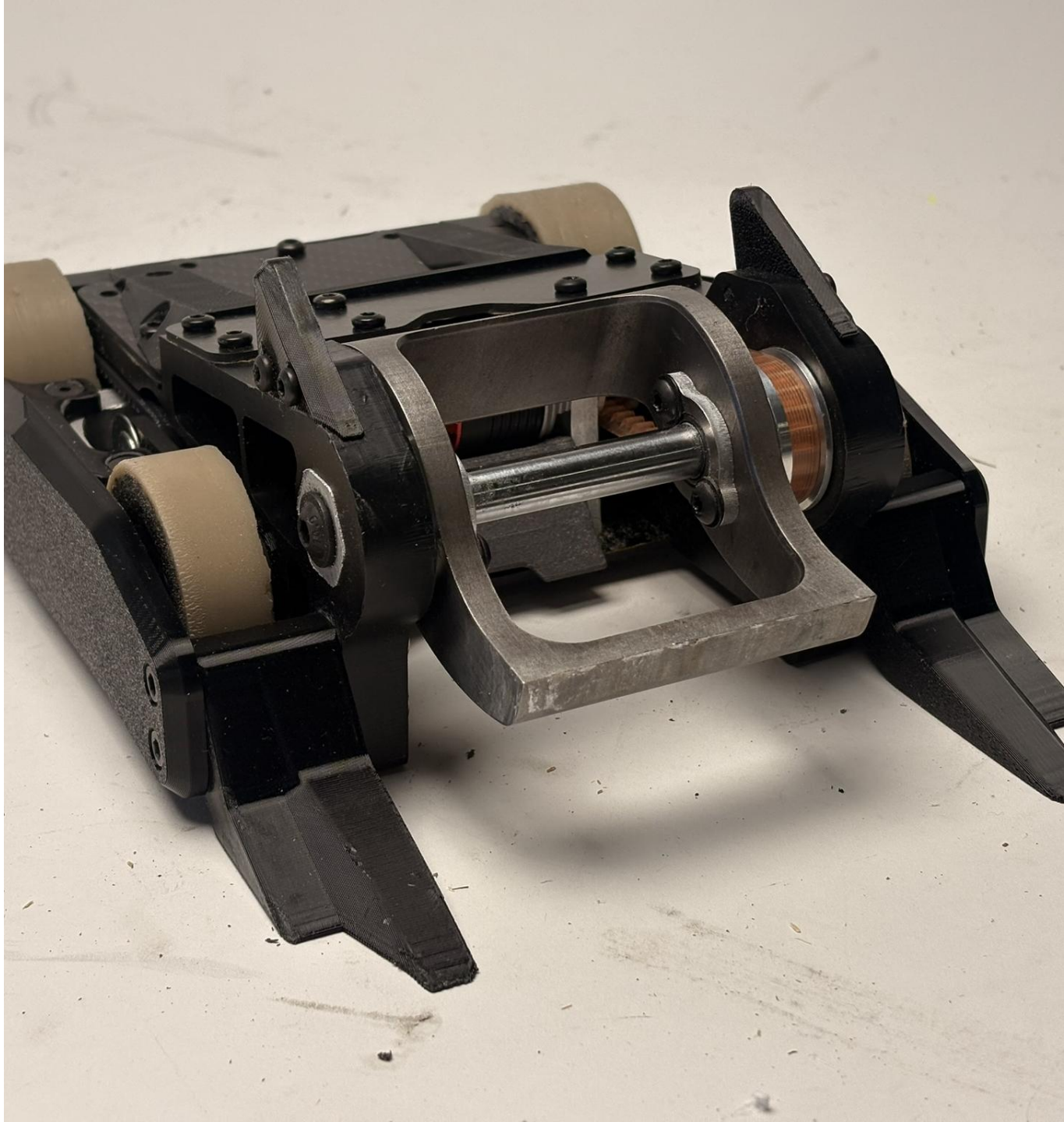
Lincoln Wen

Engineering Portfolio

B.S. Mechanical Engineering, Worcester Polytechnic Institute
Class of 2029 | Presidential Scholar

Mechanical Engineering Intern, Johnson & Johnson MedTech
Secretary, WPI Combat Robotics Club
Former Technical Lead, FRC Team 254

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Stardust V2: 3 lb Beetleweight Combat Robot



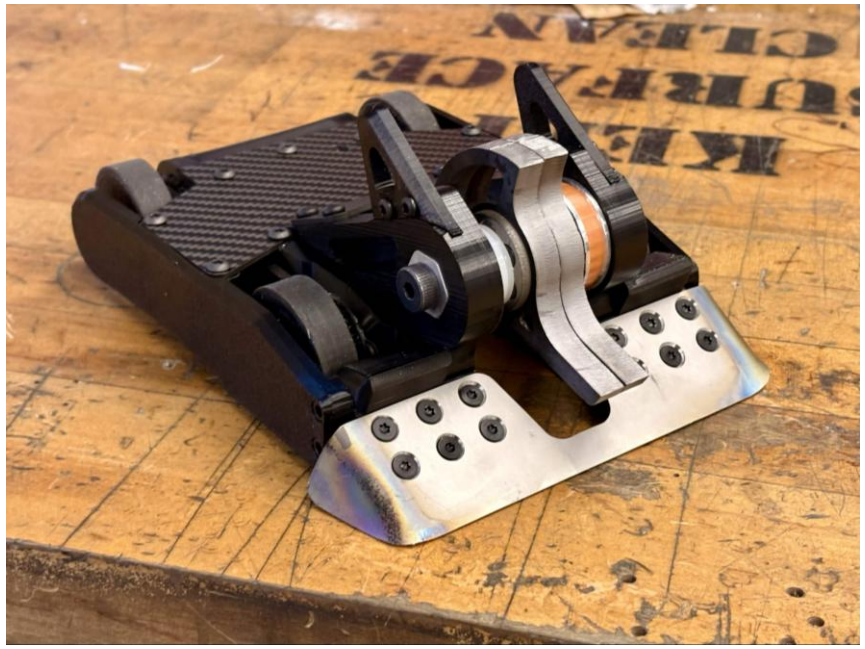
Stardust V2, fully built copies

Stardust V2 was a full redesign of V1 from the ground up. The goal for V2 was a higher performance ceiling which meant a beater bar instead of a thick disk, a belt-driven 4WD chassis, and swappable fronts for different opponents.

Role: This was an individual project so I did everything from design to manufacturing to wiring to controls.

Spec	Value
Weight class	3 lb (1,361 g)
Weapon	Beater bar, 4340 steel
Weapon speed	~28,000 RPM
Tip speed	313 mph
Stored energy	1,064 J
Drivetrain	Belt-driven 4WD

V1 to V2: Design Changes

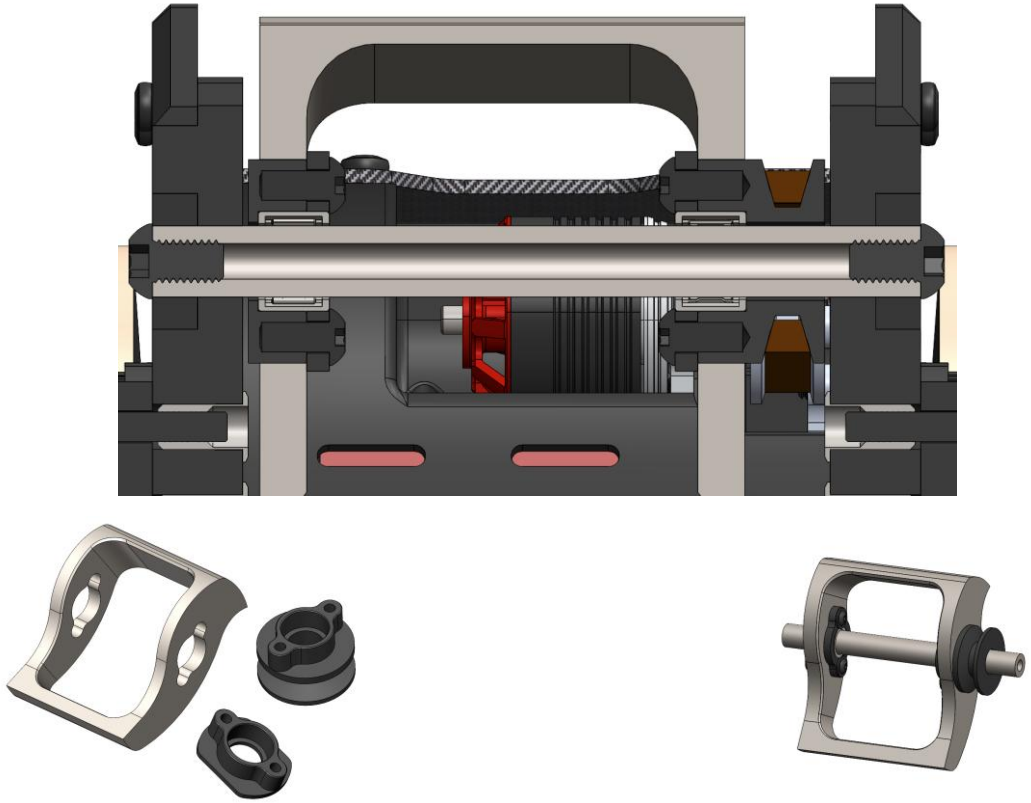


Stardust V1 at NHRL: upset the #3 seed in a field of 80 and reached reached the round of 16

V1 was competitive, but its thick disk and drivetrain limited how far I felt it could go. V2 utilized my utilized my learnings from V1 to redesign the robot from the ground up. Some of the significant significant changes are shown below.

Change	Reason
Thick disk to asymmetric beater bar	More hitting surface and more stored energy
Indirect, belt-driven 4WD	Better drivetrain reliability and durability
Wider but shorter wheelbase	More precise control
Wide rear wheels	Better traction, turning, and control
Four swappable fronts	Match the front to each opponent's weapon
Printed hubs, cast urethane tires	Light, compliant wheels that absorb hits
Dedicated electronic space	Packaging features to reduce EMF & RFI interference between components
Swappable modules	Swappable modules to decrease repair time during competitions

Weapon System



Weapon assembly (top); beater bar and hubs, exploded and assembled (bottom)

Beater bar

- 3.75 in swing diameter, ~2.7 in balance tooth
- 5° tooth rake
- 4340 steel, hardened to 45–47 HRC
- Custom 6061 hubs, 8-32 fasteners

Shaft and bearings

- Hardened 10 × 108 mm hollow steel shaft, tapped M6 through
- Two 10 × 14 × 10 mm needle roller bearings
- Hex inserts in the UHMW uprights stop the bores from ovaling
- Laser-cut plates and flanged screws retain the bearings

Power transmission

- 2L080 V-belt, 0.8 in to 1.1 in pulleys (0.73:1)

Weapon Motor Selection

Motor	Mass	Published power	Notes
Emax ECO II 2807	47.6 g	Not published	FPV motor; no power rating to compare
Repeat Belt Drive 2812	85 g	583–953 W peak (4S test)	Built for combat with a 5 mm shaft, but heavier
BadAss 2310	57.8 g	600 W continuous, 5S max	Not rated for the 6S pack; slower spin-up
BadAss 2315 (selected)	75.2 g	820 W continuous, 6S	Best rated power per gram in its line (10.9 W/g)
BadAss 2320	91.7 g	980 W continuous, 6S	16.5 g heavier for a small spin-up gain

KV chosen for tip speed

2315 KV option	Tip speed
1110 KV	235 mph
1480 KV (selected)	313 mph
1800 KV	381 mph

Motor Selection

- The BadAss Airplane motors are light and efficient, with N52 magnets rated to 150 °C
    - Having N52 magnets are important because I am running these motors past its expected load case, and the motors can get very hot.
- The trade-off is a thin 4 mm shaft, so the V-belt is meant to slip under big impacts and protect it
- It also had the best rated power per gram which helps create a really weight efficient but power dense system
- KV was selected to be in the range of 300mph to win tip speed fights against other vertical spinners

Weapon Energy Calculations

Inputs

Input	Value
Weapon diameter	3.75 in
Moment of inertia (from CAD)	0.84 lbm·in²
Weapon motor	BadAss 2315, 1480 KV, 820 W
Battery	6S LiHV, 4.35 V/cell
Belt ratio	0.727 (0.8 : 1.1 in)

Results

Output	Value
Weapon speed	28,093 RPM
Tip speed	313 mph
Stored energy	1,064 J
Bite per tooth pass	0.47 in
Spin-up time / current	1.3 s / 31.4 A (estimates)

Weapon speed

$\omega = KV \times V \times \text{ratio}$

$= 1480 \times 26.1\ V \times 0.727$

$= 28{,}093\ \text{RPM} = 2{,}942\ \text{rad/s}$

Stored energy

$E = \frac{1}{2} \times I \times \omega^2$

$= \frac{1}{2} \times 2.458 \times 10^{-4}\ \text{kg·m}^2 \times 2{,}942^2$

$= 1{,}064\ \text{J}$

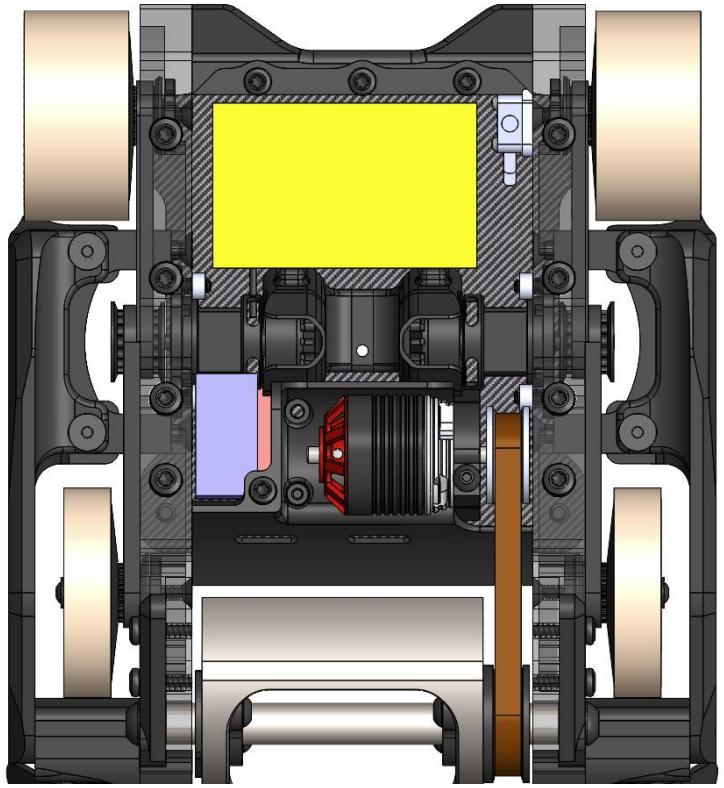
Tip speed

$v = \omega \times r$

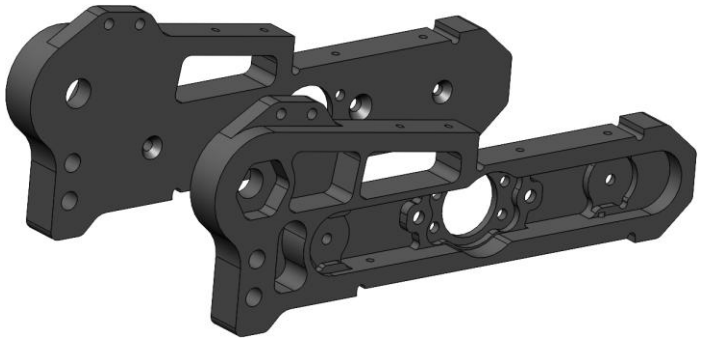
$= 2{,}942\ \text{rad/s} \times 1.875\ \text{in}$

$= 313\ \text{mph}$

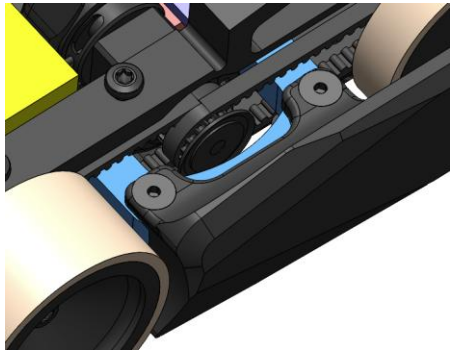
Chassis and Drivetrain



Top view, cover removed



Drive rail, side view



Pulley guard and side-armor mount

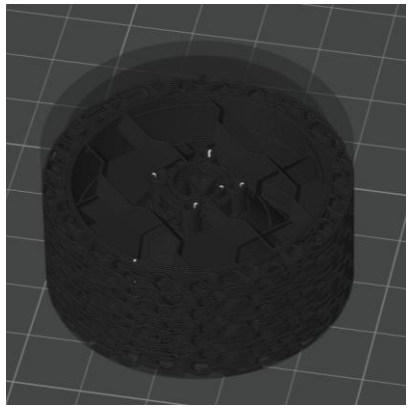
Drive

- Indirect belt drive on Repeat Compact MK2 motors (pre-release)
- 17T dual pulleys driving 16T, 2 in OD wheels
- 15.3 mph top speed, throttle-limited for control

Structure

- ½ in machined UHMW uprights
- 0.1 in 6061 motor plate with a 0.125 in tapped plate
- ⅜ in pulley guard doubles as the side-armor mount (16.4 g)
- PA6-GF electronics mounts and guards; TPU rear panel

Wheels: Printed Hubs with Cast Urethane



Hub in the printer slicer: gyroid interface that locks in the urethane, reinforced pulley core



A batch of wheels curing in printed molds

The wheels are TPU hubs with urethane surrounding. The urethane also acts as structure and armor for the wheels.

Retention

Gyroid interface geometry mechanically locks in the VytaFlex 30A urethane.

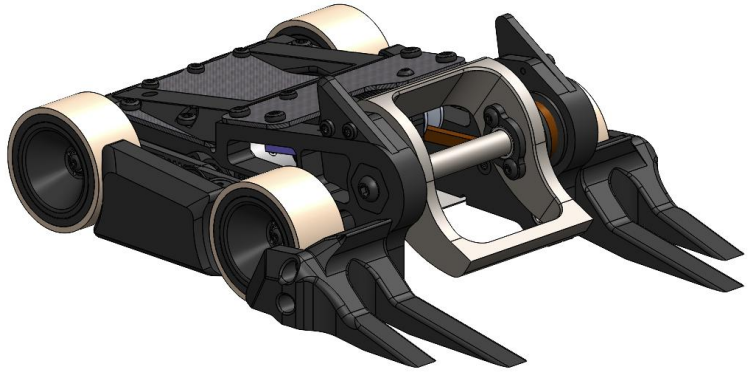
Compliance

Very light infill and thin walls cut weight and let the whole wheel flex to absorb hits.

Torque transfer

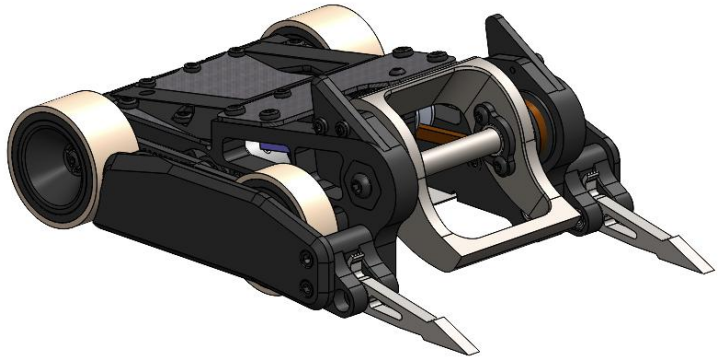
Slicer modifiers reinforce only the pulley section, so drive torque transfers properly into the wheel.

Front Configurations (1 of 2)



Default: TPU ground game

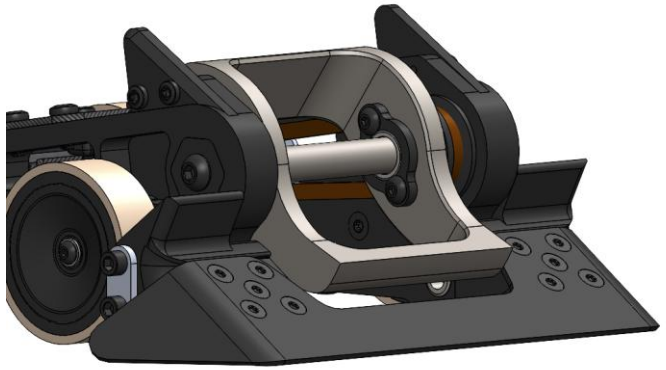
- Large TPU forks to win the ground game and absorb hits until the weapon connects
- Front wheels partially shielded
- Side armor sticks out past the wheels to protect against side hits
- Large wheels to have great traction and control.

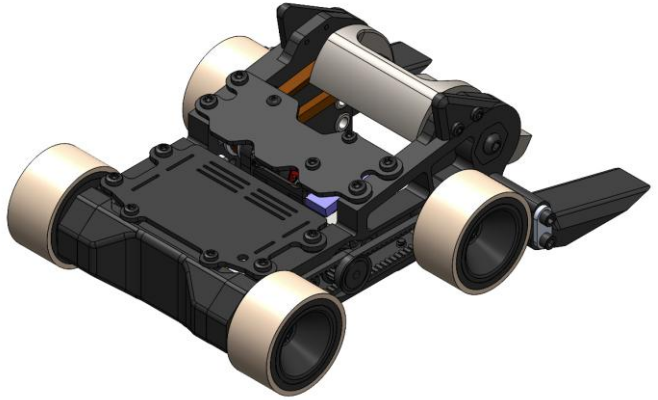


AR600 forks: vertical spinners

- ¼ in AR600 forks take hits without deforming
- Integrated mounts let the forks rotate up/down to 10°, then stop, so they can't be sprung up/down
- Full side armor protects the front wheels

Front Configurations (2 of 2)





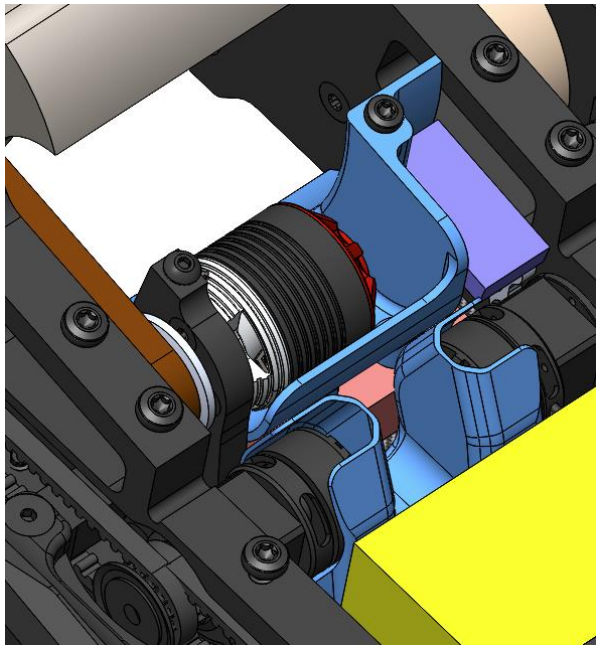
Titanium wedge: horizontal spinners

- 1.6 mm Grade 5 titanium; slope reduced from 45° to 36° so opponents enter the weapon more gradually and I am less likely to get thrown
- Larger cross-sections and more surface area for longer life
- Stronger mounting with full TPU backing to absorb impact energy

Overhead armor: hammersaws

- 2.5 mm SR500 steel top armor on TPU shock mounts keeps weapons away from the electronics
- Wide front wheels for traction; shallow TPU forks to get under a hammersaw's long forks
- Spring steel over the CF bottom plate protects the robot if flipped (not shown)

Electronics



Electronics bay, section view

Function	Component	Reason
Battery	GNB 6S 850 mAh 120C LiHV	More capacity than V1, same voltage
Weapon motor	BadAss 2315, 1480 KV	See motor selection (p. 5)
Drive motors	Repeat Compact MK2	Pre-release units
ESC	T-Hobby F66A Mini 4-in-1	Well regarded in FPV racing for performance and reliability
Receiver	RadioMaster ER4 (ELRS)	EdgeTX mixing for differential drive
BEC	Pololu D24V7F5	Small package; same as V1
Switch	Lynx switch	Small package; same as V1

Manufacturing and Sourcing

Overseas & Internal CNC

Prepared drawings and RFQs for a CNC shop in Hong Kong. They cut the weapon and hardened it (4340 steel). Aluminum parts were CNC milled/lathed by myself at WPI's machine shop.

Heat treatment

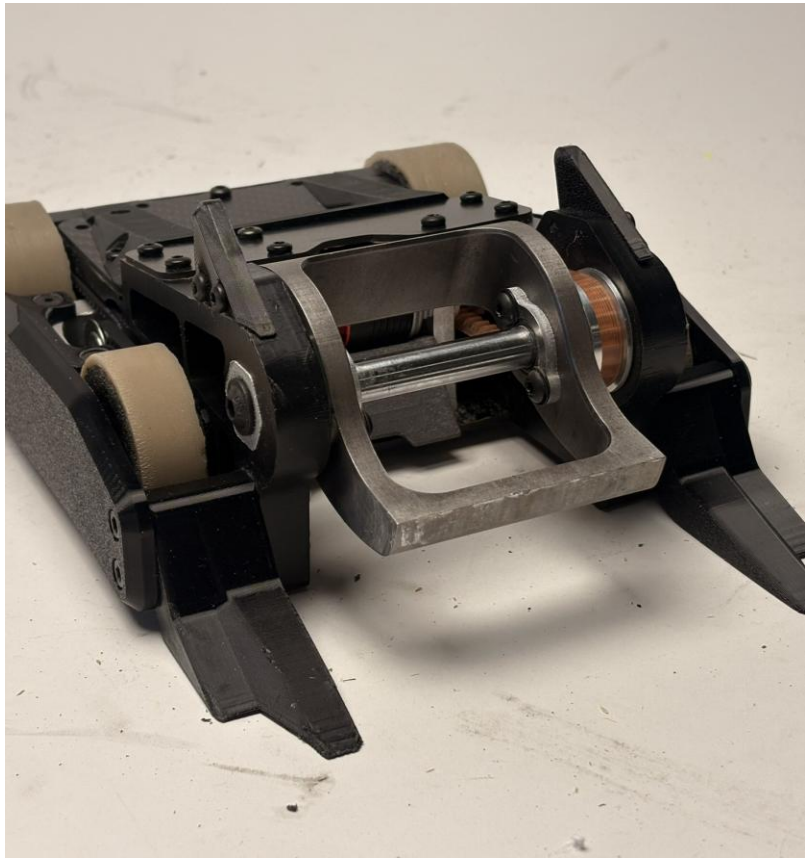
Specified 45–47 HRC. Turned down machining from pre-hardened stock because of micro-crack risk; bars are milled soft, then hardened.

Printed parts

PA6-GF, PA6-CF and TPU on a Bambu P1S, chosen per part for stiffness or impact absorption.

CAM and sheet parts

Mastercam toolpaths for the CNC parts; laser-cut plates from SendCutSend.



Finished robot

Johnson & Johnson MedTech

Summer 2025

Mechanical Engineering Intern, Strategic Robotics R&D | Santa Clara, CA

I am under a NDA, so no images, designs or technical details can be shown.

Process

1. Gathered necessary information to design a V2 robotic surgical instrument subsystem from V1.5 to V2.
2. Created test plan and methods to do baseline testing on existing design.
3. Executed and analyzed test results, used results to define subsystem requirements and key features.
4. Designed, built and tested an initial architecture concept. During testing, found a 5% failure rate for a critical feature.
5. Ran root cause analysis and started two alternative architectures to address failures.
6. Prototyped and tested those concepts in Solidworks through several design validation cycles.
7. Ultimately selected the architecture that had the highest performance at the lowest cost. Advanced that architecture through further prototyping.
8. Created test plan and methods to do preliminary verification and testing on prototype to meet subsystem specification requirements.

Outcome

- Took a robotic surgical instrument subsystem from V1.5 to a re-architected V2.0
- One architecture exceeded performance targets
- Presented findings and next-phase options to the VP of Strategic Robotics

FRC Team 254: 2025 Robot



Competition robot; full CAD; subsystems I led

Role: Technical Lead; lead designer of the drive base, elevator and climber

Results: World Championship Division Finalist, 2 regional wins, 6 awards

- Owned the full cycle for my subsystems: requirements, architecture, prototyping, detailed design, fabrication, assembly and testing
- Integrated all subsystems into the 115 lb competition robot
- Used FEA and iterative CAD prototyping to improve strength-to-weight
- Built about 75% of the wiring harnesses on a CAN-FD electrical system
- Led a 60+ member team; set and enforced the build schedule and led assembly of the practice and competition robots
- Team 254 won the 2022 World Championship and placed top 5 globally from 2022 to 2025

FRC Team 254: 2024 Robot



2024 competition robot

Role: shooter architecture, wiring and assembly lead

Results: World Championship Finalist, 2 regional wins, 7 awards

- Led early ideation and prototyping of the ring shooter, which drove the architecture selection; pivoted to a new architecture mid-season
- Main CAD role was high-level design and architecture
- Built 80–90% of the wiring harnesses, using industrial sensors for robustness
- Led assembly and wiring of the practice and competition robots
- Built a 15-student outreach team from scratch that helped international teams at every event we attended, reaching 100+ teams

Antweight Robots (1 lb)



Horizontal impactor (no material limits)

- AR500 impactor designed for high moment of inertia and durability
- Torque-speed and motor power analysis to pick the motor for spin-up and weapon speed
- Designed for easy service and predictable failure modes to simplify repairs between matches



Clankatron (3D-printed PLA only)

- Vertical drum designed for an aggressive bite and high moment of inertia
- Iterated chassis geometry and reinforcement to survive repeated impacts
- Very light drivetrain for precise control
- Tested PLA formulations against each other for toughness under impact
- **Result:** won the WPI Combat Robotics Club internal PLAnt competition

Thank you

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