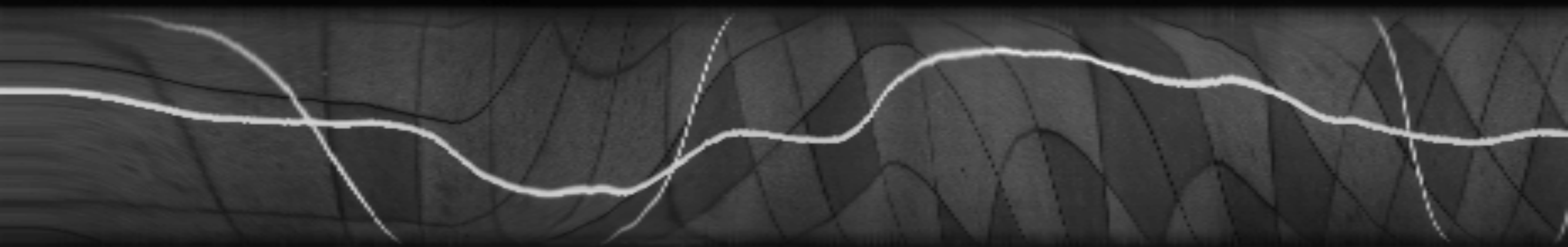
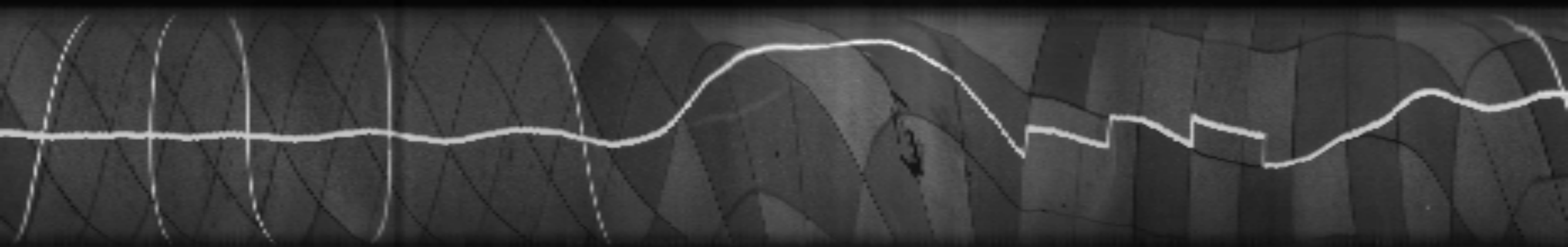
Team 1



Lee-Huang Chen
Casey Duckering
Cheng Hao Yuan



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Vehicle Electronic Hardware

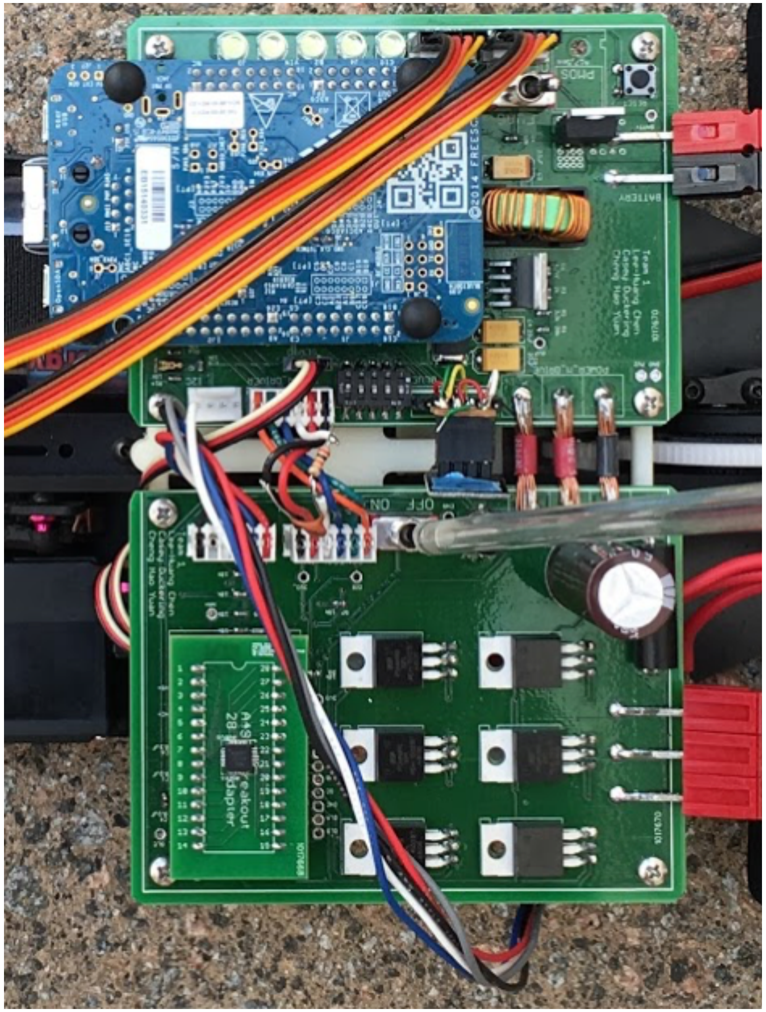
Two circuit boards

Main board

- Power supply
- Voltage level boosting/reduction
- Near and far cameras
- FRDM K64F microcontroller
- Provides power and signal to motor driver board.

Motor driver board

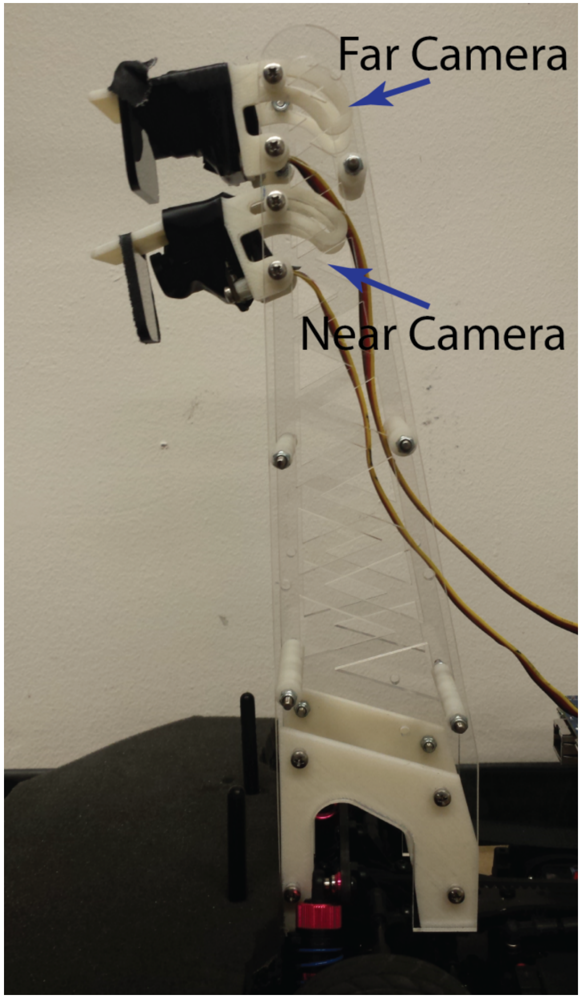
- A4931 pre-driver
- six N-MOSFETs for brushless motor.

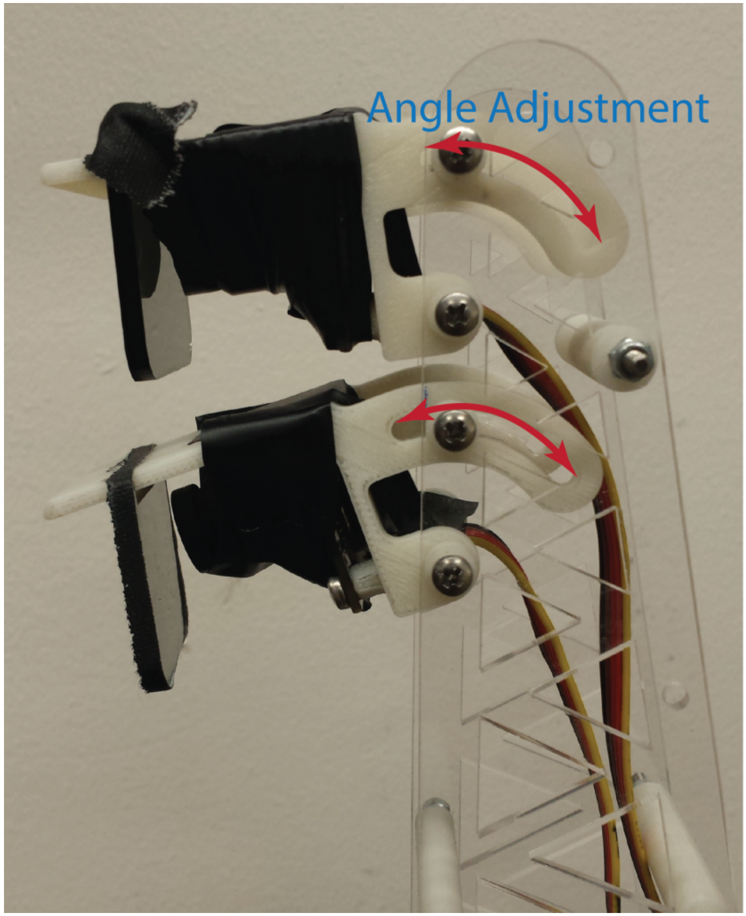


Vehicle Mechanical Hardware

Camera Mount:

- 2 cameras
- 4 screws used to secure each camera
- Camera holder has slots for adjusting the angle alignment.
- Camera holder increases the stiffness of the camera tower.





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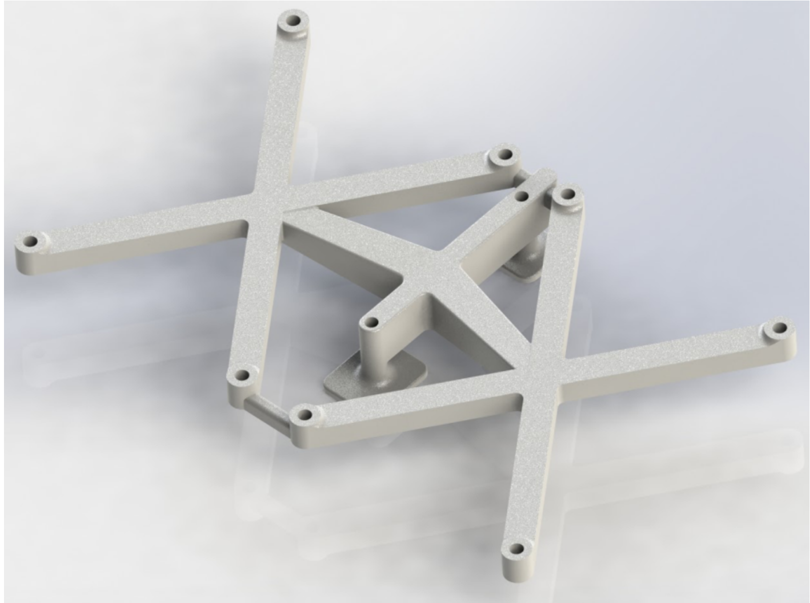
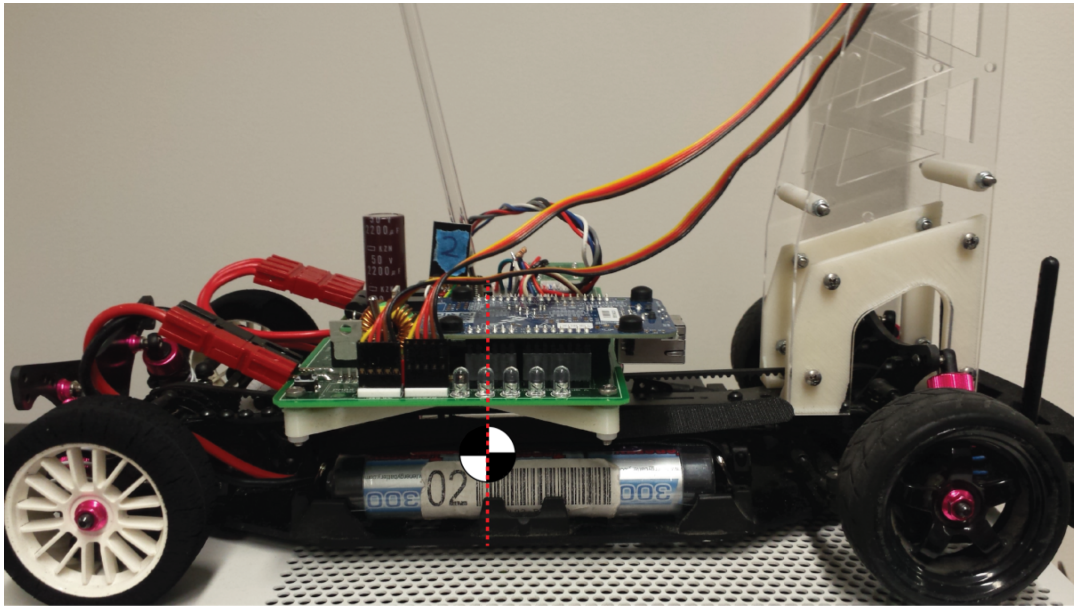
Vehicle Mechanical Hardware

Circuit Board Mount

- Attaches the 2 circuit boards to center post of the car.
- Adjust the center mass of the car by attaching the boards toward the back of the car.





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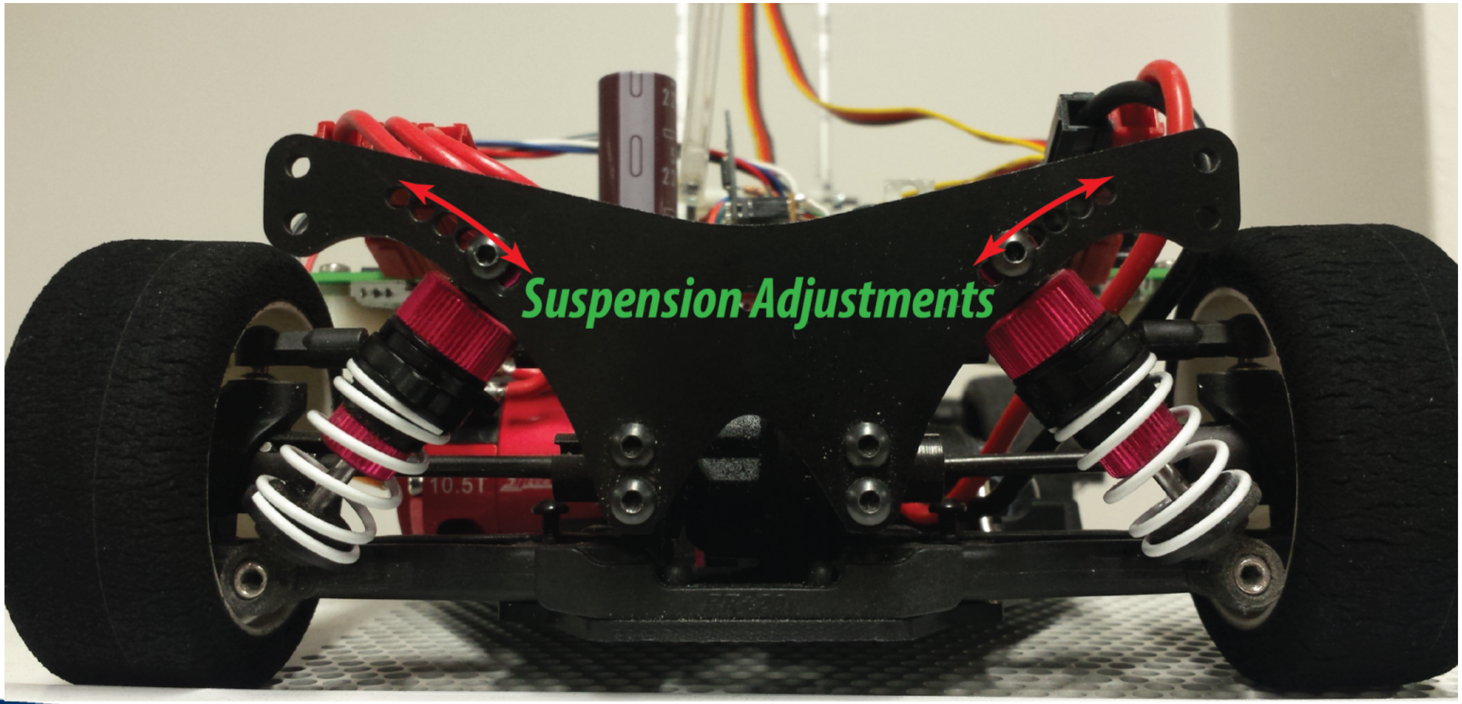
Vehicle Mechanical Hardware

Suspension/Tires

- Rubber road tires on the front wheels
- Foam tires on the rear wheels
- Different stiffness springs to control traction and steering
- Control over-steering and under-steering



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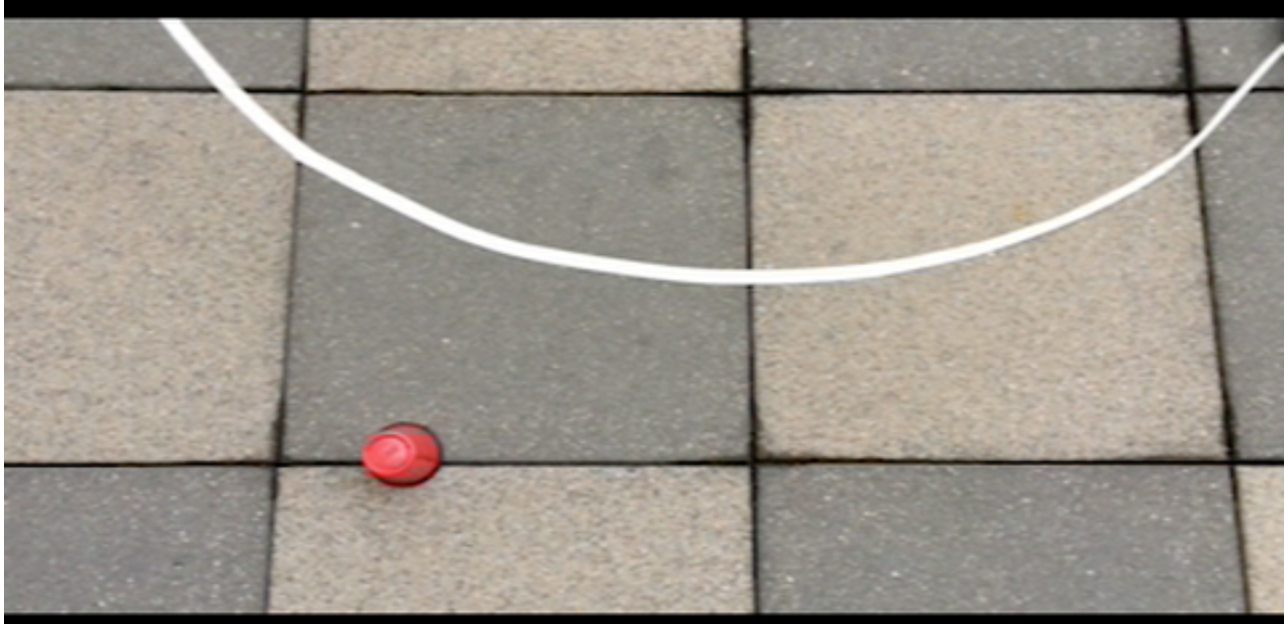
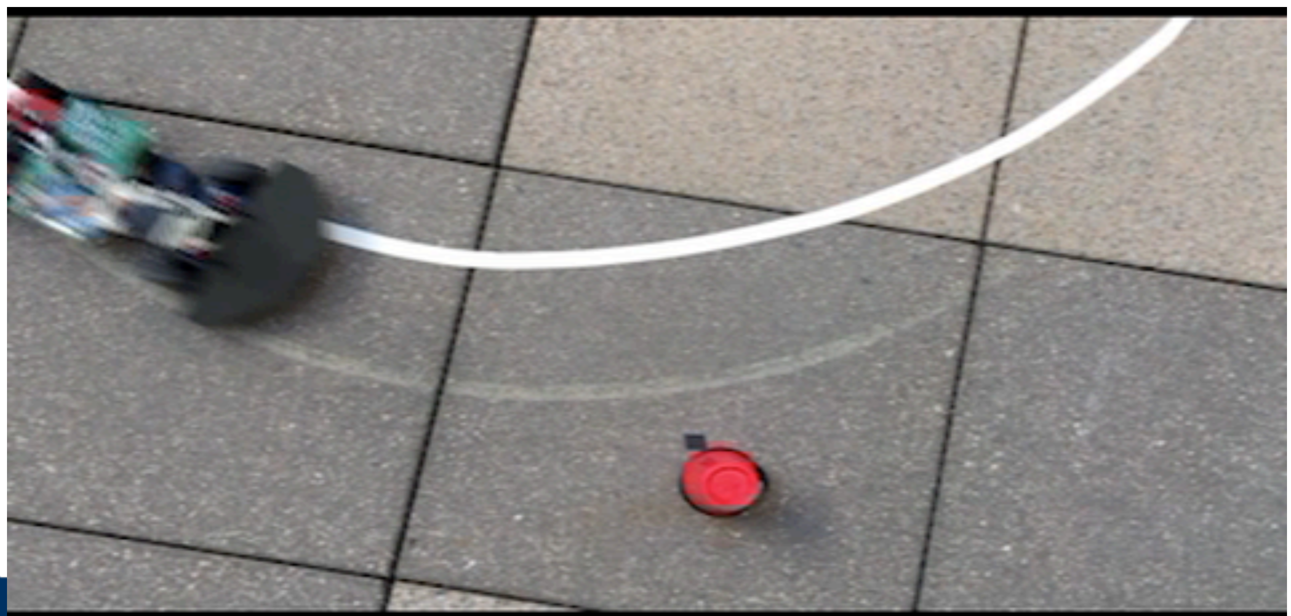
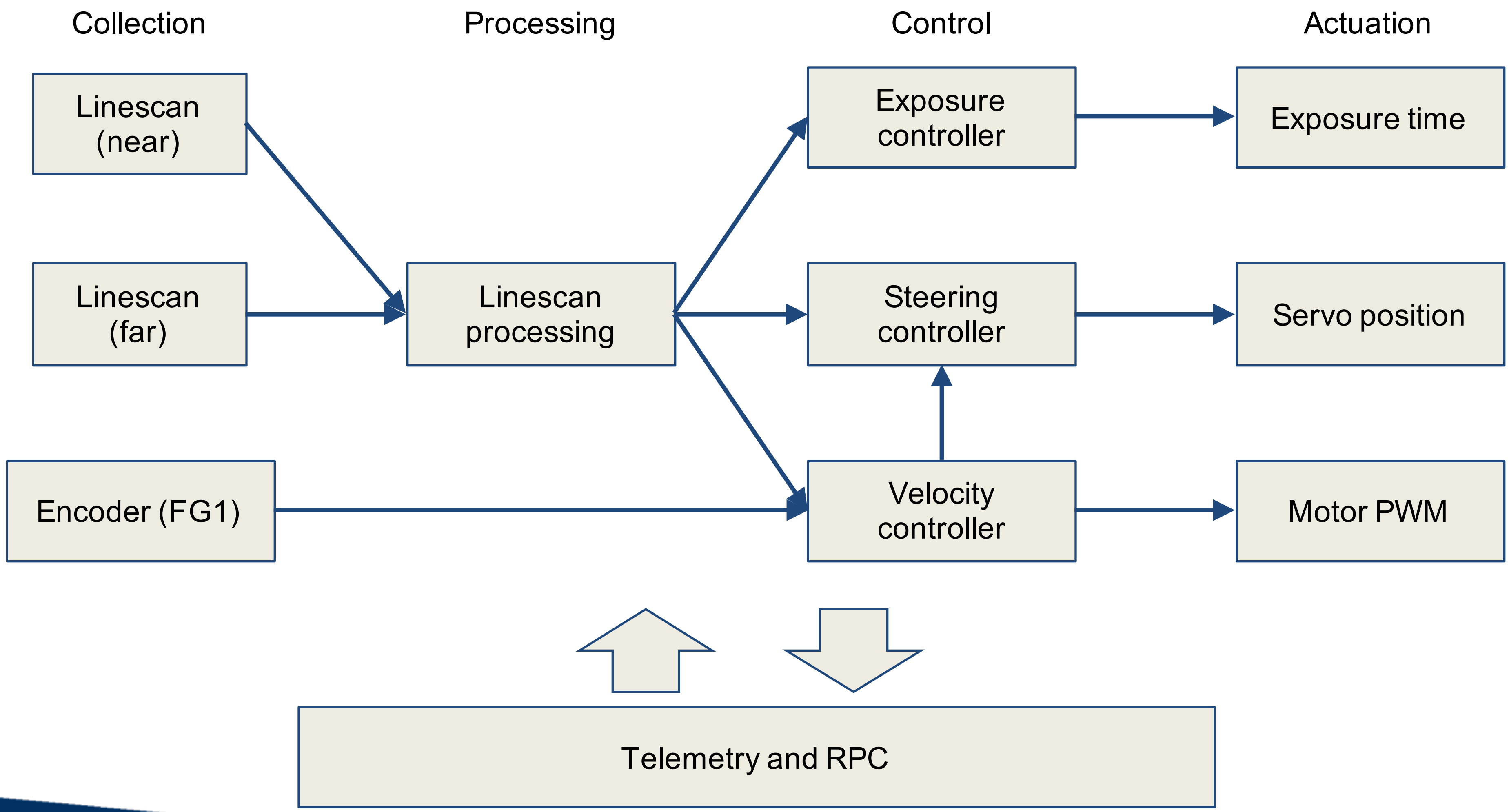
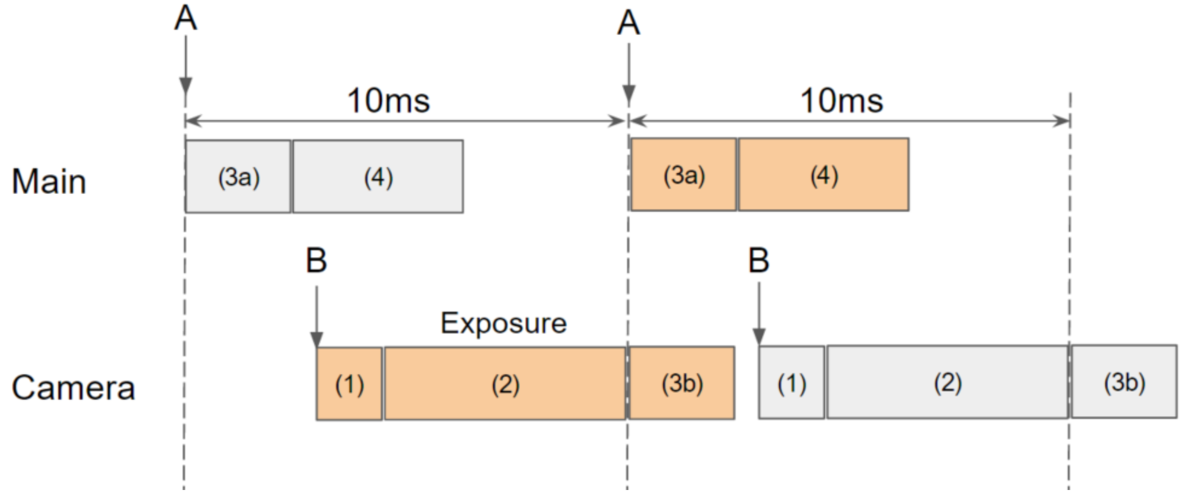




Software Block Diagram



Software Timing



- Interrupt (A) triggers main loop at 100 Hz.
- Interrupt (B) triggers camera read (and subsequent exposure)
- (B) will be triggered such that the end of the desired exposure period is aligned with (A).
  - (1): Clear pixels (dump integration).
  - (2): Exposure duration.
  - (3a): Main loop start; (3b): camera pixel read.
  - (4): Processing, controls, telemetry.

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Software Highlights

- Fixed-rate loop at 100 Hz, independent of exposure duration.
  - Camera frame capture
  - Controls calculation
  - Actuator update
- Auto-exposure
  - Weighted sum of average brightness and peak brightness.
- Linescan processing
  - Anti-vignetting based on the image of a white background.
  - Line detection by normalizing and thresholding.
  - Crossing/bright spot rejection by using the closest peak.
  - Maintain previous steering if line not found.
- Fast ADC reads (400us for two cameras)

Controls

- PI velocity control
  - Kp = 0.14 PWM fraction/(m/s)
  - Ti = 1.5 seconds
  - Positive output -> throttle PWM
  - Negative output -> full brake
- PD steering control
  - Kp = 0.041 steering fraction/pixel
  - Td = 0.002 seconds
  - if (speed > 1.0) Kp = Kp / (pow(speed , 0.33));
  - Use far camera to steer when going at high speed
- P exposure control
  - Kp = 100000
- Empirically tuned gains after extensive testing
- Simulation provided a qualitative feel

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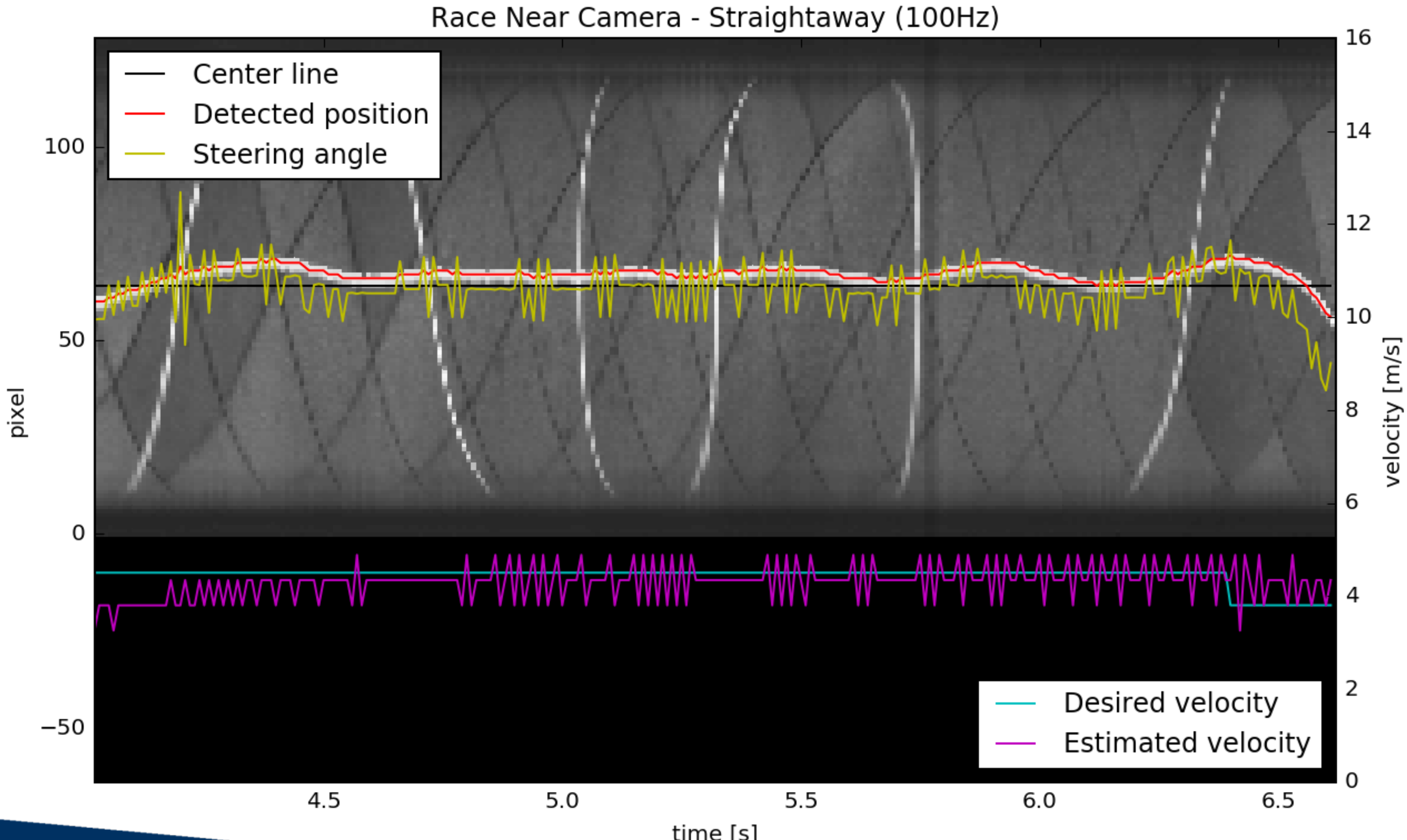
How well did it work?

- 3.7m/s cornering speed.
- 4.4m/s straightaway speed.
- Steering and velocity control is stable and responsive all parts of the track.
- Exposure control works well across shadows and sunlight.
- Line recognition is robust and accurate.
- Line position close to frame edge when cornering.
  - Very close to tire grip limit.
- Straightaway speed can be improved.
  - Limited by the elevation change in the Cory courtyard.



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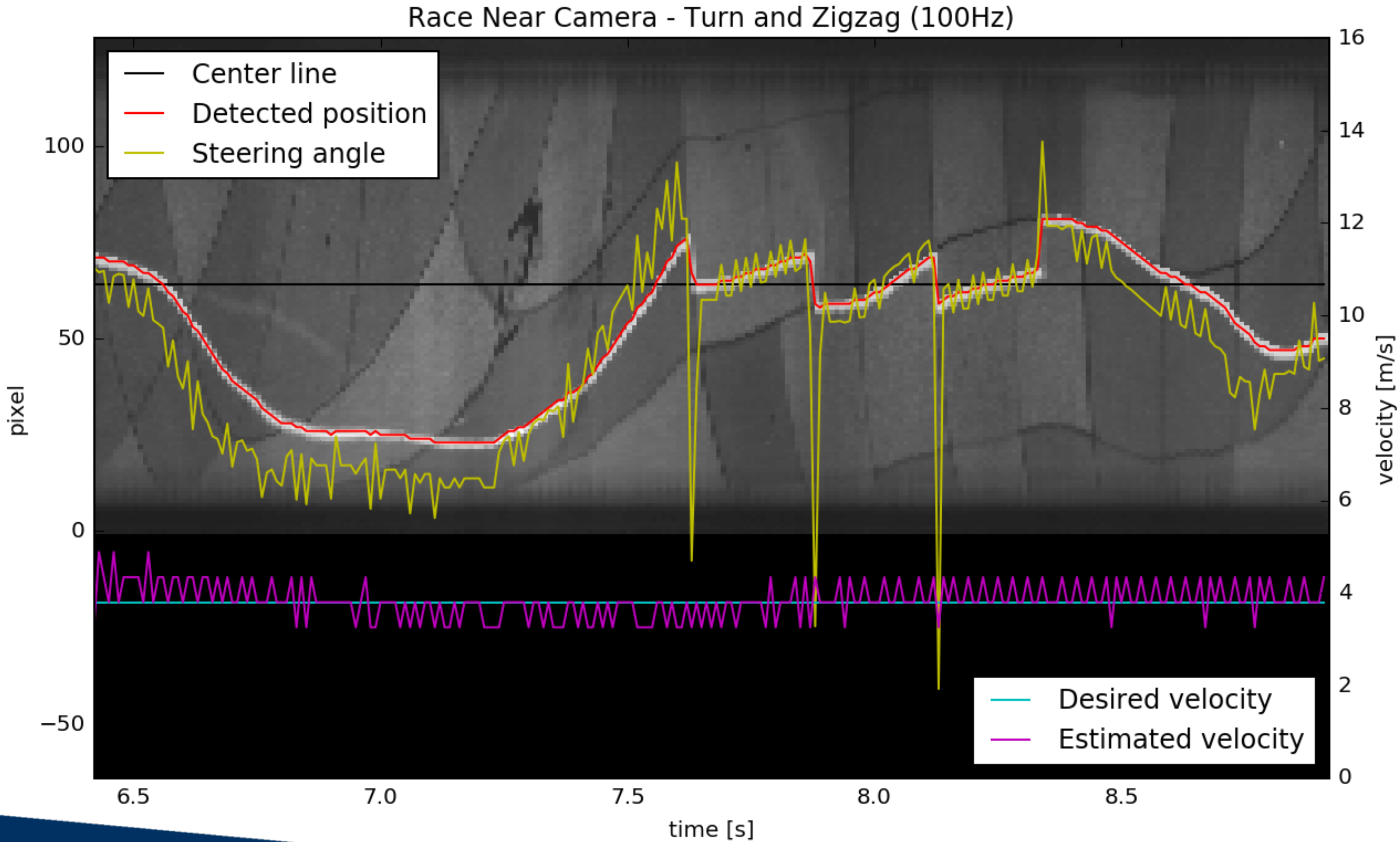

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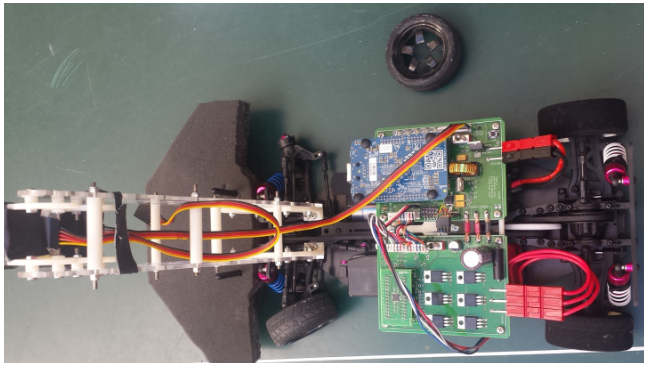
Lessons Learned



- Memorable failures:
  - Predriver unreliability.
  - Cheng soldering the bypass diodes to the wrong spot and blowing everything up.
  - Broken wheel right before race 2.
- Tools:
  - Build toolchain: ARM-GCC toolchain with make file.
  - Telemetry - for tuning and debugging.
  - RPC - for tuning.
  - Flashing OTA - for tuning and fast code testing and iteration.
  - WiFi radio - enables faster flashing.
  - Adjustable camera mount.
- Advice:
  - Get telemetry and RPC working as soon as possible.
  - Mechanical tuning is important for the 1/10 scale chassis.

Roles and Contributions

Lee

- Mechanical design and construction
- Board design and construction
- Mechanical tuning

Casey

- Board design and construction
- Code debugging, optimization, and advanced features
- Extra software features

Cheng

- Board design and construction
- Code debugging
- Mechanical tuning


Thank
you