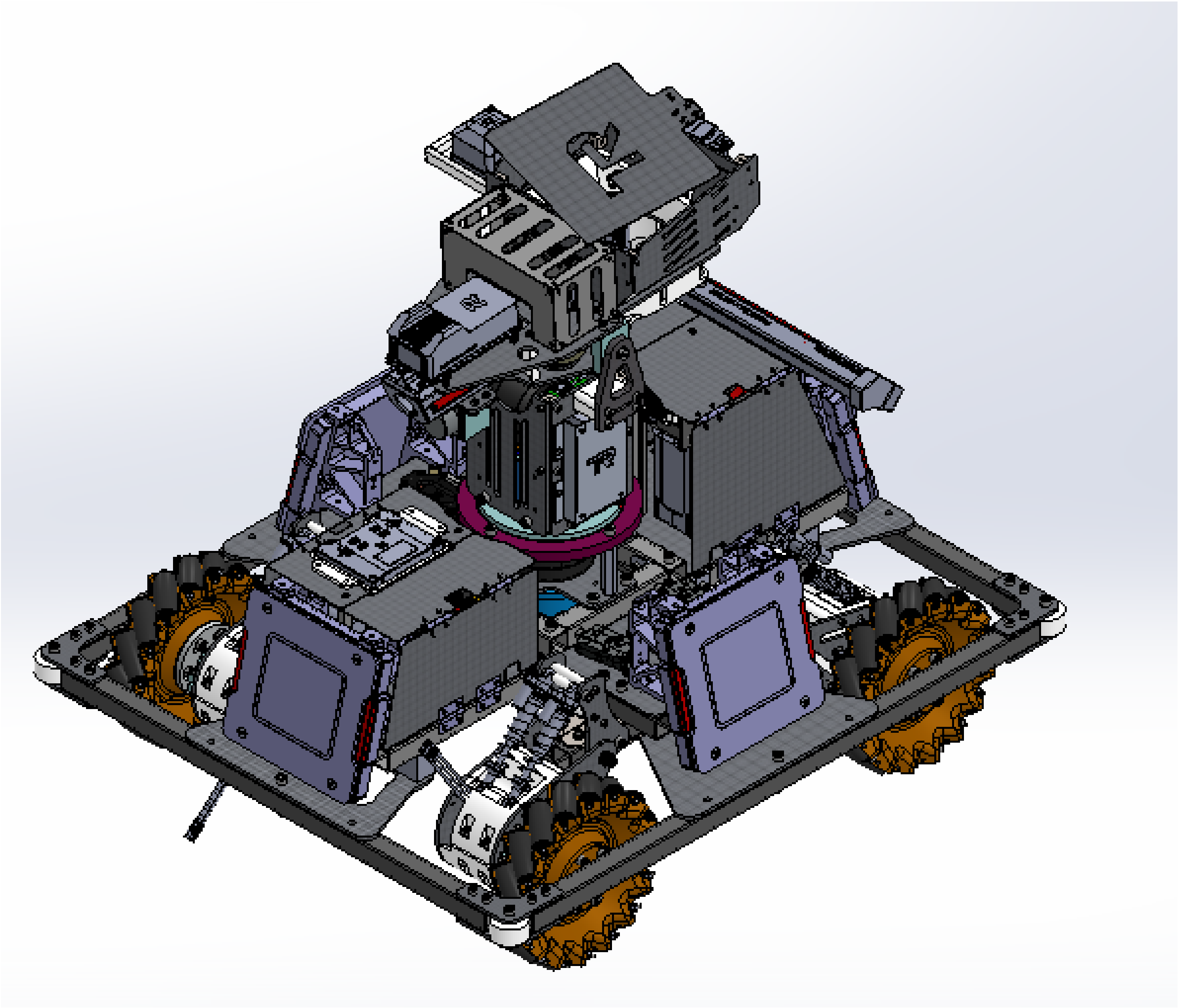
Infantry 2021-22 Assembly Report

RoboMaster 2021-2022

Contributors: Roger Nguyen, Kenny Wang



(CAD Model)

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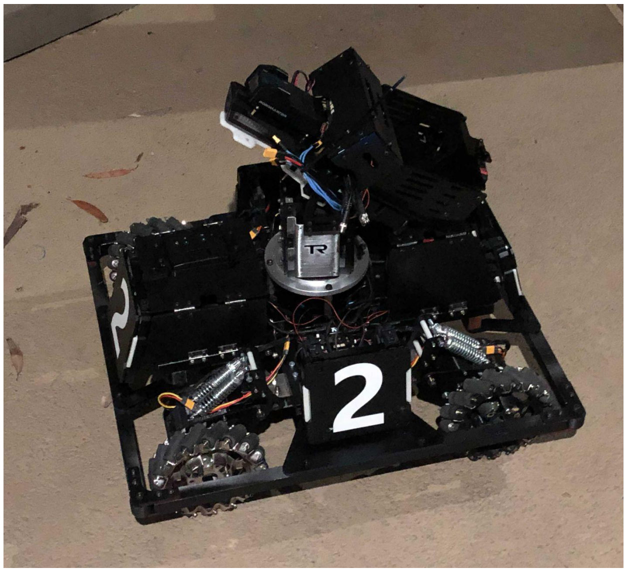
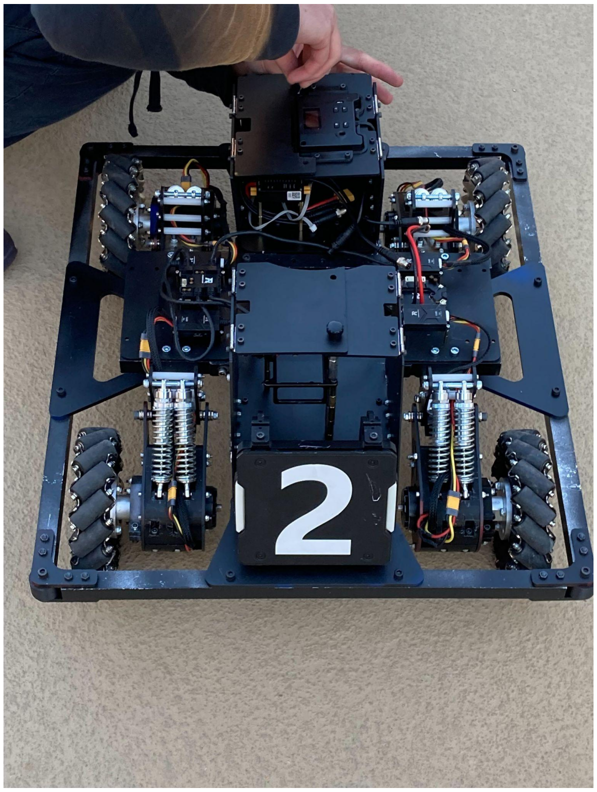


(Physical Model)



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[1] Introduction

This document is a detailed overview of the Infantry robot and the purpose of this document is to allow the reader to understand the different intricacies of this robot related to both mechanical and hardware decisions, as well as advantages and disadvantages of the design.

[1.1] Design Focus

Infantry is a ground robot and is expected to maneuver around the playing field agilely due to its lightweight and smaller size compared to other ground robots. Its mobility allows it to quickly kill robots using guerilla tactics. Due to the low ammo cost, low revival time, and low amount of experience points needed to level up, it is common for the Infantry to have a major influence during competition.

In order to maintain Infantry's high mobility, the design focus is compactness, lightweight, modularity, and ease of access to electronics. Modularity is important in Infantry's design to make the repair process quick. During the RMUL 2021, many components were connected to each other with multiple screws. Removing these screws was tedious when a specific component needed to be repaired and some screws could not be removed at all due to its importance to the structural integrity of the robot. In the new 2021-2022 design, efforts are being made to make the robot more modular like the suspension system. Similarly, ease of access to electronics was an important consideration due to the fact that during the RMUL 2021 competition, opening Hero's bulky interior to access the electronics was a relatively difficult task due to how the wires and electronics were just crammed inside of the main cavity. The hinge design allows easier access, while also shielding the electronics from flying projectiles.

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[2] Design Requirements

[2.1] Robot Building Specification Manual

- 2.3.3

Operating Mode	Maximum Power Supply	Maximum Voltage Supply	Strength	Launching Mechanism	Max Weight	Maximum Dimensions (mm)	Referee System
Regular	200 Wh	30V	Free-falling from a vertical altitude of 0.2 m three times without any damage to any	A 17mm Launching Mechanism	25 kg including battery weight, but not the weight of Referee System Referee system weighs 3.25 kg →	600*600*500 (L*W*H, Initial) 800*800*800 (L*W*H, Expansion)	4x Small Armor Modules, 1x 17 mm Speed Monitor Module, 1x Camera Image Transmission Module (transmitter), 1x RFID Interaction Module, 1x GPS Module, 1x Main

			part of the body		Actual: 28.25 kg		Controller Module, 1x Power Management Module, 1x Light Indicator Module, 1x 17 mm Fluorescent Projectile Charging Device.

[2.2] Rules Manual

- 3.9.2

Chassis Type	Maximum Chassis Power	Initial HP (Max HP)	Initial Projectile Speed Limit	Barrel Heat Limit	Barrel Cooling Value Per Second	Projectile Launch Speed Limit	Chassis Power Limit
Initial	40W	100	15 m/s	50	10	*See 3.2.2 in Rules Manual*	*See 3.2.3 in Rules Manual*

- 2.6.2 Projectile: 17mm (3.2g) w/ (90A Shore Hardness) made of TPU

[2.3] Functional Requirements

<u>General</u>

- **S23** Armor Module cannot be blocked.
- **S27** The lines of the robot are neat and not exposed. Exposure that is unavoidable requires line protection using materials such as drag chains and cable managers.
- **S28** Do not use materials that will have an obvious impact on the aesthetics of the robot, such as washbasins, plastic bottles, corrugated paper, bed sheets, white foam boards, bubble wrap, etc
- **S30** Avoid sharp structures that may damage the site or harm any person.
- **S33** A robot must display two school badges or team badges, each facing a different side. The size of a single school badge or team badge must not be larger than 100mm*100mm. The school badges or team badges must be displayed prominently on a robot, and their distance with the Armor Light Indicator must be more than 30 mm.
- **S40** Except Aerial and Sentry, robot Launching Mechanism must stably launch projectile
- **S41** Each Launching Mechanism must be installed with a Speed Monitor Module in accordance with the rules. 17mm Launching Mechanism must be mounted with a 17mm Fluorescent Projectile Energy-Charging Device according to specifications.

<u>Electrical Components</u>

- **S76** No electromagnetic shielding material (including but not limited to metals, carbon fiber, conductive rubber, wave-absorbing materials, and conductive complexing agents) or other equipment carrying electromagnetic interference should be placed within a 70 mm radius, with the center being 14.5 mm directly below the center point of the logo.

- **S80** Each port on the Power Management Module is protected, to prevent damage by projectiles. However, the outer casing cannot be completely wrapped, so as to ensure good heat dissipation.
- The outer casing of the Power Management Module heats up under high power conditions. Do not touch it with your hands. Avoid installing the Power Management Module on non-heat resistant materials, such as 3D printing materials
- **S87** When the Light Indicator Module of a Ground Robot is being installed, it must be ensured that the light source must be situated at least 200 mm from the ground.
- **S93** A mounted Armor Module and Support Frame must be rigidly connected to the chassis to form a whole body. During the competition, the Armor Module and the chassis must not shift relative to each other. The rigid connection of the Armor Module is defined in the figure below. A vertical upward force of 60N is applied to the midpoint of the lower edge of the Armor Module. Angle α of the Armor Module's impact surface must not change by more than 2.5°
- **S101** Teams should design safety rods for ground robots to reduce any damage caused by collision of Armor Modules.
- **S104** The lower 105° area, and the upper, left and right 145° areas of the impact surface on the Armor Modules of Standard and Hero must not be blocked.
- **S113** The phototube must not be blocked
- **S119** A Speed Monitor Module must be installed at the end of the Launching Mechanism. Measure the launch speed of a projectile after it has fully accelerated
- **S124** The rear of the RFID Interaction Module should be free of interference from strong currents or high frequency signals (such as motor cables, RoboMaster Center Board, CAN cables and supercapacitors).
- **S125** The front and rear of the RFID Interaction Module must not be obstructed by any metal, and the rear surface must be kept at least 30 mm away from the metal plate
- **S127** As the Transmitter's antenna is located at the top of the Module, the top should not be blocked by any metal
- **S134** Positioning System Module should be horizontally installed with the top facing up. The 145° area above the Positioning System Module must not be blocked by any conductor
- **S135** The Positioning System Module must be at a distance of at least 100 mm from any motor, Video Transmitter Module or parts that are magnetic or create a magnetic field when operating. Such parts should preferably be installed at a distance of at least 200 mm away.
- **S136** The UV light panel must be in close contact with the metal parts, or heat dissipation panels should be installed to extract heat. Heat dissipation panels used can be those provided with the equipment or self produced.
- **S138** The UV light panel must cover the standby projectile next to the launching projectile to ensure the proper charging of the projectile
- **S142** The Capacitor Management Module must be installed on a place easy for the robot to operate, so that it can be operated during Pre-Match Inspection.

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[3] Summary of Current Design

[3.1] Basic Information

- Dimension(mm): 599.72mm x 513.72mm x 492.8mm (LWH).
- Weight(kg): TBD
- Maximum ammo capacity: TBD

[3.2] General Performance

- Maximum moving speed(m/s): TBD
- Maximum acceleration(m/s^2): TBD
- Maximum shooting rate(per sec): TBD
- Maximum shooting speed(m/s): TBD
- Maximum Turret Angle of Elevation: [TBD] Degrees
- Maximum Turret Angle of Depression: [TBD] Degrees
- Maximum Turret Yaw Degree of Freedom: No limits

[3.3] Advantages

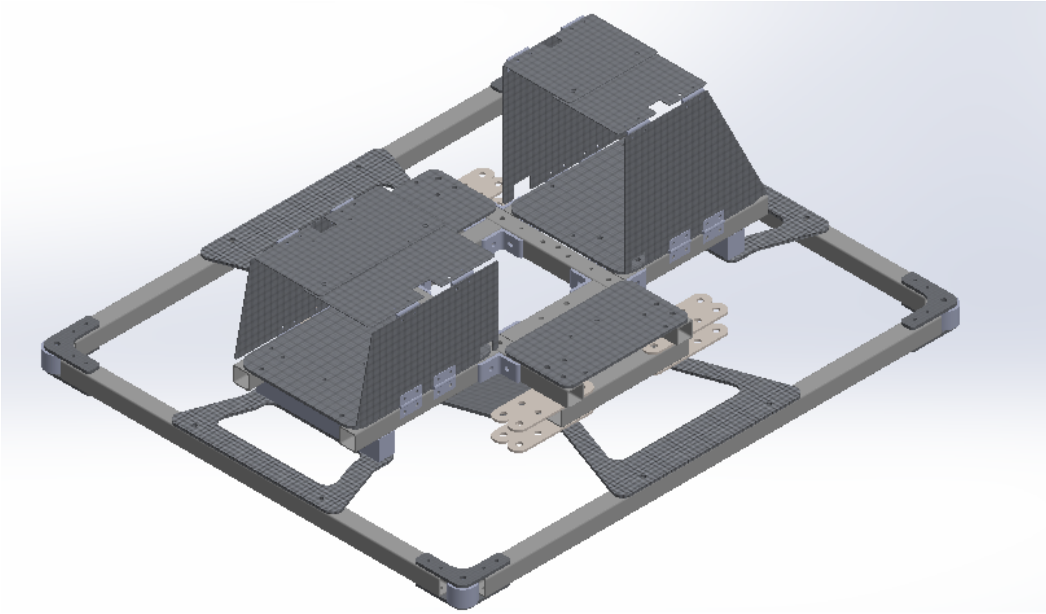
- New Suspension System and Modularity: the suspension system was changed to make the shock absorbers parallel to the front and back direction instead of using a double wishbone suspension system. The modularity allows for ease of disassembly for shipping.
- Chassis' Ease of Access to Electronics: the outer casing is secured with 4 knob screws, 2 at the front and 2 at the back, which allows for quick access to the electronics inside. The plates that make up the outer casing have pre-cut holes that allow wires to go through.
- Compact Turret Base: the turret base is designed so that the Pitch motor can fit inside the base so that there is less rotational moment of inertia, releasing some burden from the Yaw motor. The pitch motion is then controlled by a virtual four-bar linkage.

[3.4] Disadvantages

- Size: With the protective frame, the Infantry is at 599/600 mm in terms of length, while the width has more wiggle room at 517/600 mm.
- Compactness: Compared to last year's Infantry design, there is much less room to mount electronics. This is due to the fact that the chassis frame is not layered. As a result, the electronics are all in close proximity.
- Higher Precision Manufacturing: The current prototype consists of parts that are 3D-printed, laser cut, and hand drilled. For further iterations, all carbon fiber parts and metal parts need to be made using either manual machining or CNC machining.

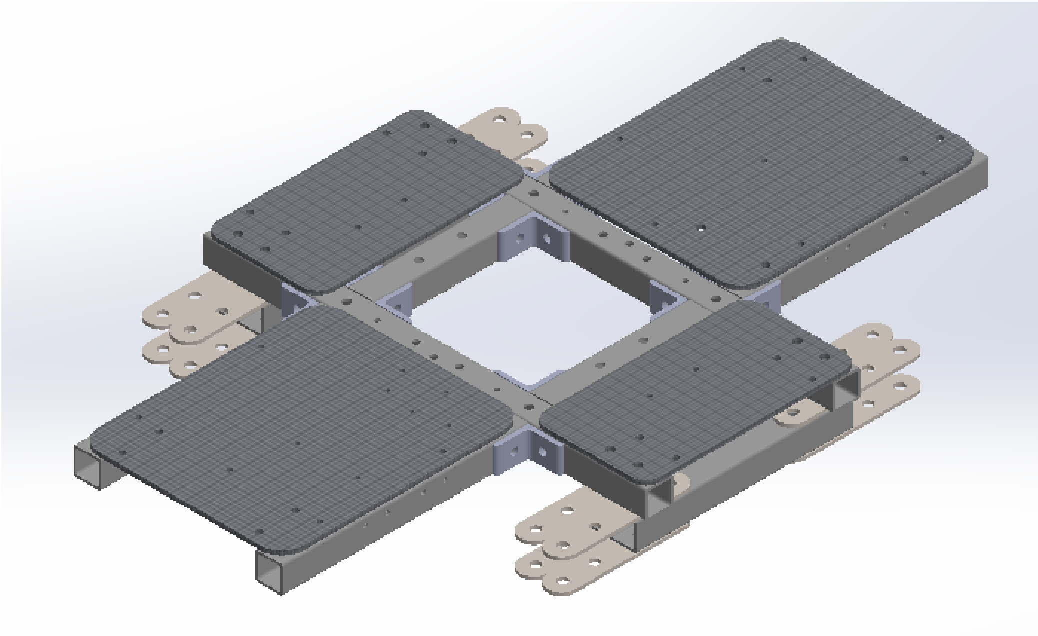
[4] Chassis

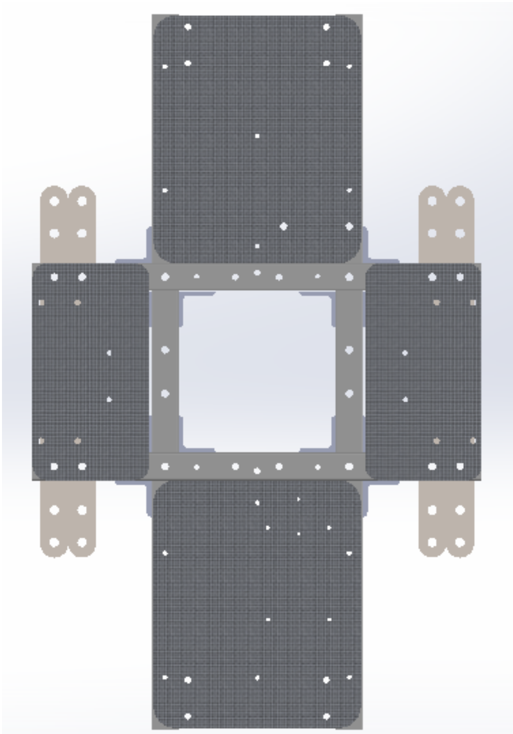
[4.1] Summary



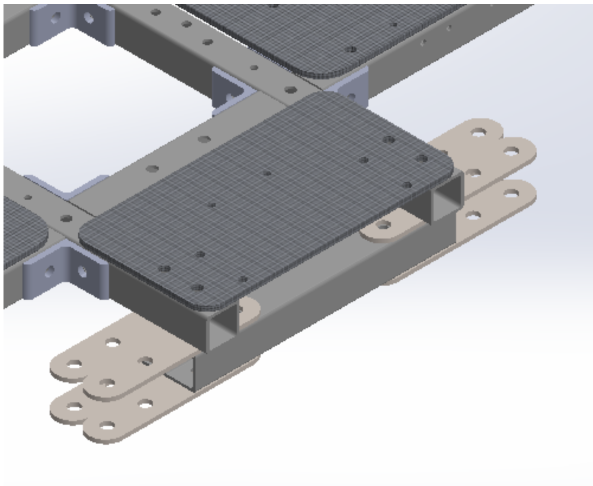
The 2021-2022 chassis frame utilizes square tubing and carbon fiber/acrylic plates. Using L-brackets, the square tubing forms the foundation and the frame of the chassis, while the plates are used to mount various electronics. In order to protect the electronics from projectiles, an outer casing was made consisting of plates and a hinge design. In a similar regard to the chassis frame, the protective frame enclosing the chassis is also made of square tubing and plates with rollers at the end to prevent damage to the armor modules during collisions.

[4.2] Chassis Frame



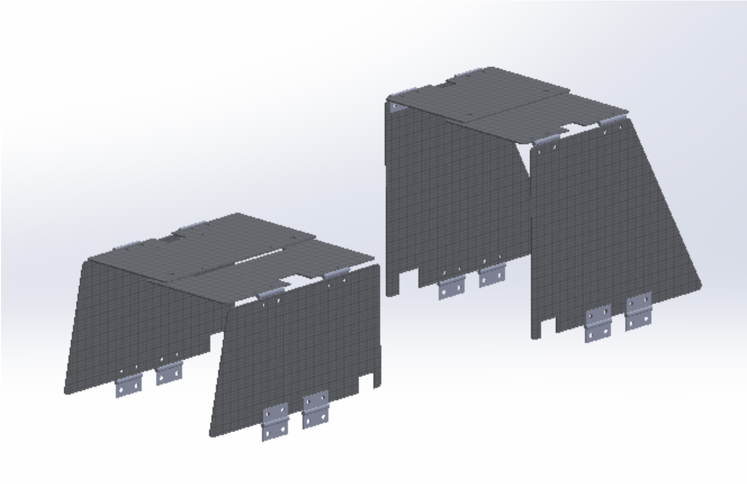


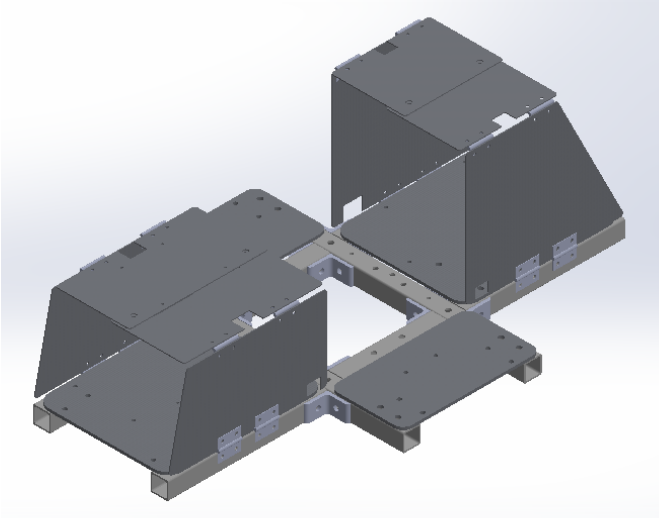
The shape of the chassis frame is rectangular with a front and back arrangement that is apparent from the sides. While the chassis has a rectangular shape, the mecanum wheels are still positioned in a square configuration in order to prevent drag on the rollers. As a result of the rectangular shape, the chassis frame is more compact allowing for an individual to use an under-arm method to carry the chassis easier compared to a square frame.



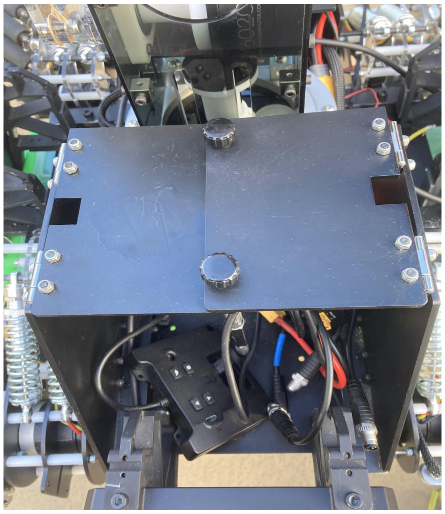
Using 4-hole flat strut brackets, the suspension system will be able to mount onto the chassis. This will be further elaborated in the [suspension section](#).

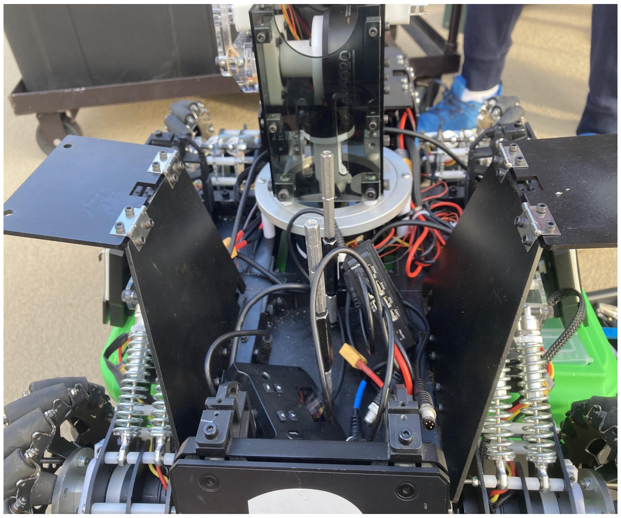
[4.3] Electronics Shield



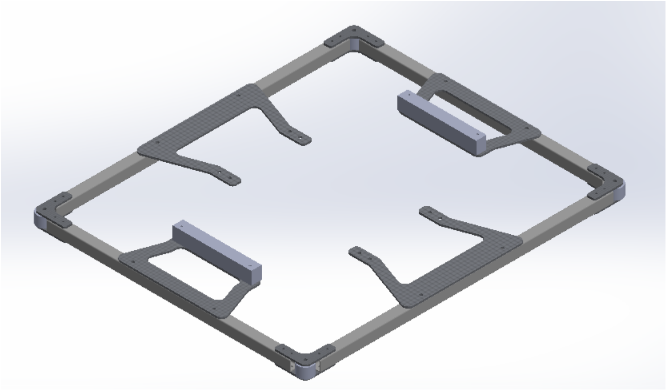


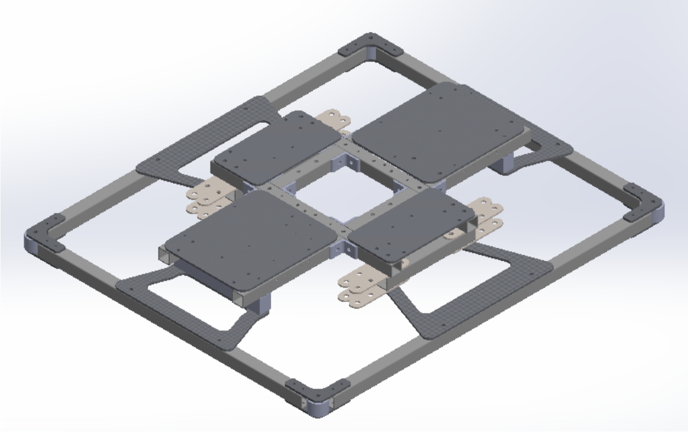
The electronics shield consists of plate and hinge design. As shown in the above image, the hinges will mount onto the chassis frame and are able to open, similar to a door, to allow access to electronics. Standoffs and a knob screw are used to join the left and right plates together at the overlap over the base plate, as well as make the casings more rigid. The back of the chassis has the higher of the two plates to accommodate for the battery height. In a later iteration, protective shielding was added to the side plates; these were made to be 3D printed.





[4.4] Protective Frame

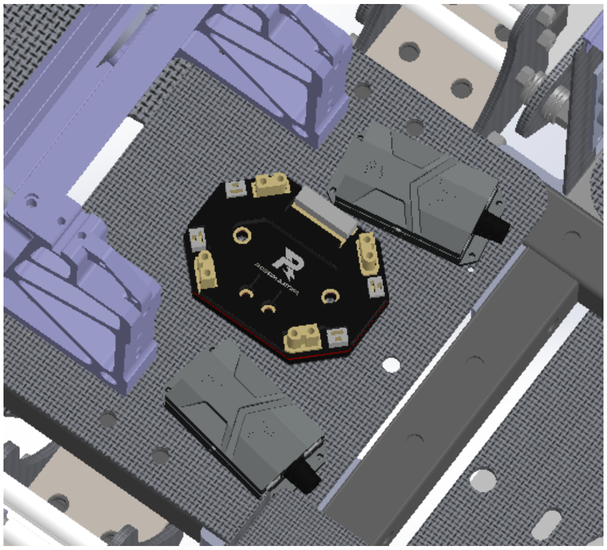




The protective frame for the chassis consists of square tubing and plates, along with a roller at the corner that will take the majority of the force during a collision but also reduce the impulse during impact. Custom brackets are used to mount to the bottom of the chassis. The roller is currently 3D printed in order to reduce costs; a vibration dampener mount would be a good replacement.

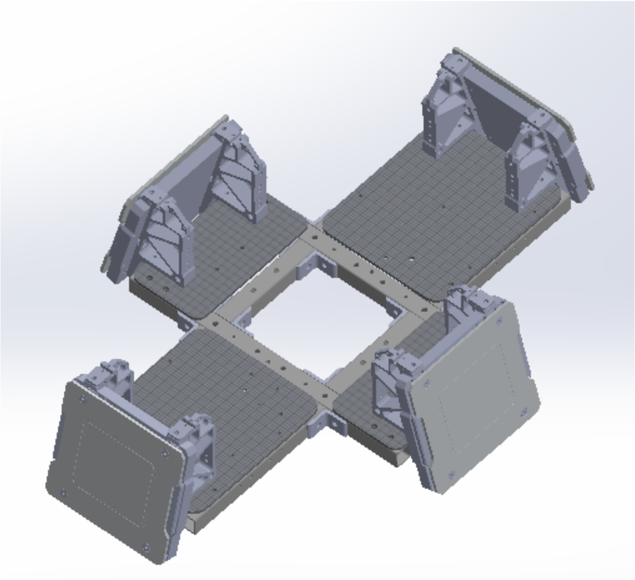
[4.5] Electronics Mounting

[4.5.1] Centerboard and ESCs



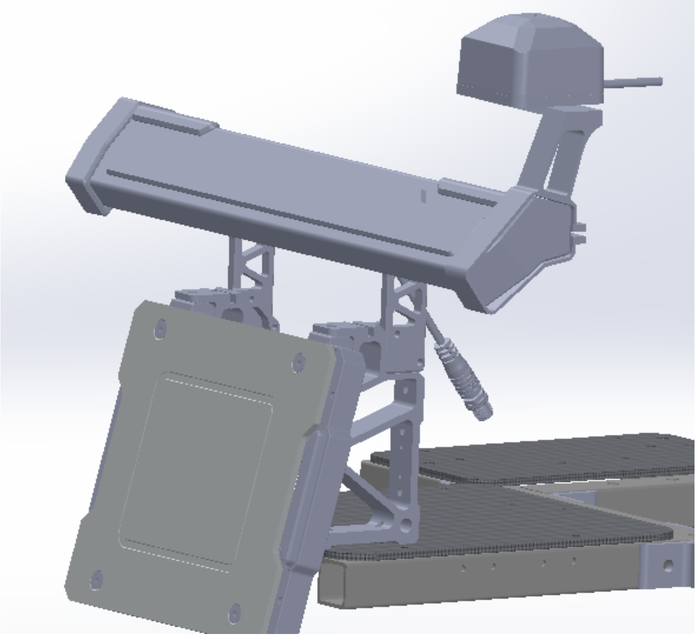
The centerboard and the ESCs will directly mount onto the side plates of the chassis.

[4.5.2] Armor Module



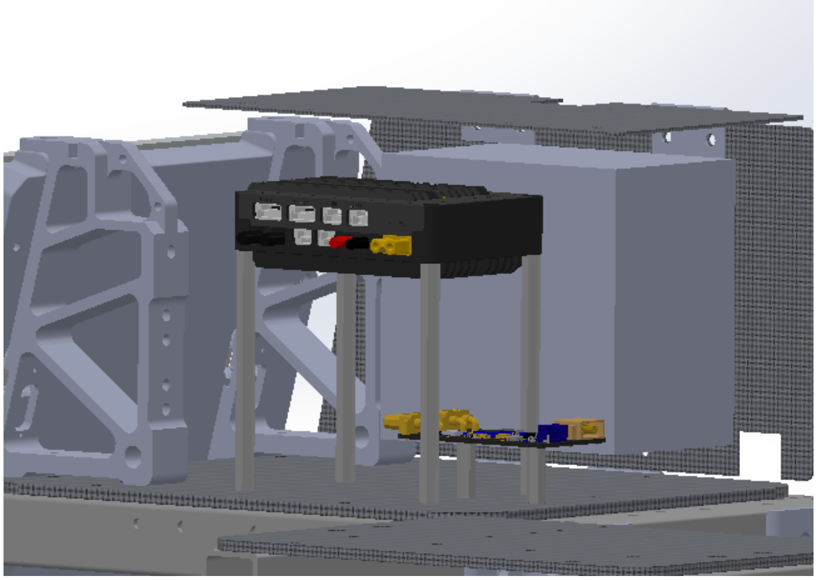
Much like previous designs, the armor modules will mount onto the ends of the chassis frame directly through the base plates.

[4.5.3] Light/Health Bar and GPS/Positioning Module



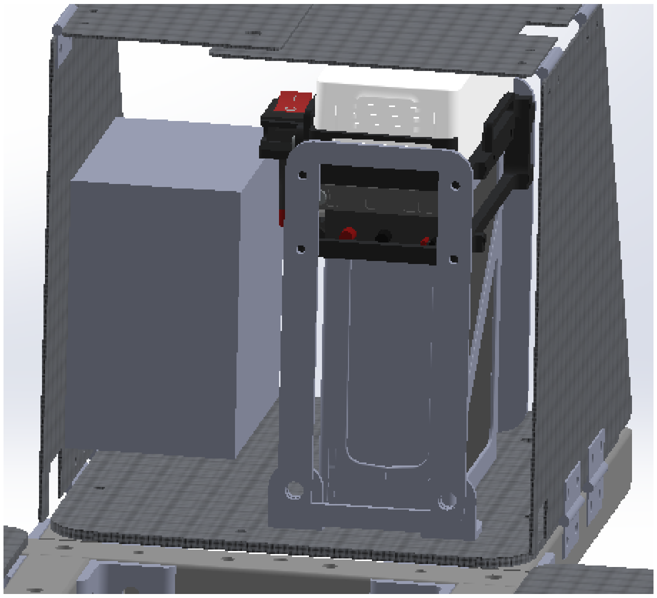
The light bar will mount onto the armor module that is on the back of the chassis frame and the GPS module will mount onto the light bar with a mount. The GPS mount uses a clamp design with a screw to clamp onto the light bar.

[4.5.4] Power Management Module, Supercapacitor Management Module and Proprietary Power Distribution Module



These components will mount on the front of the chassis frame. The supercap and power management module will use standoffs to mount onto the chassis. In the image, the PPDM (gray rectangular prism) is mounted onto the electronics cover to save space.

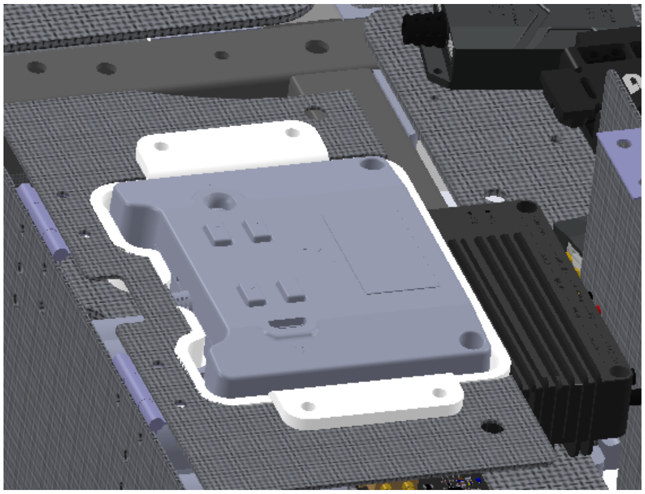
[4.5.5] Supercapacitor Bank and Battery



These components will mount on the back of the chassis frame. The battery uses a custom mounting bracket with L-brackets to mount onto the chassis plate. The supercap bank mounts onto the electronic cover. In a later interaction, the custom mounting bracket of the battery has been changed to become a 3d print and altered to become more compact.

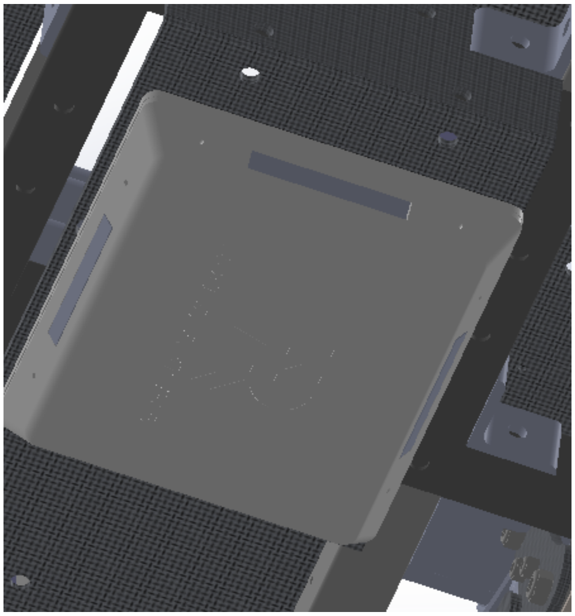
Similar to the change mentioned above, the supercap bank (gray rectangular prism) is expected to mount vertically and this will allow the battery mount to move inward and directly mount through the base plate, an important change since it had to mount onto the square tubing due to lack of space.

[4.5.6] Main Control Module



Currently, the main control module mounts directly onto the top of the electronics shield with a 3d print. The 3d printed part is recessed into the plate.

[4.5.7] RFID Module



The RFID module mounts onto the underside of the chassis in the geometric center.

[4.6] Overall Advantages and Disadvantages

[4.6.1] Advantages

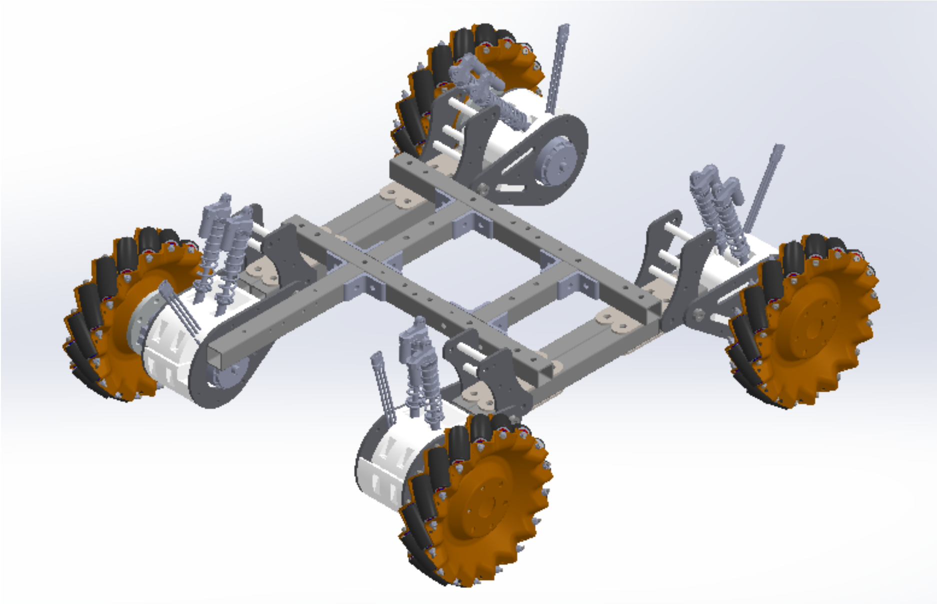
- Compactness: Compared to the old infantry, the compact design allows for an individual to carry it much easier
- Ease of access to electronics: Compared to the old hero, the hinge design allows for an individual to access the electronics by just removing the knob screws
- Electronics shield: The old infantry used a two layer chassis frame, where important electronics were protected under one layer. However, this still exposed some electronics. The electronics shield along with the armor module provides adequate cover for the electronics
- Relative Ease of Manufacturability: The old infantry and hero design used large plates for the chassis. The new infantry design uses smaller plates and square tubing, which are much easier to manufacture through the machine shop or design studio

[4.6.2] Disadvantages

- Protective frame: Due to the nature of the design, the protective frame is much heavier compared to the old infantry which used a single plate and styrofoam at the corners. This one part most likely will make the robot heavier than the older infantry. Efforts to make it lighter and a modular system are currently in progress.
- Compactness: Due to the reduced size and the new supercap electronics, the electronics are placed close to one another and even required stacking with the use of standoffs to make them fit
- Weight: Due to the square tubing, the infantry chassis might weigh more than the old infantry design that used strictly plates. This has not been tested yet

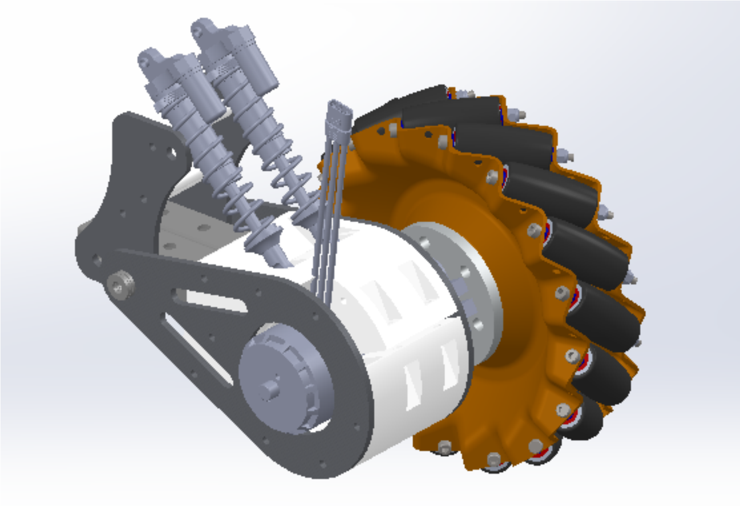
[5] Suspension System

[5.1] Summary



The suspension system uses a design where the shock absorbers are parallel to the mecanum wheels. In order to prevent tilting due to the weight of the chassis on the suspension assembly, a cover with a clamping design is used in hopes that it would distribute the load more evenly across the suspension arm. Compared to previous years, the suspension system is modular.

[5.2] Design

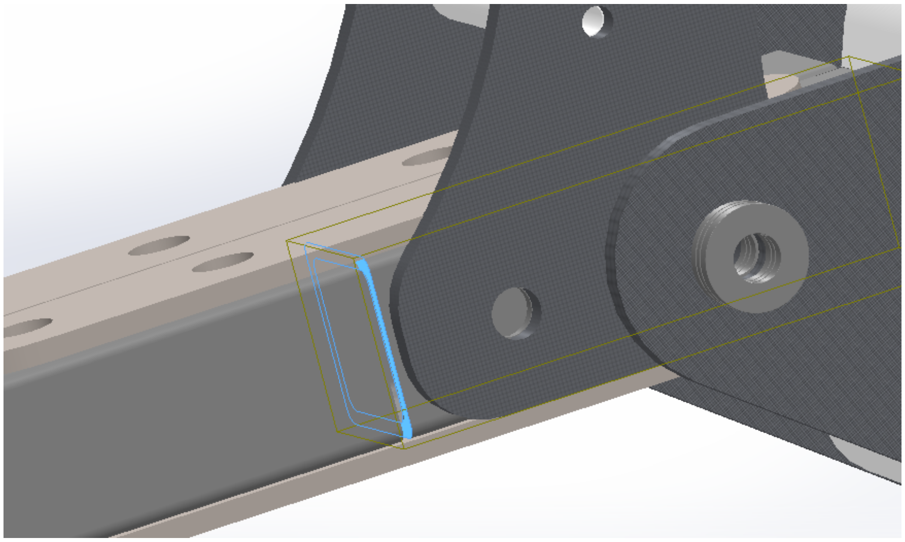


Instead of the traditional double-wishbone design that was used in the previous infantry and last year's hero, The suspension system uses a design where the shock absorbers are parallel to the mecanum wheels. During RMUL

2021, the wishbone design caused the hero to wobble during translational movement. This wobble was emphasized when the chassis moved back and forth. Due to the fact that the most common movement is back and forth, the shock absorbers are positioned to absorb the momentum during this translational movement. Although the old infantry performed fine even with double-wishbone, the design change was made in effort to standardize the suspension systems across the hero and the infantry robots. I am unsure as to whether or not the engineer (the other ground robot) will use a similar suspension system.

A significant problem with this design is the tilting of the suspension arm due to the weight of the chassis. To alleviate this problem, a suspension cover was added (white) with a clamping design that would clamp onto the motor. Not only would this fill the space, but make the assembly more rigid since it was no longer a hollow space (prevent some flexing) but also distribute load evenly to reduce the moment.

[5.3] Mounting



For modularity, the suspension system was designed in such a way that it could easily detach itself from the chassis by unscrewing four screws for each wheel. This is an effort to make traveling easier since the robot would need to be disassembled for shipping. The mounting point is a 4-hole flat strut bracket.

[5.4] Overall Advantages and Disadvantages

[4.6.1] Advantages

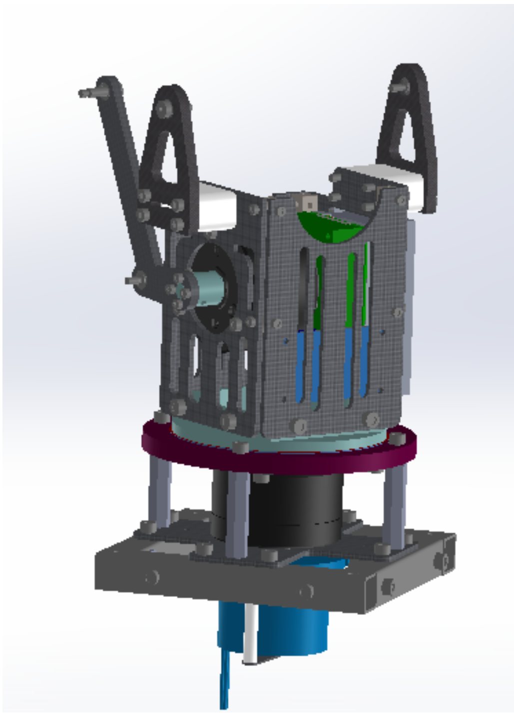
- Modularity: By implementing modularity into the design, disassembling the robot for shipping is made much easier
- Suspension System: By having the shock absorbers parallel to the suspension arm, there is less vibrations when moving back and forth

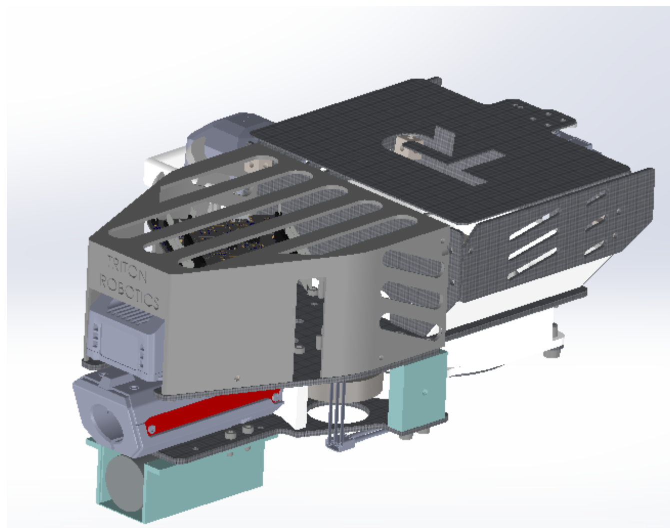
[4.6.2] Disadvantages

- Suspension System: Due to the nature of this design, the weight of the robot causes tilting that was not seen in the double-wishbone design. This could be a big problem for Hero since the chassis is much heavier.
- Naming: Whenever this design is referred to, the words used are “the suspension system with parallel shock absorbers”. There is no one concise word like MacPherson or double-wishbone.

[6] Turret

[6.1] Summary

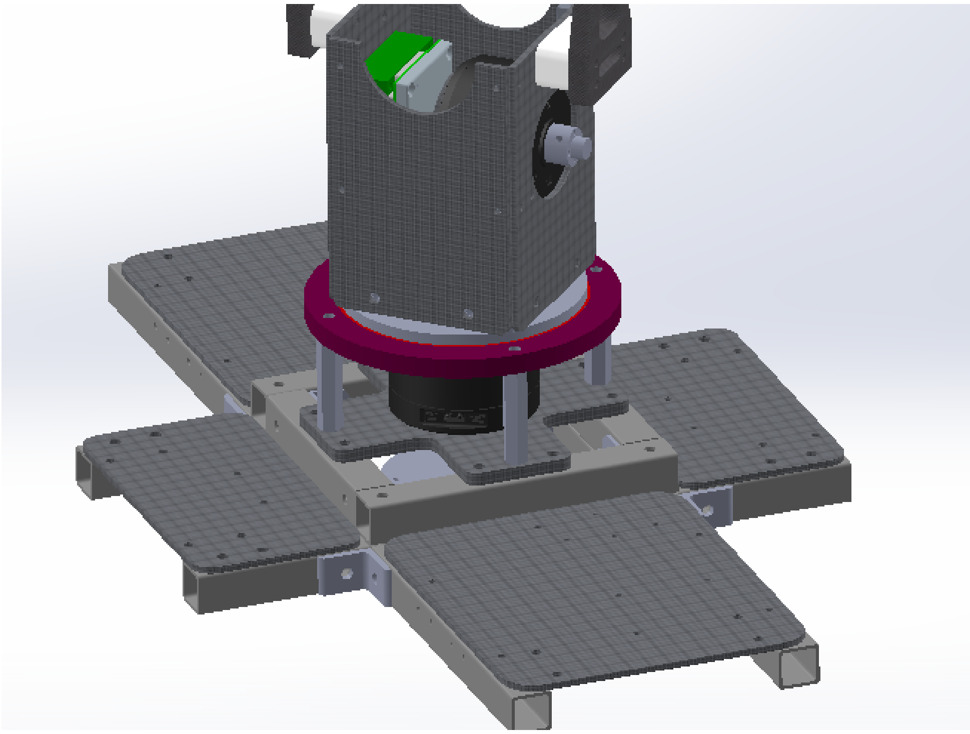




The image on the left is the second design of the turret base, while the image on the right is the design of the turret . This turret design will incorporate the Jetson for auto-aiming purposes, a new larger slip-ring that was deemed necessary due to the added electrical components compared to last year, the usage of the nucleo board, and a new serializer design.

The new turret design uses a 4-bar linkage mechanism to pitch the turret rather than using direct drive. This new design was used in order to make the turret base more compact by moving the pitch motor inside the turret base, as well as reducing the moment of inertia about the yaw axis as a result.

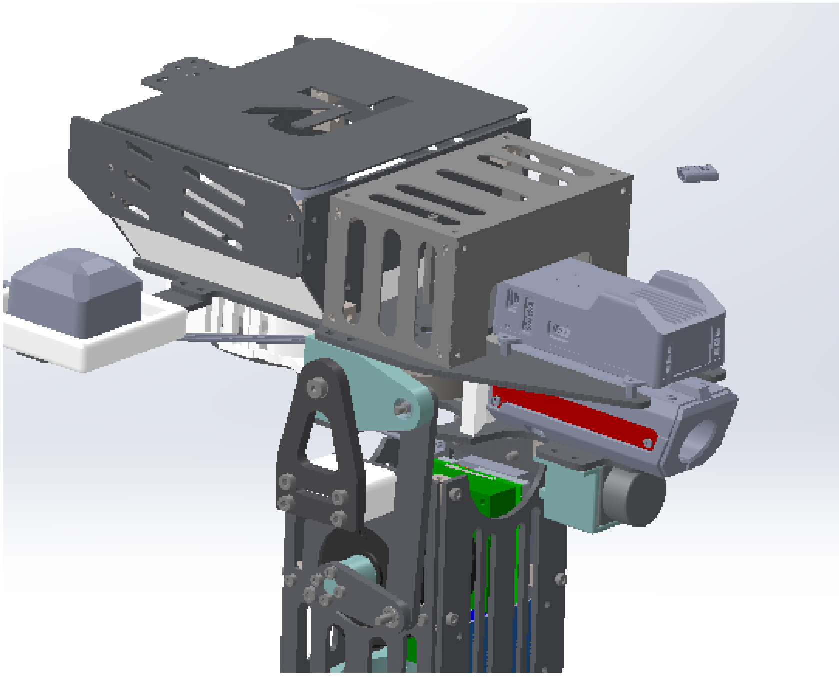
[6.2] Turret Base



The turret base uses a slew bearing (also known as a turntable) to yaw the turret instead of directly driving the base; this was designed to reduce the load on the motor. It mounts onto the chassis through square tubing and a custom cross-bracket. In order to make the turntable more secure, cube-nuts are going to be used inside the square tubing for extra threading.

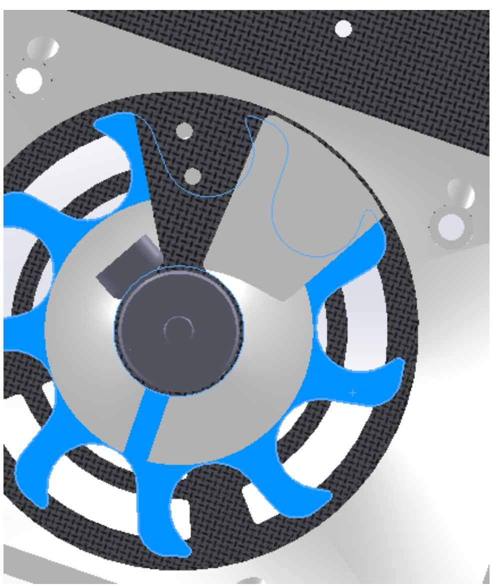
Similar to the first design, a rectangular enclosure is used in order to protect the electronics inside. This was used in order to save space. The plan is to have the Jetson, the buck converter, and pitch motor inside the enclosure. The picture includes an older design, but the mounting procedure is the same.

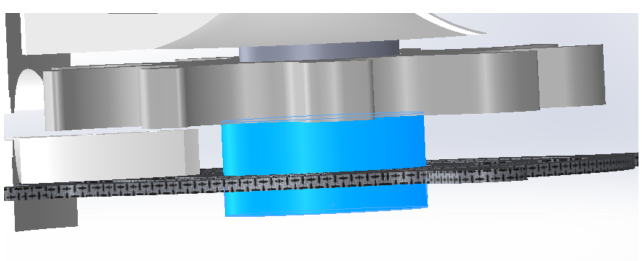
[6.3] Rest of Turret



Due to the fact that the pitch motor was moved below the turret, a linkage mechanism was used to pitch the turret. As far as I know, no analysis was done to determine if we still had enough torque to pitch the turret; however after testing the design, it was deemed sufficient.

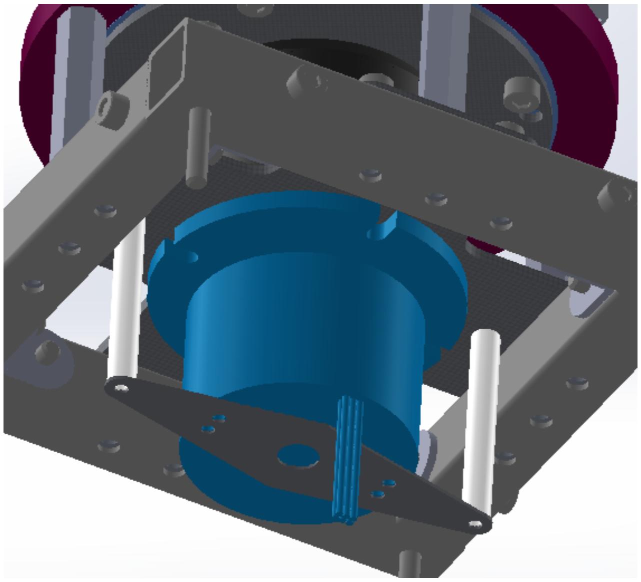
The serializer is currently in progress. This year's design is very similar to the previous year's design, utilizing a lead rail to guide the balls into the barrel. The most prominent difference is that the motor used was moved to be inside the ammo box instead of outside to reduce the chance of damage from flying projectiles.





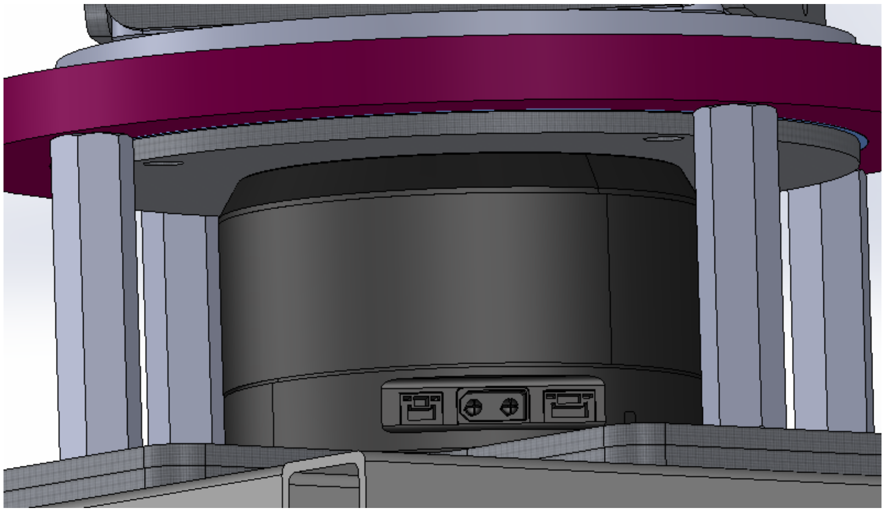
[6.4] Electronics Mounting

[6.4.1] Slip Ring



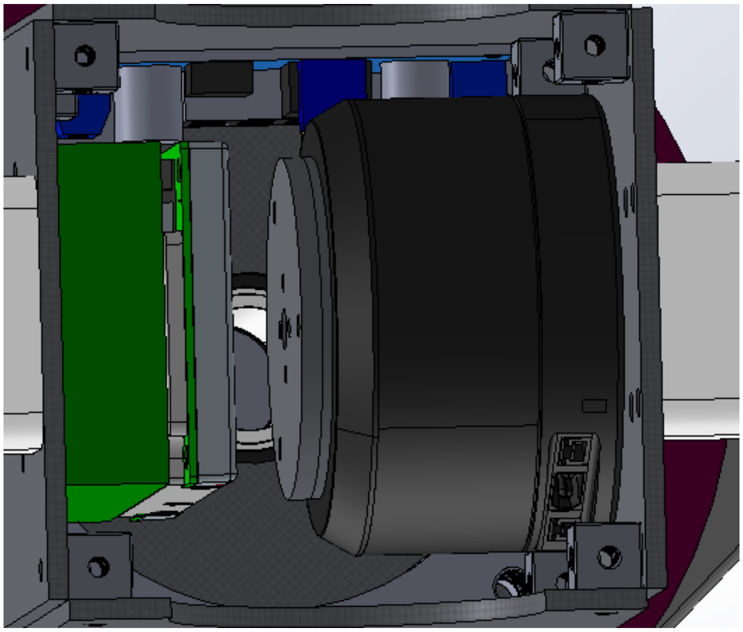
Due to the size of the slip ring, the slip ring mounts under the yaw motor.

[6.4.2] GM6020 Yaw Motor



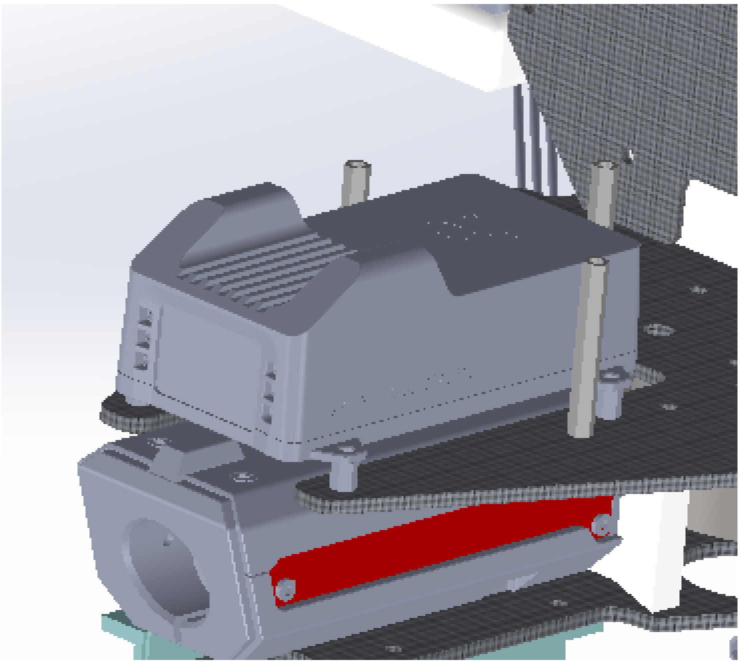
The yaw motor will mount onto the center of the chassis with a cross-bracket. It will also mount to a turntable that yaws the turret base.

[6.4.3] Jetson TX2, 24V to 19V Buck Converter, and GM6020 Pitch Motor



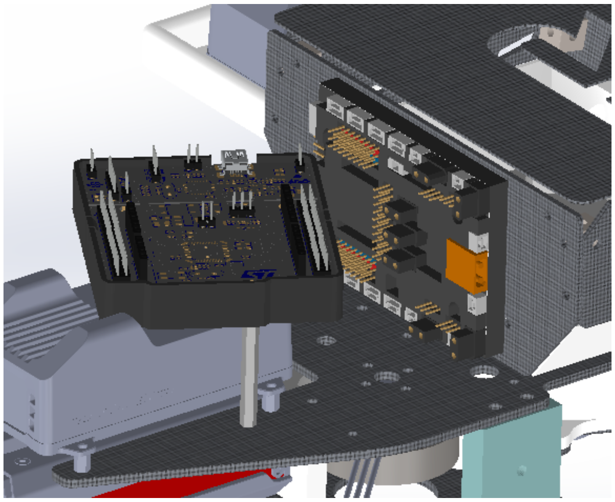
These electrical components will be inside the turret base.

[6.4.4] Video Transmitter and Speed Monitor Module



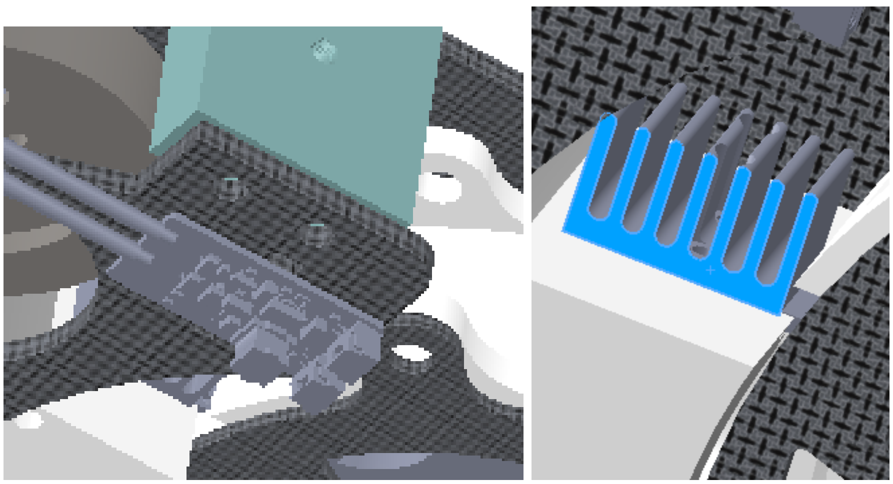
The VTM will mount on top of the speed monitor module and the speed monitor will mount onto the barrel.

[6.4.5] Nucleo Board and Development Board Type A



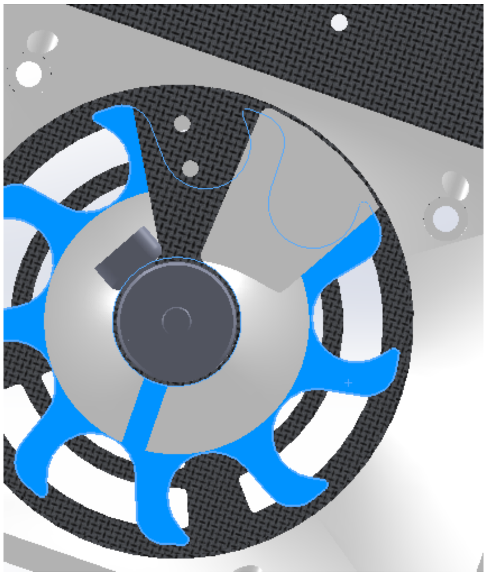
The nucleo board will be mounted via standoffs while the development board will be mounted using velcro.

[6.4.6] LED Driver Module and UV Panel



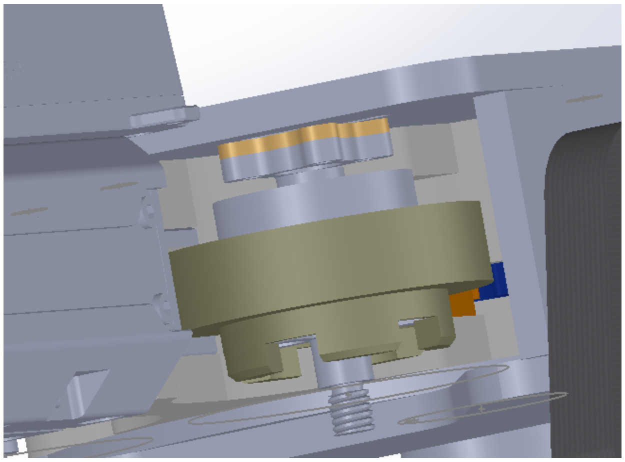
The LED driver module will be mounted to the bottom of the turret plate using velcro while the UV panel will mount directly to the barrel holder.

[6.4.7] M2006 Motor (Serializer)



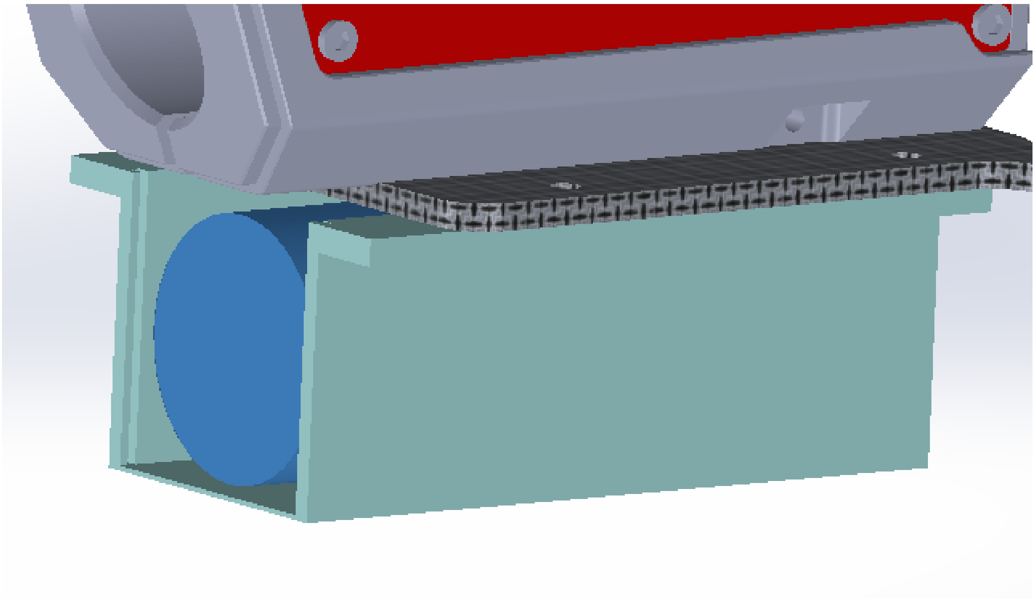
The serializer will mount to the turret plate and be inside of the ammo box.

[6.4.8] Snail Motor (Flywheels)



The snail motors will mount to the revolver top plate. There are plans to have the bottom be mounted to some level in order to reduce vibrations.

[6.4.9] High Speed Camera

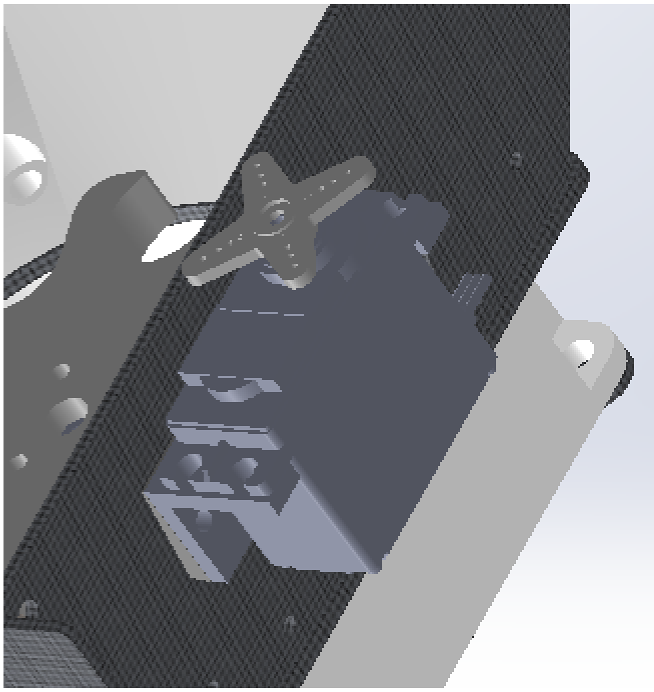


The camera is mounted directly under the speed monitor and is protected with a 3D printed part.

[6.4.10] DR16 Receiver

The location of this component is unable and historically has been mounted with velcro onto an open location on the turret.

[6.4.11] Servo for Ammo Box



The servo mounts to the back of the ammo box and controls the lid.

[6.5] Overall Advantages and Disadvantages

[6.5.1] Advantages

- Compactness: The compact design of the turret base reduces wasted space while also reducing the moment of inertia about the yaw axis.
- Turntable: By using a slew bearing, the load onto the yaw motor is reduced, increasing motor life.

[6.5.2] Disadvantages

- Less pitch torque: Since the pitch mechanism is no longer directly driven and instead uses a linkage mechanism, the torque efficiency decreases. Currently, there is no alarm for energy, but depending on the weight with all the electronics, this might pose a slight problem.

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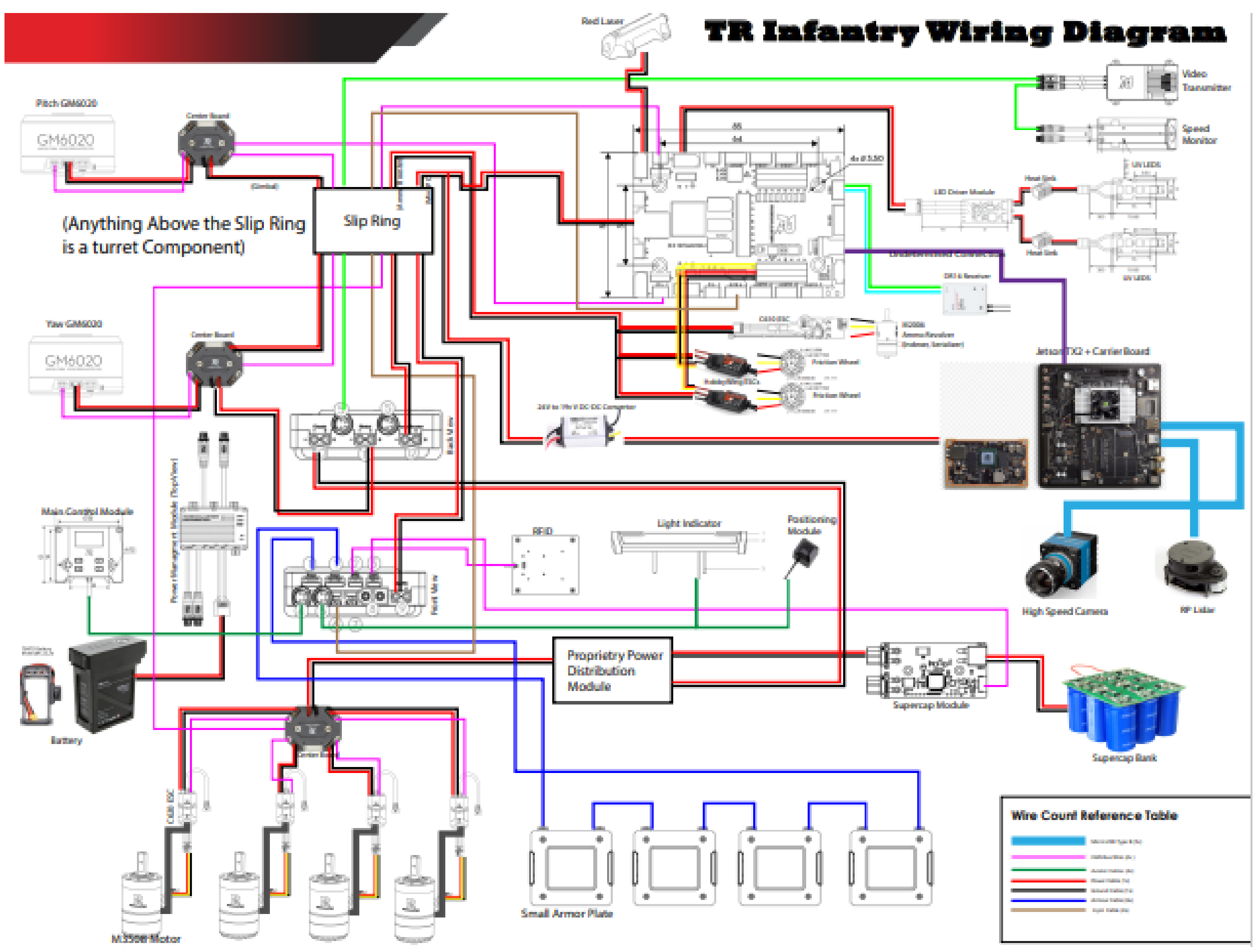
[7] Wiring Diagram



[8] Manufacturing Process

As mentioned in Section 3.4, the current ideal design consists of mainly carbon fiber plates, aluminum square tubing, and 3d-printed parts. Depending on the part, acrylic would be a suitable substitute to reduce cost.

Due to COVID restrictions, manufacturability has proven to be difficult since CNC mills are necessary to cut carbon fiber plates. Similarly, accuracy and precision are important for square tubing to reduce the number of times needed for corrections with a hand drill.

Once COVID restrictions have been lifted, it is possible to manufacture the design. Roger got in contact with Steve from the machine and it is okay to cut carbon fiber with the CNC mills. As long as the design and the Gcode is approved by either Steve or Tom, and they check the material, the carbon fiber parts can be made. Similarly, with access to the manual mills, greater accuracy and precision can be achieved when drilling holes through the square tubing.

[9] B.O.M

Raw Materials:

- 19.05 mm aluminum square tubing
- 1-3 mm carbon fiber plates
- 3 mm acrylic plates
- PLA for 3D printing
- Aluminum stock for CNC cutting

Standard Components:

- Standoffs
- Plastic spacers (not 3d printed)
- Hinges
- Shock absorbers
- M2-5 Screws + (Lock) Nuts
- Knob screws
- 15 mm cube nuts
- L-brackets
- Flat strut brackets
- Roller bearings
- Slew bearing (turntable)