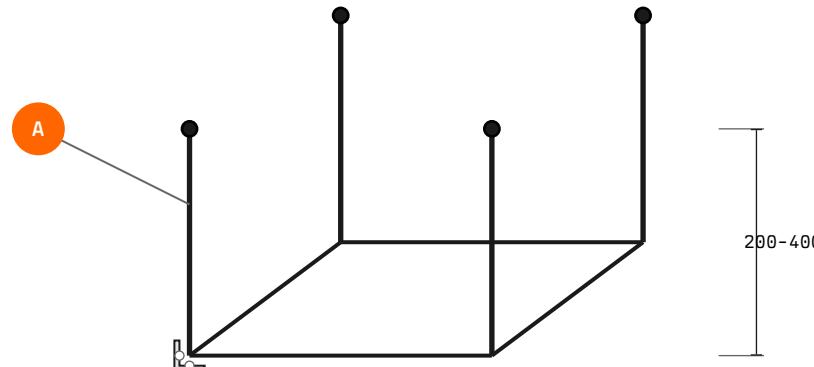
Assembly Steps:

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

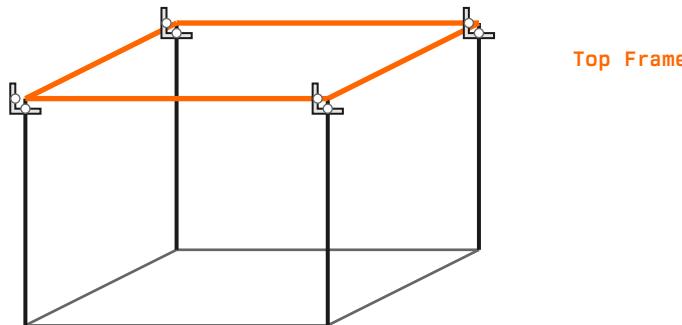
Use blind joint connectors for cleaner look.

- 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



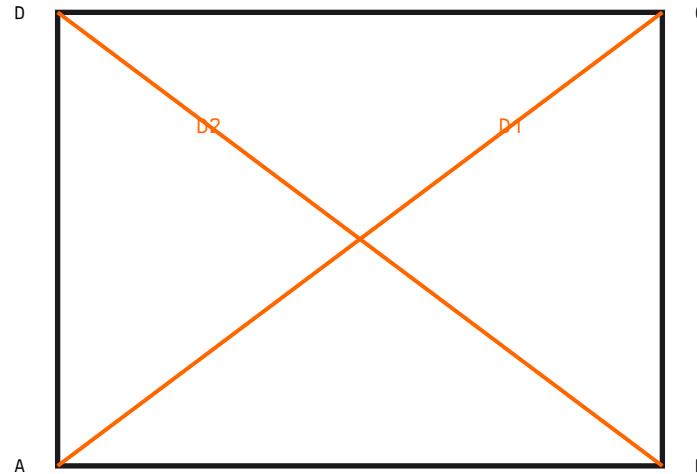
Complete the box structure with the top frame.

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



$D_1 = D_2 \pm 1\text{mm}$

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

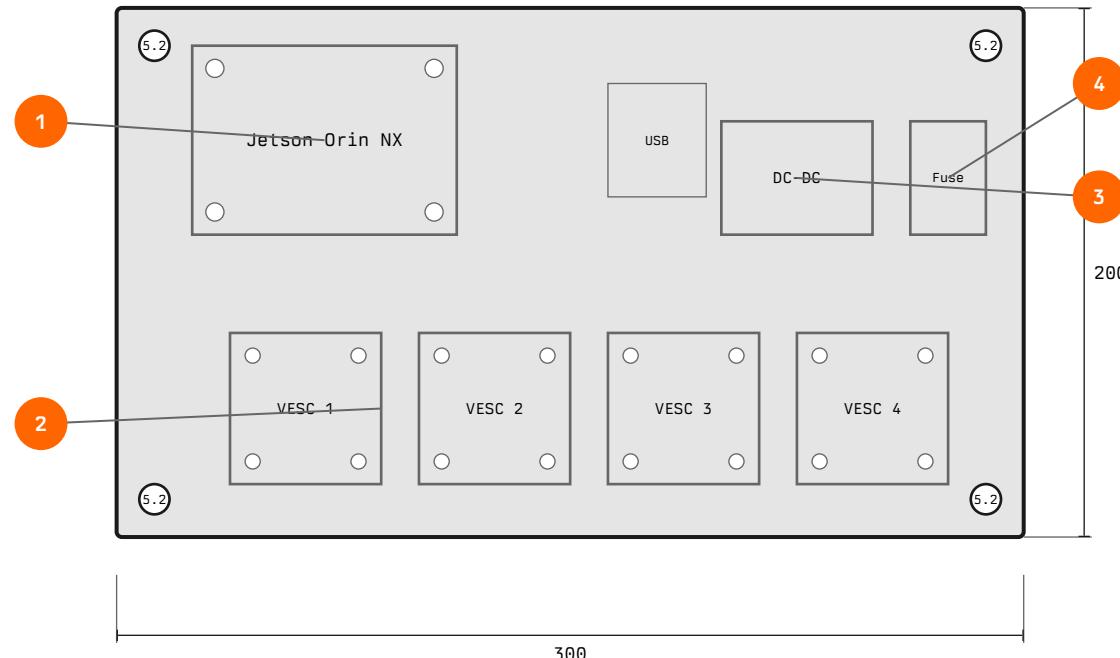
Rigidity Test:

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

- 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

Final Checklist:

Electronics Plate Layout



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

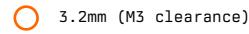
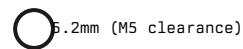
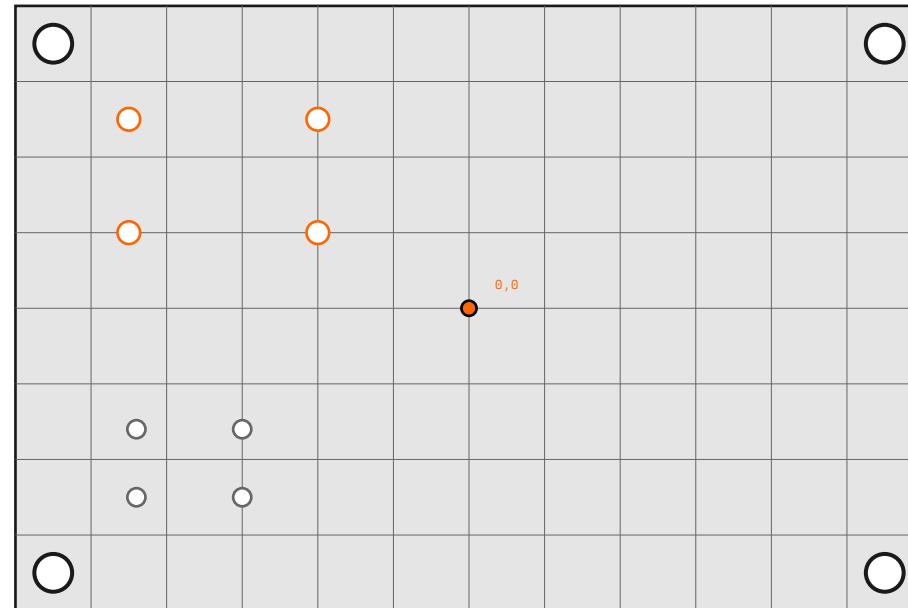
Components:

- 1 Jetson Orin NX (69x45mm)
- 2 VESC 6.7 x4 (60x40mm 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



10mm grid

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

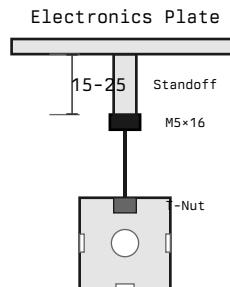


Figure 15: Cross-section: standoff mounting provides airflow under plate.

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× M5x16 or M5x20 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

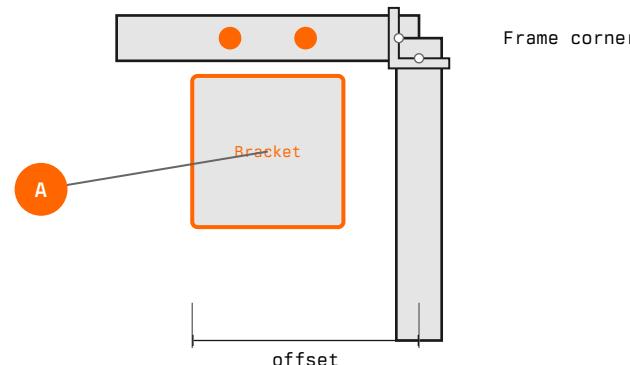


Figure 17: Motor bracket position at frame corner. All 4 corners mirror this layout.

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 M5x10 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

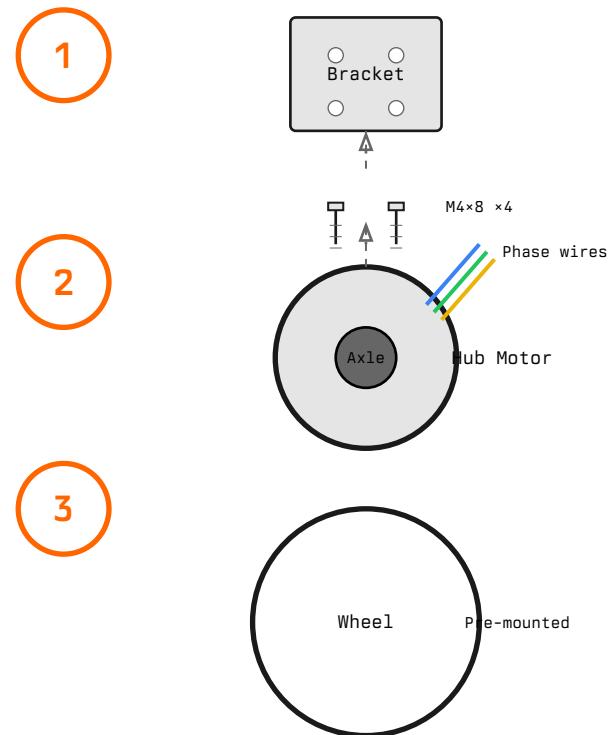


Figure 18: Motor installation sequence. Wheels typically come pre-mounted on hub motors.

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 M4×8 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

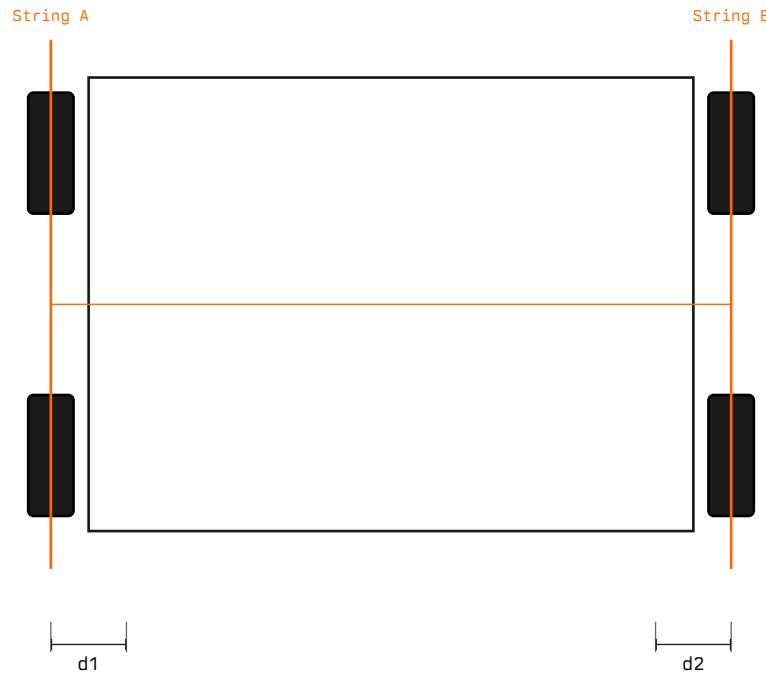


Figure 19: String alignment method. Stretch strings parallel to frame sides.

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

Battery Tray

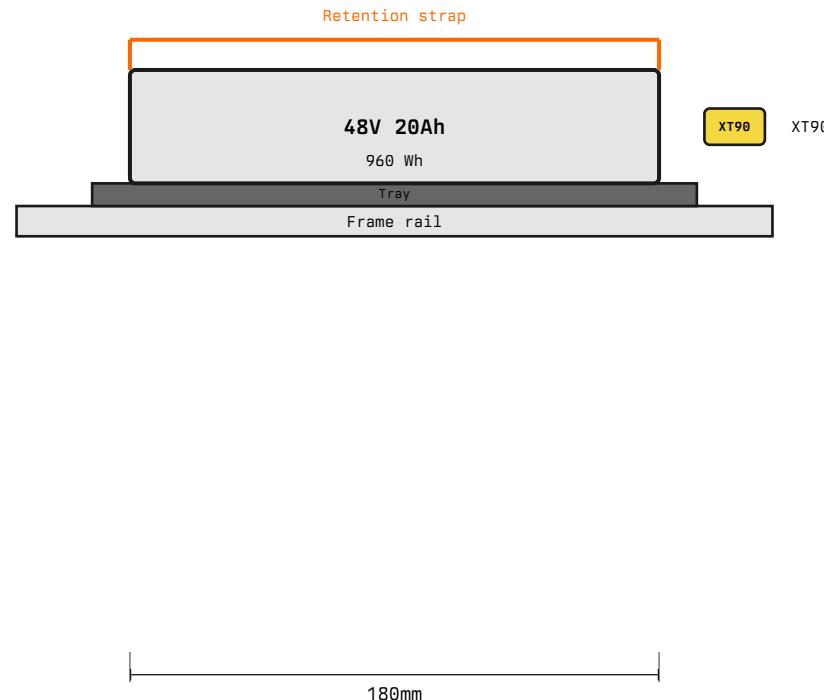


Figure 20: Battery mounted on tray with retention strap. XT90 connector for quick disconnect.

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

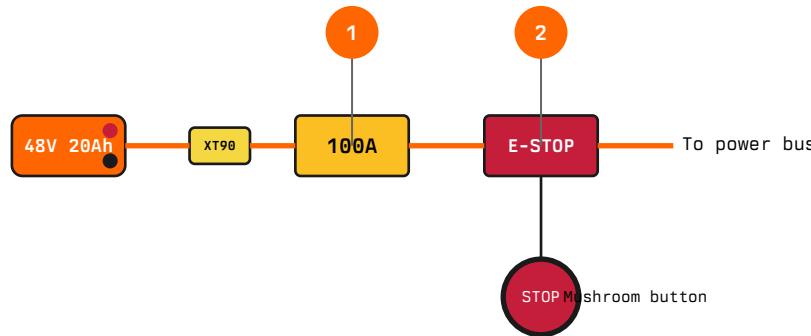


Figure 21: Power flows: Battery → XT90 → Fuse → E-Stop relay → Power bus

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

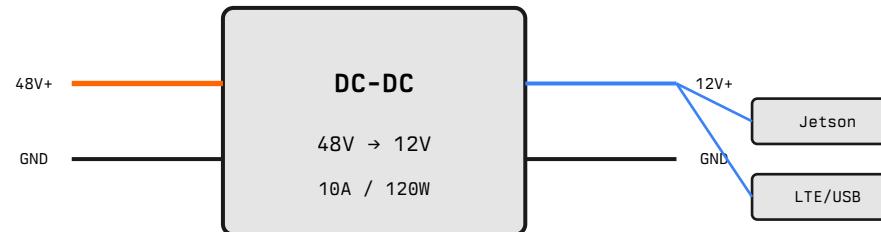


Figure 22: DC-DC powers all 12V devices from the 48V main bus.

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

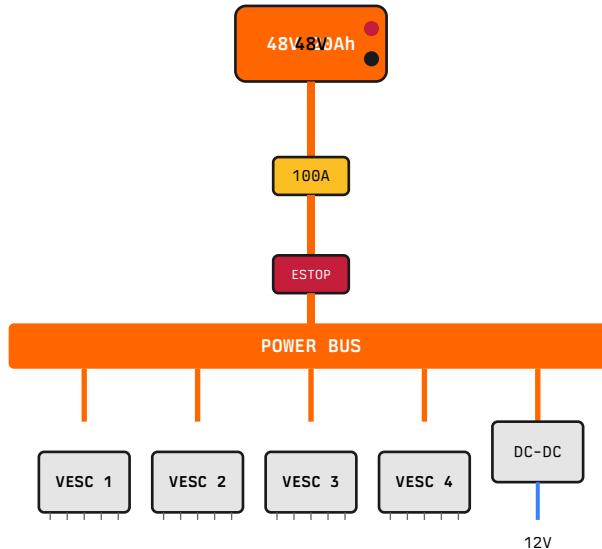


Figure 23: Power distribution topology. All 48V loads connect to central bus.

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 4x XT60
- Simpler for prototypes
- Higher resistance

VESC Mounting

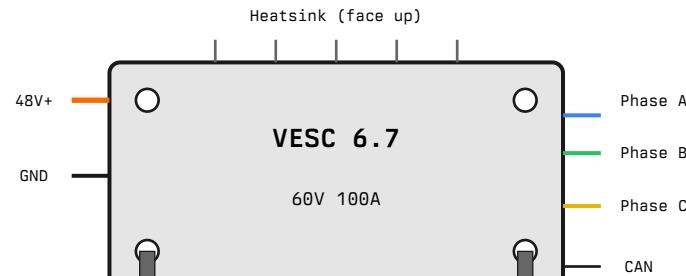


Figure 24: VESC mounted on standoffs for airflow. Heatsink faces up.
M3 standoffs (6-10mm)

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

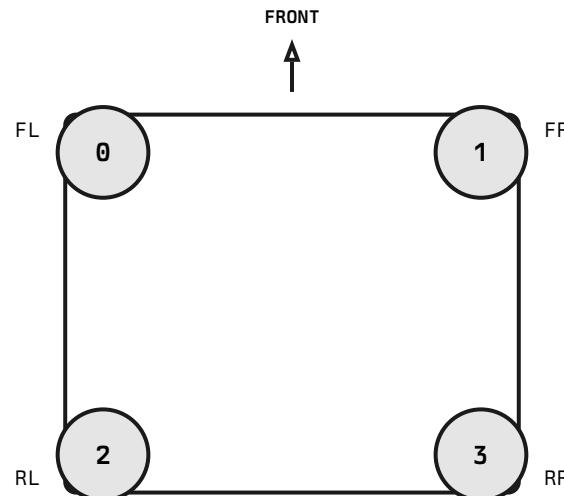


Figure 25: CAN ID assignment. ID 0-3 for wheels, ID 10+ for tools.

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

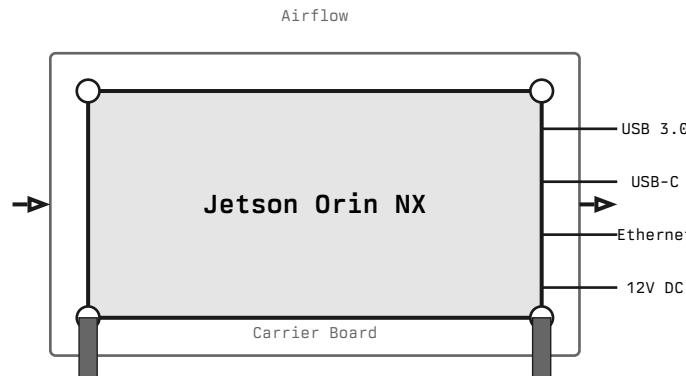


Figure 26: Jetson mounted on standoffs. Ensure airflow around heatsink.

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
- bvr0 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

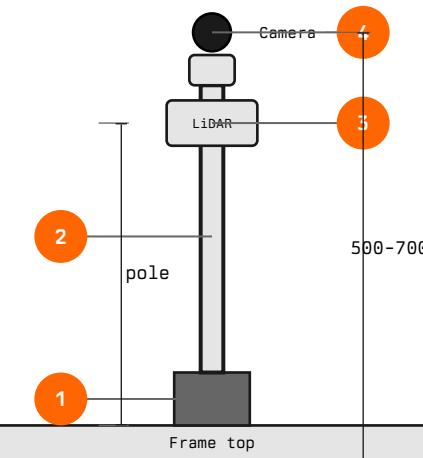


Figure 28: Sensor mast with LiDAR below camera for unobstructed 360° view.

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

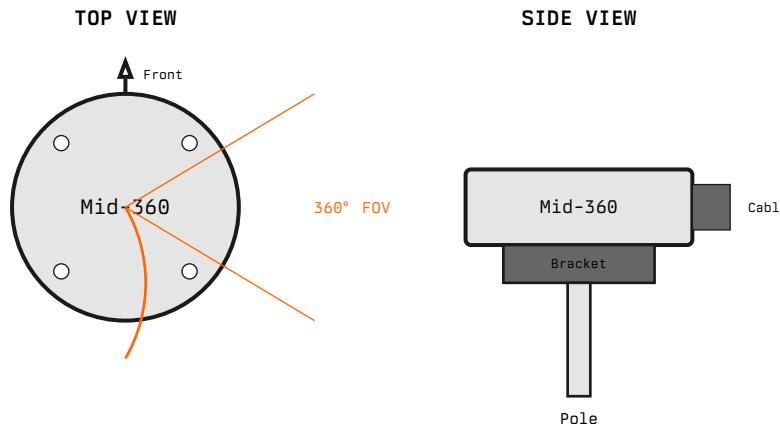


Figure 29: LiDAR mounted level with 360° horizontal FOV. Cable routes down pole.

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

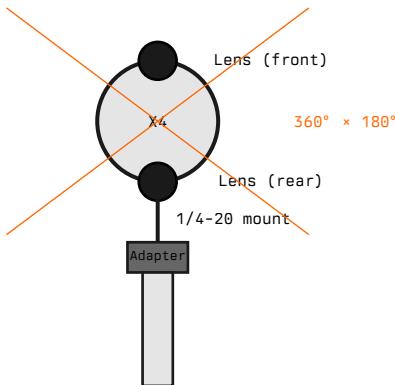


Figure 30: Camera at mast top. Dual lenses capture full spherical view.

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

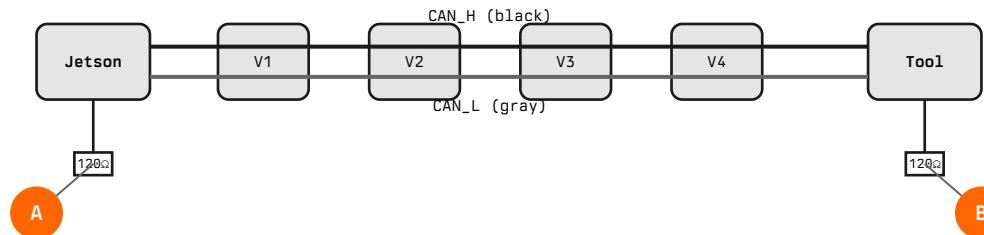


Figure 31: CAN bus with 120Ω termination at each end (A and B).

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

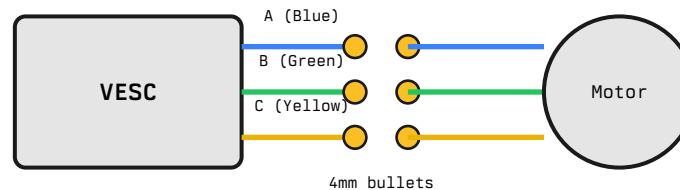


Figure 32: Phase wires connect VESC to motor via bullet connectors.

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

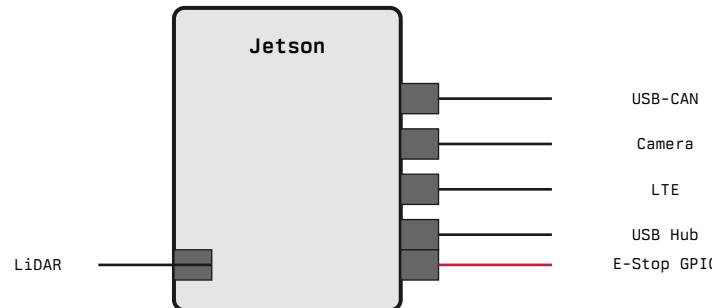


Figure 33: Jetson connections. USB for peripherals, GPIO for E-Stop, Ethernet for LiDAR.

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

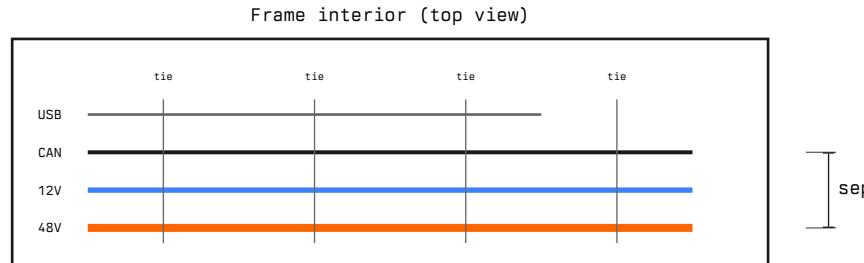


Figure 34: Route power and signal cables separately. Secure every 150mm.

Organize and secure all wiring for reliability and serviceability.

Labels on power cables

Routing Rules:

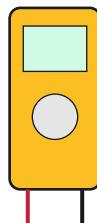
- Separate power (48V) from signals by at least 25mm
- CAN bus twisted pair reduces interference
- Use cable ties every 100-150mm
- Leave service loops at connectors
- Label both ends of each cable

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 (VSCCs)
- 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)	

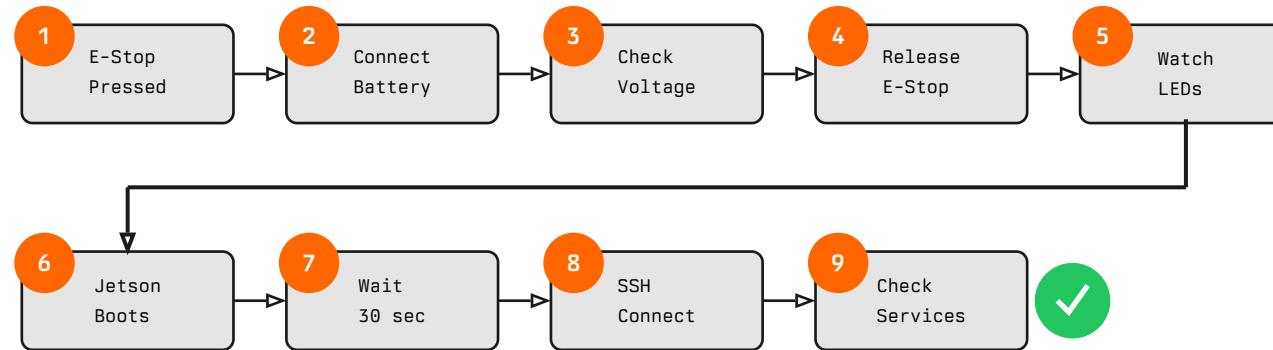
- All connectors fully seated
- Polarity correct (red to +, black to -)
- No pinched wires
- Fuse installed and correct rating
- E-Stop button in pressed (safe) position

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

Visual Inspection:

- No exposed wire or bare conductors

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

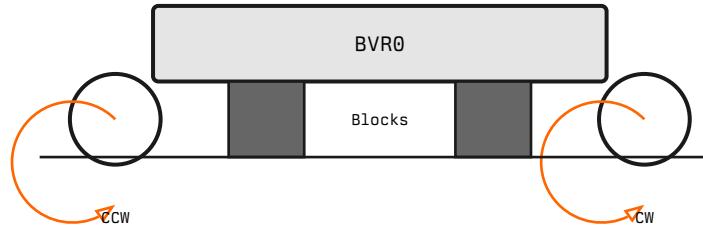


Figure 37: Test with wheels elevated. Verify each motor spins correct direction.

Verify all motors respond correctly before road testing.

- No unusual sounds or vibration
- VESCs not overheating

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

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

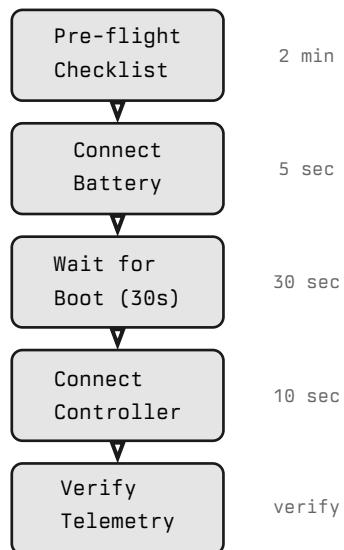


Figure 38: Startup takes approximately 3 minutes.

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

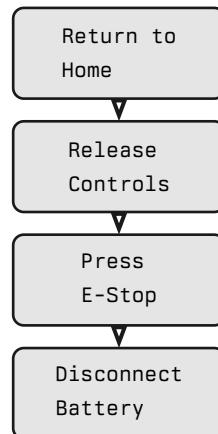


Figure 39: Always press E-Stop before disconnecting battery.

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

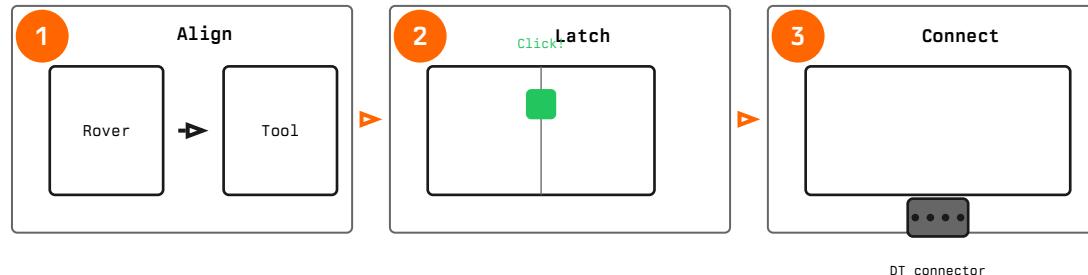


Figure 40: Tool attachment: align rails, latch, then connect electrical.

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

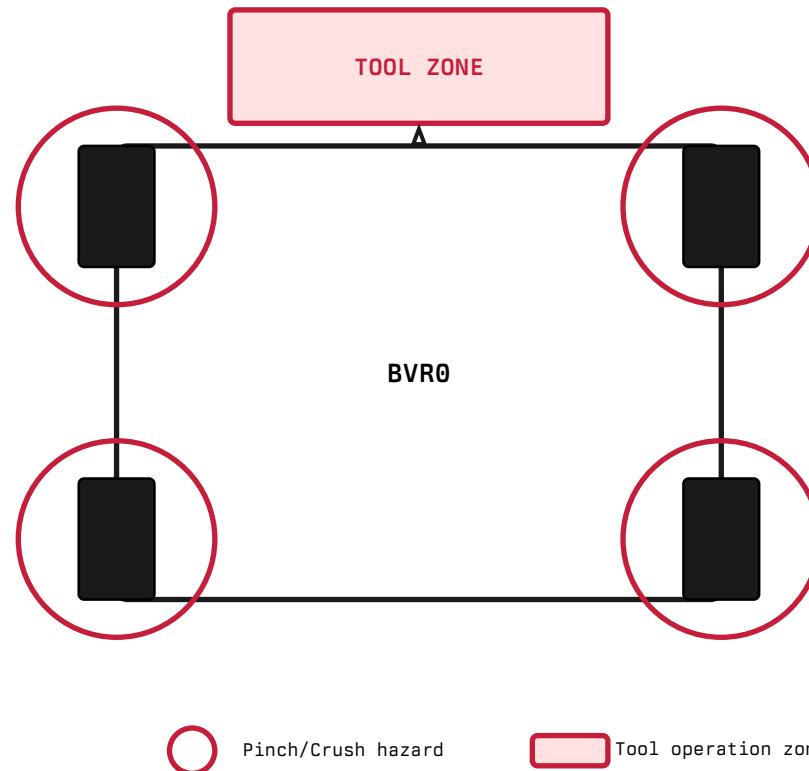


Figure 41: Keep hands, feet, and loose clothing clear of marked zones.

Areas requiring clearance during operation.

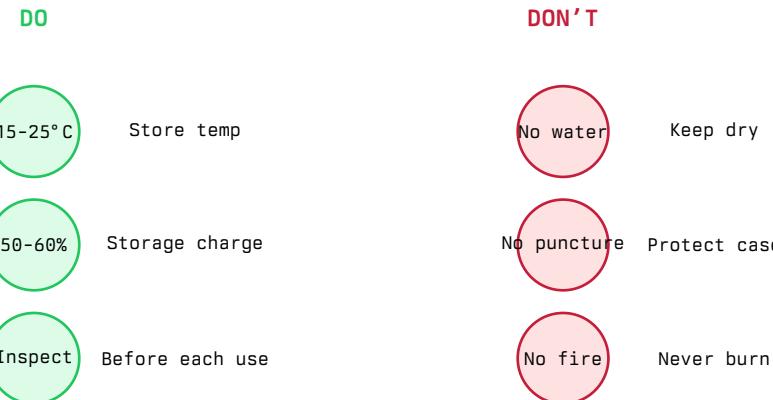
DANGER Stay clear of marked zones during operation.
Serious injury possible.

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



Lithium battery handling and emergency procedures.

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

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

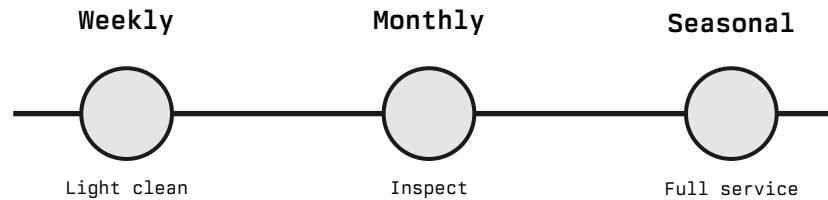
Signs of Battery Damage:

- 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 | Monthly | Seasonal |
|--|---|---|
| <ul style="list-style-type: none">• Clean wheels and chassis• Wipe camera lens• Wipe LiDAR lens• Check connector seating• Verify wheel spin• Test E-Stop function | <ul style="list-style-type: none">• Inspect all wiring• Check bolt torque• Clean electrical contacts• Check battery health• Update firmware• Review error logs | <ul style="list-style-type: none">• 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	
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 bvrd -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