Autonomous Arctic Rover

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Abstract

Autonomous Arctic Rover is a fully autonomous arctic research mobility platform. Designed to perform autonomous data logging on the Greenland ice sheets. Powered by solar energy the rover can operate continuously. Utilizing iridium communication data can be transmitted to and from the rover. This allows for updating routes as well as progress monitoring. The modular platform allows for a multitude of research application. The initial operation is based around a Leica GPS 1200, allowing for high-precision positional data, used to determine topography and changes in topography.

Contents

1 Safety Information

1.1 General safety instructions

DANGER
Danger to life or serious injury can occur when live parts are touched. Do not touch or modify electrical installations without proper training or guidance.

DANGER
Danger to life or serious injury can occur if personnel are in front of the vehicle during operation. Always act with caution when moving near the vehicle. During autonomous operation stay clear of the front, and never operate vehicle autonomously near crowds.

WARNING
Danger to life, serious injury, or equipment damage can occur due to incorrect handling of equipment. When remote controlling vehicle, always check surroundings, and never drive near people.

WARNING
Serious injury or equipment damage can occur due to moving parts. Keep hands and limbs clear during operation.

WARNING
Danger to life, serious injury, or equipment damage can occur due to live batteries. Always disconnect batteries before modifying electrical circuits.

WARNING
Danger to life, serious injury, or equipment damage can occur due to incorrect handling of equipment. Only trained personnel may service or modify system.

CAUTION
Risk of equipment damage due to incorrect assembly. Always ensure bolts and nuts are sufficiently tightened according to specifications before operating vehicle.

2 Overview

2.1 Components

The Autonomous Arctic Rover is a fully autonomous arctic research mobility platform. The platform consists of four primary components. Chassis, Solar Panels, Front Motor and Suspension, and Rear Ski and Suspension.

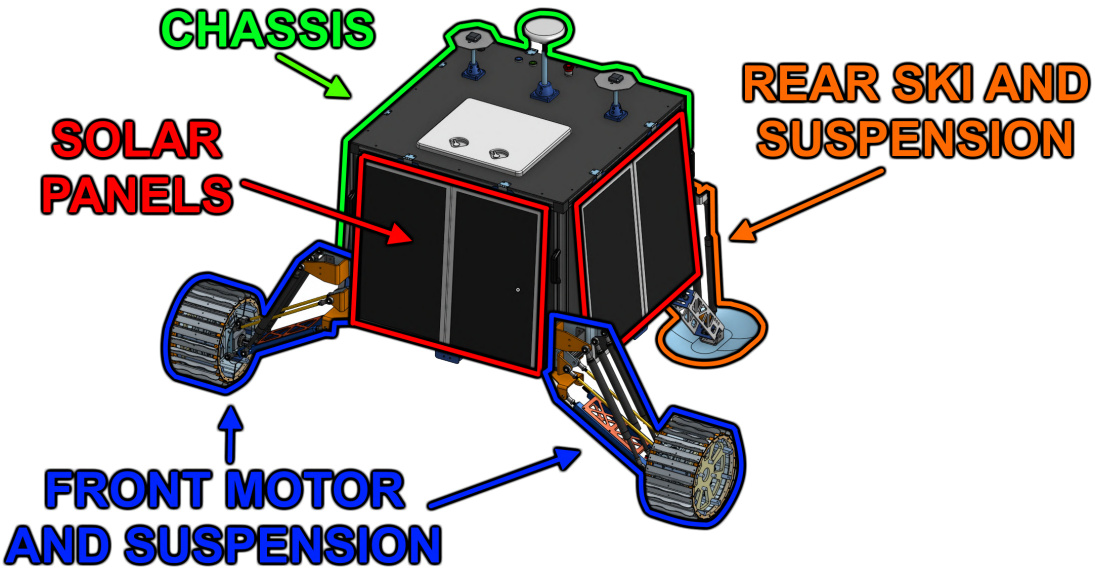


Figure 1: System Components.

2.2 Description

Powered by solar energy the rover can operate continuously. Utilizing iridium communication data can be transmitted to and from the rover. The modular platform allows for a multitude of research application.

2.2.1 Chassis

The primary compartment, this acts as the base of the rover. Everything is mounted to and connected inside the chassis. An internal insulated and heated compartment controls all primary functions of the rover. Eight NiMH battery modules (12x BK1100FHU[1]) 2 modules in series and 4 pairs in parallel acts as the power storage for a total of 1400 Whr at 24 V. The voltage range at full capacity is 33.6V and at zero capacity 24 V.

2.2.2 Solar Panels

Solar energy acts and the primary power generation. A total of eight 30W monocrystalline solar panels ([2]) are surrounding the Rover. The solar panels are connected two in series to fit the battery modules 33.6V at full charge.

2.2.3 Front Motor and Suspension

Primary propulsion of the rover is generated from two G1.1 GEM motors[3], generating a total of 120 Nm torque. Custom wheels allows for high grip on ice and snowy surfaces.

Suspension dampens terrain vibrations during movement, reducing measurement noise and allows for adjustable ground clearance.

2.2.4 Rear Ski and Suspension

Passive rear support with custom ski and suspension. Suspension again dampens terrain vibrations during movement, reducing measurement noise and allows for adjustable ground clearance.

3 Assembly Process

3.1 Overview

The rover is shipped in five parts, this section describes the primary steps needed to assemble the Rover for a full deployment. With the exception of one Li-Po battery, needed for the remote controller, the entire system is contained within the following components:

Figure 2: System packaged for transport,
2x Euro Pallet, 2x 40x80x60 ZARGES crate, 1x 40x40x60 ZARGES crate.

A Chassis - Euro Pallet, primary vehicle chassis, mounted and framed around a euro pallet with shipping dimensions: 120x120x82cm and 140 kg.

B Solar Panels - Euro Pallet, all solar panels are mounted and framed onto a euro pallet with shipping dimensions: 40x120x80cm and 80 kg.

C Front Motor and Suspension - 523A, both of the front motor and suspensions are packed in a 40x80x60 ZARGES crate weighing 60 kg.

D Additional Parts - 592A, spare motor, rear suspension, remote control, bolts, nuts and additional parts are packed in a 40x80x60 ZARGES crate weighing 45 kg.

E Batteries - 469, all batteries, along with a safety sheet are packed in a 40x40x60cm ZARGES crate weighing 30 kg.

The system can be seen fully assembled in Figure 3 and Figure 4. Figure 3 shows the system in its Hard Surface Configuration; wheel protection and rear dolly instead of ski.

Figure 3: Fully Assembled System (Hard Surface Configuration).

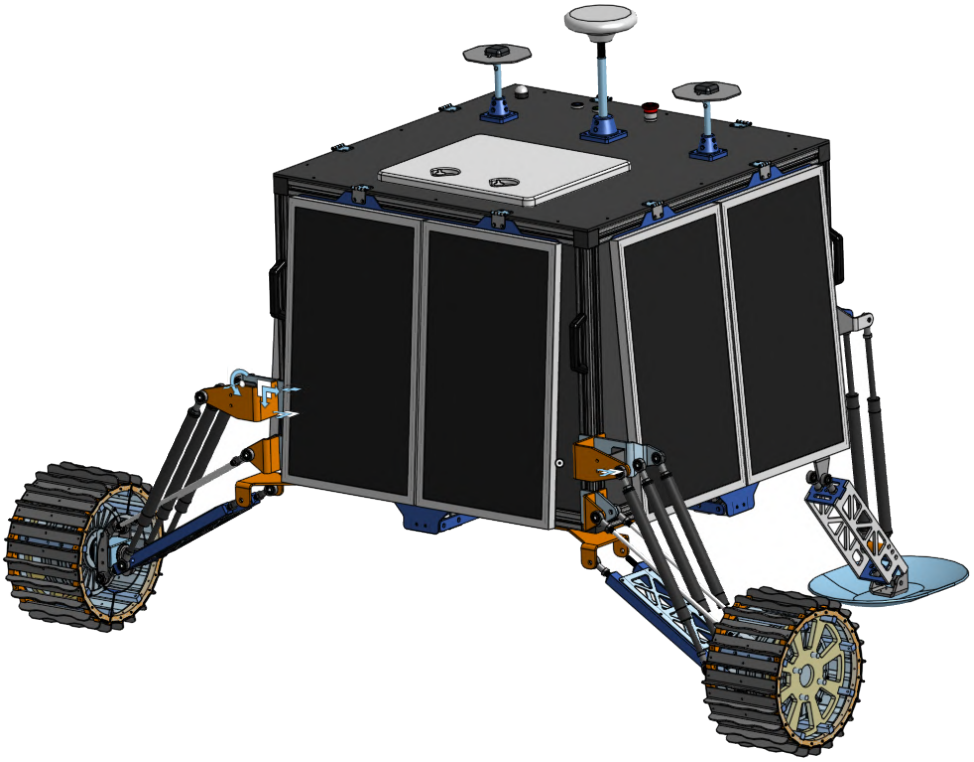


Figure 4: Fully Assembled System (CAD).

3.2 Chassis

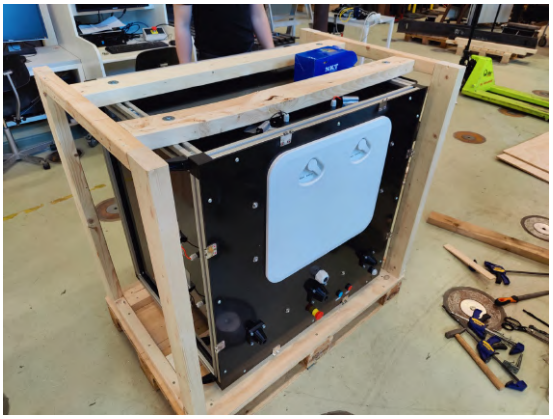
The chassis is shipped in a full wooden frame on a euro pallet. Dimensions are 120x120x82 cm and weighs 140 kg.

3.2.1 Unpacking

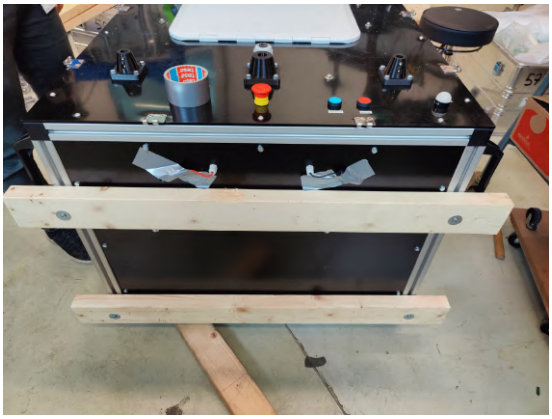
Remove wooden frame around chassis by unscrewing all surrounding panels, frame, and bottom support.

(a) Surrounding panels.

(b) Side panels.



(a) Wood frame.



(b) Bottom support.

3.2.2 Handle Position

Unscrew handles closest to hatch and move to side so handles are positioned as shown in Figure 8.

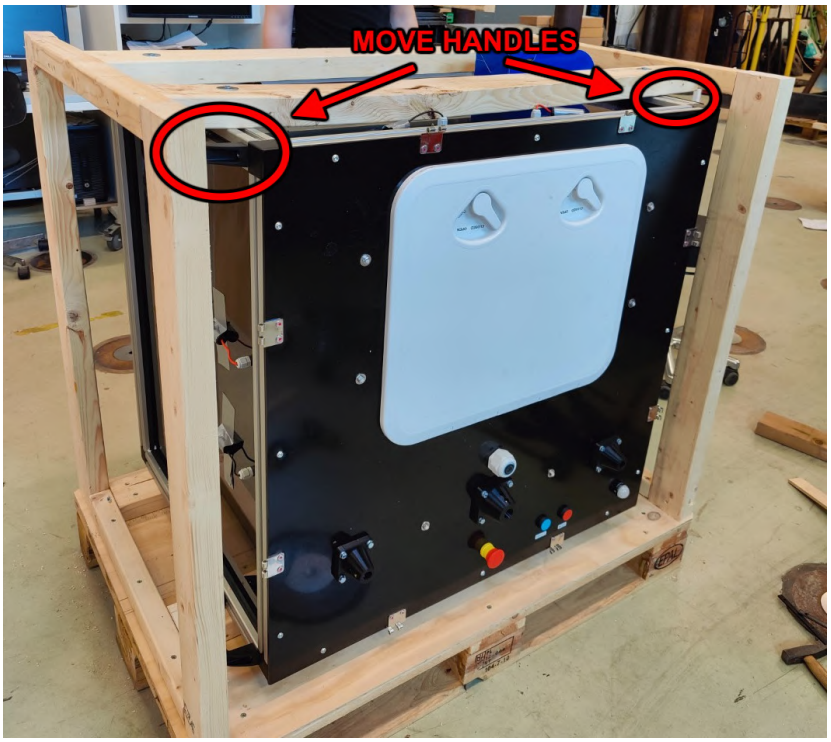


Figure 7: Shipped handle position.

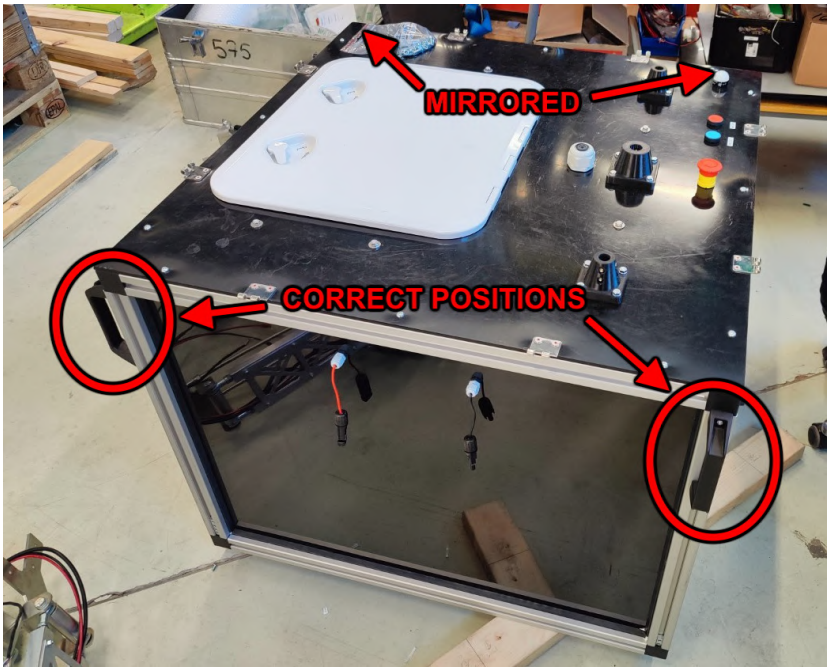


Figure 8: Assembled handle position.

3.2.3 Internal Protection

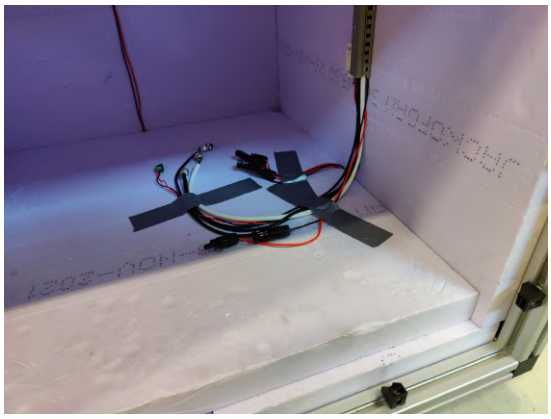
Remove rear cover panel and remove internal felt.

(a) Rear cover panel.

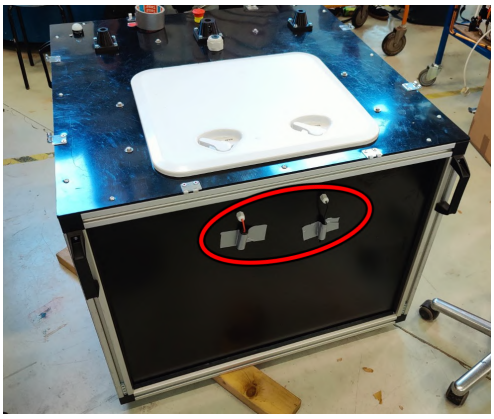
(b) Felt filler.

3.2.4 Cable and Connectors

Remove duct tape securing internal cables and solar panel connectors.



(a) Duct tape securing cables.



(b) Duct tape securing solar panel connectors.

3.2.5 System Antennas

Attach system antennas found in **592A** Additional Parts, inside box below electrical box using set screws found in 6.1.6 Chassis Figure 89b. Feed antenna cables through antenna mounts, top layer insulation and guide along cable trays.

Figure 11: System Iridium and GNSS Antenna.

(a) Mounted Iridium Antenna.

(b) Mounted GNSS Antenna.

3.2.6 Sensor Antenna - Optional

Attach antenna found in **592A** Additional Parts, inside box below electrical box using set screws found in 6.1.6 Chassis Figure 89b. Feed antenna cable through cable gland, top layer insulation, and guide along cable trays.

Figure 13: Sensor Antenna.

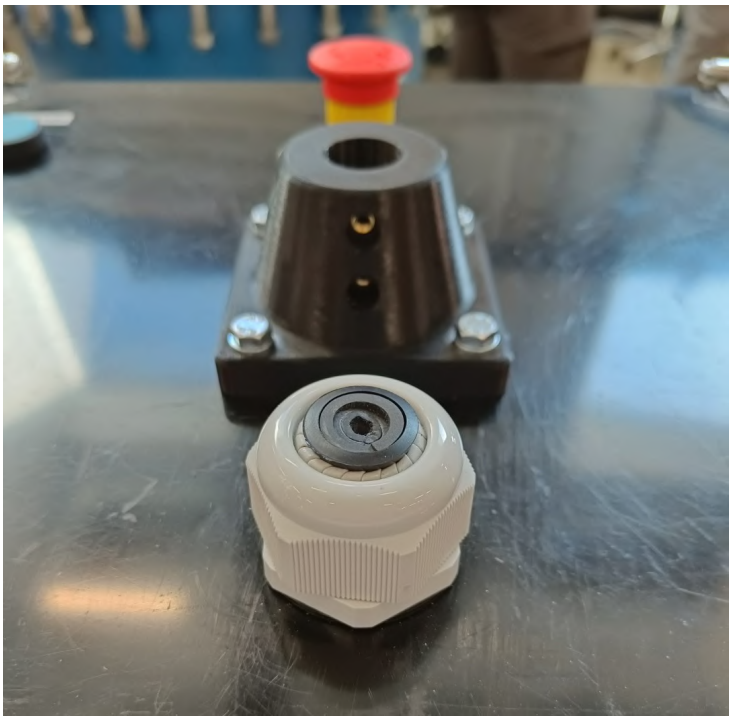


Figure 14: Sensor Antenna mounting position and cable gland.

3.3 Front Motor and Suspension

The front suspension and motor are packed in a 40x80x60 ZARGES crate **(523A)** and weighs 60 kg. The following instructions are repeated for both Left and Right side.

3.3.1 Chassis Orientation

Start by raising the chassis off the ground to get ground clearance. The Chassis and Rover orientation is depicted in Figure 15 and shown fully assembled in Figure 16.

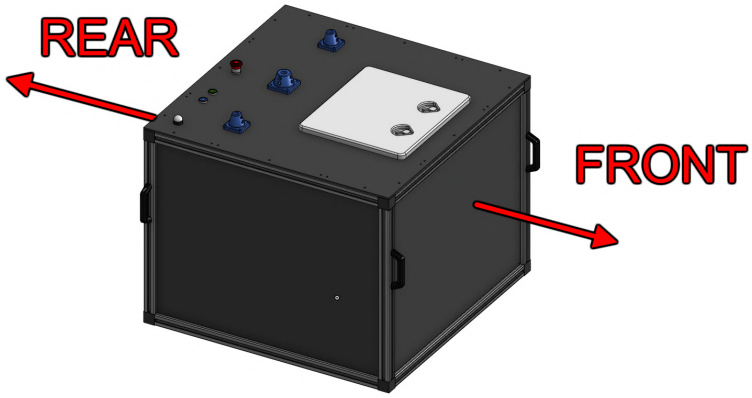


Figure 15: Chassis and System Orientation.

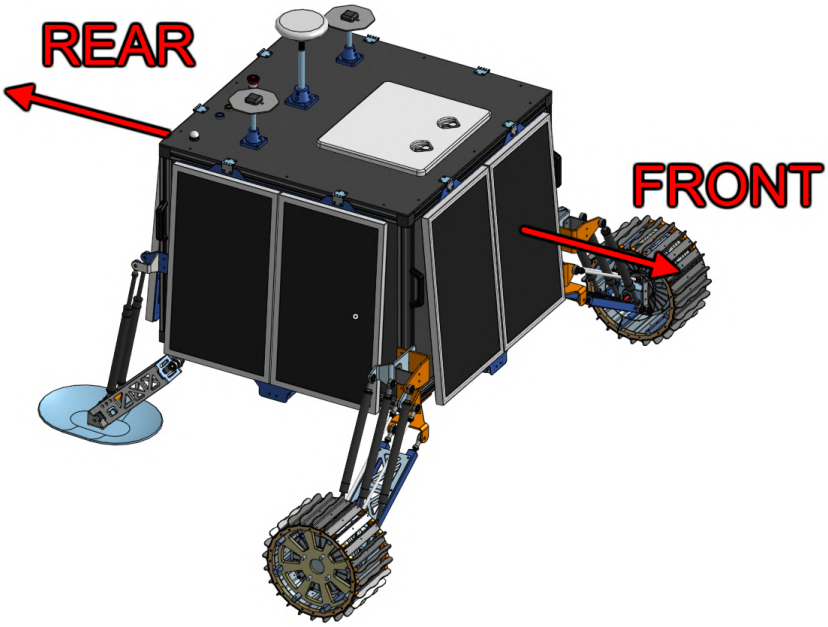


Figure 16: Chassis and System Orientation, Fully Assembled.

3.3.2 Unpacking

Unpack motor and suspension from ZARGES crate, which contains Motor and Wheels attached to Lower Support Arm (LSA) and Upper Support Arm (USA), and Suspension arms attached to Suspension Bracket.

Figure 17: Packaged front suspension and motor ZARGES (523A).

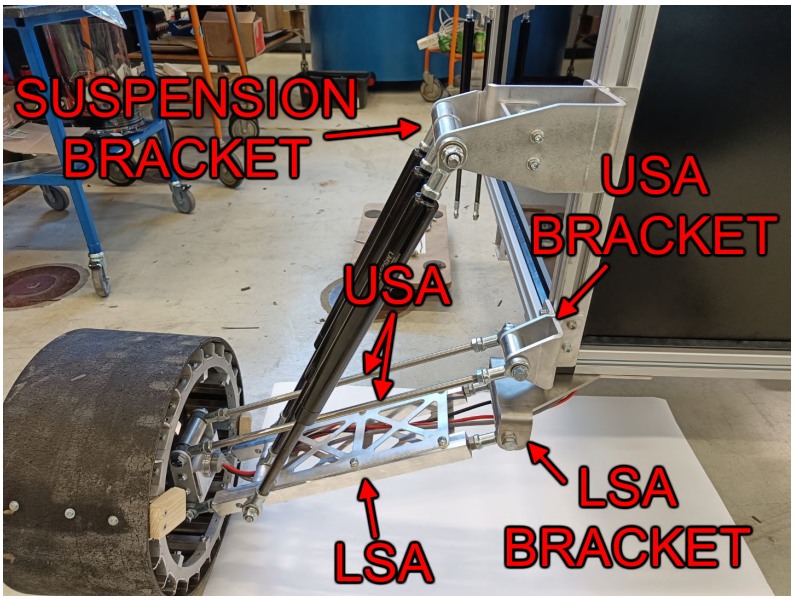


Figure 18: Front Suspension and Motor Components
Lower Support Arm (LSA), Upper Support Arm (USA).

3.3.3 Lower Support Arm (LSA)

Attach Lower Support Arm (LSA) bracket to bottom of chassis using M6x16 bolts and washers found in 6.1.3 Suspension, Figure 82c.

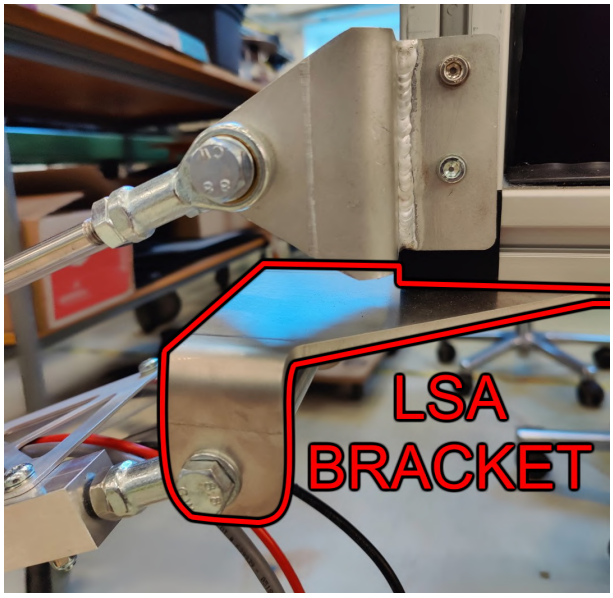


Figure 19: Lower Support Arm (LSA) bracket.

Figure 20: Mounting Lower Support Arm (LSA) bracket to chassis bottom.

3.3.4 Upper Support Arm (USA) Bracket

Attach Upper Support Arm (USA) bracket to corner of chassis using M6x16 bolts and washers found in 6.1.3 Suspension, Figure 82a.

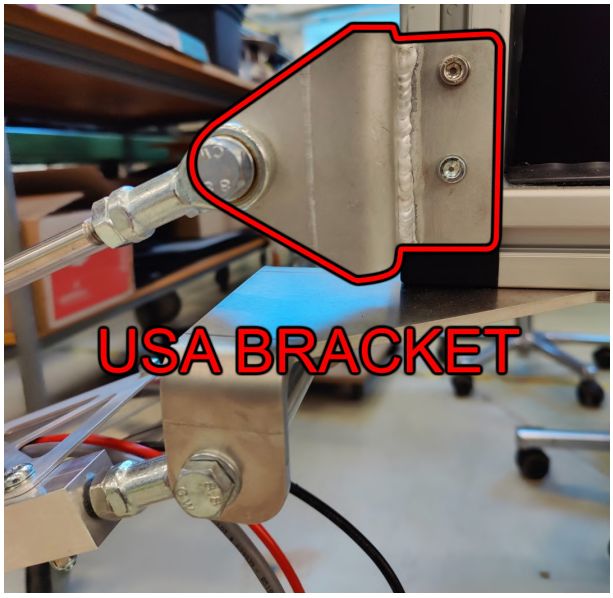


Figure 21: Upper Support Arm (USA) bracket.

Position USA bracket 2 cm from LSA bracket as shown in Figure 22.

Figure 22: Upper Support Arm (USA) bracket position 2 cm from LSA Bracket.

3.3.5 Mount Suspension to LSA

Using threaded rods and spacers mount suspension assembly to LSA. One of two mounting positions can be selected based on desired strength of suspension. Selecting mounting position closest to the motor results in the a weaker suspension.

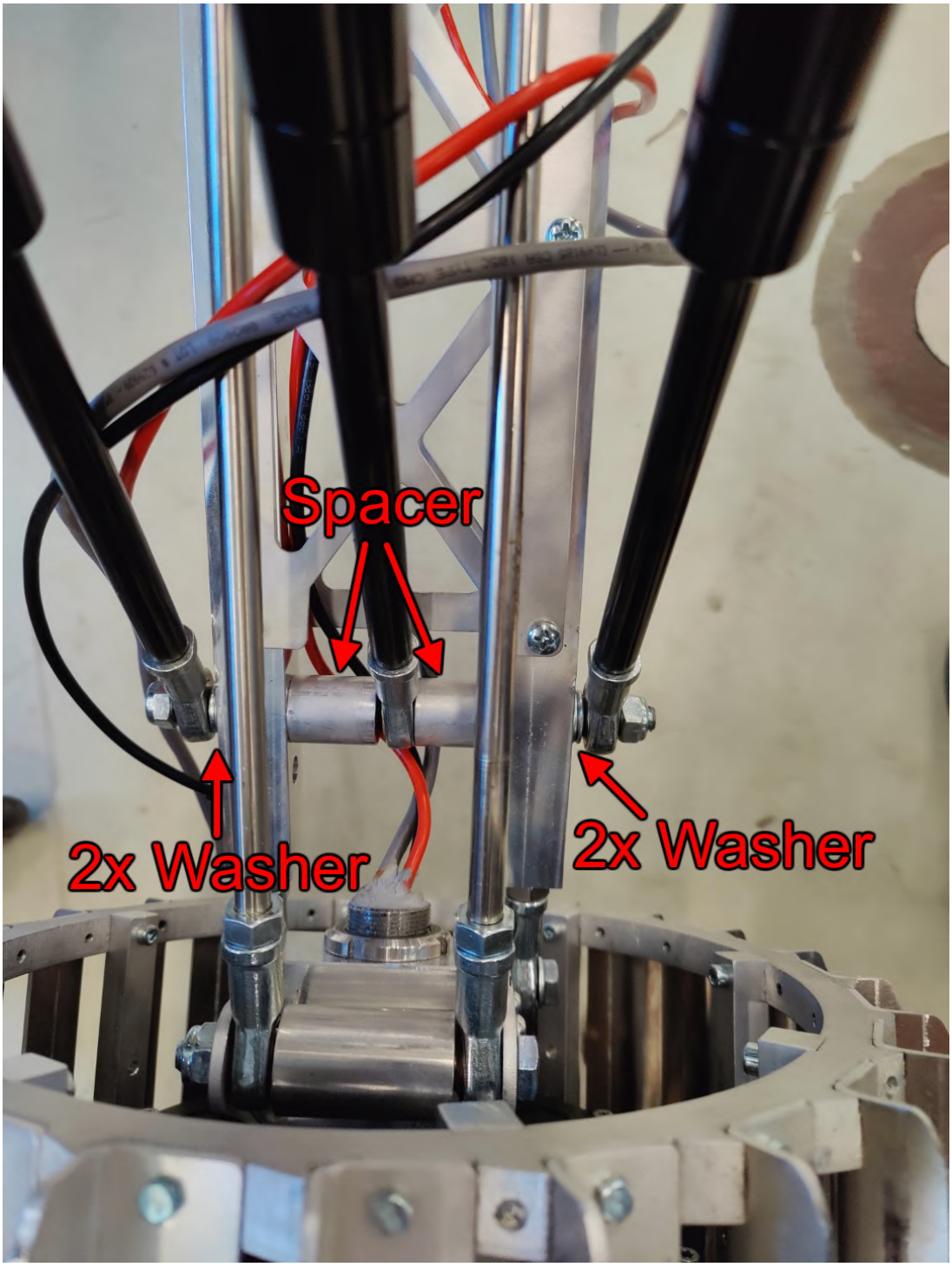


Figure 23: Suspension mounted to LSA.

3.3.6 Front Suspension Bracket

Mount suspension bracket to chassis corner using M6x16 bolts and washers found in 6.1.3 Suspension, Figure 82a. Adjusting the position of the Suspension Bracket will affect ground clearance. A suggested starting height is 25-30 cm above LSA bracket.

Raising bracket position will reduce ground clearance, while lowering bracket position will increase ground clearance.

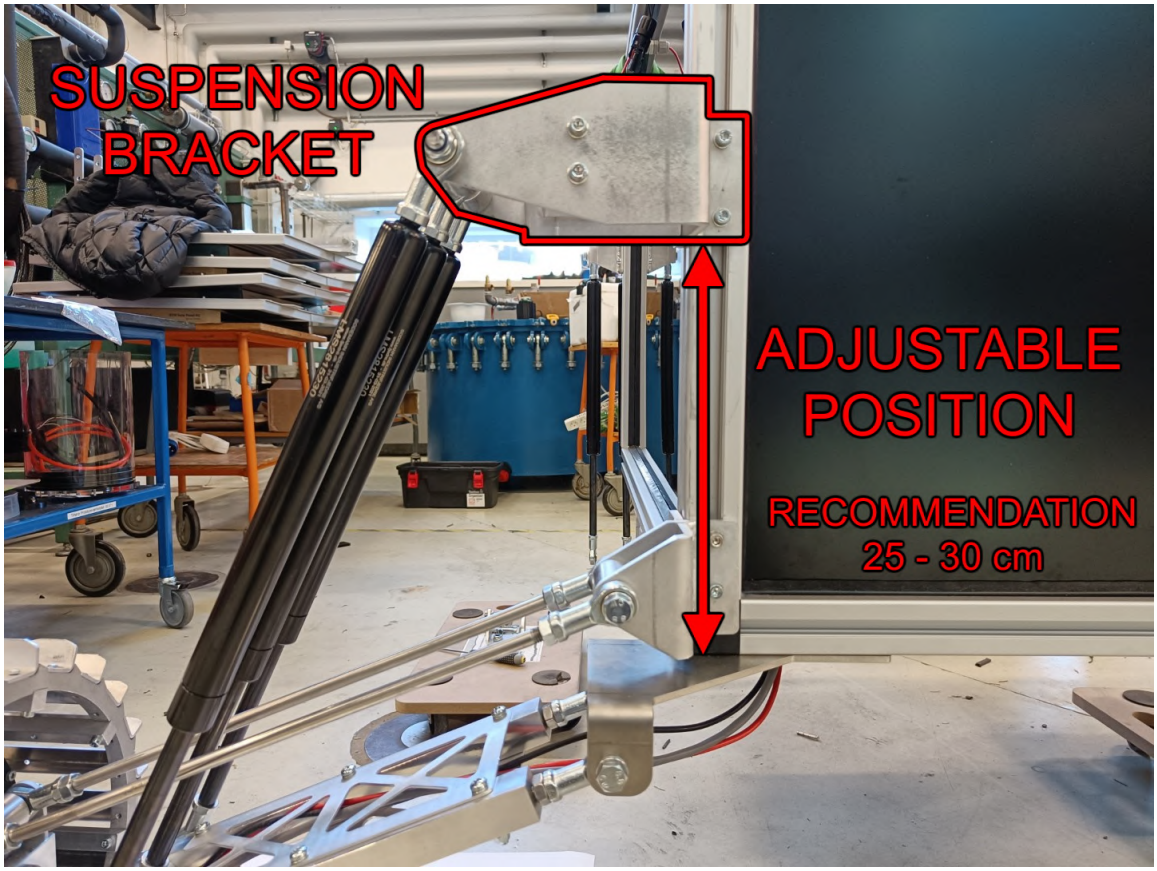


Figure 24: Suspension Bracket mounted to Chassis.

3.3.7 Motor Cables

Push motor power and signal under suspension spacers and pass cable through cable gland at bottom of chassis. Make sure to leave sufficient cable slack to avoid cable damage during suspension movement.

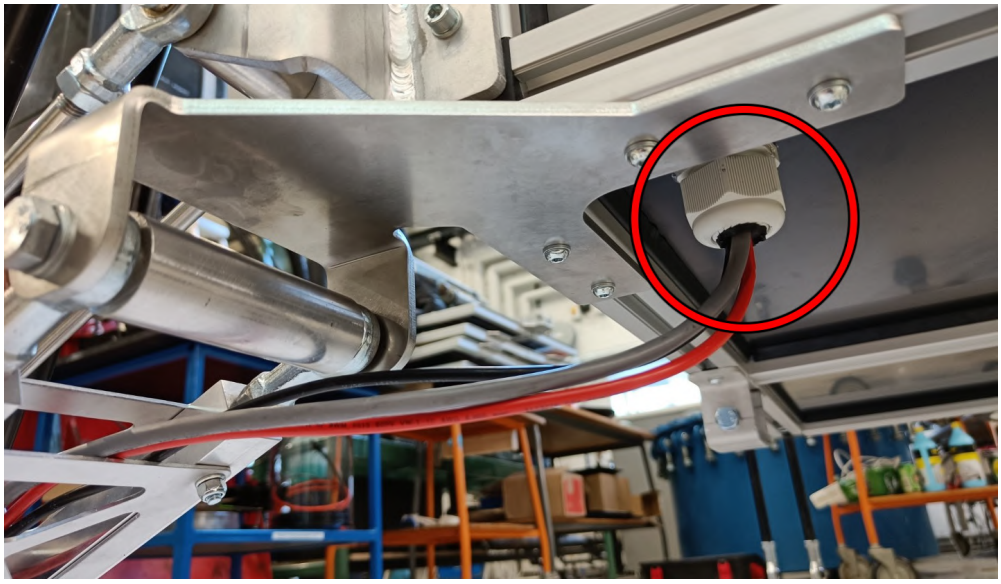


Figure 25: Motor Cables feed into chassis.

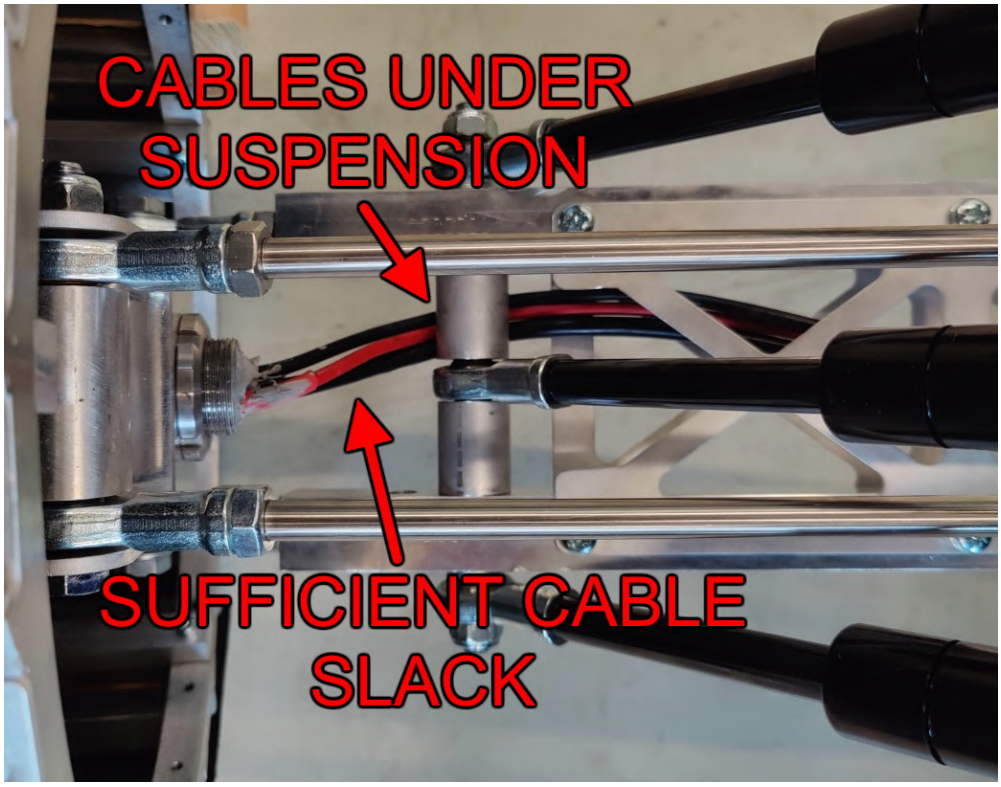


Figure 26: Motor Cables feed into chassis.

3.3.8 Suspension Configuration

If disassembling suspension be sure to reassemble as shown in 3.3.5 Mount Suspension to LSA and below to avoid suspension flex during movement.

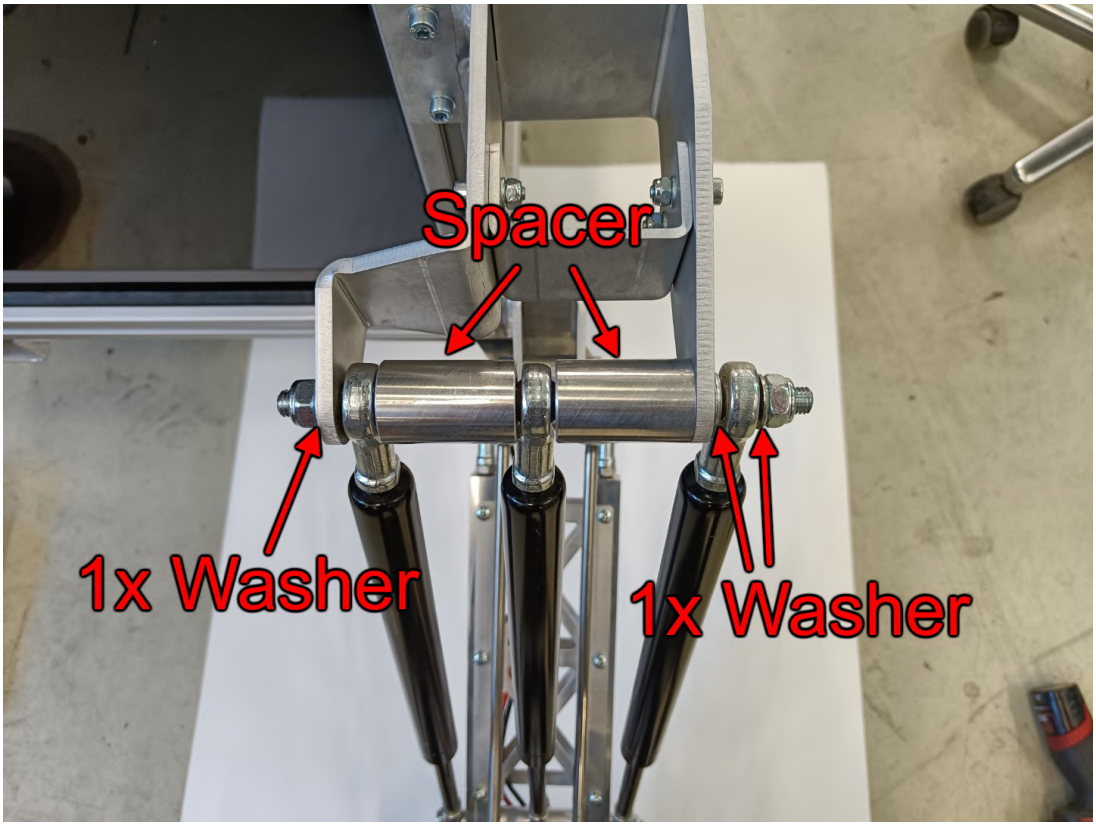


Figure 27: Front Suspension Spacer Configuration Top.

3.4 Rear Ski and Suspension

The rear suspension and ski are packed in a 40x80x60 ZARGES crate **(592A)** the total weight is 45 kg. The following instructions are repeated for both Left and Right side.

3.4.1 Unpacking

Unpack ski and suspension from ZARGES crate, positioned under the electric box.

Figure 28: Packaged ZARGES crate (592A), containing Rear Suspension and Ski.

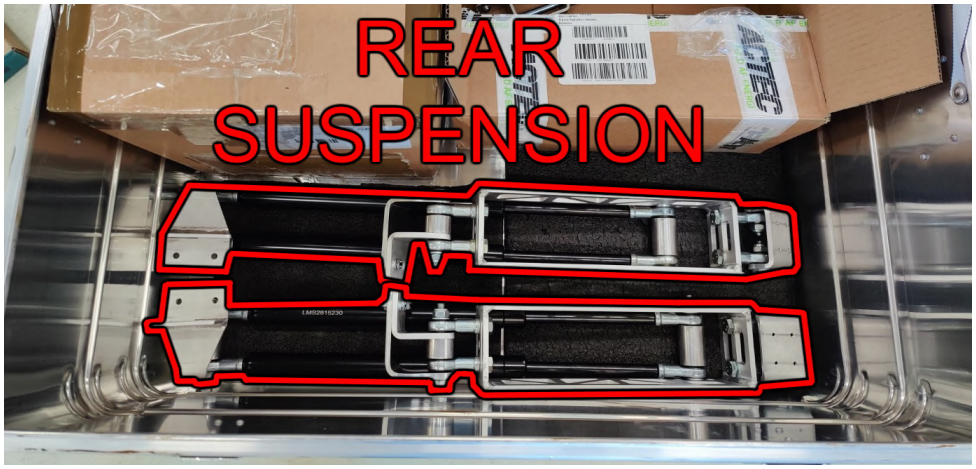


Figure 29: Rear Suspension.

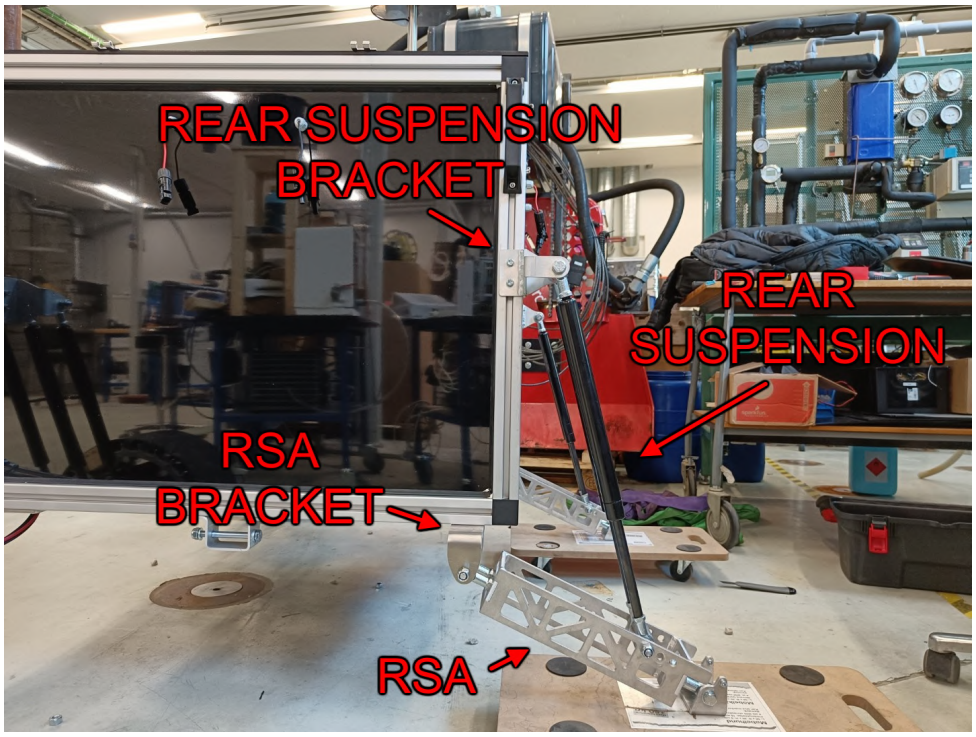


Figure 30: Rear Suspension, Rear Support Arm (RSA), Suspension and Brackets.

3.4.2 Attach Ski to Hinge Bracket

Mount each ski to lower part of suspension using M5x10 found in 6.1.4 Rear Ski Figure 85b.

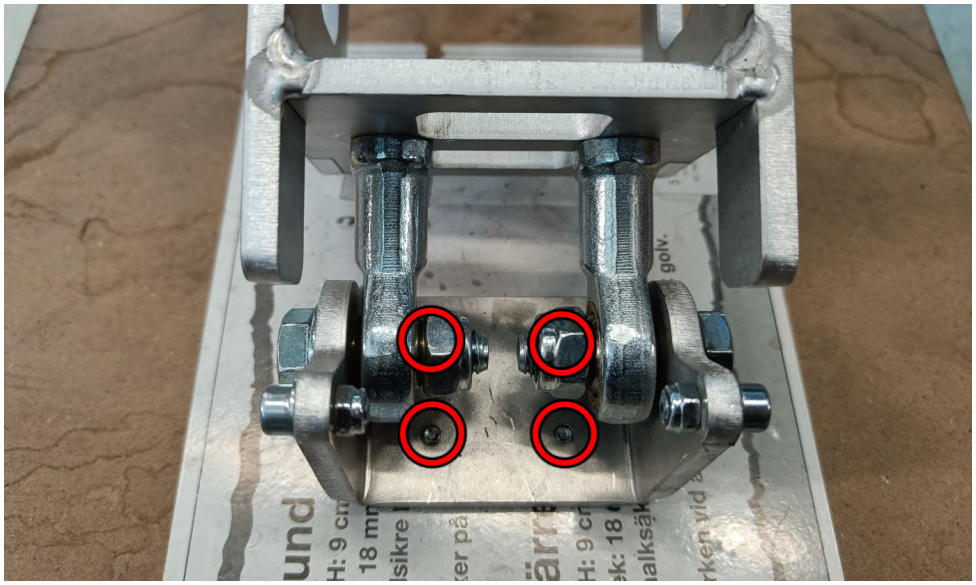


Figure 31: Hinge bracket attachment.

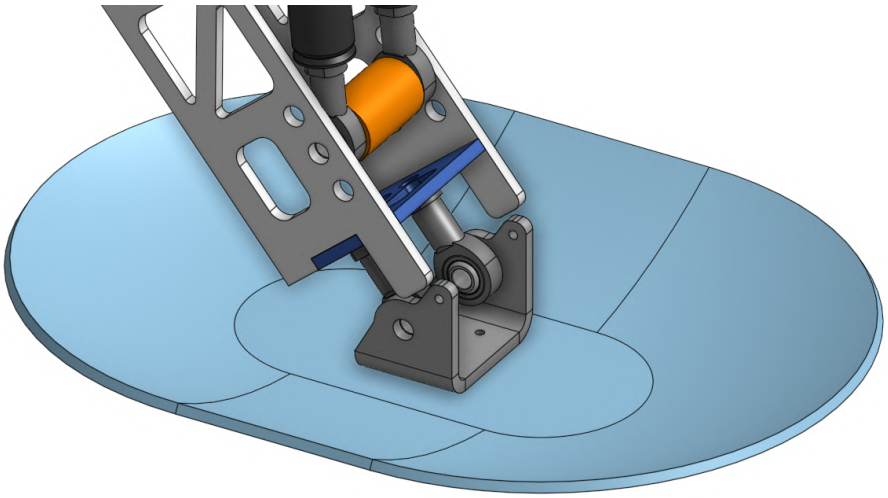


Figure 32: Hinge bracket attachment.

3.4.3 Rear Support Arm (RSA)

Attach Rear Support Arm (RSA) bracket to bottom of chassis using M6x25 hex bolts and 2x washers found in 6.1.3 Suspension, Figure 84a.

Figure 33: Rear Support Arm (RSA) bracket.

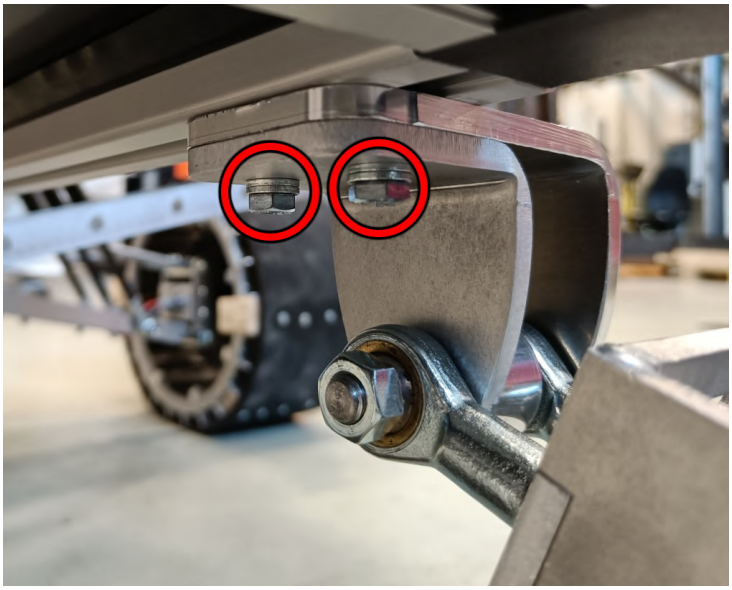


Figure 34: Rear Support Arm (RSA) bracket mounted (2x washers).

Position RSA bracket 5 cm from edge of chassis.

Figure 35: Rear Support Arm (RSA) bracket mounting position 5 cm from edge.

3.4.4 Rear Suspension Bracket

Attach Rear Suspension bracket to chassis using M6x16 bolts found in 6.1.3 Suspension, Figure 84c. Adjusting the position of the Rear Suspension Bracket will affect ground clearance. A suggested starting height is 30-35 cm above RSA bracket.

Raising bracket position will reduce ground clearance, while lowering bracket position will increase ground clearance.

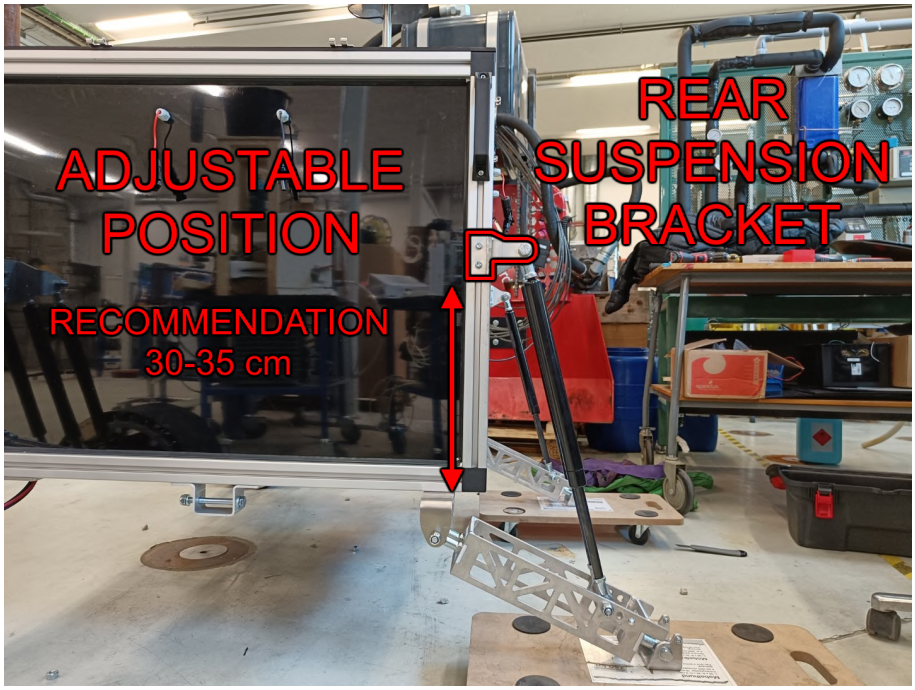


Figure 36: Rear Suspension Bracket and Adjustment.

3.4.5 Suspension Configuration

If disassembling suspension be sure to reassemble as shown below to avoid suspension flex during movement.

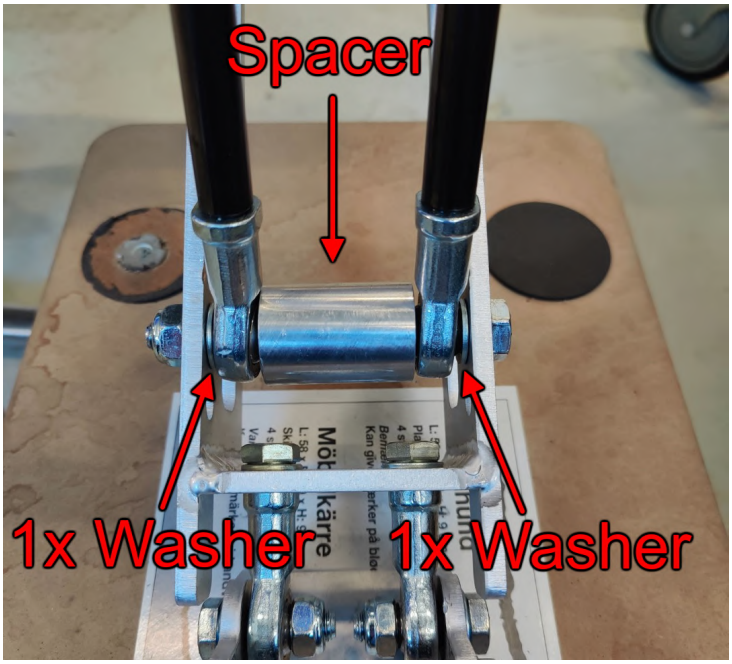


Figure 37: Rear Suspension Spacer Configuration Bottom.

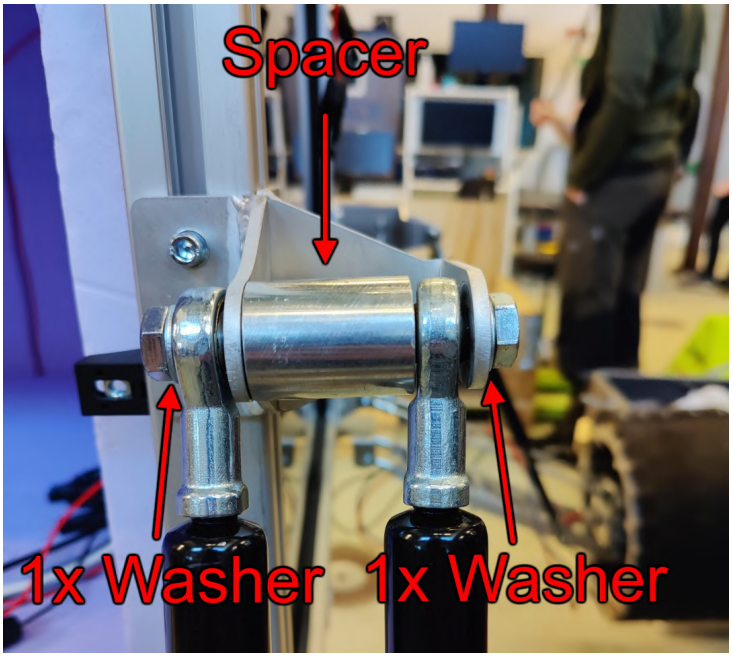


Figure 38: Rear Suspension Spacer Configuration Top.

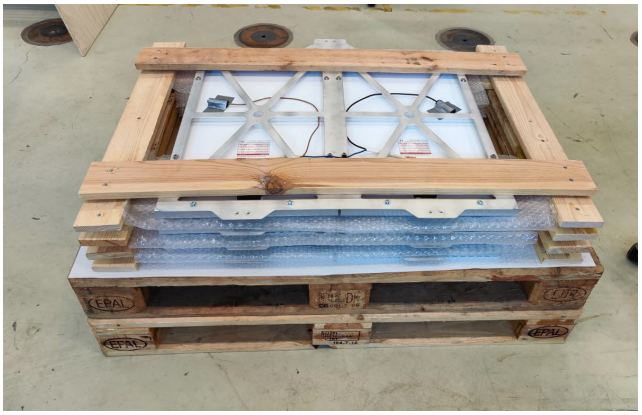
3.5 Solar Panels

The Solar Panels are packed on a pallet 40x120x80cm with a weight of 80 kg. The following instructions describe the mounting process.

3.5.1 Unpacking

Remove wooden frame around solar panels by unscrewing all surrounding panels, frame, and support.

(a) Solar Panel Pallet.



(b) Wood frame.

Unpack Adjustment Brackets found in **592A** Additional Parts, inside box containing antennas and box with all nuts and bolts. Angle Adjustment Beams can be found in **592A** Additional Parts, under the electrical box, next to the rear suspension.

(a) Angle Adjustment Brackets.

(b) Angle Adjustment Beams.

3.5.2 Upper Hinges

Attach two hinges found in 6.1.5 Solar Panel, Figure 87b to each solar panel using the countersunk bolts and lock nuts on each hinge.

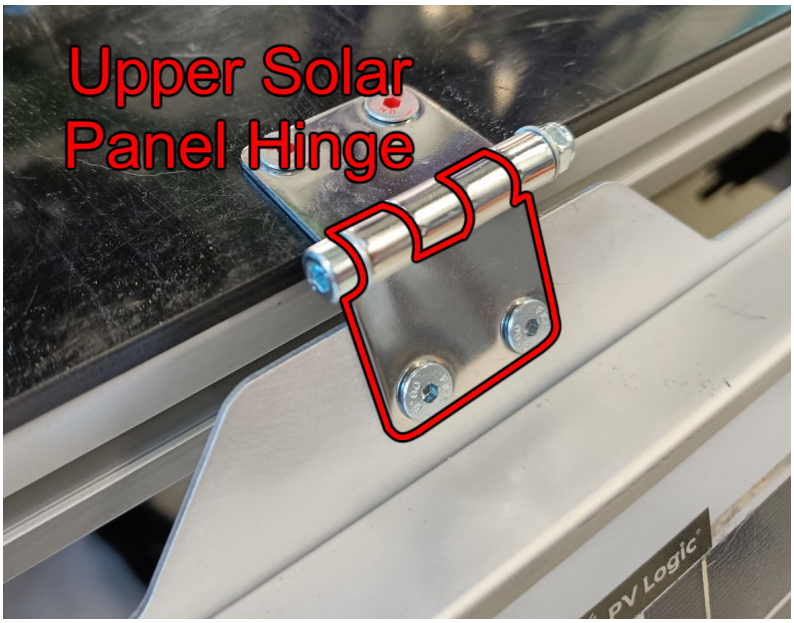


Figure 41: Solar Panel Upper Hinge.

3.5.3 Hinge Bolt

Attach each solar panel to the chassis hinge using the hinge bolt found in 6.1.5 Solar Panel, Figure 87c.

Note: Skip mounting solar panel at rear cover panel until all assembly is complete.

Figure 42: Solar Panel Hinge Bolt.

3.5.4 Angle Adjustment Beams

Attach Angle Adjustment Beams to Solar Panels with M5x16 found in 6.1.5 Solar Panel, Figure 86a.

Figure 43: Angle Adjustment Beams.

3.5.5 Angle Adjustment Bracket

Attach Angle Adjustment Bracket to Chassis bottom with M6x16 button head and washers found in 6.1.5 Solar Panel, Figure 86c.

Figure 44: Angle Adjustment Beams.

Attach Angle Adjustment Beams to Brackets. Each mounting position is an increment of 5 degrees, set according to geographical location.

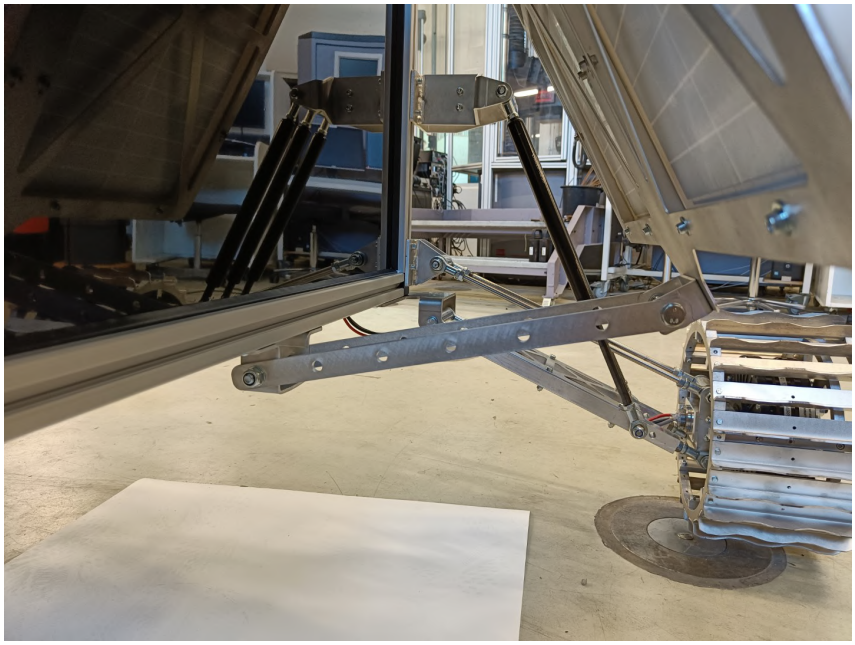


Figure 45: Angle Adjustment Beams.

3.5.6 Power Connectors

Attach each solar panel power cable to its external connectors.

Figure 46: Solar Panel power connector.

3.6 Electrical

The Electrical box is packed in a 40x80x60 ZARGES crate **(592A)** the total weight is 45 kg. The following instructions describe the connection and assembly process.

3.6.1 Cables and Connectors

Access the internal chamber of the chassis via the removable rear cover panel. Ensure motor and antenna cables are fully inserted.

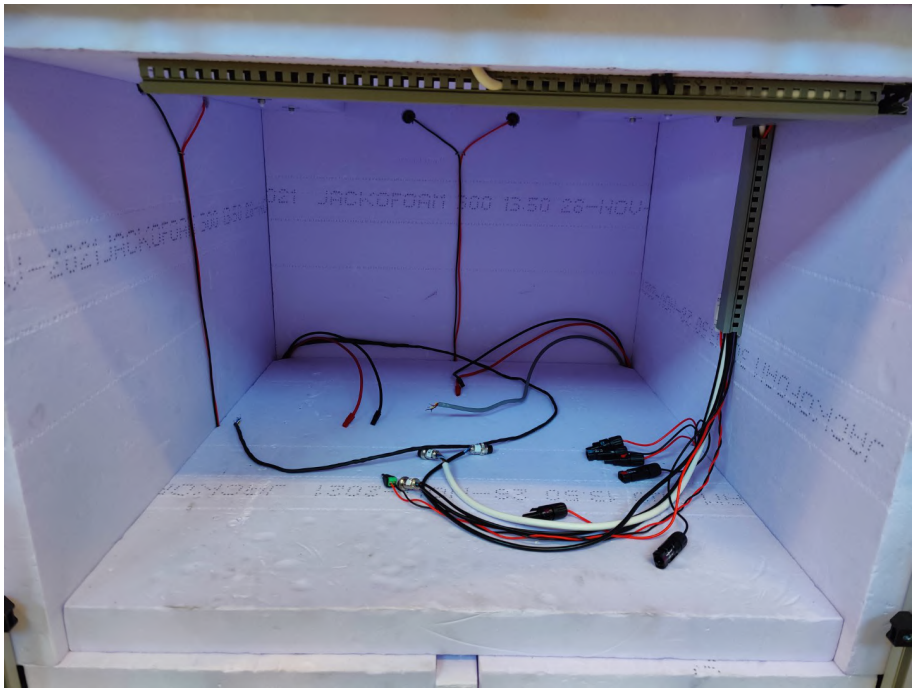
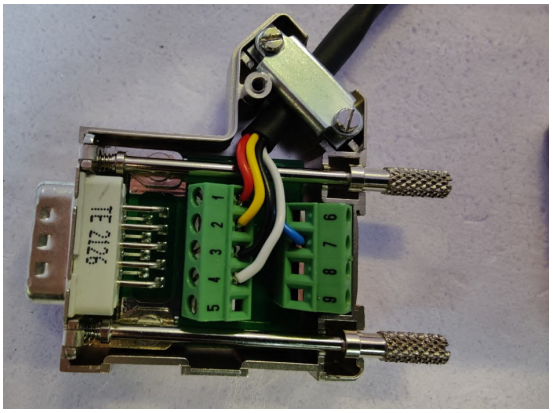


Figure 47: Power and Data cables.

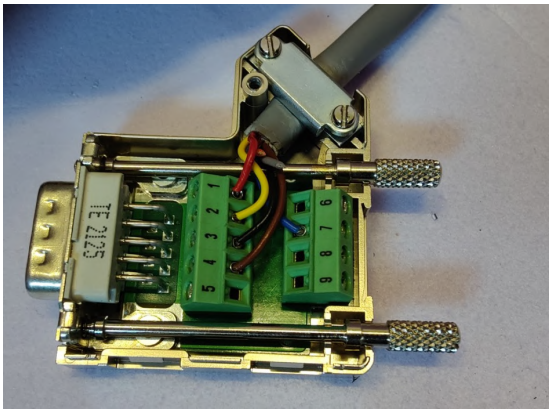
3.6.2 Motor Signal Connector

Connect motor signal cables inside the chassis as shown below, the connector (DB9) are found in 6.2 Wires and Connectors, Figure 90a.

1: VCC (Red), 2: CAN Low (Yellow), 3: GND (Black), 4: HW Enable (White or Brown), 7: Can High (Blue).



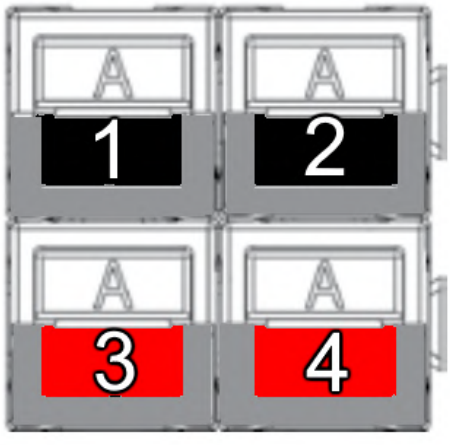
(a) Motor Signal Connector (Left).



(b) Motor Signal Connector (Right).

3.6.3 Motor Power Connector

Combine motor power connectors as shown below, compare with motor power surface connector on rear of electric box and connect.



(a) Motor Connection Configuration
1: GND, 2: GND, 3: VCC, 4: VCC.

(b) Anderson connector.

3.6.4 Electric Box - Front Connections

Position electric box in center of chassis internals. Connector cables as shown below. Take notice of LED, E-STOP, and BTN cable color and cable type. USB A-A cable can be found in 6.2 Wires and Connectors, Figure 93c.

- LED: single black thin 4-wire
- E-STOP: single white thick 4-wire
- BTN: double black thick 2-wire

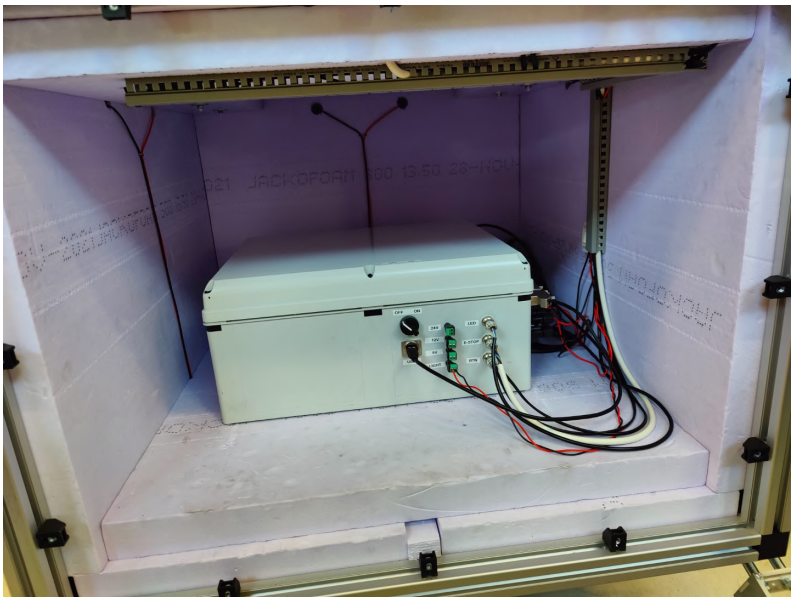


Figure 50: Electric Box.

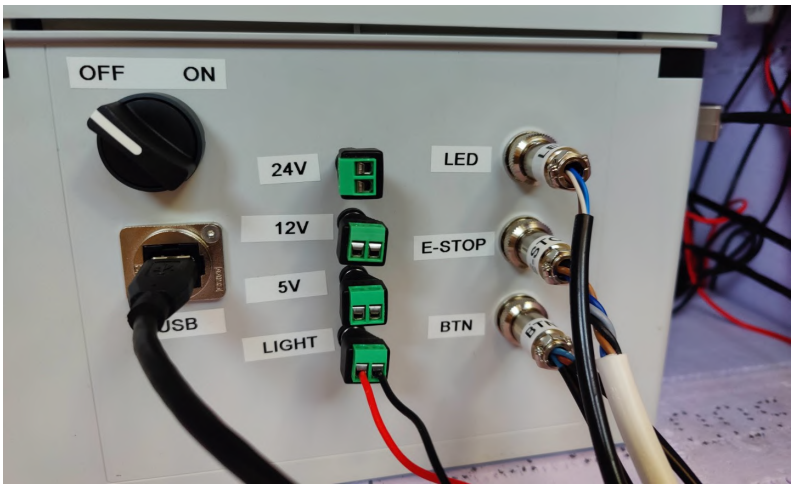


Figure 51: Front Electrical connections.

3.6.5 Electric Box - Solar Panel Plugs

Each solar panel pair (Positive and Negative Leads) are marked in colored pairs. Connect solar panels in vertical pairs as shown below.

Notice: as long as solar panels are connected together in pairs (Positive and Negative Leads) any connection can be used, connect pairs according to lengths.

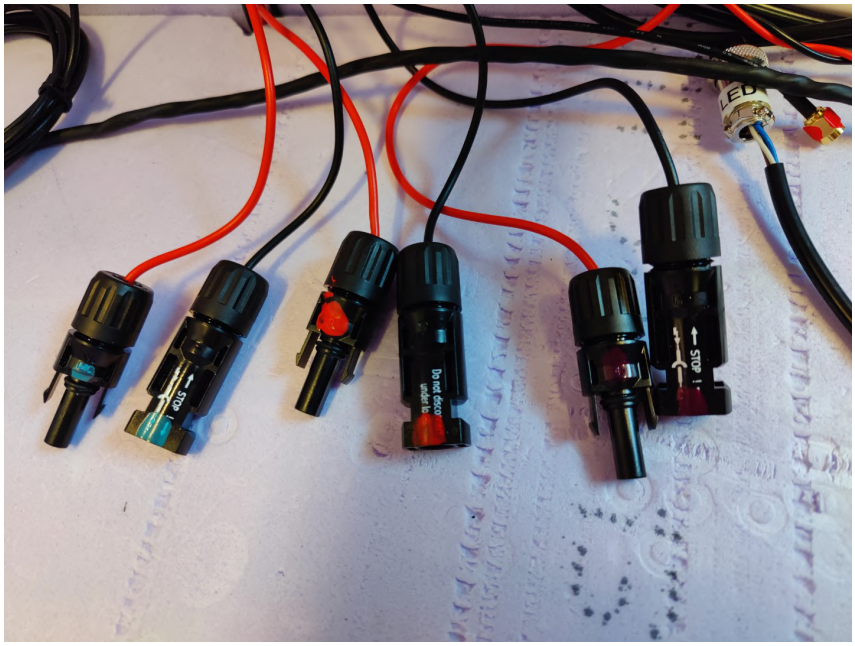


Figure 52: Solar Panel Connector Pairs.

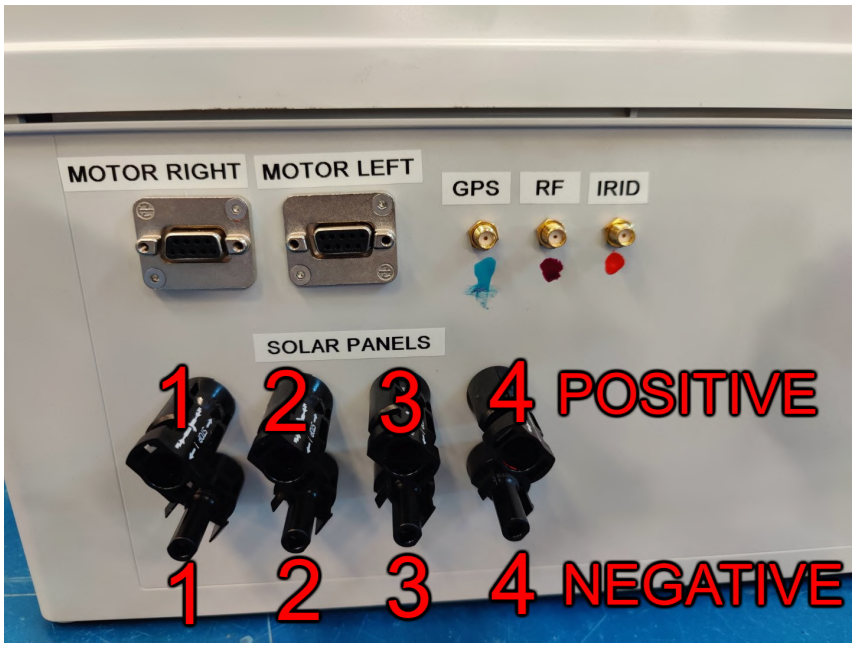


Figure 53: Electric Box, Solar Panel Vertical Pairs.

3.6.6 Electric Box - Antennas and Motor Signal

Assemble Motor Signal and Antenna connections to side connections as shown below.

Notice: Motor Left and Motor Right are interchangeable, connect cables according to lengths.

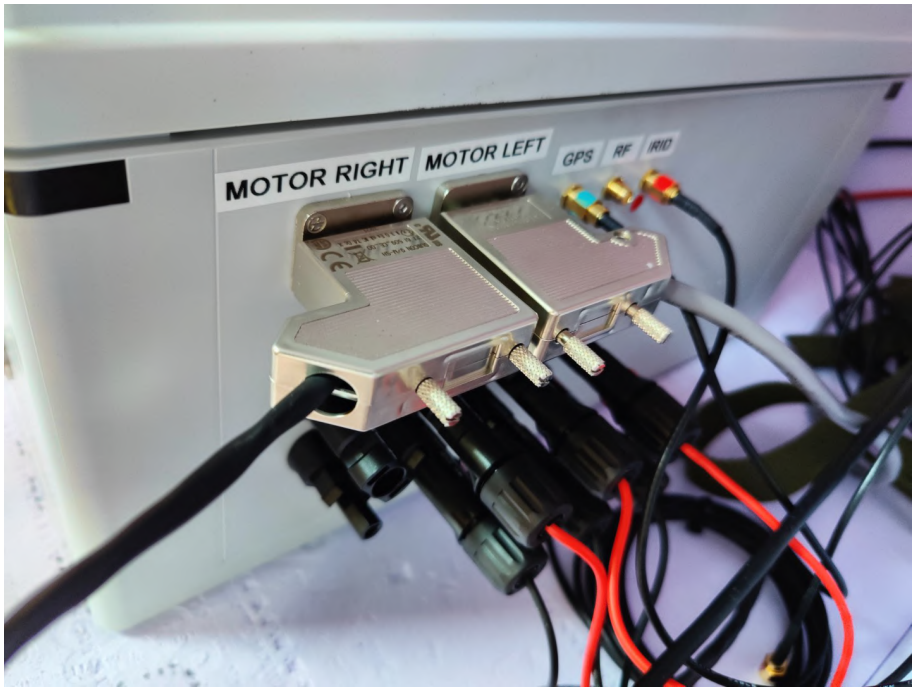


Figure 54: Side Electrical connections.

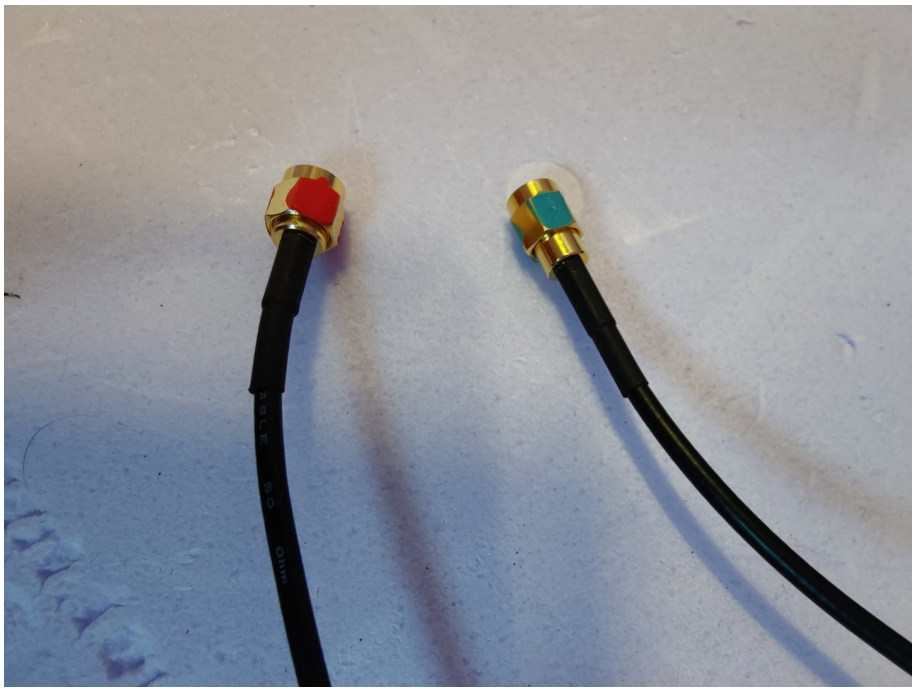


Figure 55: Antenna Cables (GPS Blue, Iridium Red).

3.6.7 Cable Channels

Secure all possible cables inside cable channels and ensure all connections are firmly secured.

Figure 56: Cable Channels.

3.7 Batteries

All batteries are packed in a 40x40x60 ZARGES crate **(469)**, with a weight of 30 kg.

3.7.1 Unpacking

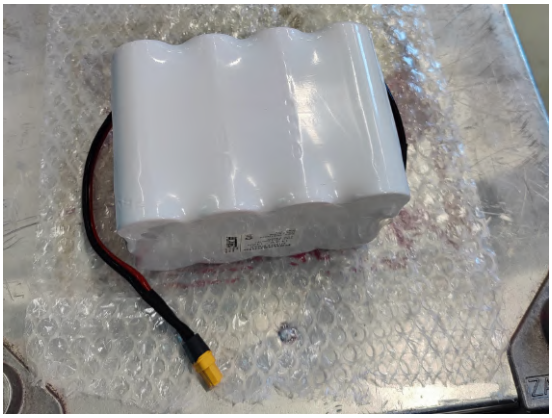
Unpack batteries from ZARGES crate **(469)**, take notice to not puncture any cells when unwrapping each pack.

(a) Battery Crate (469).

(b) Battery Packaging.

Figure 57: Battery Packaging

(a) Wrapped Module.



(b) Unwrapped Module.

Figure 58: Battery Modules

3.7.2 Installation

Battery modules are connected two in series and up to four in parallel for a total of eight battery modules. Install any even number of batteries into the system. Open the electric box and insert batteries into battery brackets.

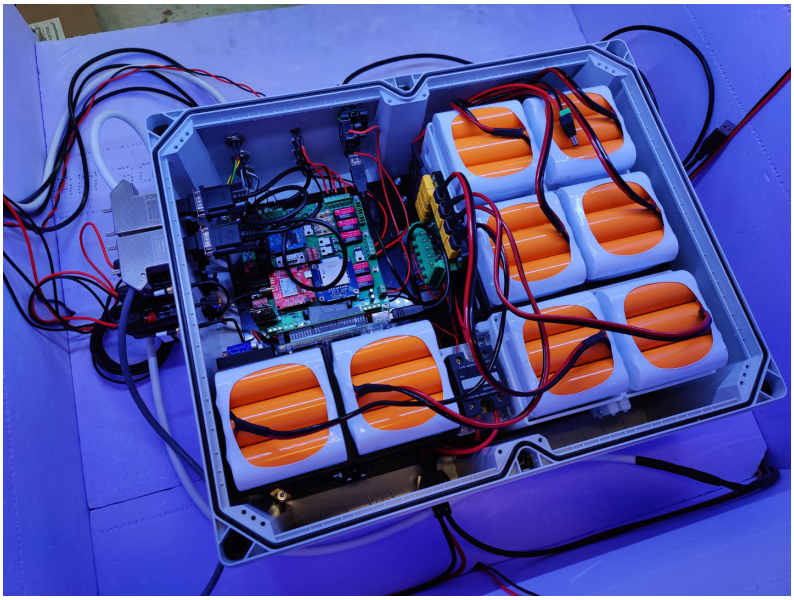


Figure 59: Eight installed battery modules.

Connect battery modules to Power Distribution Board (PDB) XT60 connectors. All modules are interchangeable, connect according to cable lengths. If less than eight battery modules are installed, be sure to connect an even number of modules in any AB configuration. AB1, AB2, AB3, AB4

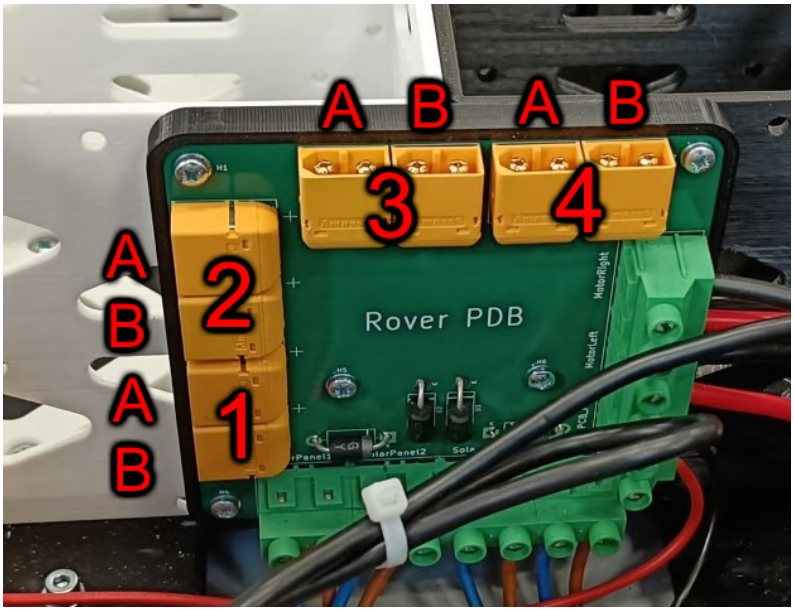


Figure 60: Power Distribution Board (PDB) module pairing.

3.8 Final Assembly

The final assembly steps runs through some initial system tests.

3.8.1 Power Distribution

Check power distribution by turning on the system. Rotate Rover power switch to the **ON** position. Once powered on system LED indicator should start flashing based on current mode.

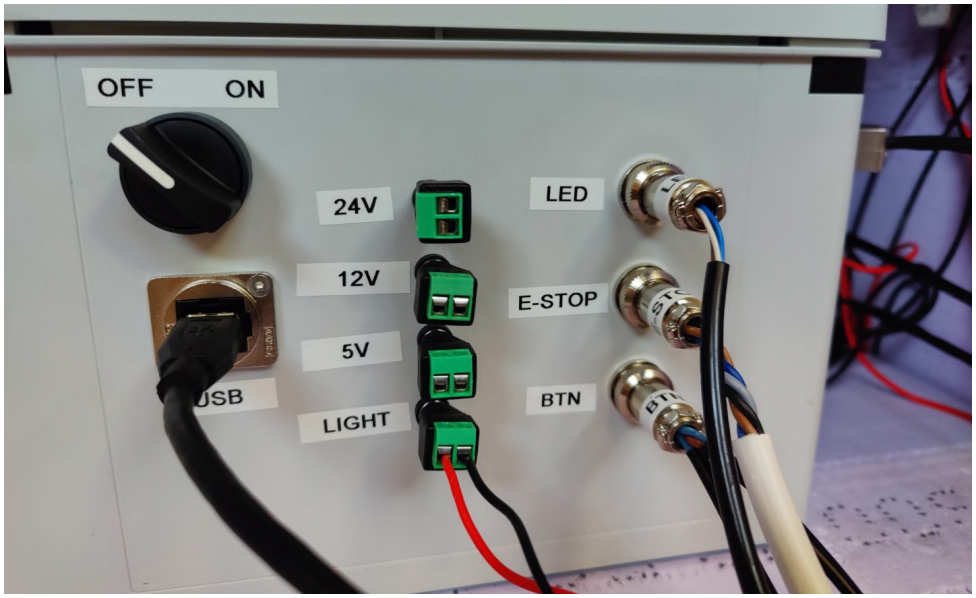


Figure 61: Power On Switch.

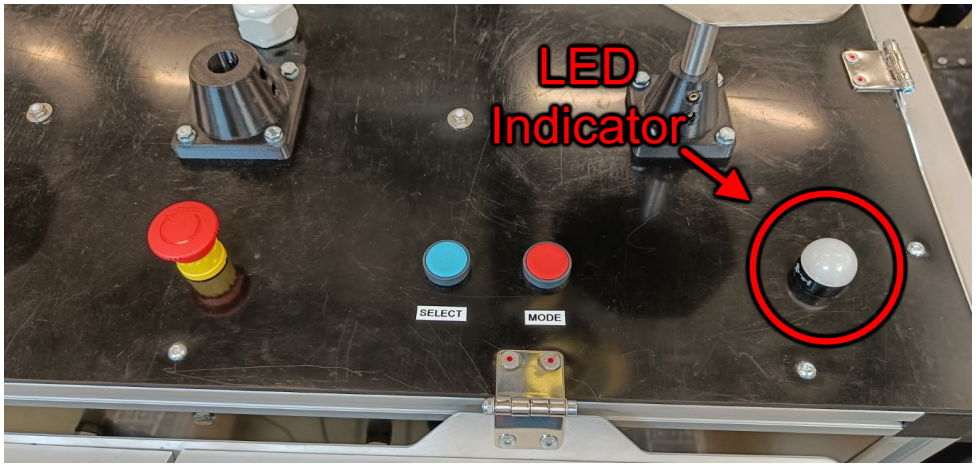


Figure 62: LED indicator.

3.8.2 LED strip

Check built-in LED strip by turning on LED switch, make sure Rover power switch is in the **ON** position.

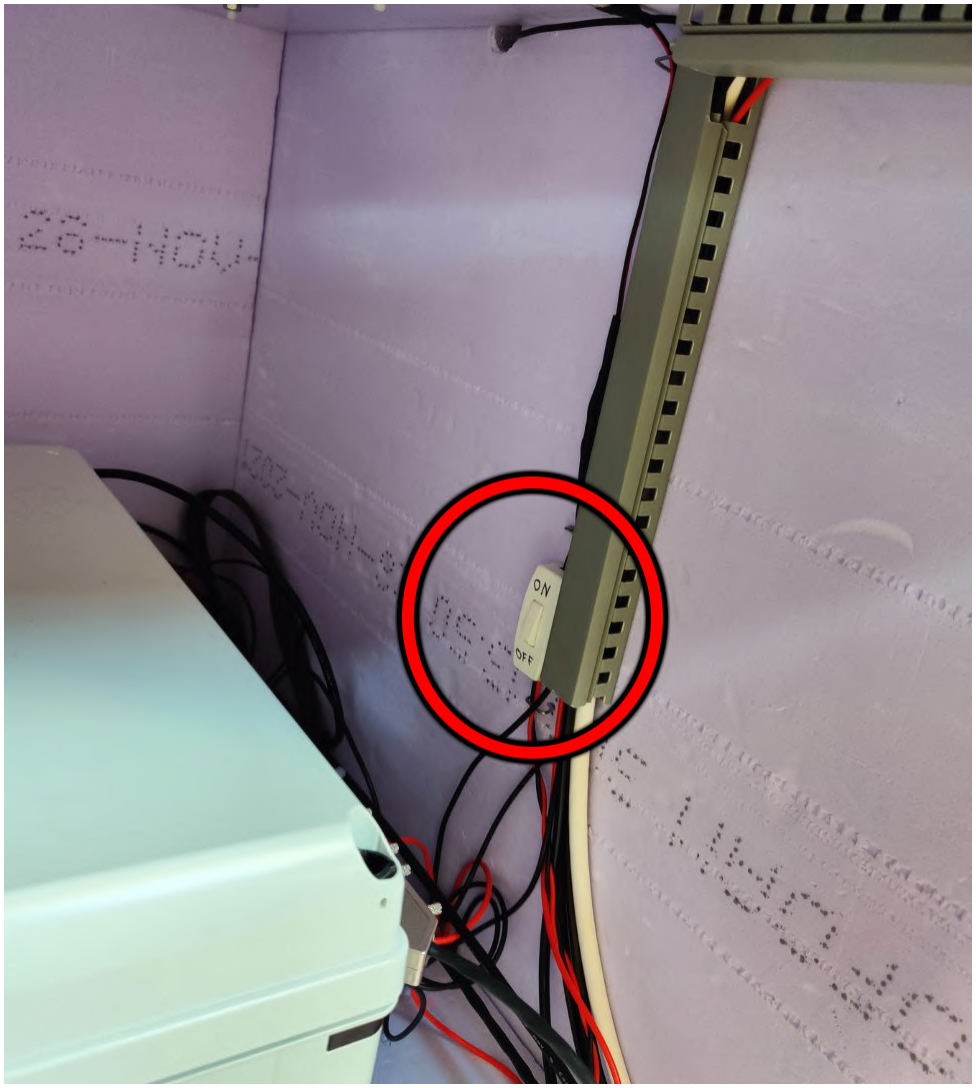


Figure 63: LED strip power switch.

3.8.3 E-STOP

Check Emergency Stop button, once pressed the LED indicator should start flashing red. Rotating emergency button to its unpressed position should reset, LED indicator should flash green followed by periodic yellow flashing.

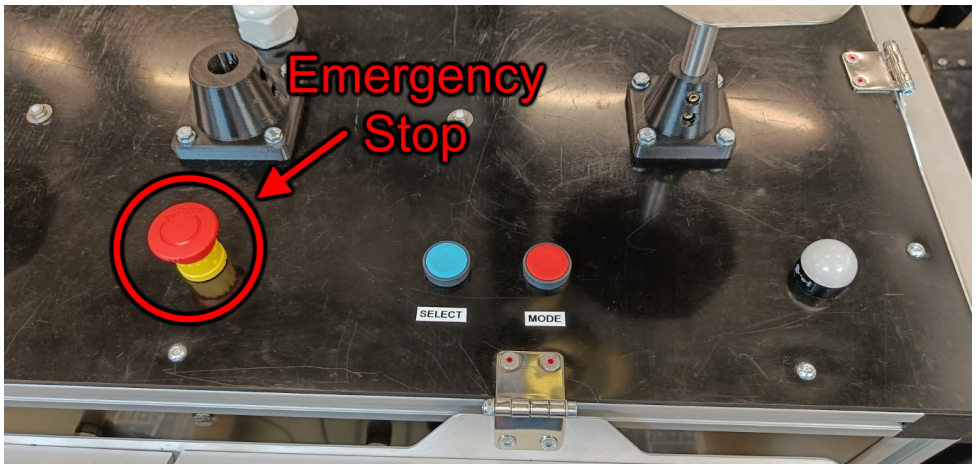


Figure 64: Emergency Stop Button.

3.8.4 Input Buttons

Check Input Buttons, pressing Mode button (Red Button) should set the rover to Mode Library. In this mode consecutive Mode Button presses cycles between available modes. This is indicated by changes in LED indicator colors.

Pressing the Select Button (Blue Button) selects the current mode, additional Select Button press activates current mode functions. Cycle mode until the LED indicator flashes Yellow and Green (Remote Control) and press Select Button. LED indicator should flash, after a second press Select Button again and the LED indicator should flash several times.

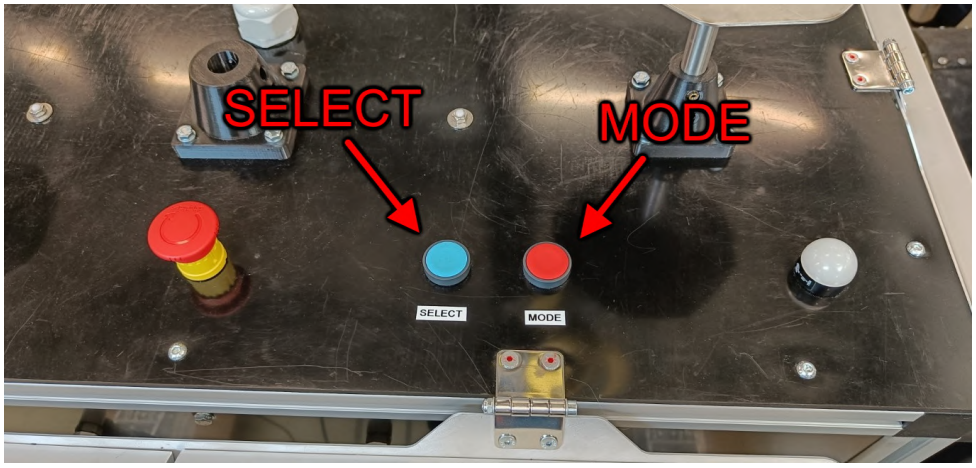


Figure 65: MODE and SELECT input buttons.

3.8.5 Reattach Electric Box Cover

Once all systems are successfully confirmed functional, reattach electric box cover. Remember to connect heating element cable attached to the electric box cover. And turn system power switch to the **OFF** position.

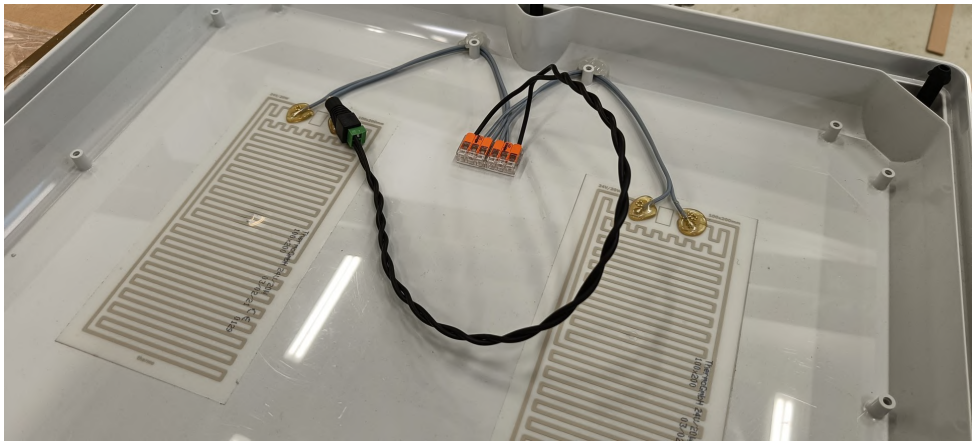


Figure 66: Heating Element positioned in electric box cover.

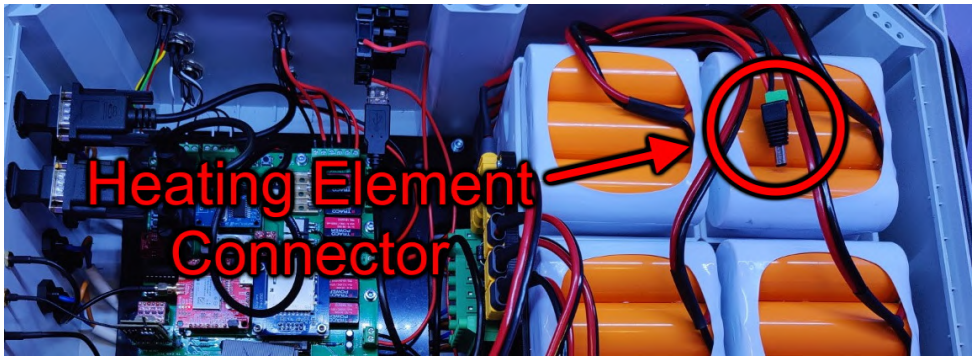


Figure 67: Heating Element positioned in electric box cover.

3.8.6 Rear Cover Plate

Install rear cover plate once all systems are successfully confirmed functional. When installing plate, connect Solar Panel plugs to the remaining two connectors on the side of the electric box. Attach rear plate with M6x20 hex bolts and washers found in in 6.1.6 Chassis, Figure 88a.

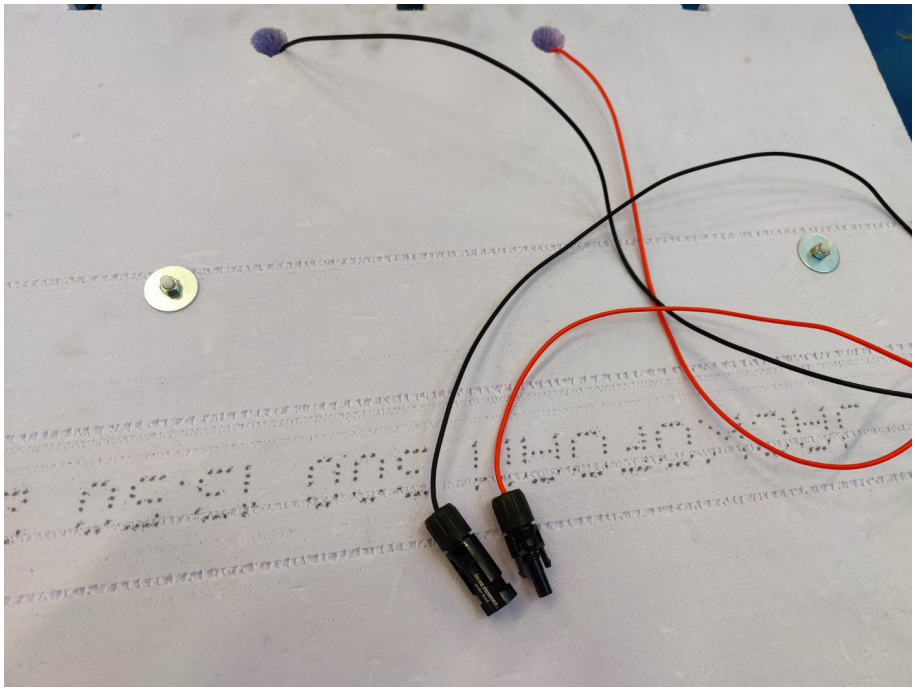


Figure 68: Rear Cover Plate solar panel connectors.

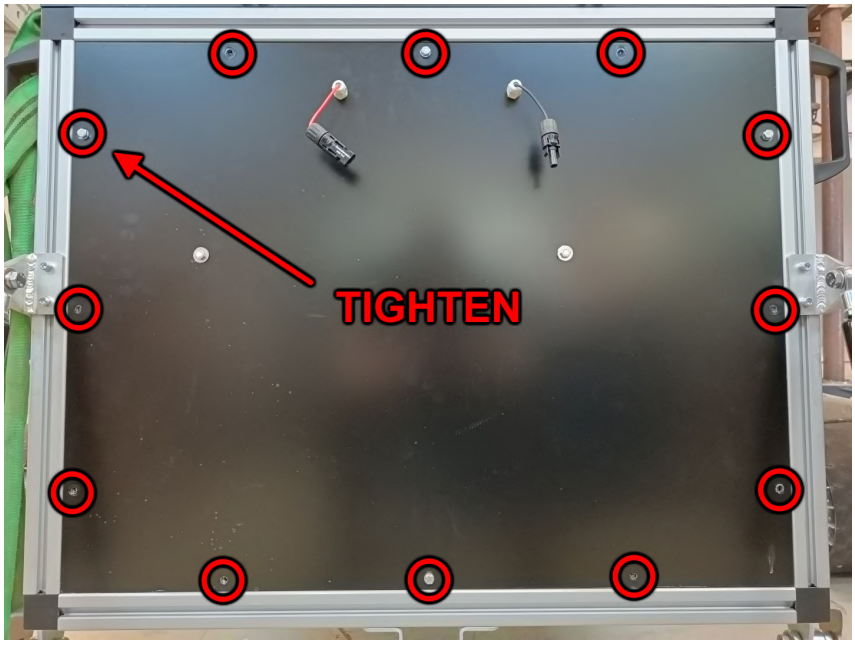


Figure 69: Rear Cover Plate Mounting.

3.8.7 Final Solar Panel

Attach the final solar panel to the rear cover plate following the procedure in 3.5 Solar Panels.

3.8.8 Suspension Adjustments

Adjust suspension height until rover is sufficiently level. The ideal configuration has the front slightly higher compared to the back. Adjustments are done as explained in 3.3.6 Front Suspension Bracket and 3.4.4 Rear Suspension Bracket.

3.8.9 Complete

The system should now be fully assembled and operational.

Figure 70: Fully Assembled System (Hard Surface Configuration).

4 System Manual

The Arctic Rover is primarily an autonomous system. A set of waypoints are specified and once active the rover will autonomously navigate between the waypoints. Once power reaches a set discharge threshold a charge cycle begins, from here driving is halted until a satisfactory power level is achieved. Once power levels have reached a recharge threshold driving resumes. This continues until the final waypoint is reached. The route can be configured as Halt At End (HAE) or Repeat At End (RAE).

Primary System Communication can be handled via USB communication directly to the on-board firmware. This is also the primary way to update onboard firmware.

Diagnostics, status and daily reports are reported via Iridium, additionally new routes and commands can be sent to the Autonomous Rover via Iridium.

The system can be remote controlled for short range mobility using a supplied FrSky Taranis X9D controller.

4.1 System Indicator

The primary system indicator is a three color LED indicator. This indicator flashes a color based on the current mode and status.

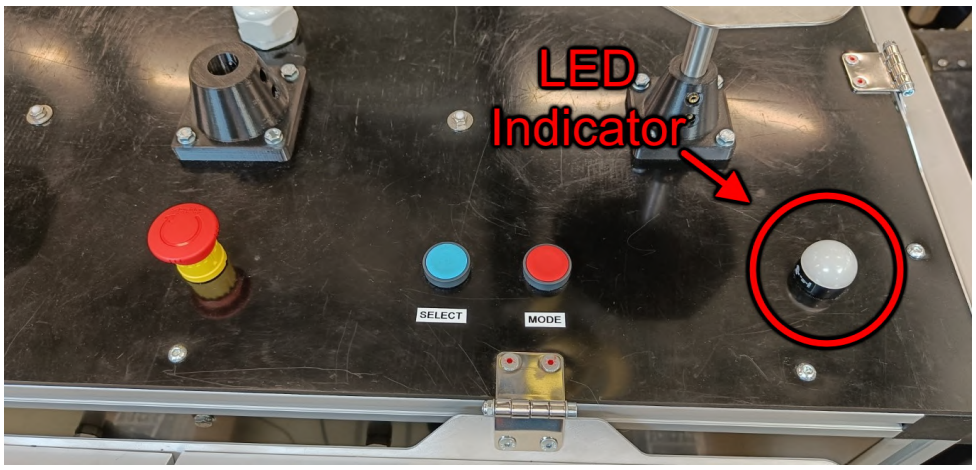


Figure 71: Three color LED indicator.

4.2 System Inputs

Five primary inputs exist for the Rover: 3x Input Buttons, 1x USB Connection, 1x Iridium Long Range Connection.

4.2.1 Emergency Stop Button

This button cuts motor power, reboots the Primary CPU and sets the mode to an Emergency Mode. When in this mode the LED indicator will continuously flash red. All system inputs are discarded until the Emergency Stop Button has been reset by rotating the Emergency Stop Button.

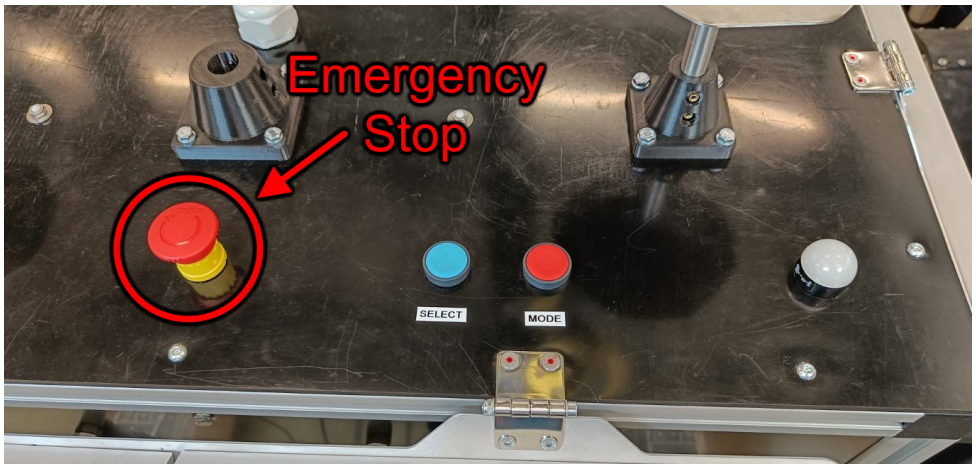


Figure 72: Emergency Stop Button.

4.2.2 MODE Button

First press of the Mode button (Red Button) activates Mode Library. In this mode consecutive Mode Button presses cycles between available modes. This is indicated by changes in LED indicator colors.

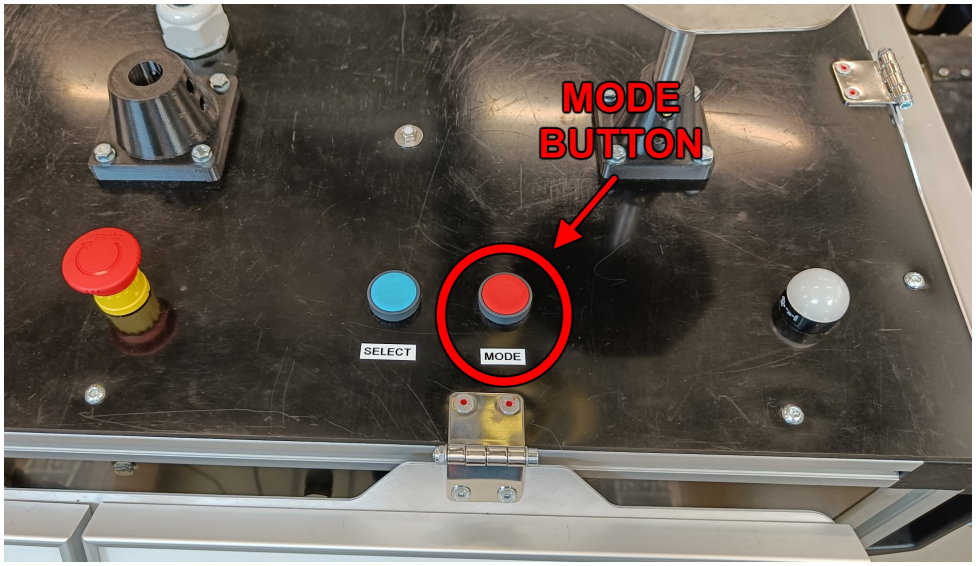


Figure 73: MODE input button.

4.2.3 SELECT Button

Pressing the Select Button (Blue Button) selects the current mode, additional Select Button press activates current mode functions.

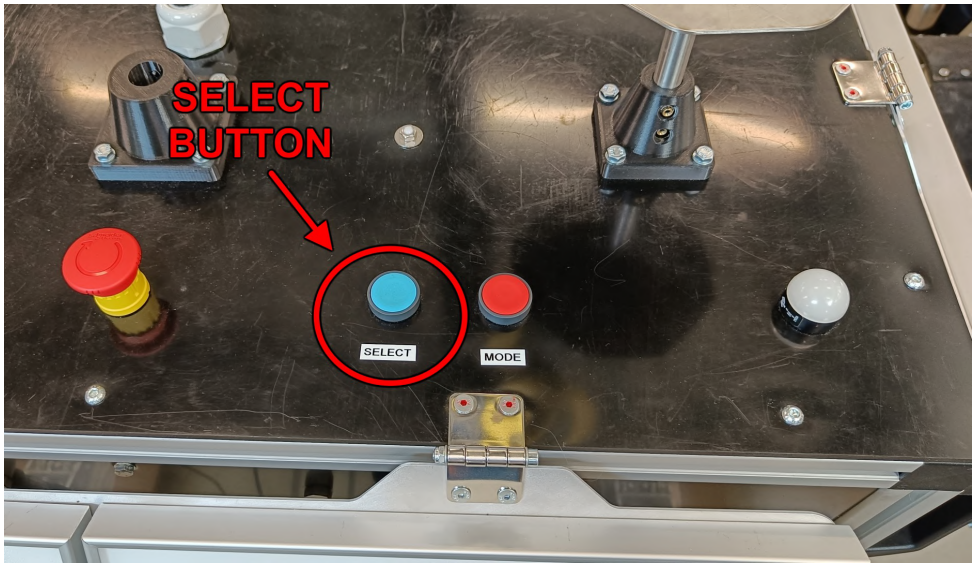


Figure 74: SELECT input button.

4.3 Modes

When cycling modes with the MODE button three modes are available: Idle, Remote Control, and Autonomous. The Status Indicator LED will flash with a color code indicating current mode.

4.3.1 Idle

Color Code: Yellow

Select Function: Non

In Idle mode the Rover all outputs except for primary (Blackbox, GNSS, and Iridium) all disabled. This mode can be used to test individual components while connected to the system via USB.

4.3.2 Remote Control

Color Code: Green-Yellow

Select Function: Toggle Remote Control and Motor Power Active.

In Remote Control mode the rover can be controlled using the supplied FrSky Taranis X9D controller. Pressing SELECT button while in this mode will toggle between an idle state and active remote control. Once pressed the LED indicator will flash several times indicating initialization process. A red light during initialization indicates an error during initialization. A clear green flashing light indicates a successful initialization and remote control is now active. Press SELECT button again to disable motor power and remote control.

4.3.3 Autonomous

Color Code: Green

Select Function: Toggle autonomy state

In Autonomous mode the rover will autonomously follow supplied waypoint routes. Pressing SELECT button while in this mode will start autonomous Pre-checks flashing the LED indicator several times indicating initialization process. A red light during initialization indicates an error during initialization. A clear green flashing light indicates a successful initialization and autonomy mode is now active. Pressing SELECT button again will disable autonomy mode.

Once system is active the rover will start navigating towards the first waypoint until either: The power gets below a discharge threshold or it gets within a specified waypoint distance from here it will navigate towards the second waypoint.

If power gets below a discharge threshold the rover will halt navigation and disable secondary systems (Motor Power). The system will stay idle until power reaches a recharge threshold. Once above recharge threshold navigation resumes.

4.4 Remote Control

Controlling the rover in remote control using the FrSky Taranis X9D controller, found in **592A** Additional Parts.

Figure 75: Packaged FrSky Taranis X9D controller.

4.4.1 Getting Started

1. Press MODE button and cycle to Remote Control (flashing Yellow-Green).
2. Press SELECT button to select Remote Control mode.
3. Power on the controller by pressing and holding the Power Switch (See Figure 76) until it vibrates.
4. Press SELECT button to activate remote control.
5. Four quick flashes of green light from the LED indicator signals a successful initialization.
6. Once motor capacitors are sufficiently charged and communication established (usually within 3 seconds) the LED indicator should continuously blink green.

4.4.2 Control Scheme

The controller has five controls setup: Enable, Gear, Speed, Direction/Torque, and Volume.

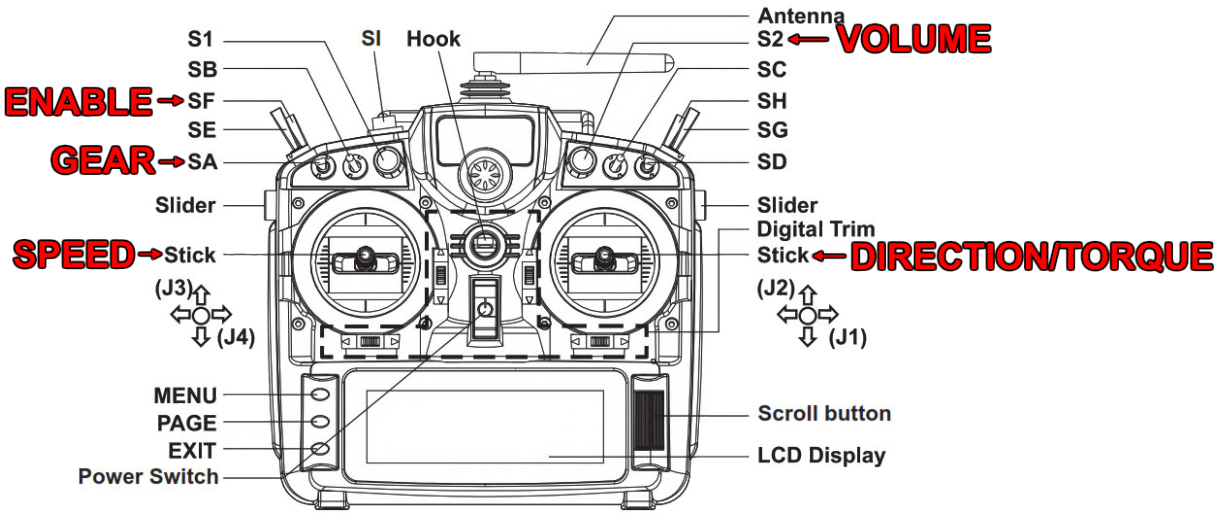


Figure 76: Remote Control, Control Scheme.

SF - **Enable** this acts as the primary enable, as long as this is in the DOWN position all inputs are ignored. Move this switch to the UP position to enable inputs.

SA - **Gear** this switch changes gears. DOWN position is Forward, UP position is Reverse, CENTER position is Torque mode.

Stick - **Speed** this is the primary speed control stick. Raising this from the bottom position while in Forward gear will accelerate the motors to a fraction of the top speed (based on stick position). While in Reverse gear a reverse speed is achieved. While in Torque gear this input does nothing.

Stick - **Direction/Torque** this is the primary direction control stick. When in Forward or Reverse gear, moving this stick sideways adjusts the speed offset between left and right side resulting in skid steering.

When in Torque gear moving this stick forward/backward applies a torque to each motor forward/backward. Moving it sideways while in Torque mode adjusts torque offset between left and right side allowing for skid steering.

S2 - **Volume** this switch raises or lowers the volume of the controller.

4.5 Autonomous Driving

In Autonomous mode the rover will autonomously follow supplied waypoint routes. Pressing SELECT button while in this mode will start autonomous Pre-checks flashing the LED indicator several times indicating initialization process. A red light during initialization indicates an

error during initialization. A clear green flashing light indicates a successful initialization and autonomy mode is now active. Pressing SELECT button again will disable autonomy mode.

Once system is active the rover will start navigating towards the first waypoint until either: The power gets below a discharge threshold or it gets within a specified waypoint distance from here it will navigate towards the second waypoint.

If power gets below a discharge threshold the rover will halt navigation and disable secondary systems (Motor Power). The system will stay idle until power reaches a recharge threshold. Once above recharge threshold navigation resumes.

To start an autonomous mission follow the Pre-Flight Check list found in 7 PRE-FLIGHT CHECK LIST.

4.6 Serial Commands

Several Serial Commands are available used to transmit commands to the Rover via serial communication using the external USB connection. These commands are intended for debugging purposes as well as further increase functionalities of the rover.

Any serial command must be wrapped with "<" and ">". Commands are placed within the wrapper and sent at a baud rate of 115,200. All commands start with a category followed by one or more follow-up parameters.

4.6.1 Module

Commands used to manually enable, disable, or test modules.

- `CMD_MODULE` `M`
- `CMD_MODULE_ENABLE` `E` Enable module
- `CMD_MODULE_DISABLE` `D` Disable module
- `CMD_MODULE_STATUS` `S` Returns status of module
- `CMD_MODULE_TEST` `T` Begins module test
- `CMD_MODULE_STOPTEST` `Q` Stops module test

Examples

Command: "<ME10>"
Enables module 10 (Short Range Communication RF)

Command: "<MD2>"
Disables module 2 (External 12V power)

Command: "<MT12>"
Enables GNSS and starts printing GNSS output.

Command: "<MQ12>"
Disables GNSS and stops printing GNSS output.

Modules

- MODULE_PWR 0
- MODULE_PWR_5V 1
- MODULE_PWR_12V 2
- MODULE_PWR_24V 3
- MODULE_PWR_MOTOR 4
- MODULE_MOTORS 5
- MODULE_MOTOR_L 6
- MODULE_MOTOR_R 7
- MODULE_MOTOR_ACT 8
- MODULE_CANBUS 9
- MODULE_RF 10
- MODULE_IRIDIUM 11
- MODULE_GNSS 12
- MODULE_ACCEL 13
- MODULE_SD 14
- MODULE_BLACKBOX 15
- MODULE_ROUTE 16
- MODULE_DBGCOMM 17
- MODULE_LED 18
- MODULE_HEATING 19
- MODULE_TEMP 20
- MODULE_BACKUPCPU 21
- MODULE_ESTOP 22
- MODULE_DEBUG 23
- MODULE_RESERVED 24

4.6.2 Files

Commands used to create, modify, remove, and write to files on the SD card. One primary use case is rewriting waypoint files.

Note: files can not have names longer than 8 characters due to file format limitations.

- `CMD_FILES` `F`
- `CMD_FILES_LIST` `L` Lists all files on SD card
- `CMD_FILES_SIZE` `S` Returns size of fileName
- `CMD_FILES_DOWNLOAD` `D` Returns content of fileName
- `CMD_FILES_CREATE` `C` Creates a new file with fileName
- `CMD_FILES_REMOVE` `R` Removes file with fileName
- `CMD_FILES_WRITE` `W` Begins writing to fileName and appends data
- `CMD_FILES_WRITENEWLINE` `N` Adds newline to open file
- `CMD_FILES_QUIT` `Q` Closes open file
- `CMD_FILES_BLCKBOX` `B` Prints 100 lines from blackbox
- `CMD_FILES_BLCKBOXEMPTY` `E` Clears content of blackbox

Examples

Command: `"<FL>"`
Returns: List of all files on SD card

Command: `"<FDwaypoint>"`
Returns: Content of waypoint.csv

Command: `"<FWwaypoint><FWHello World><FN><FQ>"`
Creates and opens waypoint.csv
Writes Hello World
Writes newline
Closes file

4.6.3 Waypoint File Creation

Example code for creating and writing a waypoint file using serial port.

Commands

```
<FRwaypoint>
<FWwaypoint><FWWaypoint Index,Waypoint Length,Operator><FN>
<FW006,8,MRJ><FN><FWIndex,Lat,Lon><FN
<FW000,561583967,102166076><FN>
<FW001,561586820,102167337><FN>
<FW002,561589297,102162337><FN>
<FW003,561591692,102157189><FN>
<FW004,561594415,102151463><FN>
<FW005,561591692,102157189><FN>
<FW006,561587165,102167209><FN>
<FW007,561584574,102166438><FN>
<FQ><FDwaypoint>
```

Description

```
Remove existing file
Open file stream
Write line
endline
Write line
Endline
...
Quit file
Print file to terminal
```

Results, the file created on the SD card "waypoint.csv" has the following content ($deg \times 10^-7$)

```
Waypoint Index,Waypoint Length,Operator
006,8,MRJ
Index,Lat,Lon
000,561583967,102166076
001,561586820,102167337
002,561589297,102162337
003,561591692,102157189
004,561594415,102151463
005,561591692,102157189
006,561587165,102167209
007,561584574,102166438
```

5 Shipping

5.1 Overview

The Rover is shipped in five part totalling 355 kg including pallets and packaging. This section describes the primary steps needed to package the rover for shipment. After following the steps in this section the entire system should be separated into the following components ready for transport.

Figure 77: System packaged for transport,
2x Euro Pallet, 2x 40x80x60 ZARGES crate, 1x 40x40x60 ZARGES crate.

A Chassis - Euro Pallet, primary vehicle chassis, mounted and framed around a euro pallet with shipping dimensions: 120x120x82cm and 140 kg.

B Solar Panels - Euro Pallet, all solar panels are mounted and framed onto a euro pallet with shipping dimensions: 40x120x80cm and 80 kg.

C Front Motor and Suspension - 523A, both of the front motor and suspensions are packed in a 40x80x60 ZARGES crate weighing 60 kg.

D Additional Parts - 592A, spare motor, rear suspension, remote control, bolts, nuts and additional parts are packed in a 40x80x60 ZARGES crate weighing 45 kg.

E Batteries - 469, all batteries, along with a safety sheet are packed in a 40x40x60cm ZARGES crate weighing 30 kg.

6 Packaged Overview

Overview of packaged assembly components, electrical components, spare parts, and more. The primary components in this section can be found in ZARGES crate **523A** inside the components box.

Figure 78: Primary components

This section is separated into three categories: Bolts, Nuts and Fasteners, Wires and Connectors, and Extra Components.

Bolts, Nuts, and Fasteners, needed to assemble the system along with additional spares for the following components; wheel, Motor, Suspension, Rear Ski, Solar Panel, and Frame.

Wires and Connectors, electrical components, extra plugs and connectors, wire for soldering, and several types of USB cables.

Spare Components, for backup and redundancy purposes.

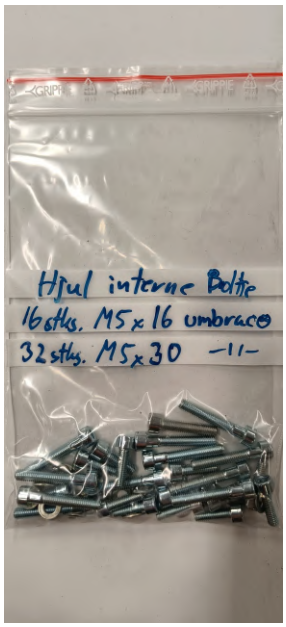
(a) Components content

(b) Antennas

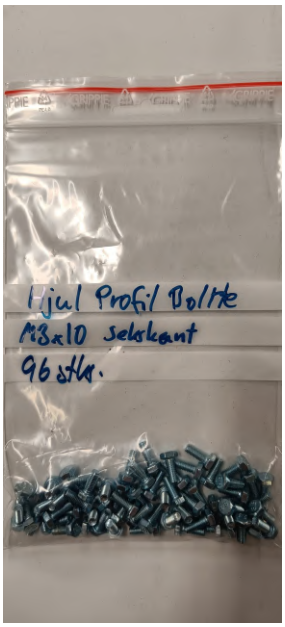
Figure 79: Extra Components

6.1 Bolts, Nuts, and Fasteners

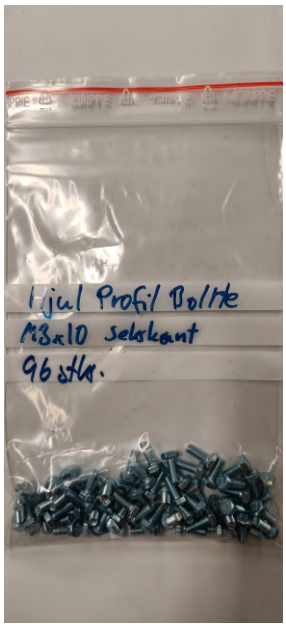
6.1.1 Wheel



(a) Internal Bolts M5x16, M5x30



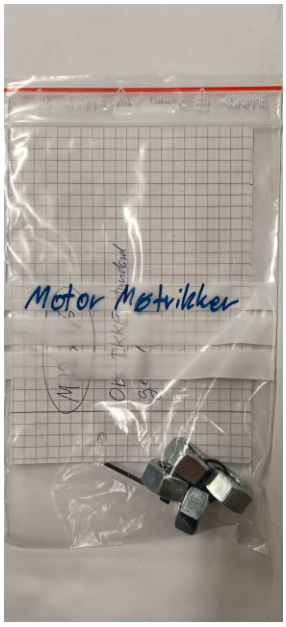
(b) Profile Bolts M3x10



(c) Profile Bolts M3x10

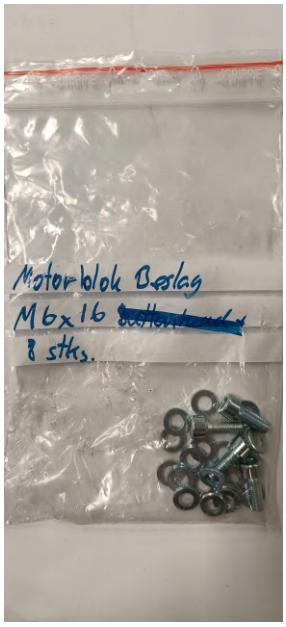
Figure 80: Wheel Bolts

6.1.2 Motor



(a) Motor-Rim, Mounting Nuts

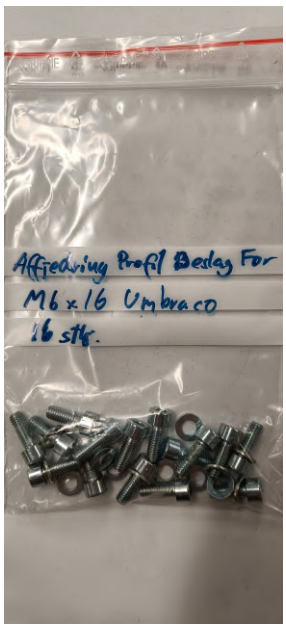
(b) Motor Axle Nut



(c) Motor Mount, M6x16

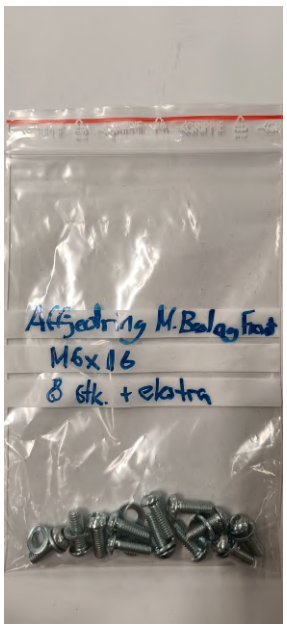
Figure 81: Motor Mounting Nuts and Bolts

6.1.3 Suspension



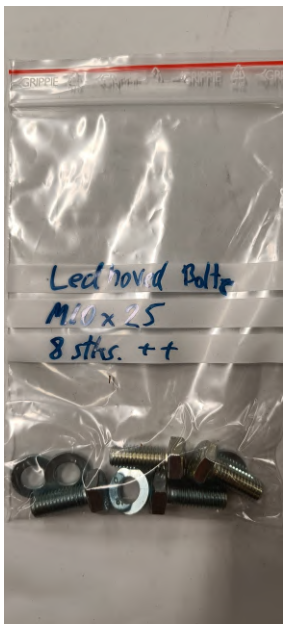
(a) Profile Mount, Front M6x16

(b) Mounting, Front M10x35, M10x100, M10x185

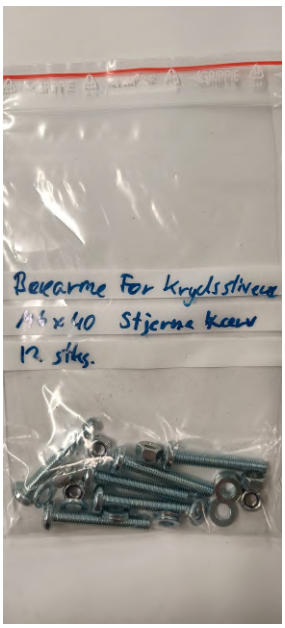


(c) Bracket, Front M6x16

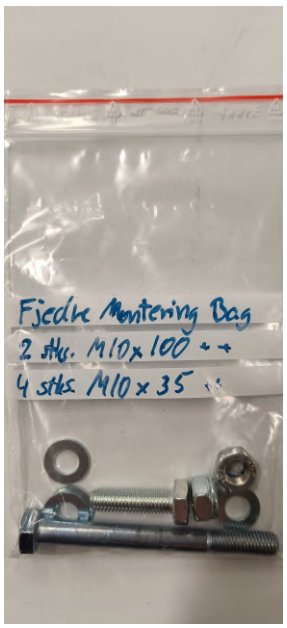
Figure 82: Suspension bolts and nuts.



(a) Joint Head M10x25

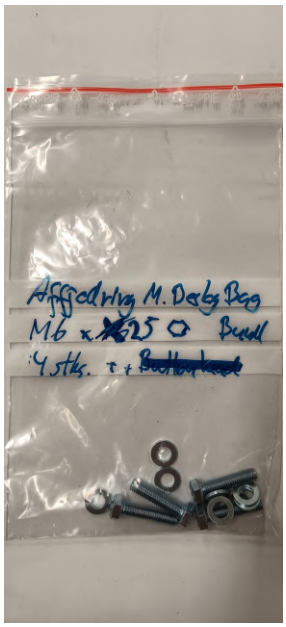


(b) Cross Braces M6x40

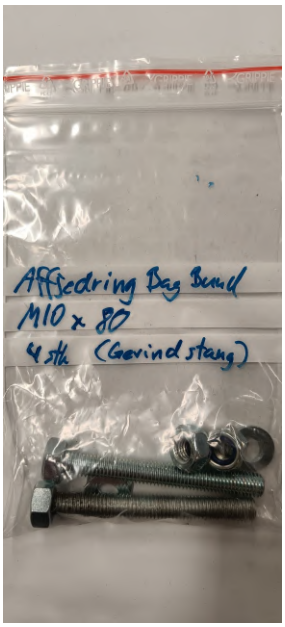


(c) Mounting, Rear M10x100, M10x35

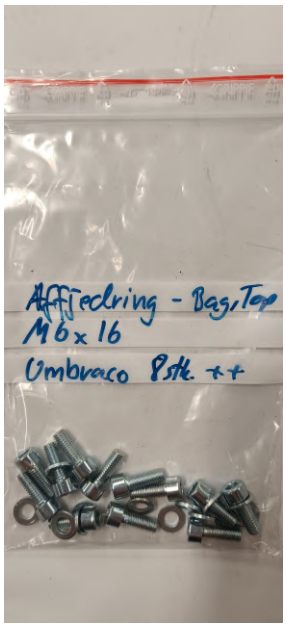
Figure 83: Suspension bolts and nuts.



(a) Bracket, Rear
M6x25



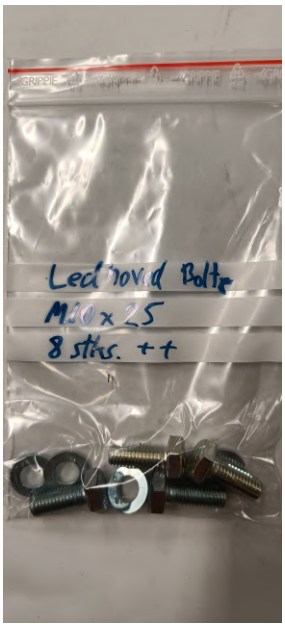
(b) Mounting Bottom, Rear
M10x80



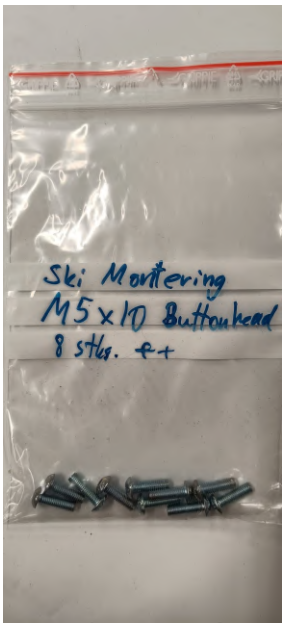
(c) Mounting, Top, Rear
M6x16

Figure 84: Suspension bolts and nuts.

6.1.4 Rear Ski



(a) Hinge bolts
M10x35

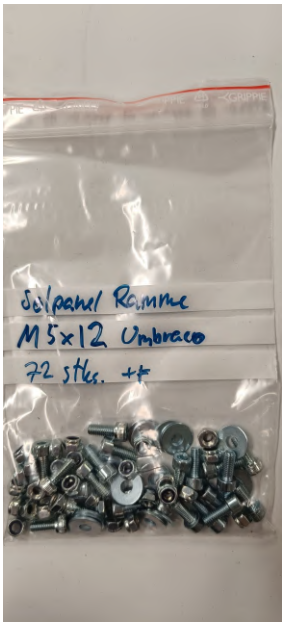


(b) Mounting Bolts
M5x10

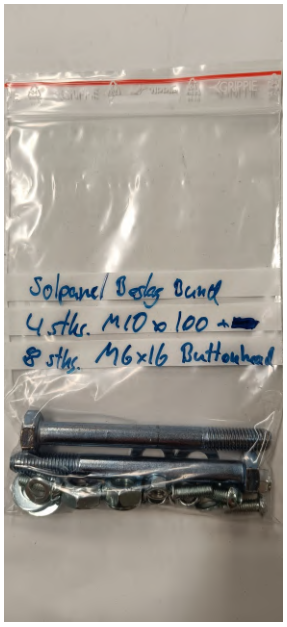
Figure 85: Rear ski bolts and nuts.

6.1.5 Solar Panel

(a) Frame, Bottom
M5x16, M10x25

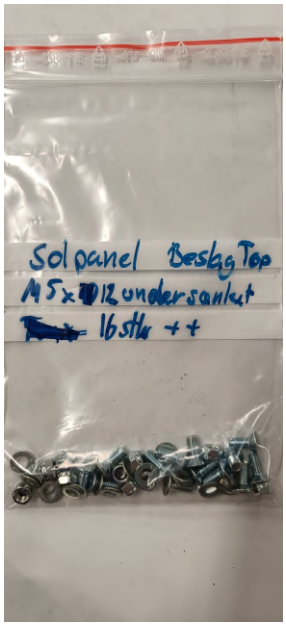


(b) Frame Bolts
M5x12 + Wash + Nut



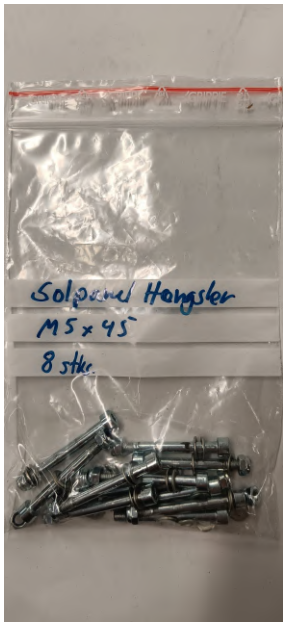
(c) Mounting, Bottom
M10x100, M6x16

Figure 86: Solar Panel bolts and nuts.



(a) Bracket, Top
M5x12

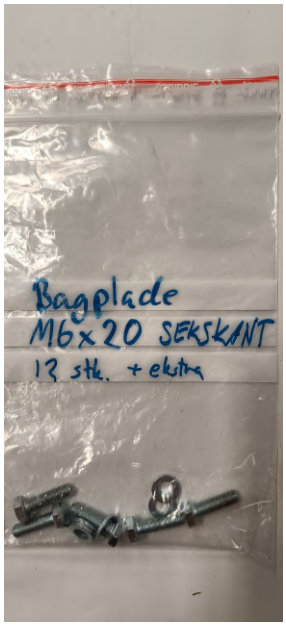
(b) Hinges



(c) Hinge Bolt
M5x45

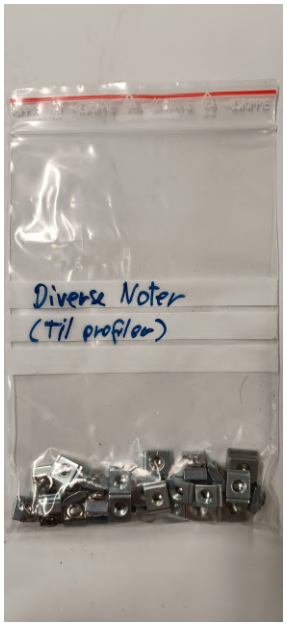
Figure 87: Solar Panel bolts and nuts.

6.1.6 Chassis



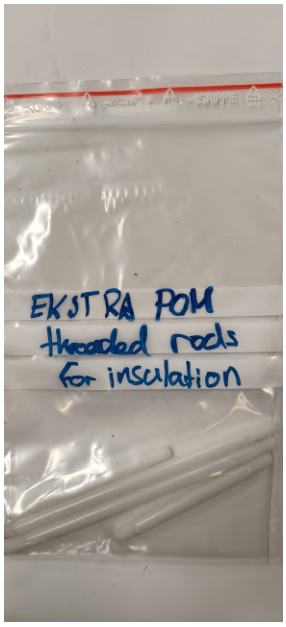
(a) Rear Cover Plate M6x20

(b) Rear Cover Plate Bracket

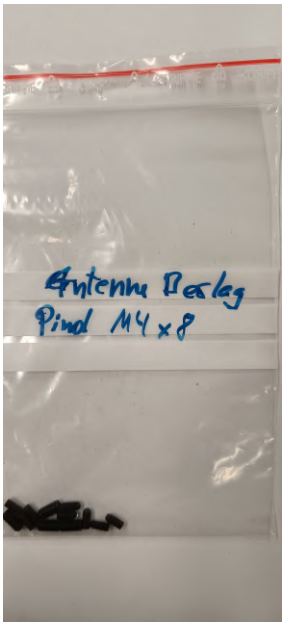


(c) Profile nut inserts

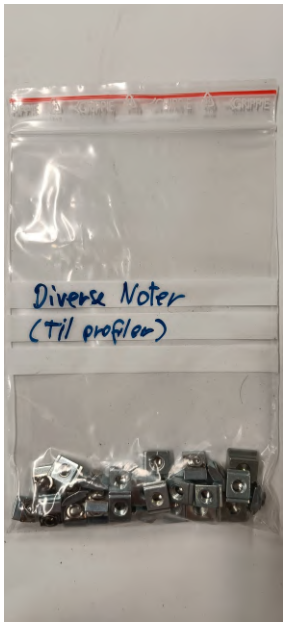
Figure 88: Chassis bolts and nuts.



(a) Insulation, threaded POM rods



(b) Antenna set screw M4x8

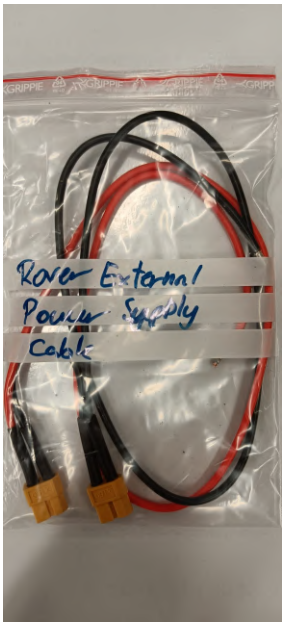


(c) Profile nut inserts

Figure 89: Chassis bolts and nuts.

6.2 Wires and Connectors

(a) Motor Signal Connector



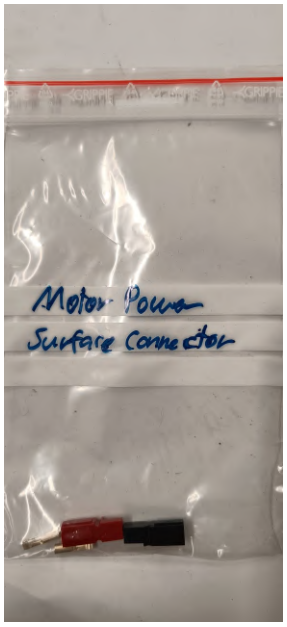
(b) External Power Cable
XT60x2 to Leads

(c) WAGO connector

Figure 90: Wires and Connectors.

(a) Solar Power Connector
Male

(b) Solar Power Connector
Female



(c) Motor Power Surface Connector (Anderson)

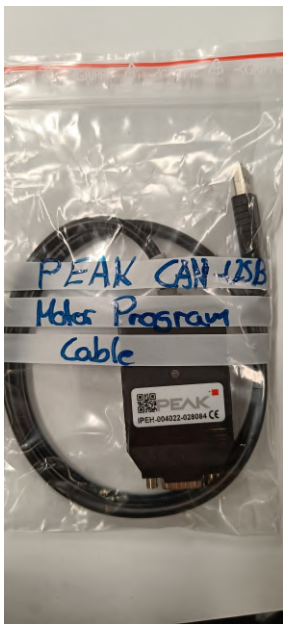
Figure 91: Wires and Connectors.

(a) Controller Charging Cable
XT90 to 0.1inch

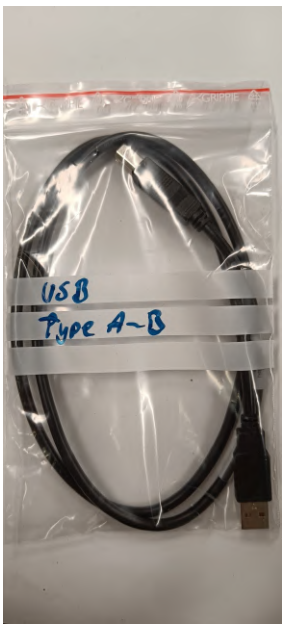
(b) 4 mm^2 wire

(c) 1.5 mm^2 wire

Figure 92: Wires and Connectors.



(a) Motor Program Cable
PEAK CAN-USB



(b) USB cable
USB A to B

(c) USB cable
USB A to A

Figure 93: USB Cables

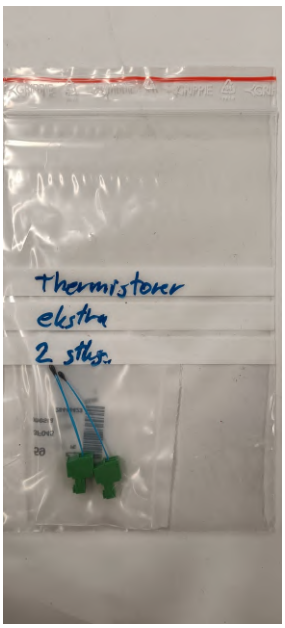
(a) External Power Connector
Male DC-Jack

(b) RF surface connectors

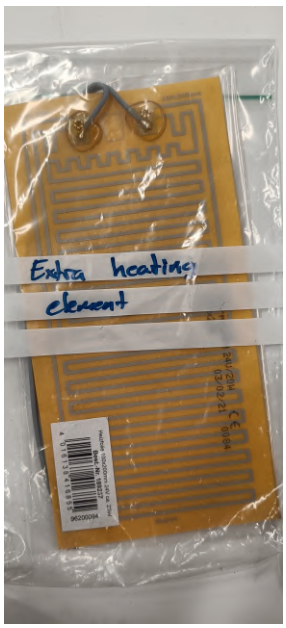
Figure 94: Wires and Connectors.

6.3 Extra Components

(a) RF antenna



(b) Backup Thermistor



(c) Extra Heating Element

Figure 95: Extra Components.

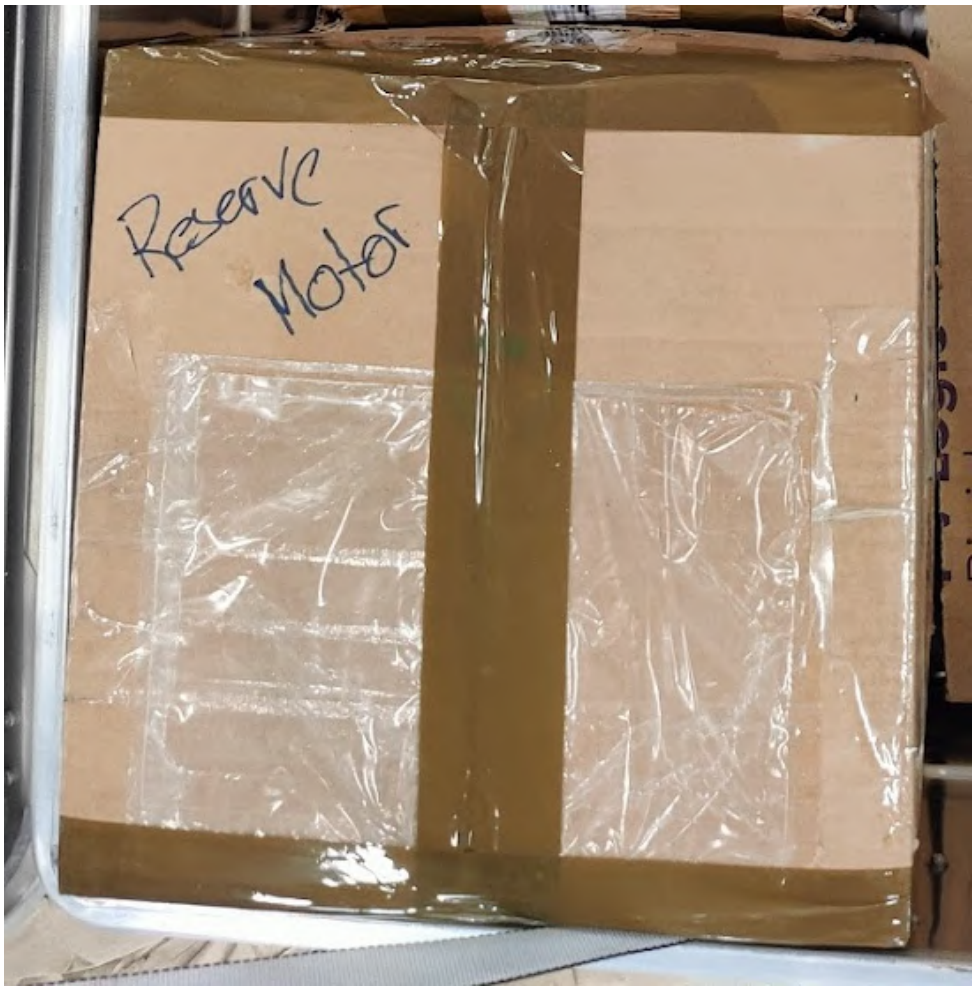


Figure 96: Backup Motor.

7 PRE-FLIGHT CHECK LIST

Found on the following page.

Autonomous Arctic Rover Pre-Flight Check List.

☐ Batteries Undamaged and Installed in AB Configuration

☐ Solar Panels Cleaned and Connected

☐ Motor and Suspension Bolts Tightened and Verified

☐ Rear Cover Panel Installed and Sealed with Silicone

☐ Sensor Equipment Connected and Verified

☐ LED strip in OFF position

☐ Power Switch in ON position

☐ Waypoint file Updated and Verified

☐ Home Position Updated and Verified

☐ Backup Home Positions Updated and Verified

☐ Iridium Communication Online and Verified

☐ GNSS Communication Online and Verified

☐ Press MODE button until LED indicator flashing Green

☐ Press SELECT button to select Autonomy mode

☐ Press SELECT button to activate Autonomous Navigation

☐ LED indicator flashing only green

☐ Rover Iridium Status Received

☐ Rover Navigating towards first waypoint

References

[1] https://industrial.panasonic.com/ww/products/pt/nickel-metal/models/BK1100FHU

[2] https://dk.rs-online.com/web/p/solcellepaneler-fotovoltaiske/9046134

[3] https://www.gemmotors.si/products/#gem-g-1-1