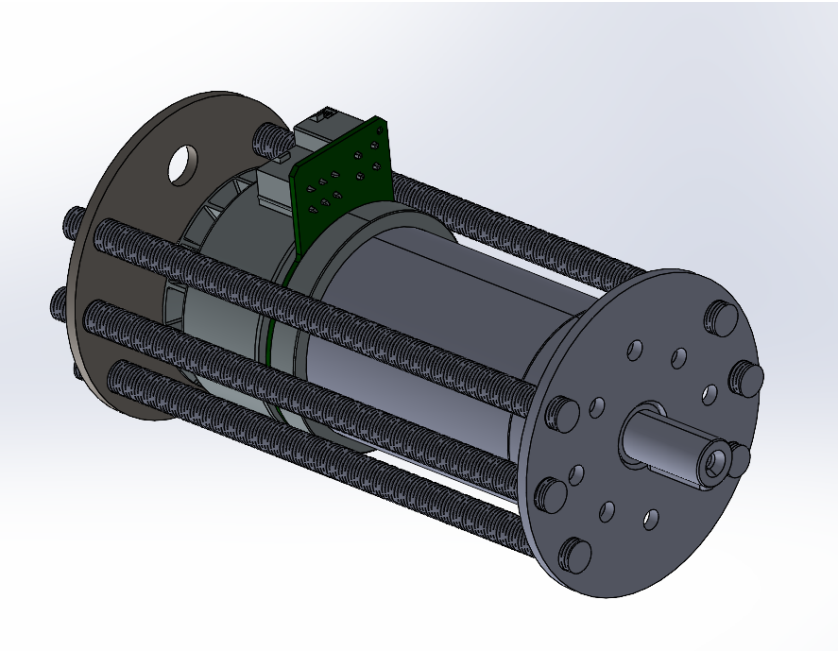
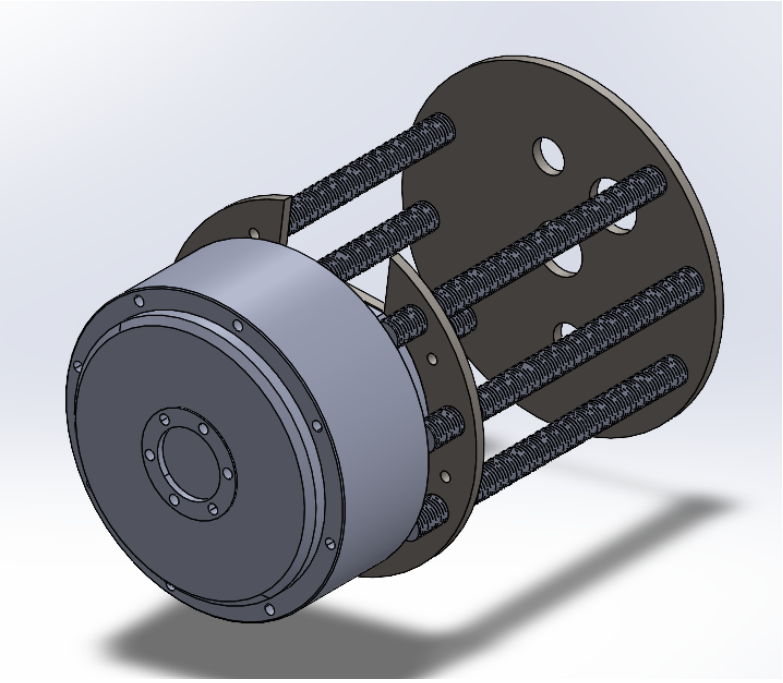
Motor Subassembly

The drivetrain report details the original **V1 concept (left)**. However, just **2–3 weeks before the qualification video deadline**, the decision to change motor suppliers and therefore motors was made. **V2 (right) is an adaptation** designed to integrate alternative motors on short notice while repurposing as many V1 hardware interfaces, adapter plates, and mounting geometries as possible. This ended up making the mouting interface between the motor and the hub quite a bit easier. The older motor had a long planeteray gearbox attached to it, which required a "cage" around the motor-gearbox combination to protect it from the spinning wheel surrounding it. This coupled with a singular point of attachemnt for the wheel requireing pre-loading on the pilot screw to prevent the screw from becoming undone during operation increased its complexity. The new motor is larger is an all in one motor/gearbox solution with 6 M3 mounting points. this made it drastically easier to mount.





1. Motor Requirements and Motor Choice

The main equations governing the torque requirements are the ones listed below. For the first time the absolute worst case scenario was chosen as no one knew the exact challenges the rover would face in the terrain department.

- Rolling Resistance: $m \cdot 9.81 \cdot C_{rr} \cdot \cos(\theta)$
- Gravity Component: $m \cdot 9.81 \cdot \sin(\theta)$
- Total force: Rolling Resistance + Gravity Component

Units	Value
Rolling Resistance (C_{rr})	0.5
Mass (kg)	75
Inclination Angle (°)	60

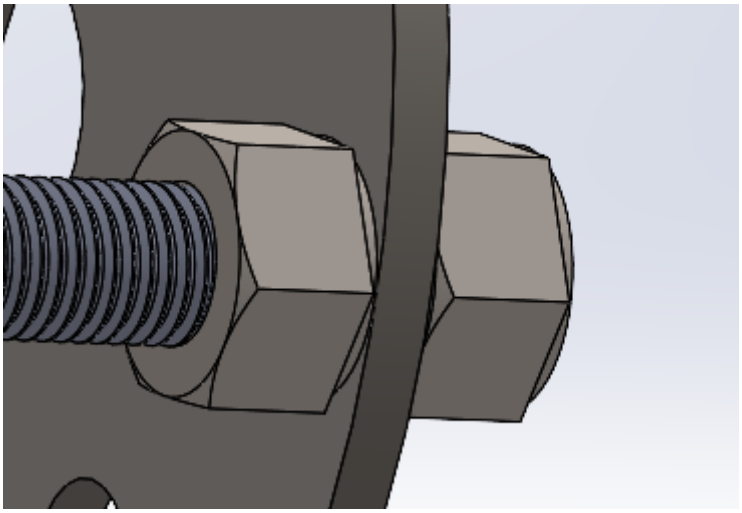
Pulling the rover up an angle of 60° sets the required force of 821N. That is why the wheel size was set to 200mm. Set the required torque to 82.1 Nm across all wheel. Since the idea of a 4 wheeled rover was always a topic of debate due to its superior maneuverability comapred to 6 wheeled rovers, the torque per wheel was calculated for 4 wheels. This was done so that the upfront investment in drive motors today would be high, however, in the long run it would be cheaper than buying 6 less powerful motors now and then 4 more powerful and more expensive motors later. This also has the added benefit that in the case that a 4 wheeled rover is made, there are more spares. The maximum speed of the rover is set at 1 m/s this means that the motor should spin at 95.5 rpm with the current wheel size.

For **V1** the **EC 60 flat Ø60 mm, brushless, 200 W** motor and **Planetary Gearhead GP 52 C Ø52 mm, 4 - 30 Nm, Ceramic Version** gearbox combination by maxon motors was chosen. But since this did not work out, for **V2** the **AK70-10 KV100 by CubeMars** was selected. This motor was not only cheaper, but supported a higher torque and higher motor output speed all while being coming in a more compact package and facilitating both 24V and 48V compatiability. This was very useful as a 24V architecture was decided on at the beginning of the year, however this motor could allow for a more efficiet 48V architecture in the future. More of its specifications are listed below.

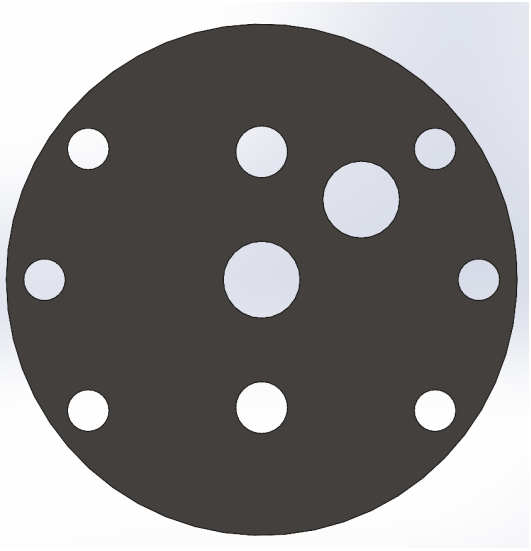
Specification			
Application	Legged Robot,Exoskeleton,AGV	Peak torque (Nm)	24.8
Driving way	FOC	Peak current (ADC)	23.2
Operation ambient temperature	-20℃~50℃	Kv (rpm/V)	100
Winding type	Delta	Kt (Nm/A)	0.123
Insulation class	H	Ke (V/krpm)	11.2
Insulation High-voltage	1000V 5mA/2s	Phase to Phase resistance (mΩ)	272
Insulation resistance	1000V10MΩ	Phase to Phase inductance (μH)	113
Phase	Three Phase	Inertia (gcm²)	753.4788
Pole pairs	21	Km (Nm/√W)	0.24
Reduction ratio	10:01	Mechanical time constant (ms)	0.74
Back drive(Nm)	0.48	Electrical time constant (ms)	0.42
Backlash (°)	0.12	Weight (g)	621
Temperature sensor	NTC MF51B 103F3950	Maximum torque weight ratio (Nm/kg)	47.6
Noise dB 65CM away the motor	58	CAN connector	A1257WR-S-4P
Basic load ratings (dyn. C) N	2000	UART connector	A1257WR-S-3P
Basic load ratings (stat.C0) N	2520	Power connector	XT30PW-M
Rated voltage (V)	24/48	Inner loop encoder type	Magnetic encoder
Rated torque (Nm)	8.3	Inner ring encoder resolution	14bit
Rated speed (rpm)	148/310	Outer ring encoder type	-
Rated current (ADC)	7.2	Outer ring encoder resolution	-
Number of encoder	1	Model Number	Ak70-10

2. Subassembly Overview

- **Primary Role:** Provide a mounting point for the motor while also also protecting it from the spinning wheel surrounding it.



- **Design Philosophy:** Since the goal at the beginning of the year was to have every component be modular and easily replaceable it was quite tricky to come up with a nice solution. Therefore, six M8 threaded rods were chosen each cut at 140mm (currently cut to 110mm for the new motor). This was done as according to rough FEM simulations, when loaded, these six rods would only bend about 1-2mm. Keeping this displacement low meant that "squatting"or unwanted camber is mitigated. The plates, where the motor is mounted and where the subassembly is mounted to the suspension, are held inplace with nuts that are tightened into each other clamping the plate between them. While this is not the best solution, it works well enough that till this point a motor subassembly has not fallen apart during operation.

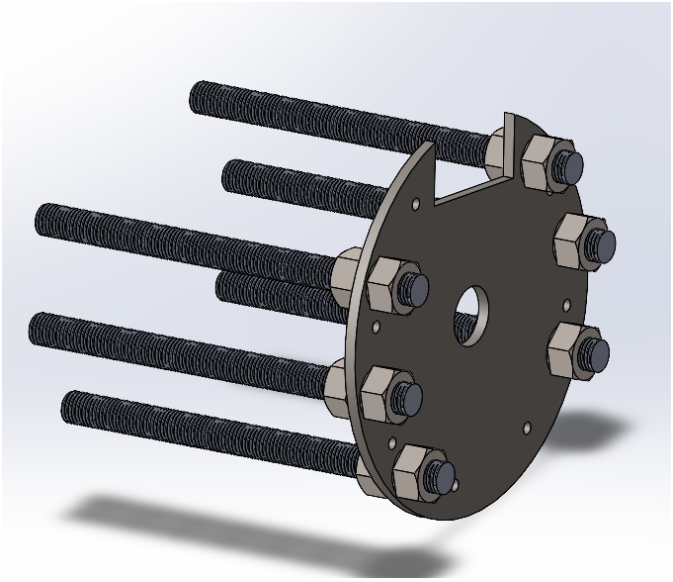


The subassembly is attached to the suspension system using two M10 bolts. The hole in the center was just a copying error from the motor mounting plate from the first version. The big hole positioned off to the right is meant for cable management. While it works at the moment, it is a bit too small. In the future, enlarging the hole in the middle and then cutting another hole in the vertial arm of the suspension system to allow cables through. This was not possible for V2 as that entire

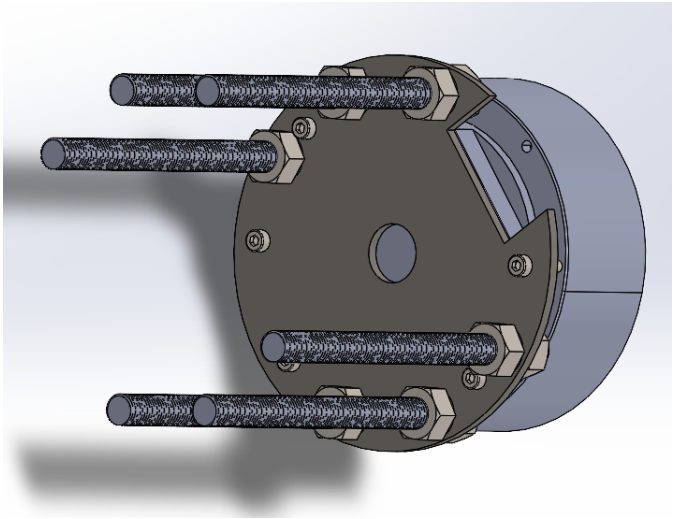
section of the motor subassembly and suspension system was designed for the V1 motor.

3. Assembly & Alignment Guide

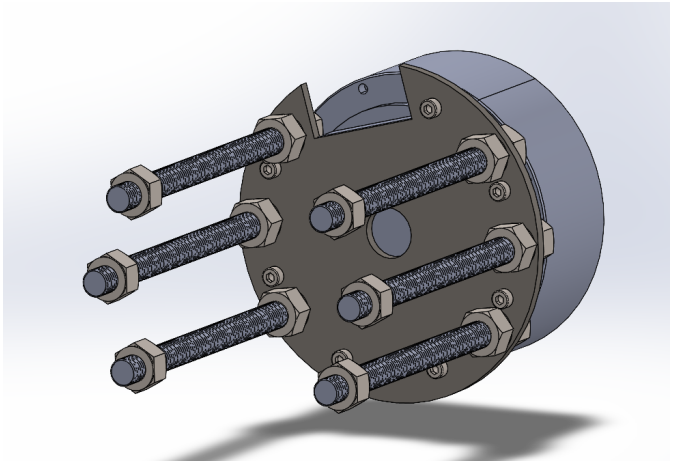
Assembly Procedure:

Step 1: Screw in the first set of nuts (these will be on the inner side of the motor mount plate) 	Step 2: Slide M8 rods into the holes cutout of the motor mouting plate, then screw in the other nuts that clamp the plate in place. 

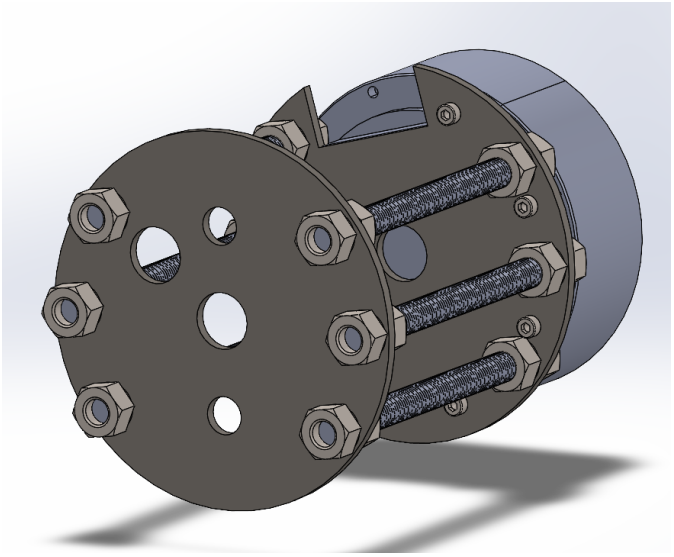
Step 3:
Attach motor



Step 4:
Screw in inner nuts for the plate that mounts the motor subassmbly to the rest of the suspension system.



Step 5:
Attach plate and clamp with the remaining nuts.



4. Known Limitations & V3 Recommendations

- **Ingress Protection (Dust & Debris):** The open threaded-rod structure leaves the motor and wiring completely exposed to dirt, sand, and moisture.
- **Alignment Issues:** Since the nuts are all hand screwed in and there is no stop, alignment has to be done by eye which can result in misaligned plates.
- **Vibration Loosening:** It has been noted that increased vibrations (tapping againt the table, vibration during driving etc.) can cause the nuts to loosen if they werent tightened enough.
- **Recommended V3 Upgrades:**
  - **More Robust Mounting:** With the new motor, many more mounitng options become avaliable. This means that the threaded rods can be removed. For a first run

they were a good proof of concept, but they have their issues. A precise mounting solution for the plates is required.
- **Enclosed Housing:** Currently the motor sits within the wheel hub so it is relativly protected from the elemets, however, dust, dirt and water can still get in. Covering the motor and its cables is quite important as these contaminants can damage these components.

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