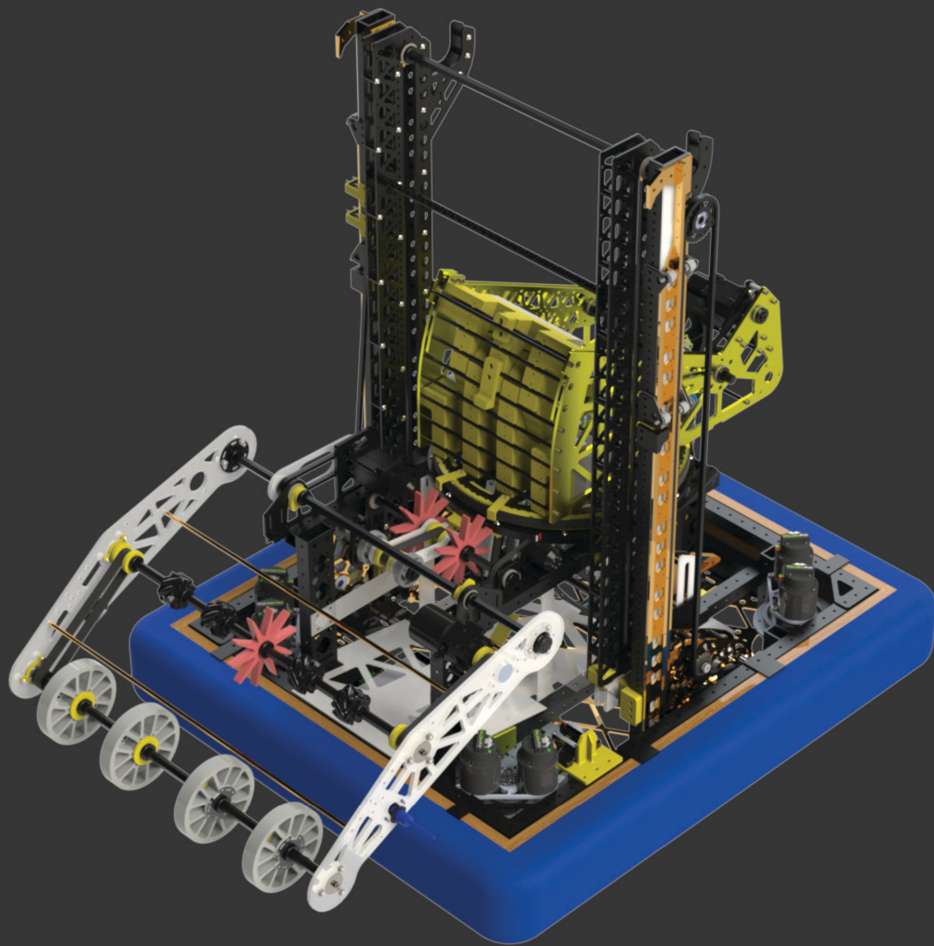
TECHNICAL MAGAZINE

FRC TEAM 2485 / THE W.A.R. LORDS



MAVERICK

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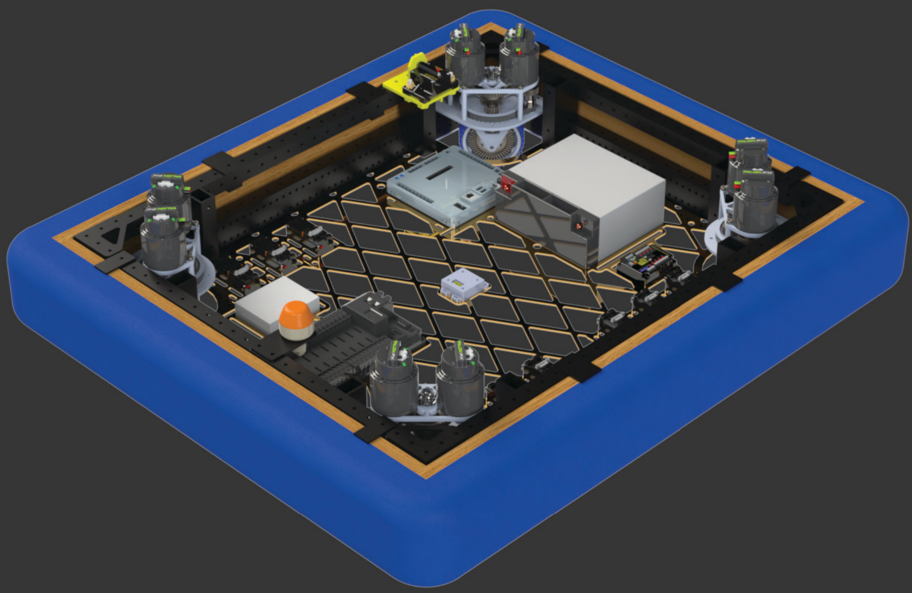
DRIVETRAIN



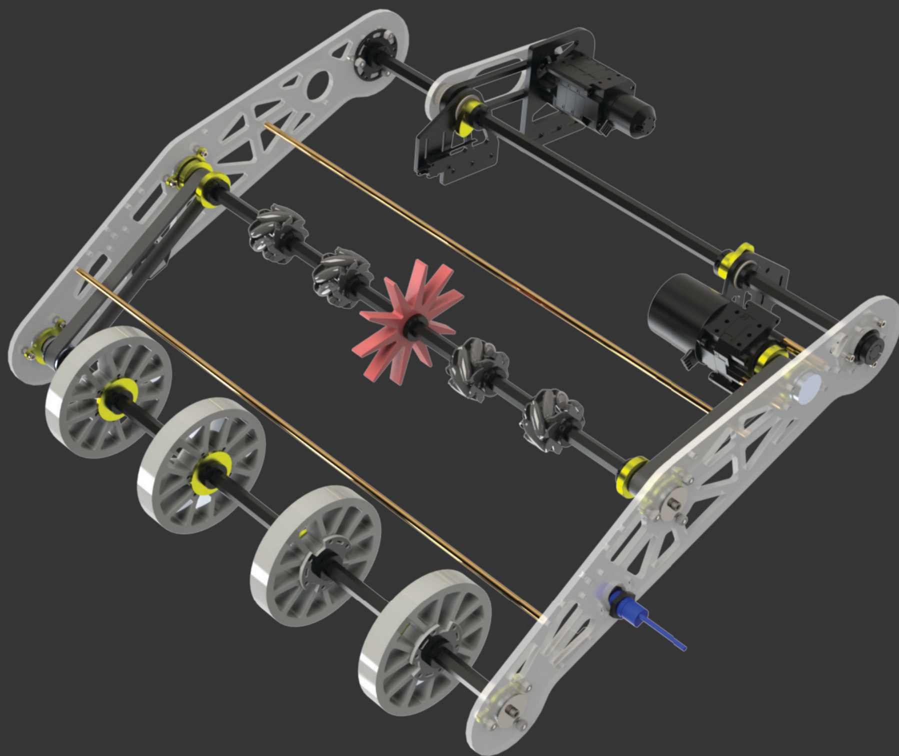
Overview

This year, the W.A.R. Lords made the exciting decision to pursue swerve drive for the first time, after a successful off-season trial using modules purchased from Swerve Drive Specialties. Swerve drive confers unparalleled maneuverability to our robot; with independent control over all four wheels, Maverick can strafe and turn in place, movements that are normally difficult or impossible with FRC-standard West Coast Drive. When combined with our turret, swerve drive lends Maverick excellent control over its shooting alignment and fine positioning, in addition to enhanced stability as compared to drivetrains with a center drop. Although swerve drives tend to be fragile due to their preponderance of small moving parts, impact resistance wasn't a primary concern this year for two reasons: first of all, Swerve Drive Specialties' modular system allows for relatively easy maintenance compared to team-manufactured solutions; and second of all, the field for Rapid React is wide open without any major obstacles on the floor.

Technical Details

- 4-wheel swerve drive
- 4x MK4 swerve modules from Swerve Drive Specialties
- 8 Falcon 500 motors (4 for steering, 4 for driving)
- L2 gearing: 6.75:1 reduction
- 16.3 ft/sec theoretical free speed
- 4" billet wheels with 1.5" wide blue nitrile tread for traction
- Frame rails: 1/8" wall 2" by 1" aluminum tube construction, 31.5" long by 26.5" wide
- Bumper rails: 1/16" wall 1" by 1" aluminum tube construction, 32" long by 27" wide
- Frame perimeter: 118"
- Bumpers: no cutouts (over-the-bumper intake), recessed 0.475" below belly pan for maximum protection against defense (1.15" ground clearance)

INTAKE



Overview

We opted for an over-the-bumper design to maximize intake width. An outer shaft with a set of 5" wheels quickly pulls in the cargo and rolls it up onto the bumper, after which 2" mecanum wheels on an inner shaft center the cargo; notably, the mecanums don't need to keep up with the robot floor speed as the cargo is already off the ground, thereby permitting cargo acquisition at high velocities.

Technical Details

- 1/4" polycarbonate side plates for impact resistance with rigidity
- Four 5" diameter compliant wheels on the outer shaft draw cargo off the floor and onto the bumper, contributing to the "touch-it, own-it" design philosophy
- Two pairs of 2" mecanum wheels on the inner shaft center cargo along bumper, before the cargo is pulled into the robot by an AndyMark entrapption star
- Both intake shafts driven by a NEO motor attached to a 4:1 1-stage MaxPlanetary gearbox
- Pivoted up and down by a NEO 550 motor attached to a 125:1 three-stage MaxPlanetary gear-box
- Placed on the opposite side of the shooter to balance Maverick's center of mass
- Mounted color sensor prevents intake of the opposing team's cargo, while a beam-break sensor informs software of the cargo's presence

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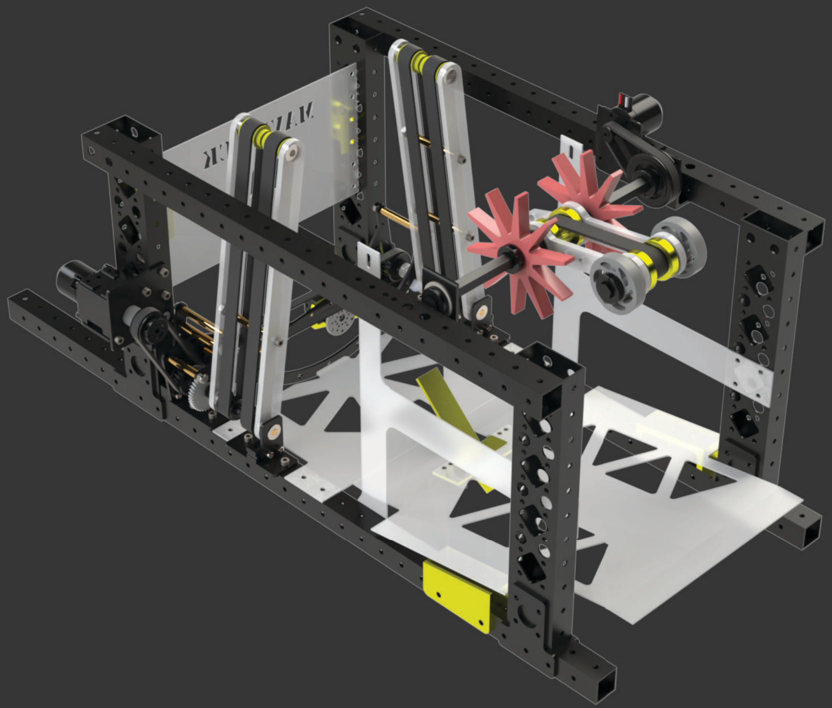

Overview

Maverick’s magazine was designed with ease of operation in mind, offering a mechanical solution to indexing without the need for extra synchronization and sensors. In order to carry the cargo across the length of the robot and through a turret opening, the magazine was divided into distinct horizontal and vertical components.

Horizontal Indexer

The horizontal indexer is quite simple in operation, designed to ensure control of the cargo throughout the length of the cargo path and prevent backflow as a result of rapid movement.

Technical Details

- Two 2” compliant wheels receive cargo from the intake
- A pair of entrapption stars push the cargo into the vertical indexer
- 1/16” polycarbonate side walls and sloped floor simultaneously protect electronics and keep cargo constrained within the magazine
- Spring activated 3D-printed lever is depressed by the weight of the cargo and acts as a one-way door (similar to one-way traffic spikes), stopping cargo from rolling back out of the magazine

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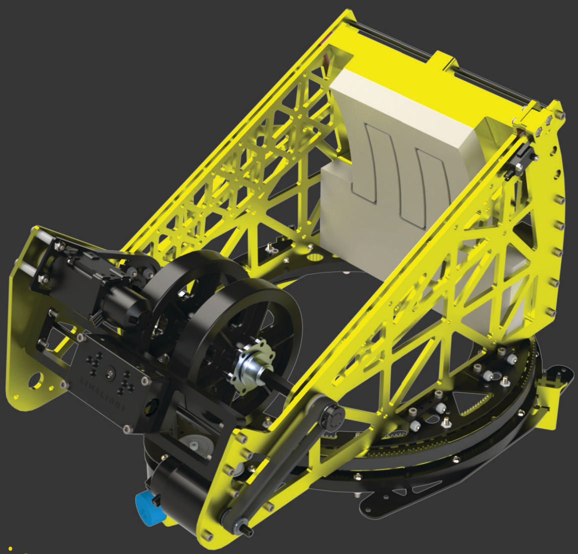
Vertical Indexer

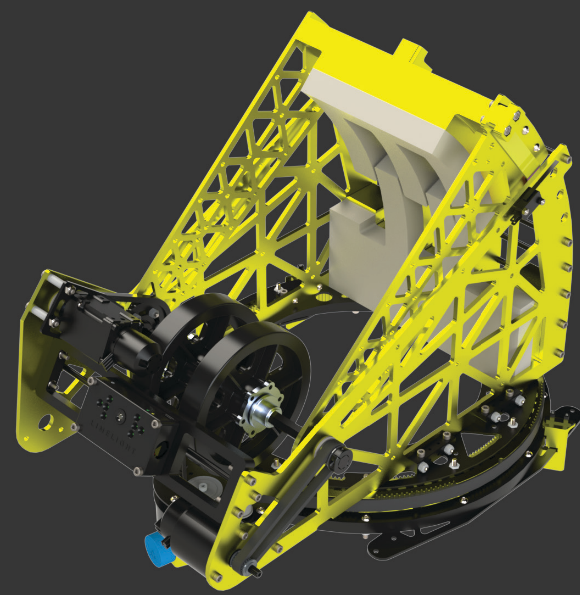
The vertical indexer delivers cargo through the turret and into the shooter. The indexer starts pivoted outward with a large opening between the belts to allow free passage of cargo into the loading location. When it's time to shoot the cargo, the belts are started and the servo pulls a linkage to pivot the belts inward, thereby putting pressure on the cargo. The belts then power the cargo upward and continue to close in, effectively propelling the cargo several inches further than parallel belts could in order to bring the cargo in contact with the flywheels. After the cargo has been launched, the servo then pivots the belts back outward so the next cargo can enter the loading zone.

Technical Details

- Four 123 tooth 5mm pitch 15mm wide HTD timing belts grip the cargo
- 1/4" polycarbonate plates mount the bearings for the HTD pulleys in addition to serving as the final bar in the linkage system
- Power for the belts supplied by a NEO 550 motor mounted to a 4:1 one-stage VersaPlanetary gearbox
- Linkage actuated by a REV Robotics Smart Robot servo

TURRET AND SHOOTER





Overview

On account of the high arcing shot necessary to score in the upper hub, we opted for a single-flywheel shooter with a rotating hood for pitch adjustment. The combination of an ARMABOT Turret240 for yaw adjustment and a Limelight for vision processing proved to be potent on last year's robot, Artemis, so we largely ported over the general design for Maverick.

Turret

Technical Details:

- Modified ARMABOT Turret240
- Heavy-duty bearing with gearbox
- Interfaces with a 5mm pitch 15mm wide HTD belt
- Weight reduced by 3D-printing the pulley segments
- 90° rotation range (±45°); constrained by climber on both sides
- Two slot sensors trigger at rotation limits
- Driven by a 775pro with a 462:1 reduction
- Free speed: 243° per second
- Custom worm gearbox designed to replace the standard
encoder with a potentiometer for angle control

Shooter

Technical Details:

- Two 6" AndyMark SmoothGrip flywheels
- 6" wheels chosen over smaller alternatives to prevent excessive backspin
- Plastic spokes and core assist in managing weight
- 3D-printed interlocking backboard offers a lightweight, modular design that's easily modified
- 1" foam backing assists in even compression despite varying cargo inflation
- Flywheels powered by a Falcon 500 on a 1.5:1 belt reduction
- Theoretical exit velocity: 55 ft/sec
- Rotating hood driven by a NEO 550 with a 100:1 two-stage VersaPlanetary gearbox
- Hood angle ranges from 25° to 42° from the horizontal

CLIMBER

Overview

In an effort to score as many points as possible, we decided to pursue a traversal climb this year. However, given the complexity of the motions necessary to reach the traversal rung (and consequent risk to the rest of our robot), any proposed mechanism had to meet several restrictive criteria: 1) minimal use of PDP slots (preferably two), 2) ability to pause the climb at either the middle or high rung, 3) minimal width (thin enough to fit outside the turret), and 4) no reliance on timed swinging or cantilevering of the center of mass. Ultimately, we were successful in finding a solution composed of two distinct mechanisms, namely a vertical slide climber and a set of rotating arms.

Vertical Slide Climber

A traditional telescoping climber was rendered impossible by the packaging constraints discussed above, and so we switched to a slide-type climber made of 1/8" aluminum plate sandwiched between UHMW strips and R4 bearings. The role of the vertical slide climber is self-explanatory, serving to hook onto a bar (the middle rung at first) and elevate Maverick vertically.

Technical Details:

Sliding plates made of 1/8" aluminum, reinforced with a central rib
Constrained relative to a 1/8" wall 2" by 1" tube with R4 bearings and UHMW strips
Driven by #25 chain bolted to the central rib and powered by a custom gearbox
Construction is mirrored on the opposite side of the robot

CLIMBER

Rotating Arms

The two rotating arms are responsible for the horizontal translation of Maverick between adjacent rungs. Once Maverick has hooked itself onto the middle rung and lifted itself off the ground with the slide climber, the arms rotate upward and snap over the high rung to become a portable rack railway. After raising the slide climber and rolling up the rack (underneath the high bar), redeploying the slide climber allows Maverick to latch onto the high rung. Then, pushing the rack forward resets the arms to their starting position; this process can be repeated to reach the traversal rung from the high rung. Two special issues had to be addressed regarding the rotating arms, the first of which was the shape of the pinion gear that rotates and traverses along them. Although the weight of the robot is largely supported by two pairs of bearings during the roll-forward stage, significant force is placed on a single pinion tooth throughout the climb (especially when the arms are rotating up). Using the Lewis equation, 20 DP teeth were found to be too susceptible to stripping, as well as being impossible to manufacture for our team; consequently, we used a lantern gear generator to design a pinion that could roll on 1/4" roll pins. The second issue was the bending stress put on the arms while the robot was evenly centered between the bars, a cantilever distance of around 16". Modeling each plate with a rectangular cross section, it was found (by calculating the 2nd moment of inertia to determine beam bending stress) that 2" of material below the slot was sufficient to manage stress and deflection.

Technical Details:

Each arm consists of four 1/8" aluminum plates bound together with numerous threaded standoffs and 1/4" diameter roll pins

Each arm has a corresponding pinion that controls its movement (both on a shared 1/2" hex shaft across the top of the robot)

At the ends of each arm are sprung hooks that latch onto the bar, to account for errors in positioning and field construction

A 3D-printed insert at the far end of each arm mates with an L-shaped latch attached to the 2" by 1" tube, keeping the arms from swinging during the match

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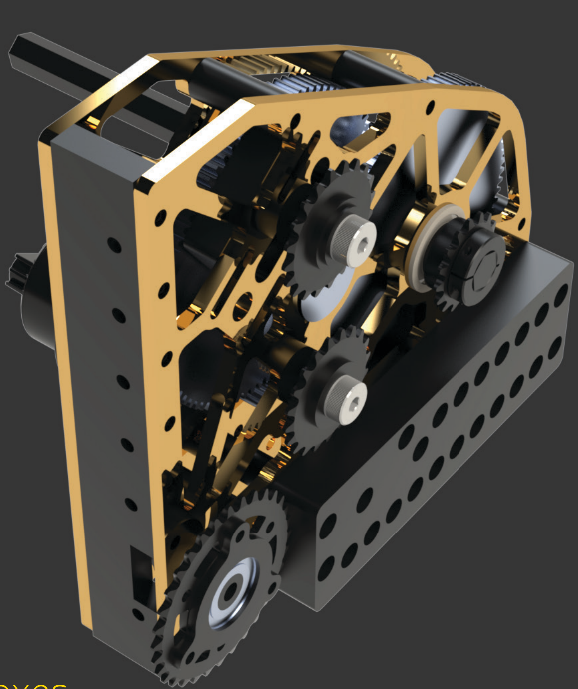
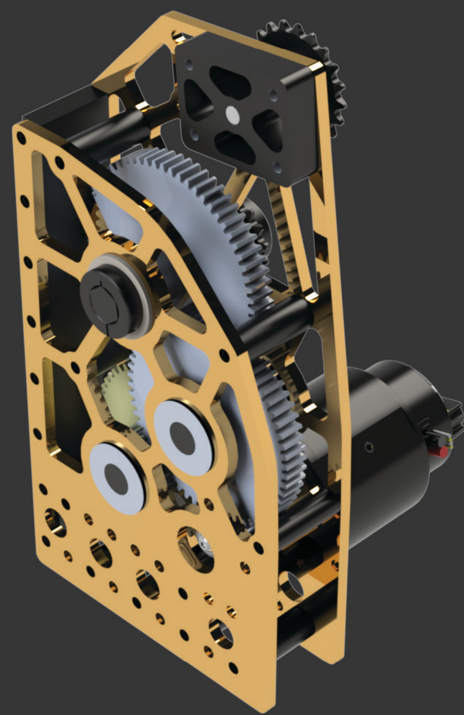




Gearboxes

In previous years, Team 2485 relied upon VersaPlanetaries for its climbing needs; however, due to the large amount of torque involved in such systems, the miniscule teeth on the gears were frequently ground into dust. Due to the increased risk of falling from this year's hangar climb, such mechanical failure was deemed unacceptable, and so we decided to make more robust gearboxes.

Vertical slide gearbox

Technical Details:

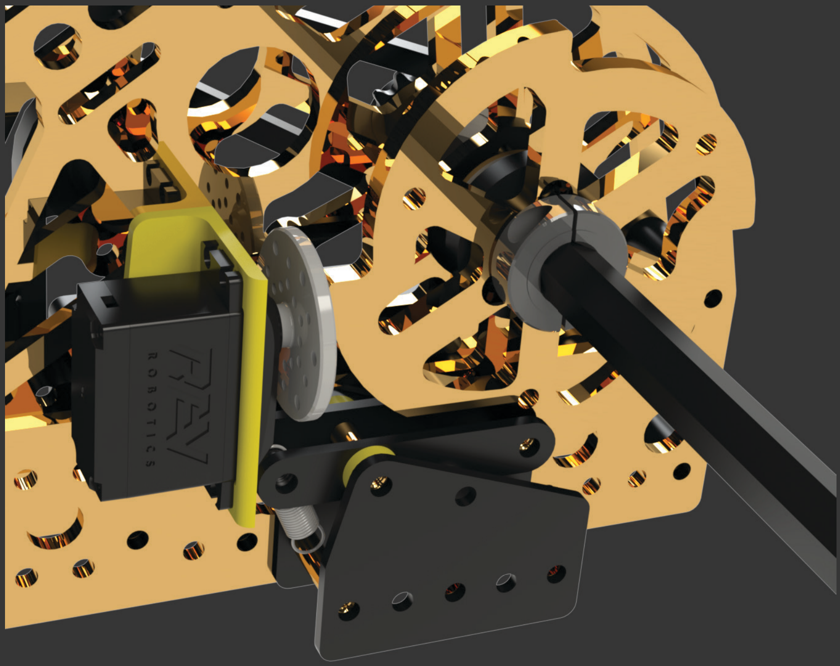
- Powered by a Falcon motor
- Two stages (84:9, 84:24) for a 32.67:1 reduction
- Side plates made from 3/16" aluminum, with a 3/8" wide strip to connect the gearbox to the 2" by 1" rails
- Serves as the major structural component connecting the 2" by 1" rails to the drive rails; gearless version required on opposite side

Rotating arm gearbox

Technical Details:

- Powered by a Falcon motor
- Three stages (54:9, 60:20, 64:20) for a 57.6:1 reduction
- Actuates several different motions of the arms, according to pinion position (engaged with locking pins or disengaged) and direction of rotation:
- Upward rotation of the arms
- Linear translation of the robot along the arms
- Forward motion of the arms during the resetting process

CLIMBER



Rachet

To prevent the robot from falling after power is cut at the end of the match (and thus to make a middle rung climb feasible), a simple ratchet system was devised to lock the output shaft of the vertical slide gearbox in place, consisting of a custom ratchet disk and spring-loaded pawl. A REV Smart Robot servo disengages the pawl from the ratchet for any motions requiring the vertical slide climber to extend. This custom ratchet was made for better reliability than off-the-shelf ratchet modules, or the dreaded wrench zip-tied to the robot.

Technical Details:

- Ratchet disk made of 1/4” aluminum to withstand brunt of force
- Pawl constructed from 1/8” aluminum and several steel standoffs
- Servo horn tied to pawl via safety wire

SOFTWARE

Control Systems

Our controls approach for this year emphasizes model-based control and motion profiling. This allows us to achieve fast and consistent control over a variety of mechanisms.

For most subsystems, we used WPILib's system identification tools to develop an empirical model in order to achieve accurate feedforward control. We also used these tools to find model-based feedback (PD) gains via a linear-quadratic regulator.

Position-based closed-loop subsystems (hood, turret, swerve turning, both climb subsystems) use trapezoidal motion profiling, as well as feedforward and feedback control, to ensure smooth and accurate motion.

Due to chain lash, we control the intake arm with a very simple control algorithm based on the position of an external encoder.

A few velocity-based subsystems (intake, indexers) on the robot are run open-loop via model-based feedforward.

The swerve drive motors are controlled via a feedforward and a P controller.

The shooter uses a bang-bang controller and model-based feedforward in order to improve recovery time and shot consistency.

Swerve Drive

We convert driver-commanded x velocity, y velocity, and angular velocity via a matrix transformation to swerve module states (speed and angle). Driving is field-relative based on our gyroscope with a manual override to drive relative to the robots.

Odometry is achieved by converting swerve module states to velocities via the inverse of the kinematics matrix. The robot knows its field-relative position at all times. Via odometry, the robot can also drive with its heading constantly facing toward the hub, minimizing turret travel distance.

In the autonomous period, the drivetrain follows quintic hermite spline trajectories via feedback controllers on states of x velocity, y velocity, and angle. Due to the flexibility of swerve drive, we can vary the heading of the robot independent of its path, which is useful for indexing.

SOFTWARE

Automation

Vision

From PhotonVision running on our Limelight, we get the corner coordinates in the camera frame of each hub retroreflective target in view. These corner coordinates are then transformed into field-relative positions using camera positioning constants and the current robot pose and turret angle. Those field-relative positions are then fit using an iterative circle-fitting algorithm to find the center of the hub in field-relative coordinates.

We fuse vision-based pose estimation with drivetrain odometry via a weighted average (when vision targets are sufficient).

Finally, this year we decided to attempt not to blind the audience, other teams, field volunteers, or ourselves. The Limelight LEDs will turn off after a waiting period when it doesn't have a valid retroreflective target, and periodically blink to see if a target can be reacquired.

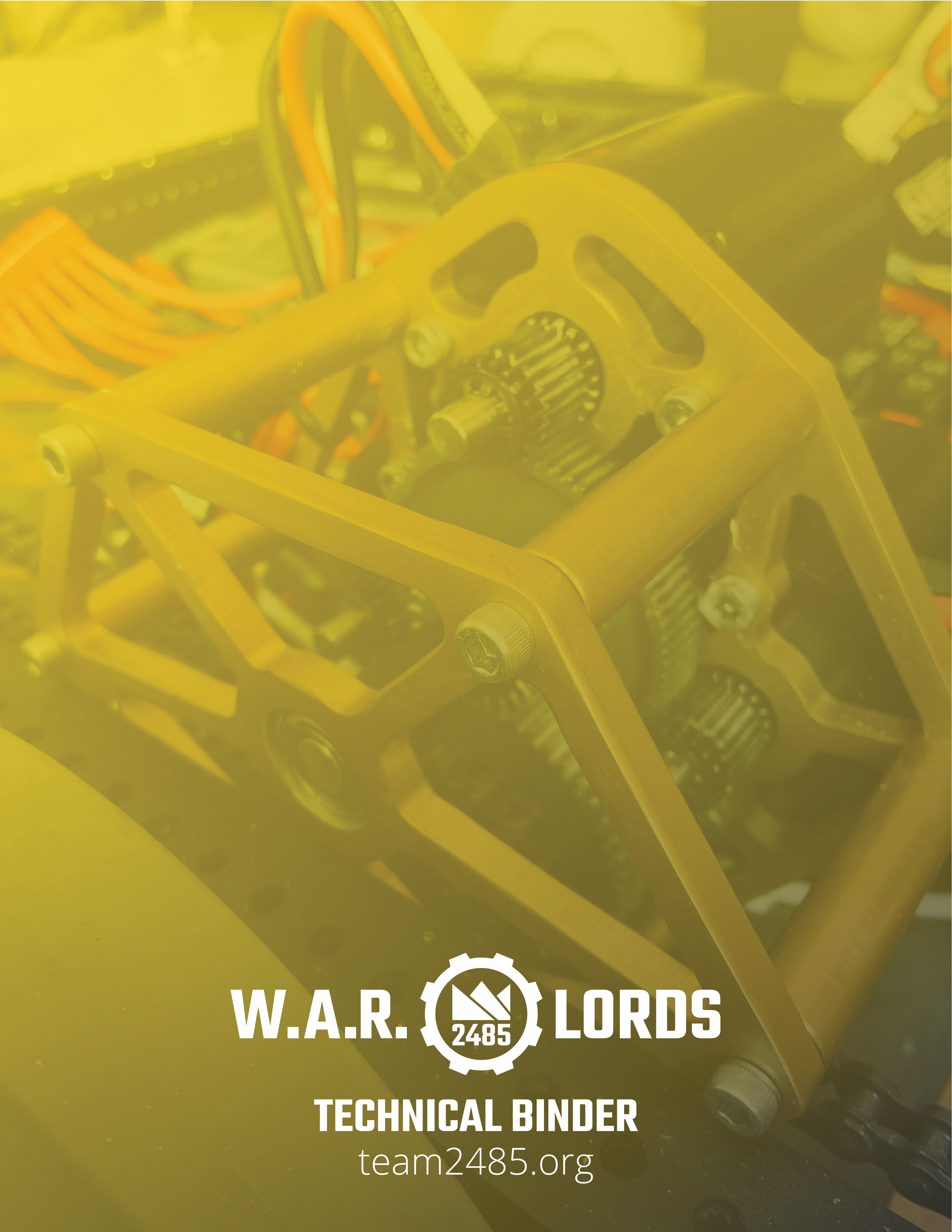
Shooting

Our accurate pose estimation based on vision and odometry makes auto-shooting much easier. The turret always aligns toward the hub (except when it cannot due to its range). Shooter and hood setpoints are found automatically from the center of the turret's current distance to the hub via an interpolation table created from known setpoints.

Shooter, turret, and hood setpoints are corrected for the drivetrain velocity via an empirically-tested time-of-flight model, allowing us to shoot while moving. This is achieved by adjusting the target position in the opposite direction of the drivetrain velocity such that the ball will land in the hub even taking into account its original velocity.

Driver/Operator automation

Making our drive teams' jobs easier via automation was a major goal this year. The driver has sticks for driving and can hold one button to intake/index/move intake arm appropriately. They also can switch into climb mode and, once climbed on mid bar, press one button to automatically climb to traverse bar. The operator holds one button to spin up the shooter, and one trigger to set the hood and feed cargo into the shooter.



W.A.R. LORDS

2485

TECHNICAL BINDER

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