GPS RTK Robot System

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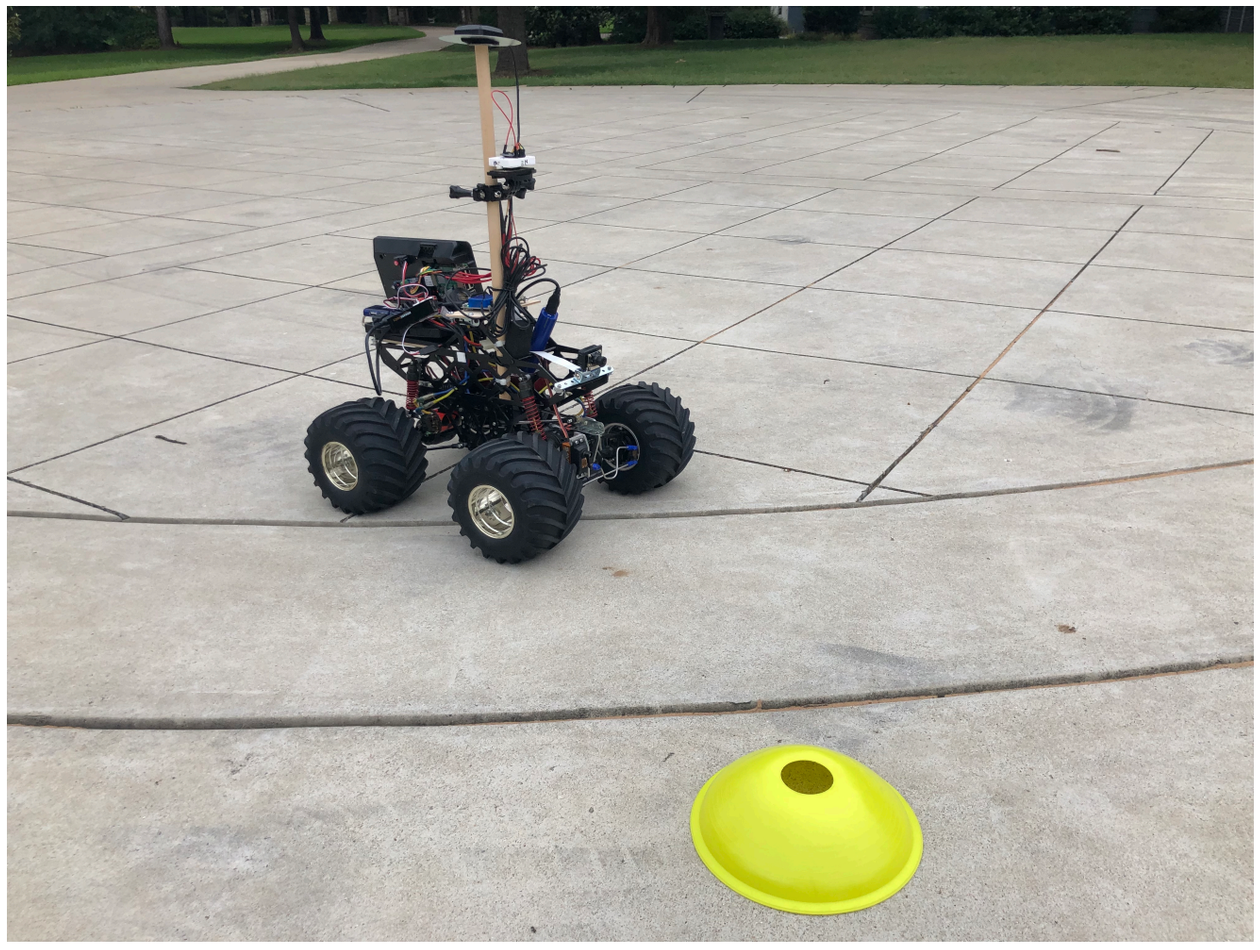
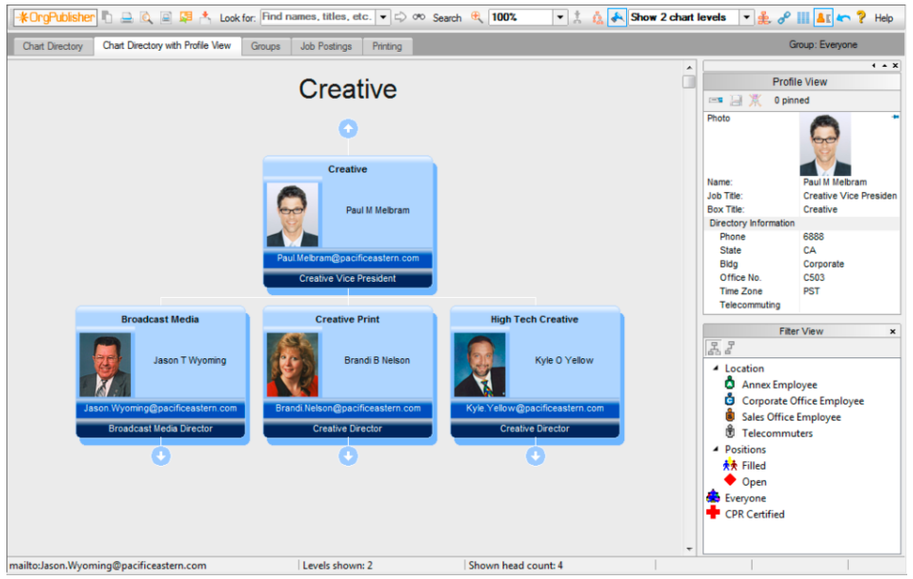


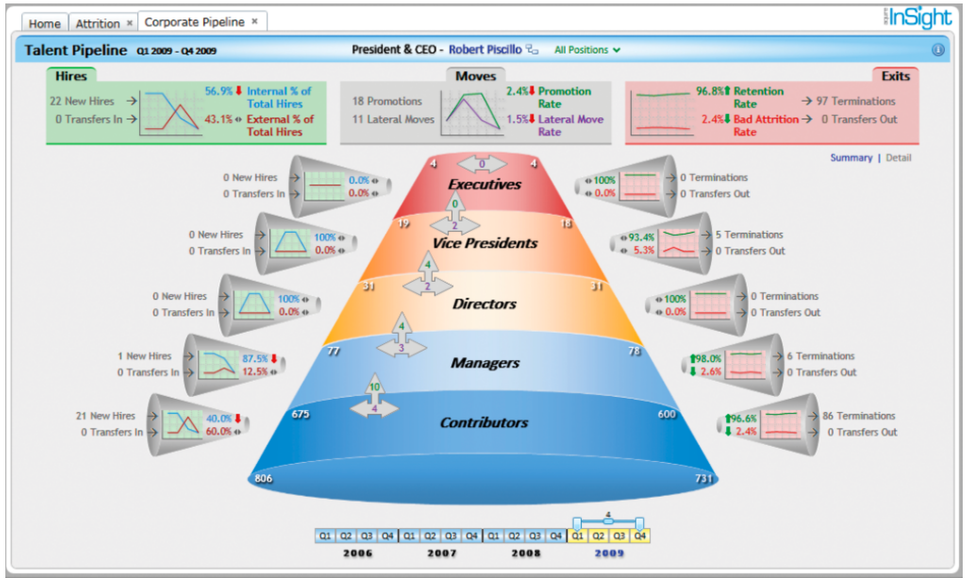
Outline

- About Ross and David
- What is RTK GPS and where is it used today
- Indoor vs. Outdoor robots (SLAM vs. GPS)
- Simulation to Reality Dilemma
- Machine Learning for Robot Navigation
- Field Testing GPS RTK
- Donkey Car
- Hardware and Software Architecture
- Building a Robot Platform
- Software Demo
- Problems encountered and What I learned

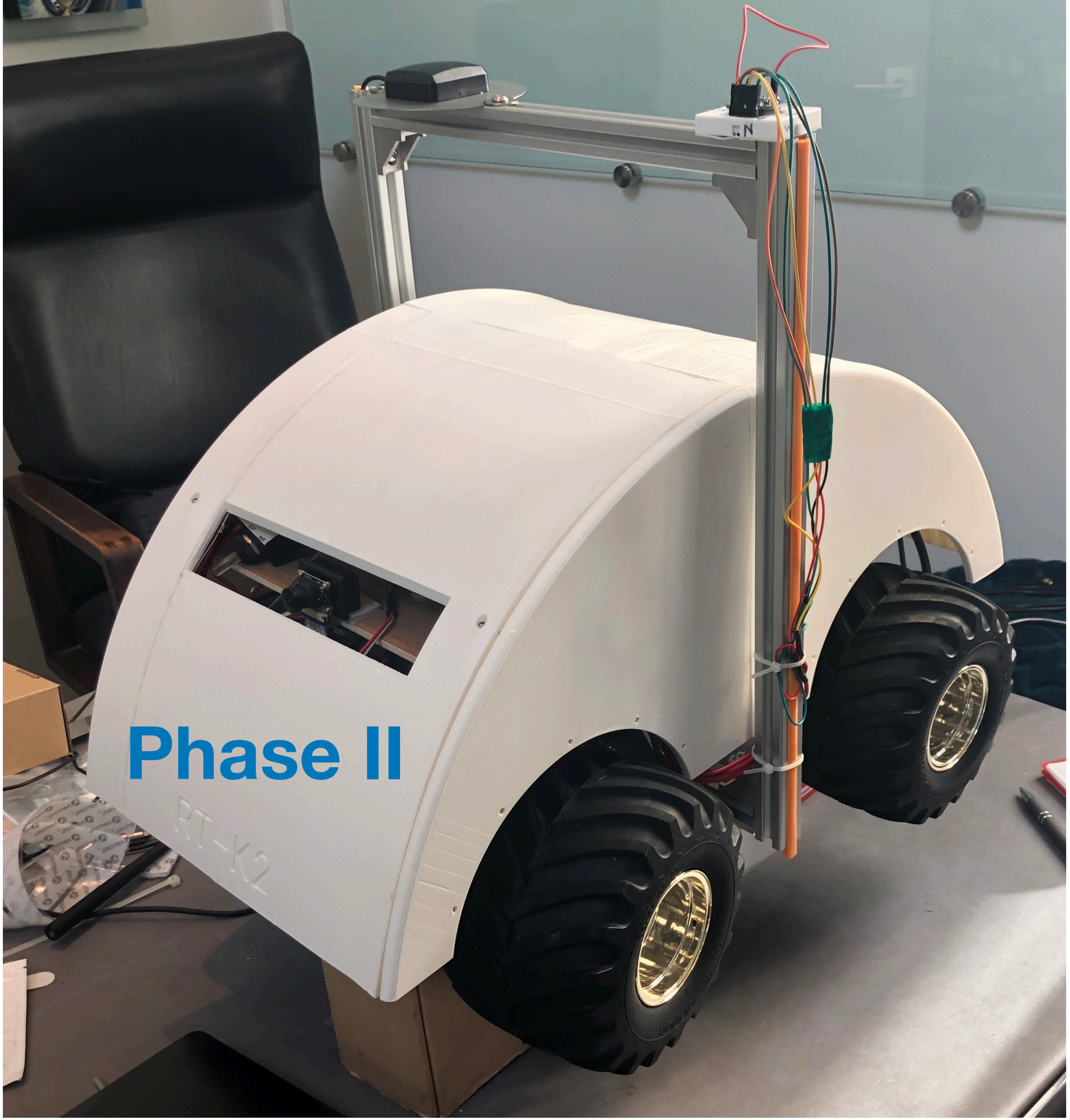
David Melbourne

Ross Melbourne



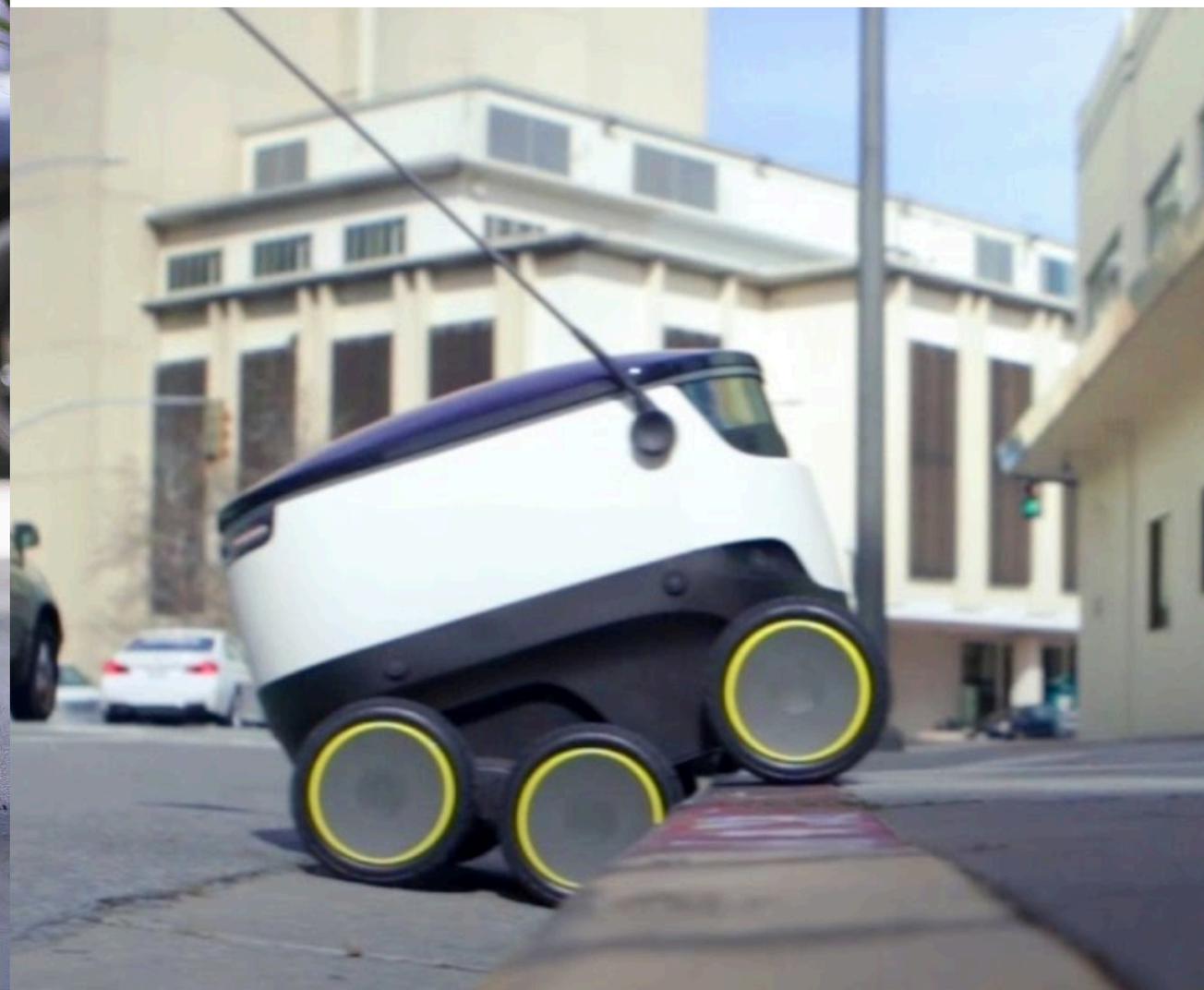


Phase I


Phase II
RT-K2

Robotic Outdoor Navigation

SECURITY
KNIGHTSCOPE
H5

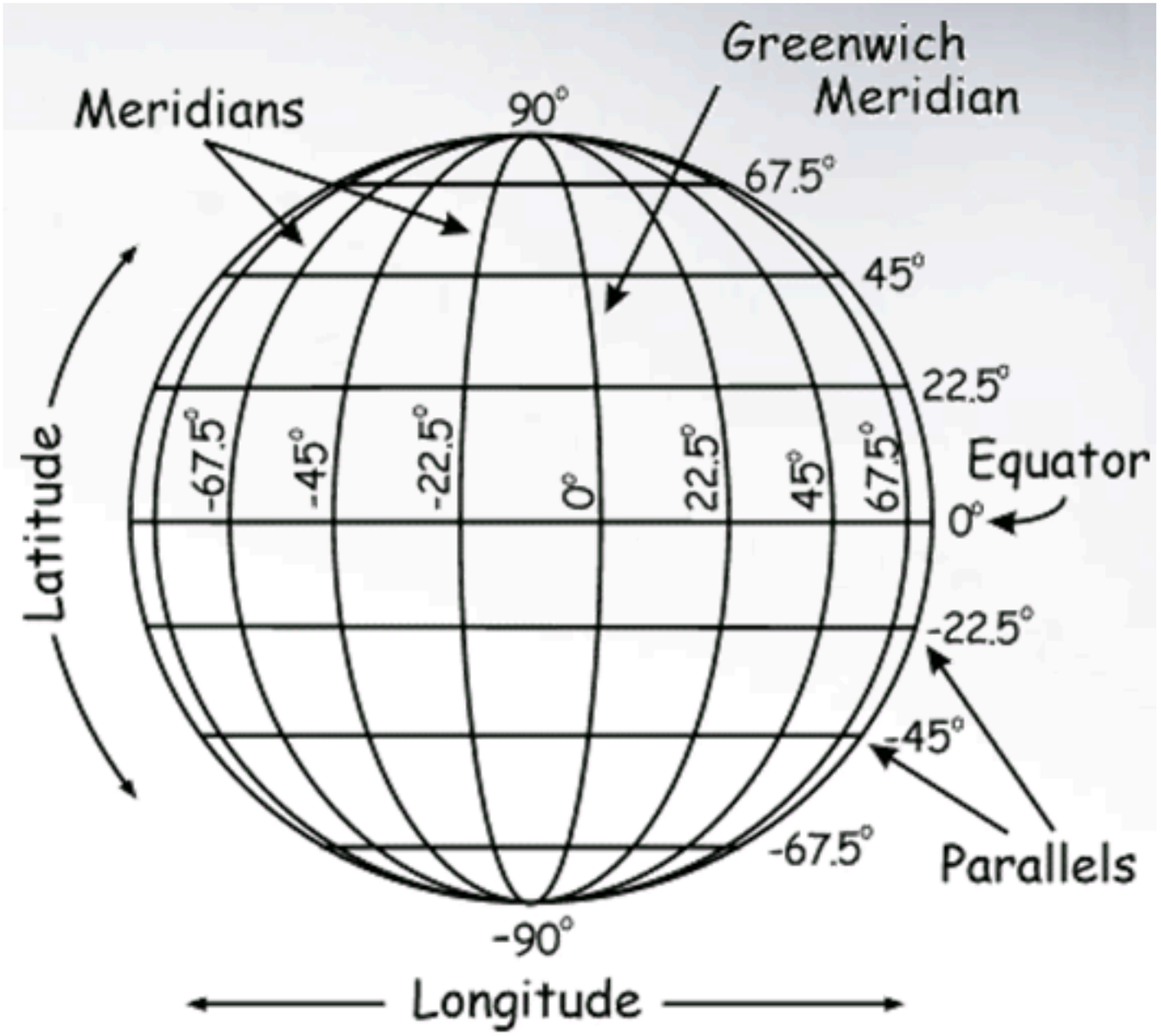


GPS Coordinate Formats

Here are examples of formats of GPS latitude & longitude:

- **Degrees**, **minutes**, and **seconds** (**DMS**): 41°24'12.2"N 2°10'26.5"E.
- **Degrees** and **decimal minutes** (DMM): 41 24.2028, 2 10.4418.
- **Decimal degrees** (DD): 41.40338, 2.17403.

GPS Coordinate System



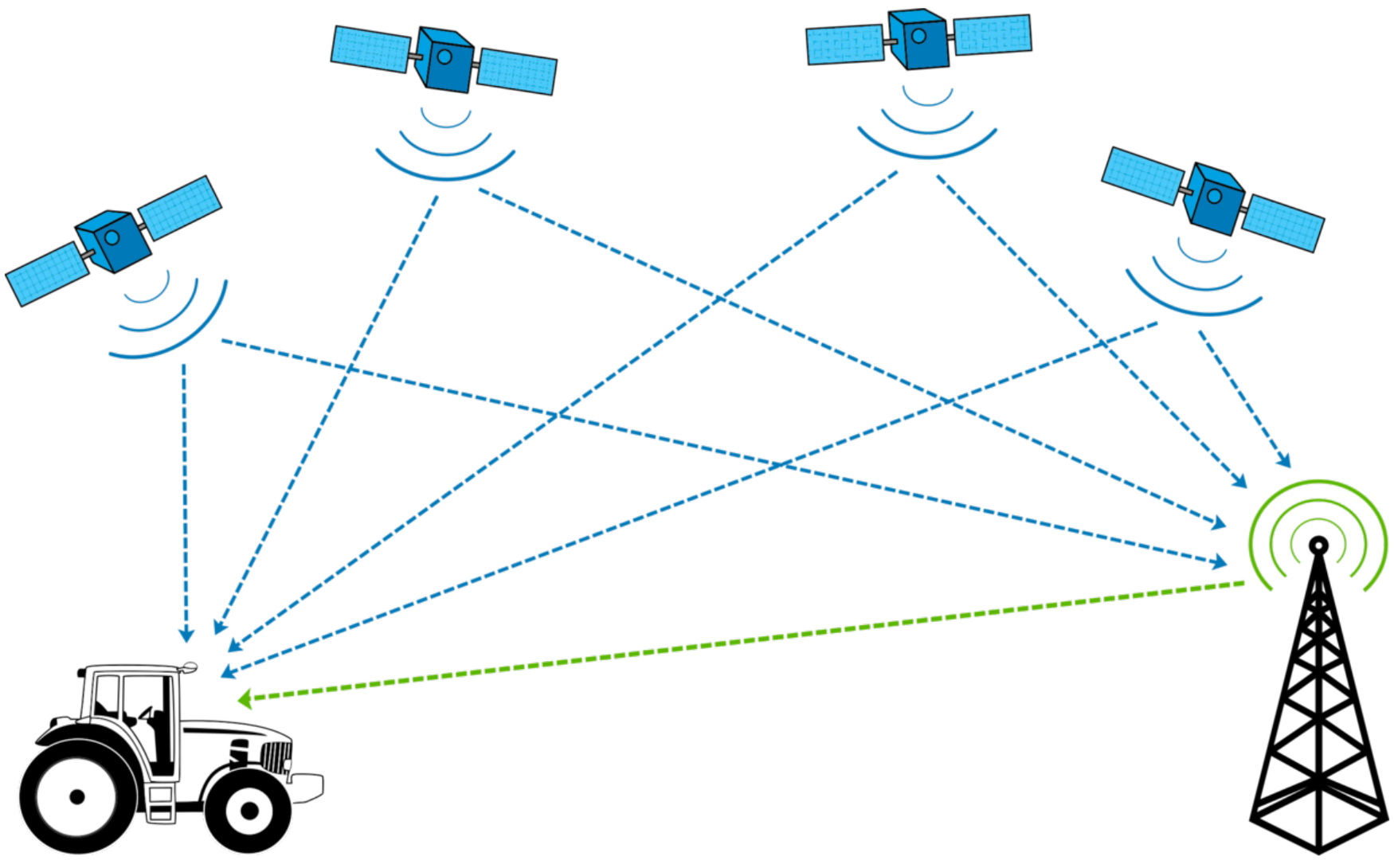
GPS Precision

Degree precision versus length

decimal places	decimal degrees	DMS	qualitative scale that can be identified	N/S or E/W at equator	E/W at 23N/S	E/W at 45N/S	E/W at 67N/S
0	1.0	1° 00′ 0″	country or large region	111.32 km	102.47 km	78.71 km	43.496 km
1	0.1	0° 06′ 0″	large city or district	11.132 km	10.247 km	7.871 km	4.3496 km
2	0.01	0° 00′ 36″	town or village	1.1132 km	1.0247 km	787.1 m	434.96 m
3	0.001	0° 00′ 3.6″	neighborhood, street	111.32 m	102.47 m	78.71 m	43.496 m
4	0.0001	0° 00′ 0.36″	individual street, land parcel	11.132 m	10.247 m	7.871 m	4.3496 m
5	0.00001	0° 00′ 0.036″	individual trees, door entrance	1.1132 m	1.0247 m	787.1 mm	434.96 mm
6	0.000001	0° 00′ 0.0036″	individual humans	111.32 mm	102.47 mm	78.71 mm	43.496 mm
7	0.0000001	0° 00′ 0.00036″	practical limit of commercial surveying	11.132 mm	10.247 mm	7.871 mm	4.3496 mm
8	0.00000001	0° 00′ 0.000036″	specialized surveying (e.g. tectonic plate mapping)	1.1132 mm	1.0247 mm	787.1 μm	434.96 μm

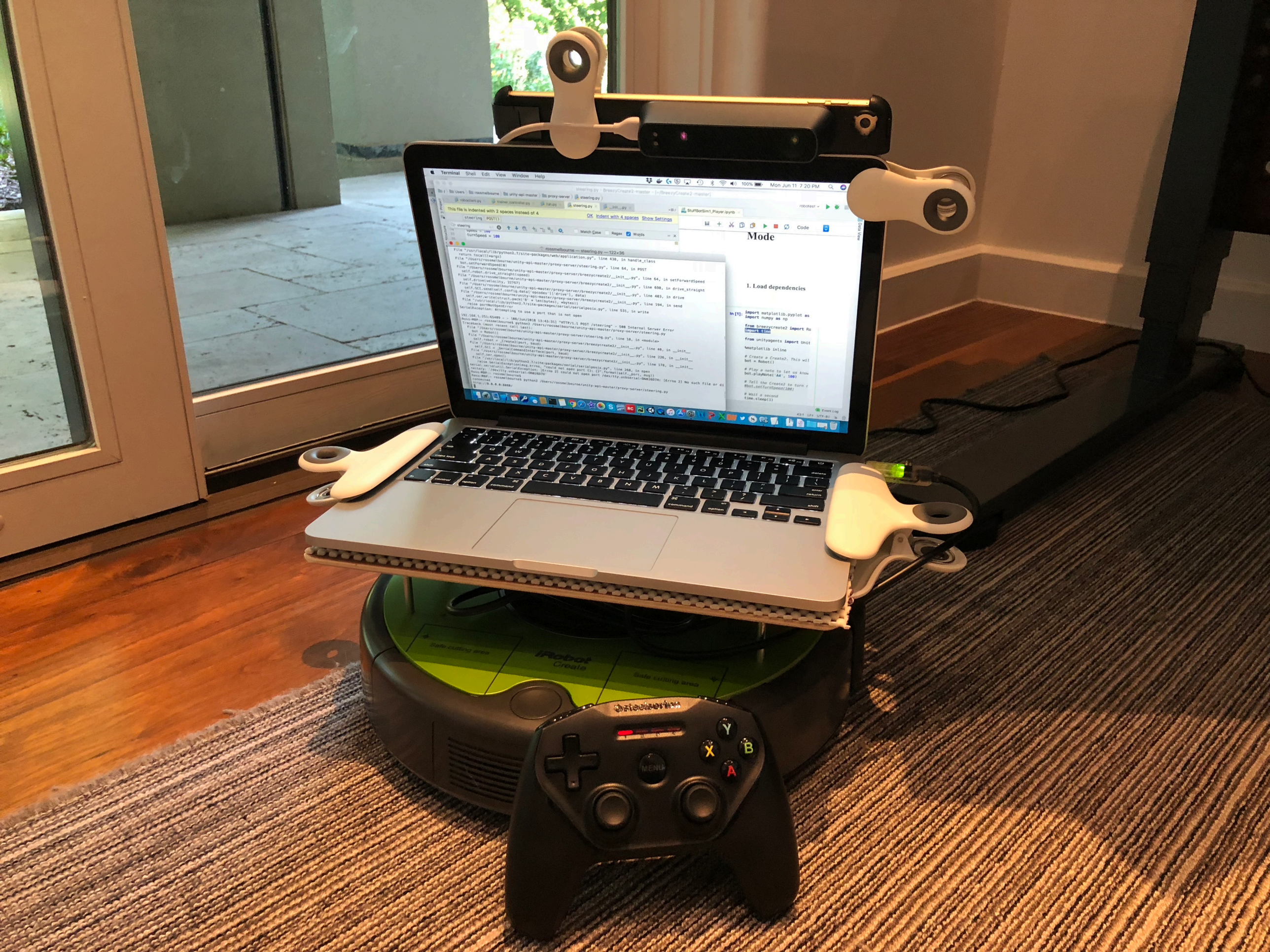
Real-time Kinematic

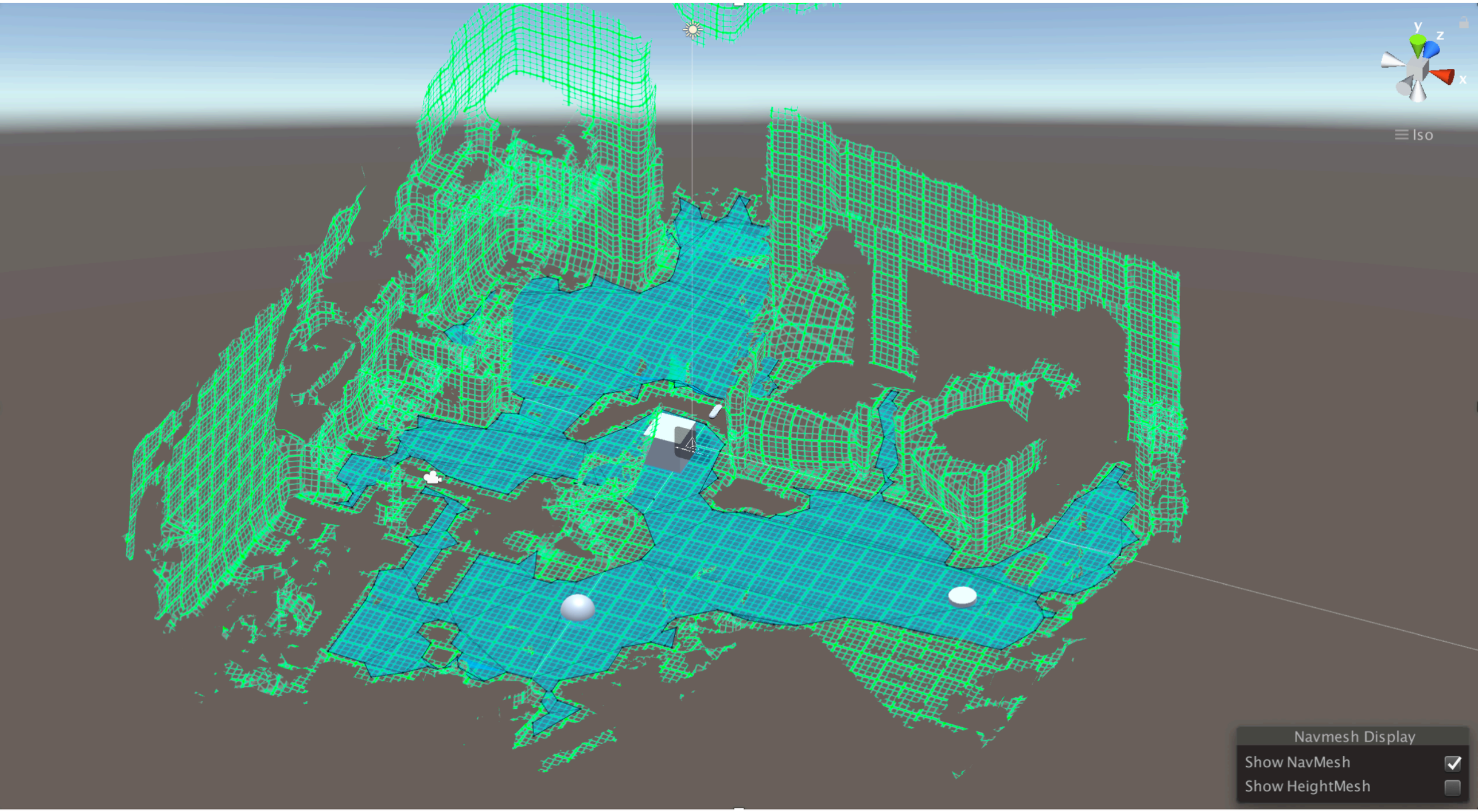
Real-time kinematic (RTK) positioning is a satellite navigation technique used to enhance the precision of position data derived from satellite-based positioning systems (global navigation satellite systems, GNSS) such as GPS, GLONASS, Galileo, and BeiDou. It uses measurements of the phase of the signal's carrier wave in addition to the information content of the signal and relies on a single reference station or interpolated virtual station to provide real-time corrections, providing up to centimeter-level accuracy.



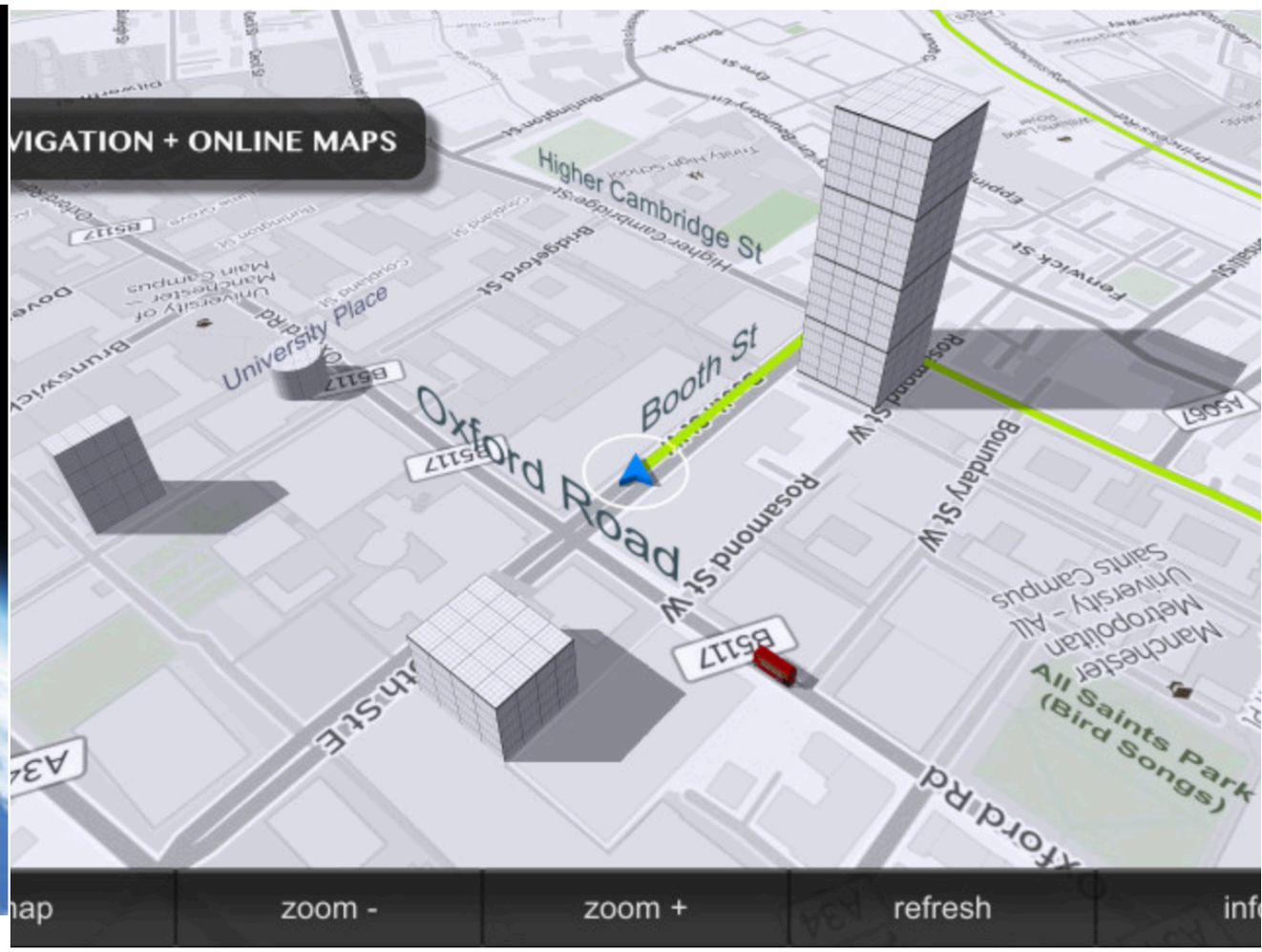
y
z
x
Persp
Game
Animation
Animator
Display 1
Inference (160x120)
Scale
1x
Maximize On Play
Mute Audio
Stats
Gizmos

iRobot® Create® 2 Open Interface (OI)
Specification based on the iRobot® Roomba® 600


Terminal Shell Edit View Window Help
Mon Jun 11 7:20 PM
Mode
1. Load dependencies
iRobot
Create
Safe cutting area
MENU
X
Y
B
A

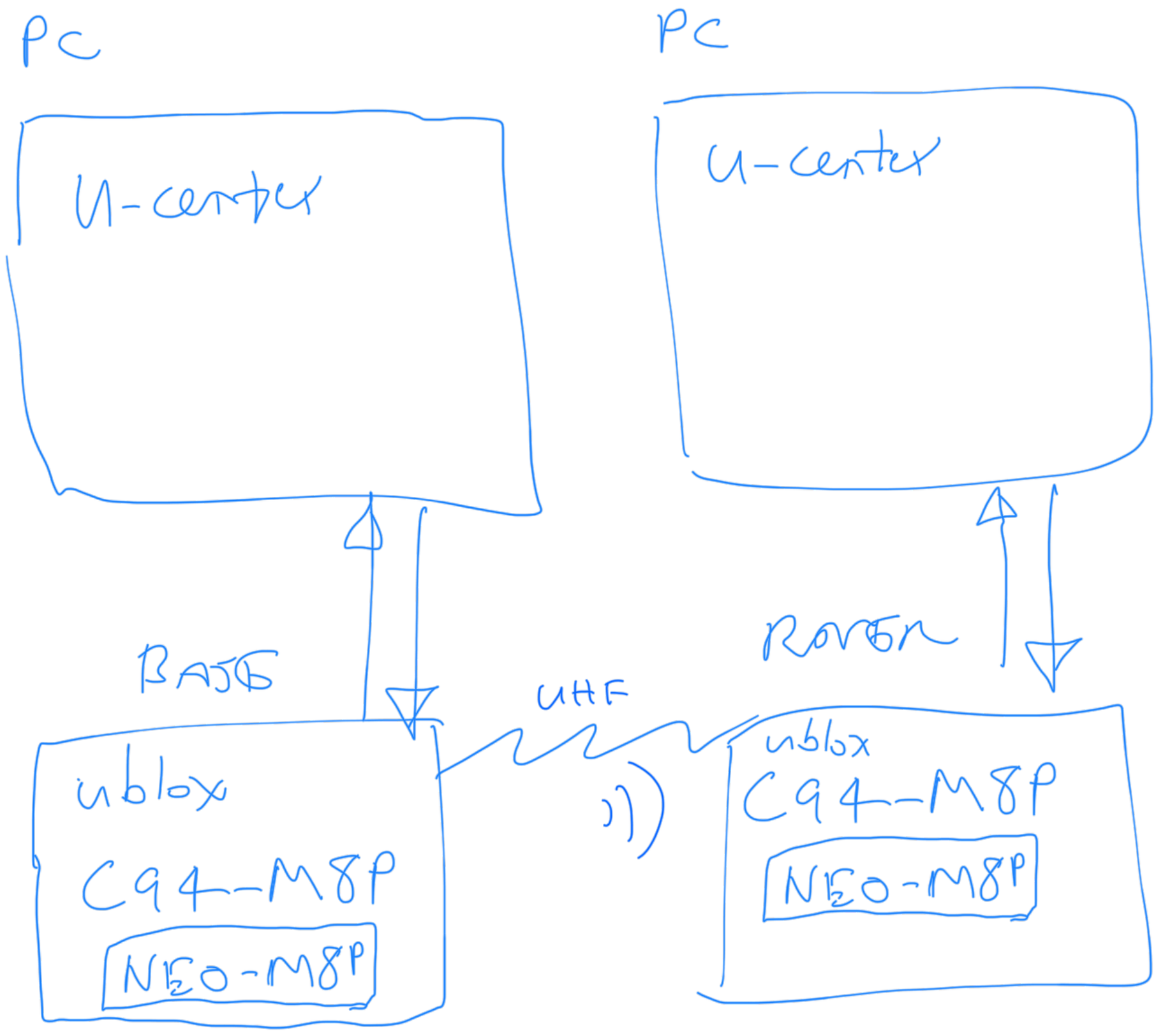

y
z
x
Iso
Navmesh Display
Show NavMesh
Show HeightMesh

MapNav Unity Plugin

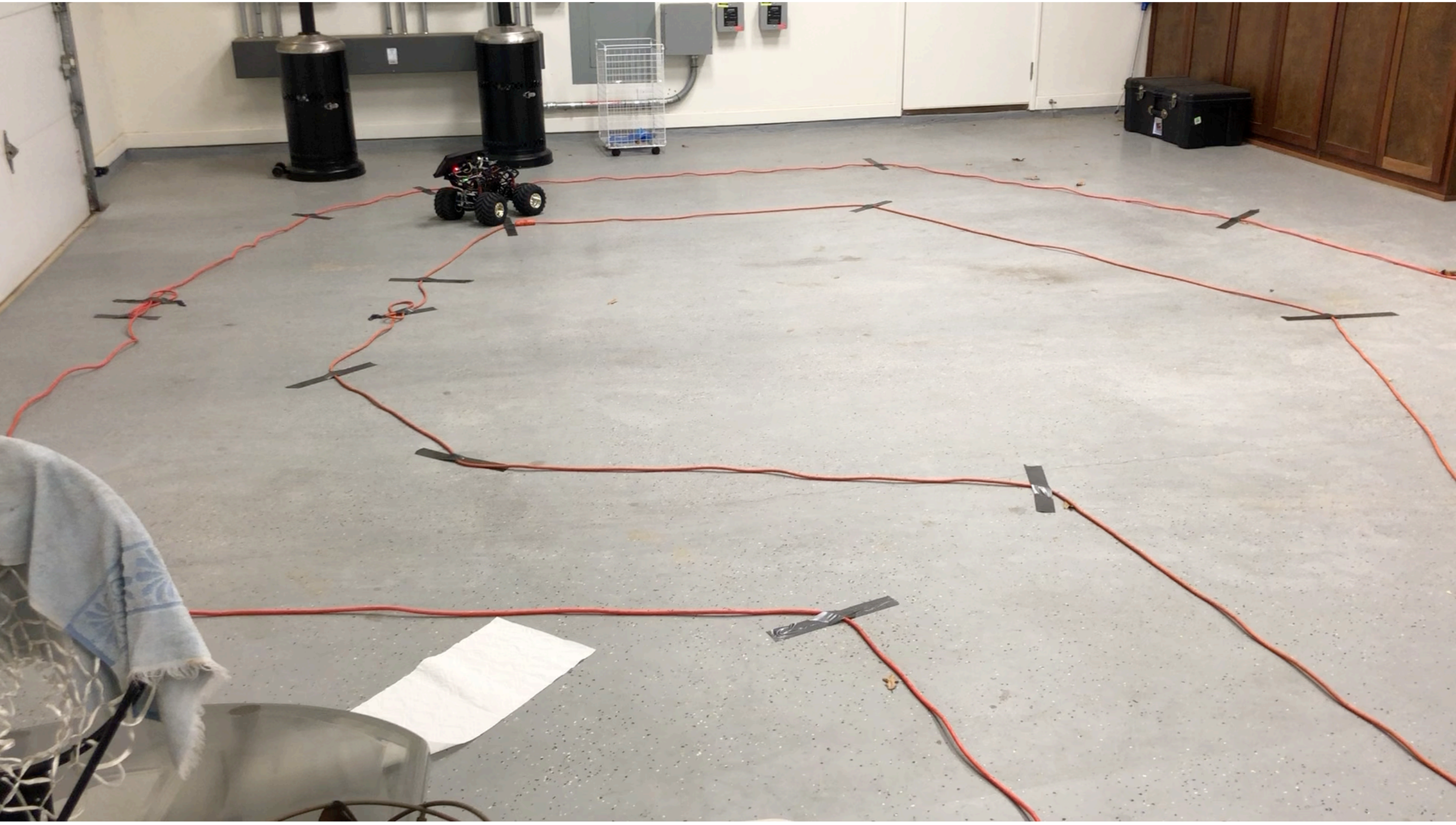


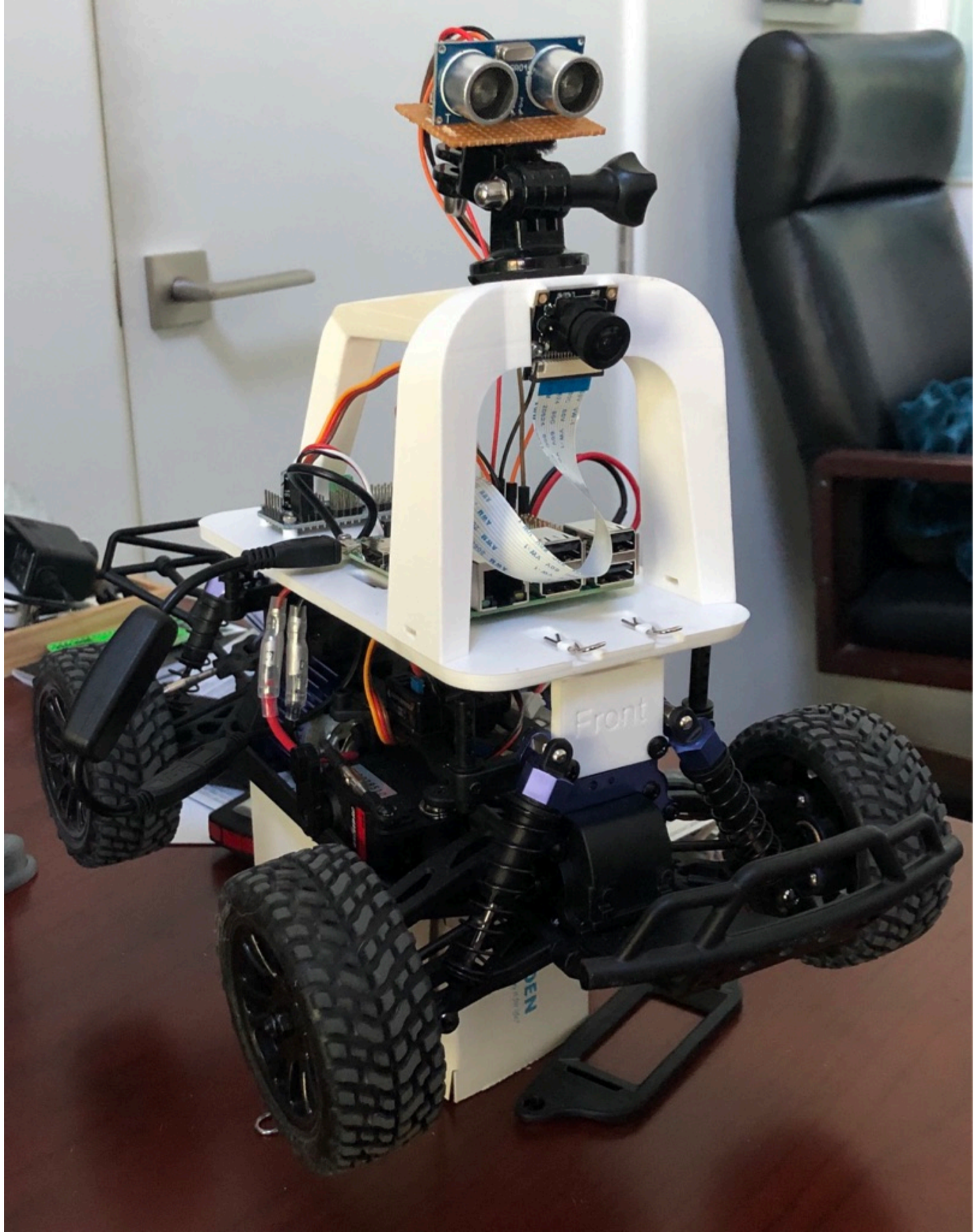
Longitude
-97.1[redacted]
Latitude
32.9[redacted]
Altitude
165.784 m
Altitude (msl)
190.800 m
TTFF
31.458 s
Fix M
3D/DGNSS/FIXED
3D Acc. [m]
0
0.02
0.1
2D Acc. [m]
0
0.01
0.1
PDOP
0
1.2
5
HDOP
0
0.6
5
Satellites

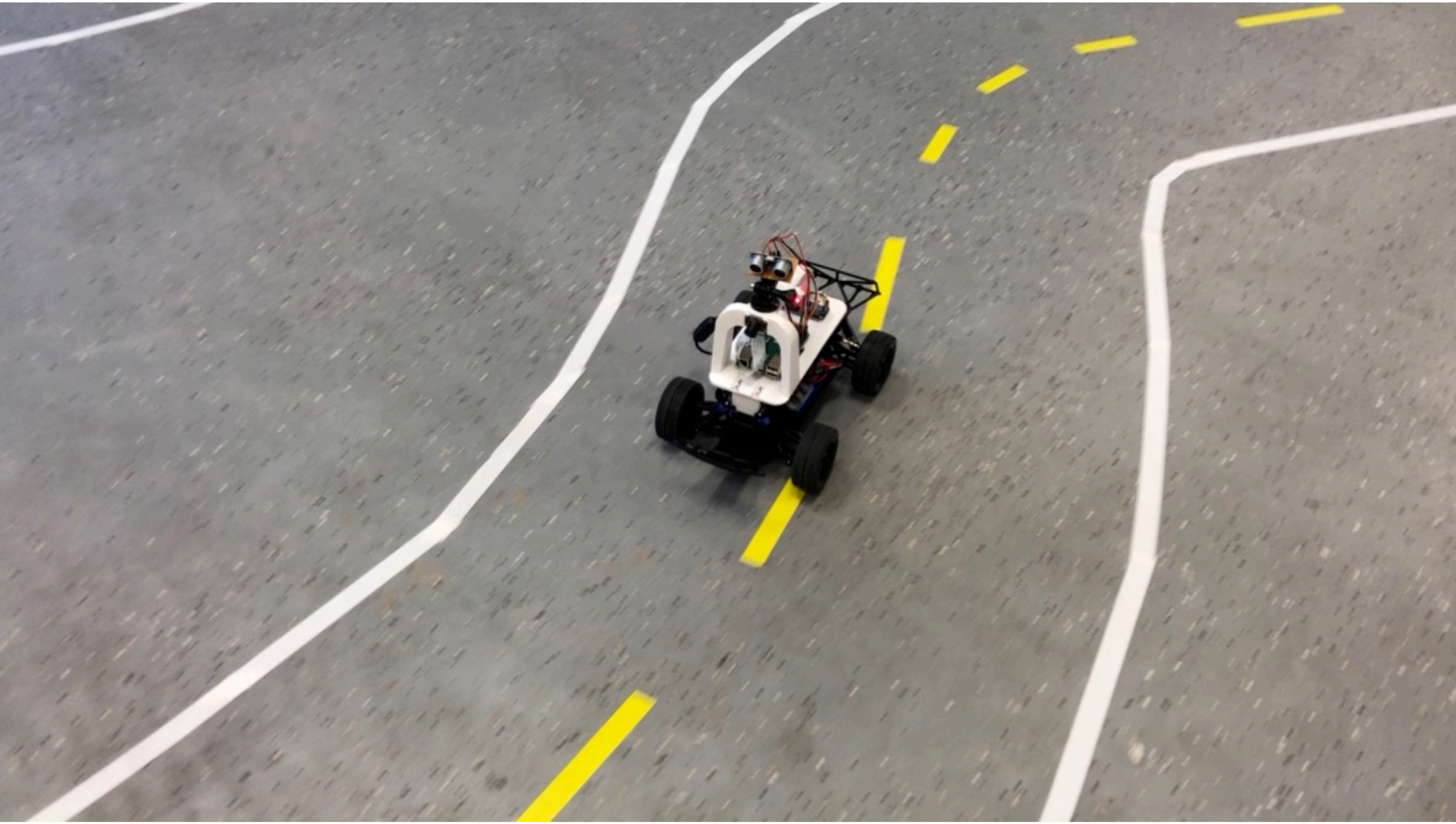
Initial RTK testing

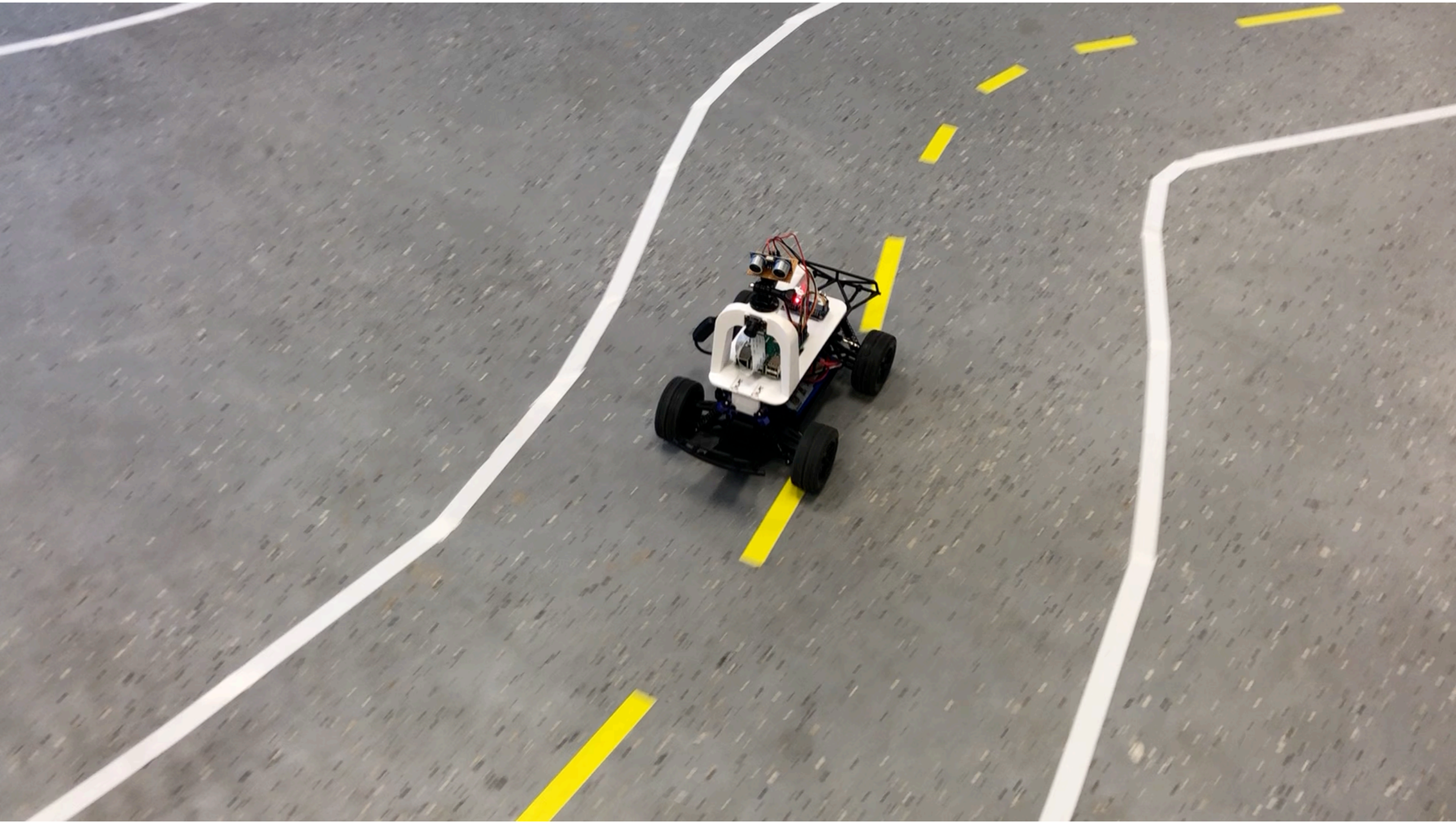


50C
5000mAh
reaction
LITHIUM POLYMER BATTERY
SAVOX

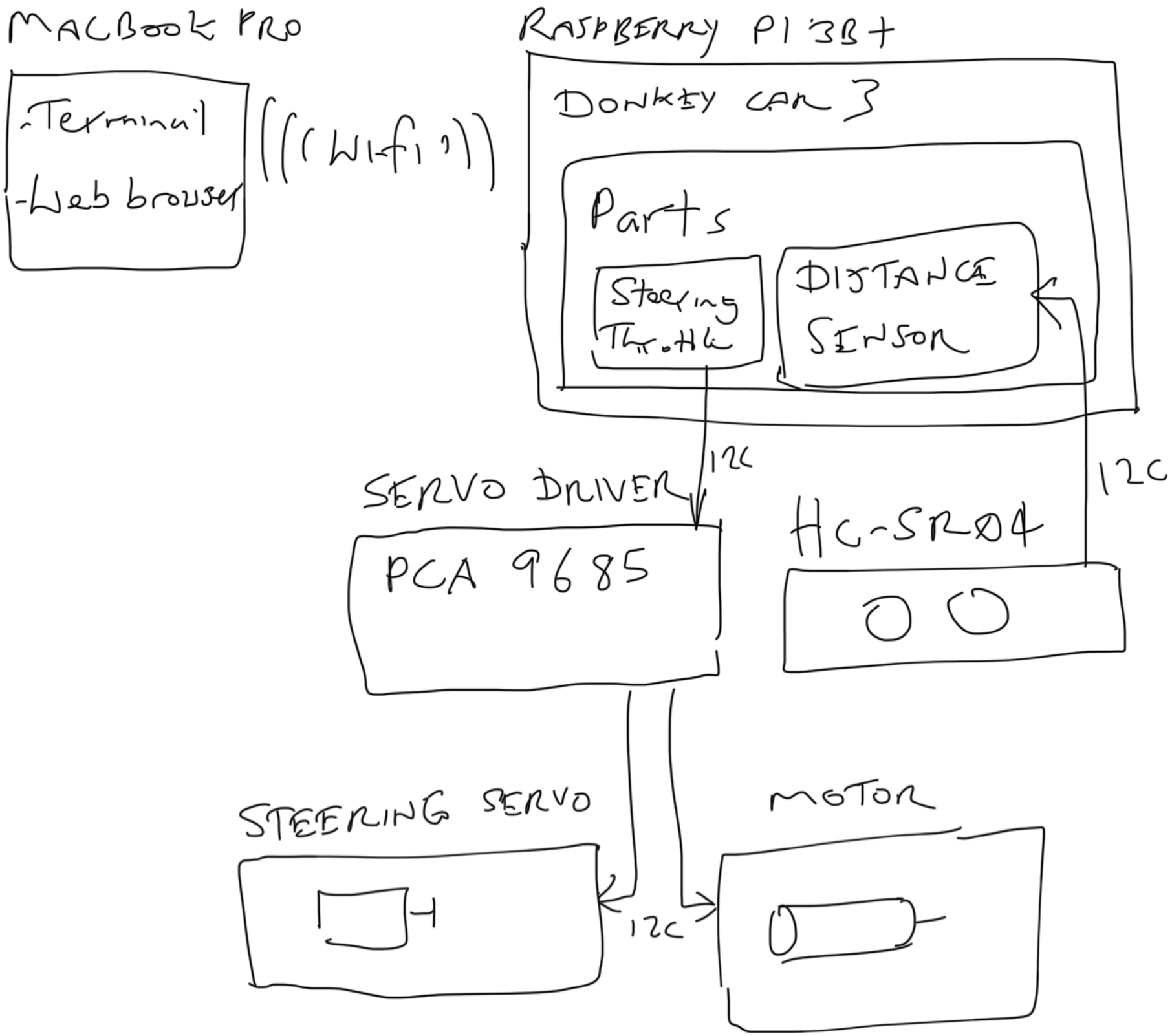



Front

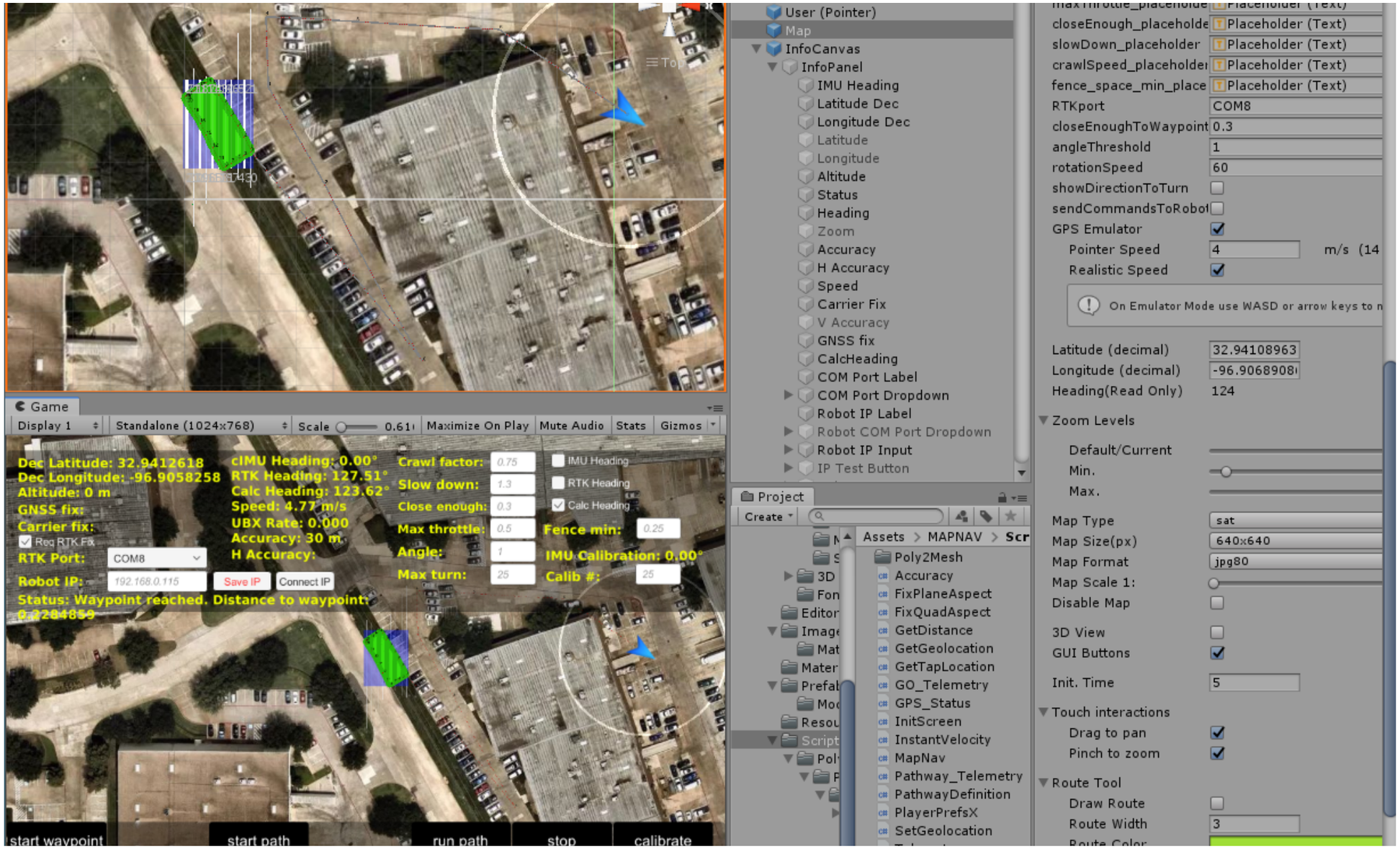




Donkey Car Architecture



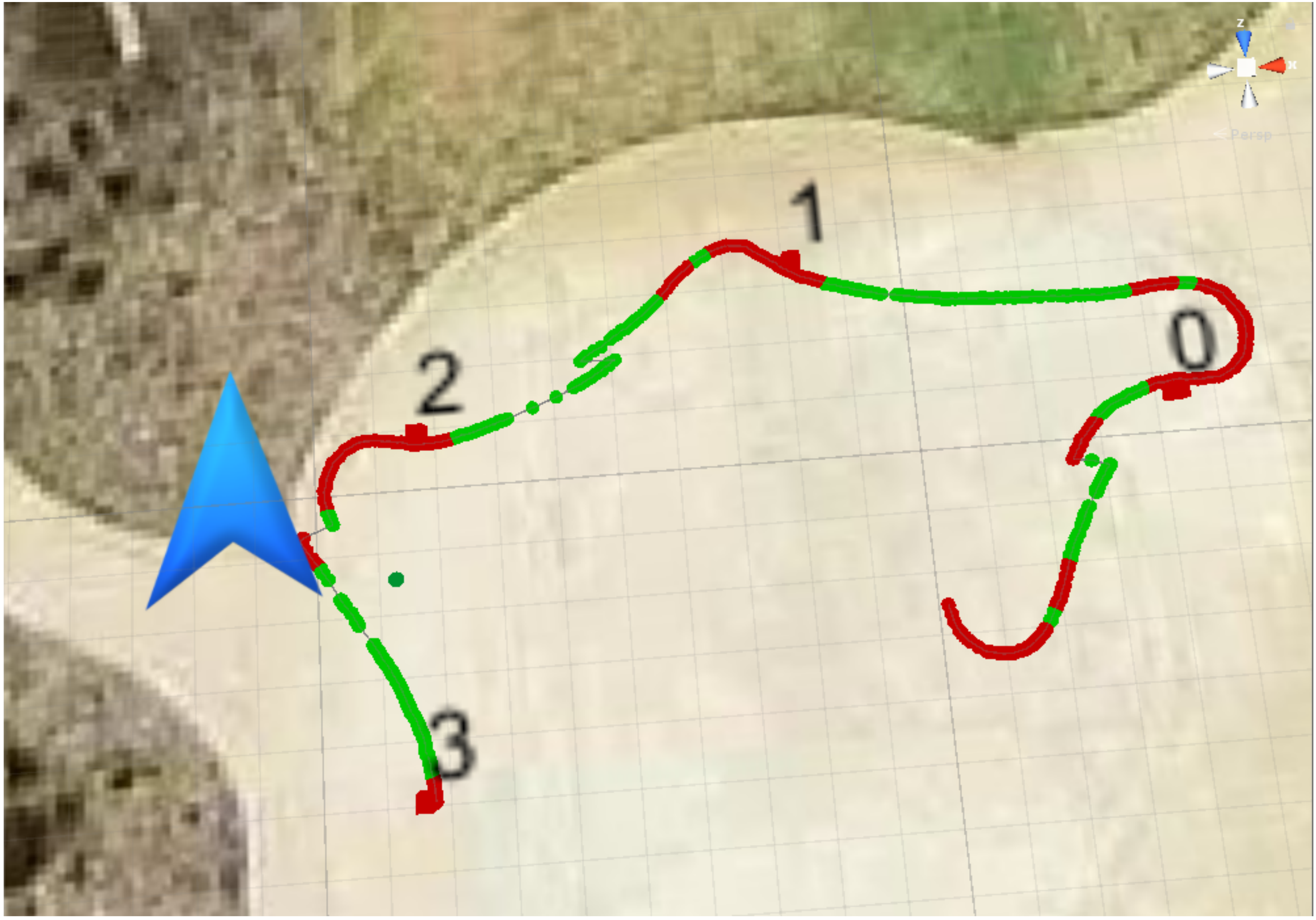
ASUS

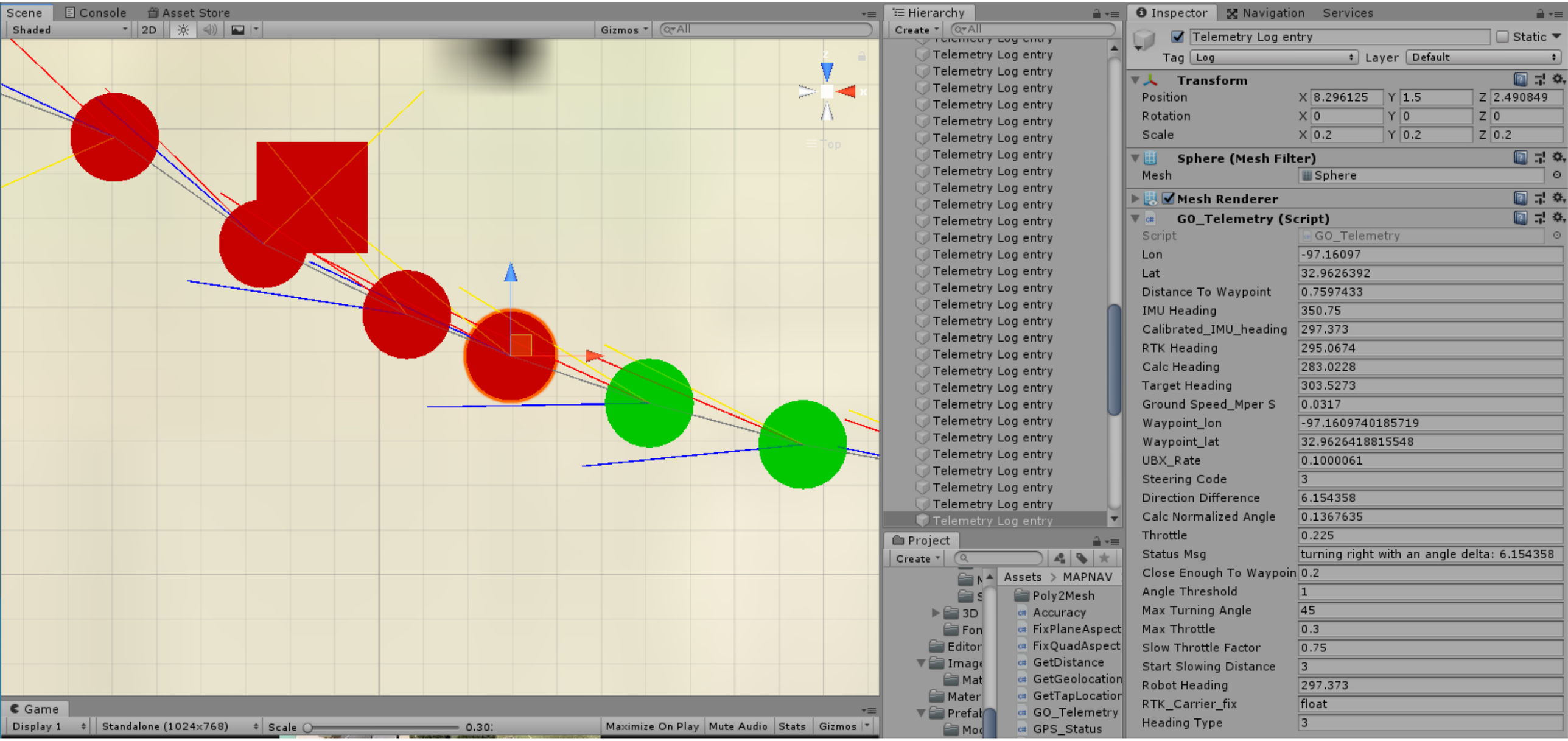

Game
Display 1
Standalone (1024x768)
Scale
Maximize On Play
Mute Audio
Stats
Gizmos
Dec Latitude: 32.9412618
Dec Longitude: -96.9058258
Altitude: 0 m
GNSS fix:
Carrier fix:
Req RTK Fix
RTK Port:
COM8
Robot IP:
192.168.0.115
Save IP
Connect IP
Status: Waypoint reached. Distance to waypoint: 0.2284859
cIMU Heading: 0.00°
RTK Heading: 127.51°
Calc Heading: 123.62°
Speed: 4.77 m/s
UBX Rate: 0.000
Accuracy: 30 m
H Accuracy:
Crawl factor:
Slow down:
Close enough:
Max throttle:
Angle:
Max turn:
IMU Heading
RTK Heading
Calc Heading
Fence min:
IMU Calibration: 0.00°
Calib #:
start waypoint
start path
run path
stop
calibrate
User (Pointer)
Map
InfoCanvas
InfoPanel
IMU Heading
Latitude Dec
Longitude Dec
Latitude
Longitude
Altitude
Status
Heading
Zoom
Accuracy
H Accuracy
Speed
Carrier Fix
V Accuracy
GNSS fix
CalcHeading
COM Port Label
COM Port Dropdown
Robot IP Label
Robot COM Port Dropdown
Robot IP Input
IP Test Button
Project
Create
Assets > MAPNAV > Scr
Poly2Mesh
Accuracy
FixPlaneAspect
FixQuadAspect
GetDistance
GetGeolocation
GetTapLocation
GO_Telemetry
GPS_Status
InitScreen
InstantVelocity
MapNav
Pathway_Telemetry
PathwayDefinition
PlayerPrefsX
SetGeolocation
closeEnough_placeholde
slowDown_placeholder
crawlSpeed_placeholder
fence_space_min_place
Placeholder (Text)
RTKport
COM8
closeEnoughToWaypoint
0.3
angleThreshold
1
rotationSpeed
60
showDirectionToTurn
sendCommandsToRobot
GPS Emulator
Pointer Speed
4
m/s (14
Realistic Speed
On Emulator Mode use WASD or arrow keys to n
Latitude (decimal)
32.94108963
Longitude (decimal)
-96.9068908
Heading(Read Only)
124
Zoom Levels
Default/Current
Min.
Max.
Map Type
sat
Map Size(px)
640x640
Map Format
jpg80
Map Scale 1:
Disable Map
3D View
GUI Buttons
Init. Time
5
Touch interactions
Drag to pan
Pinch to zoom
Route Tool
Draw Route
Route Width
3

Demo Time!

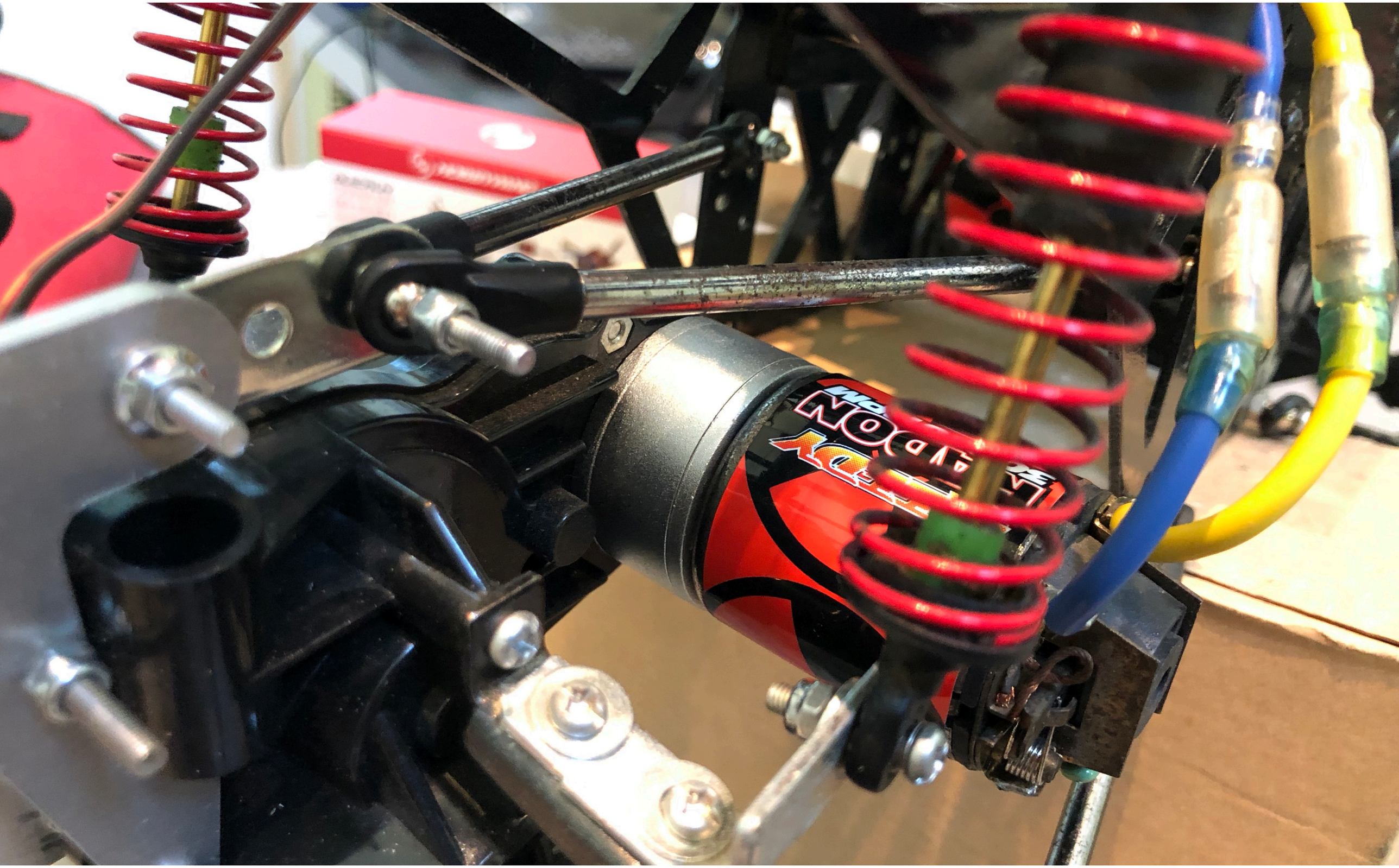
Solving Problems

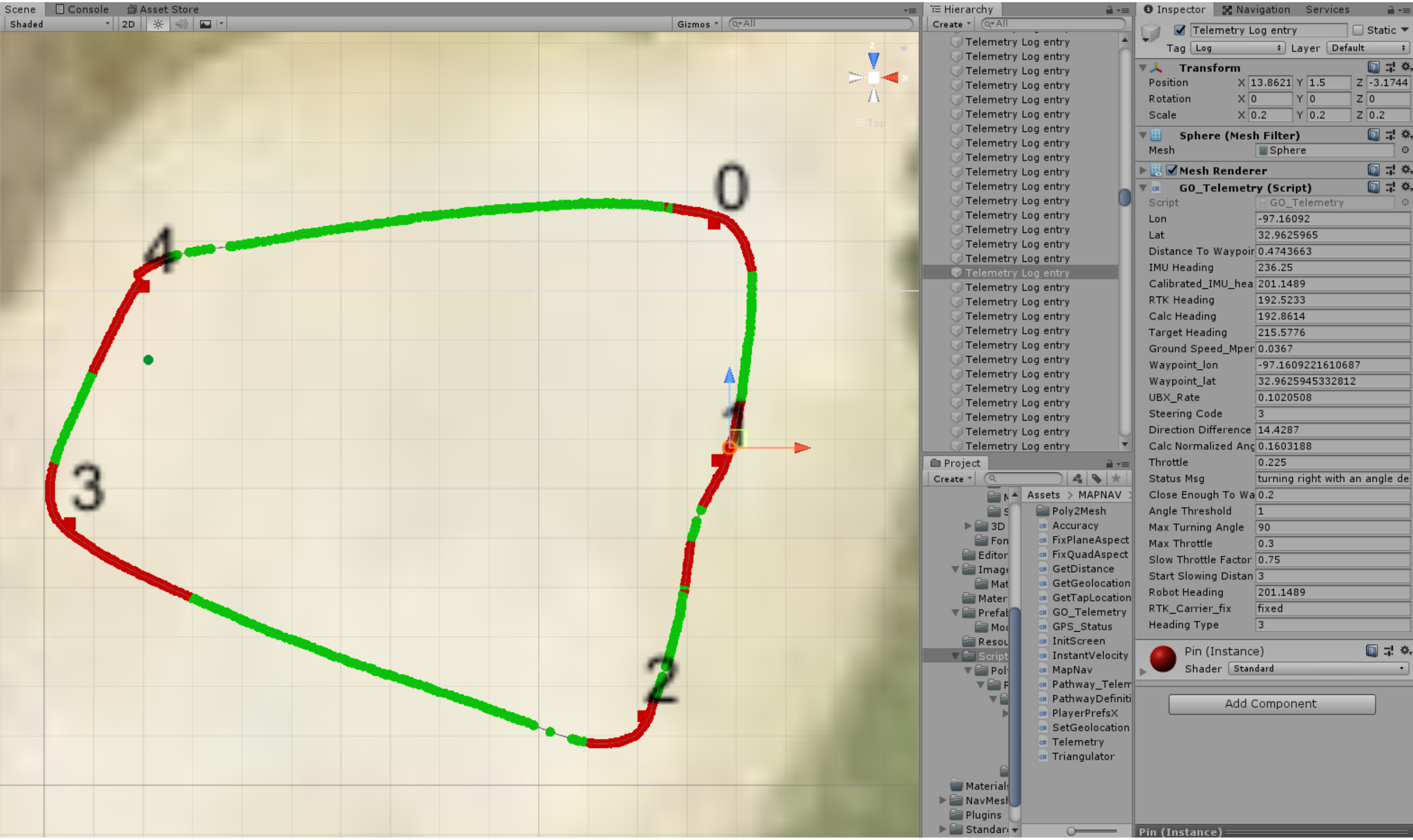
- Pi to PC bidirectional communication
- Wi-fi connectivity outside and changing SSIDs
- Wi-fi indirect manual steering lag
- GPS coordinate collection timing
- Telemetry Recording
- Heading accuracy
- Debugging and iterating


1
0
2
3
Persp

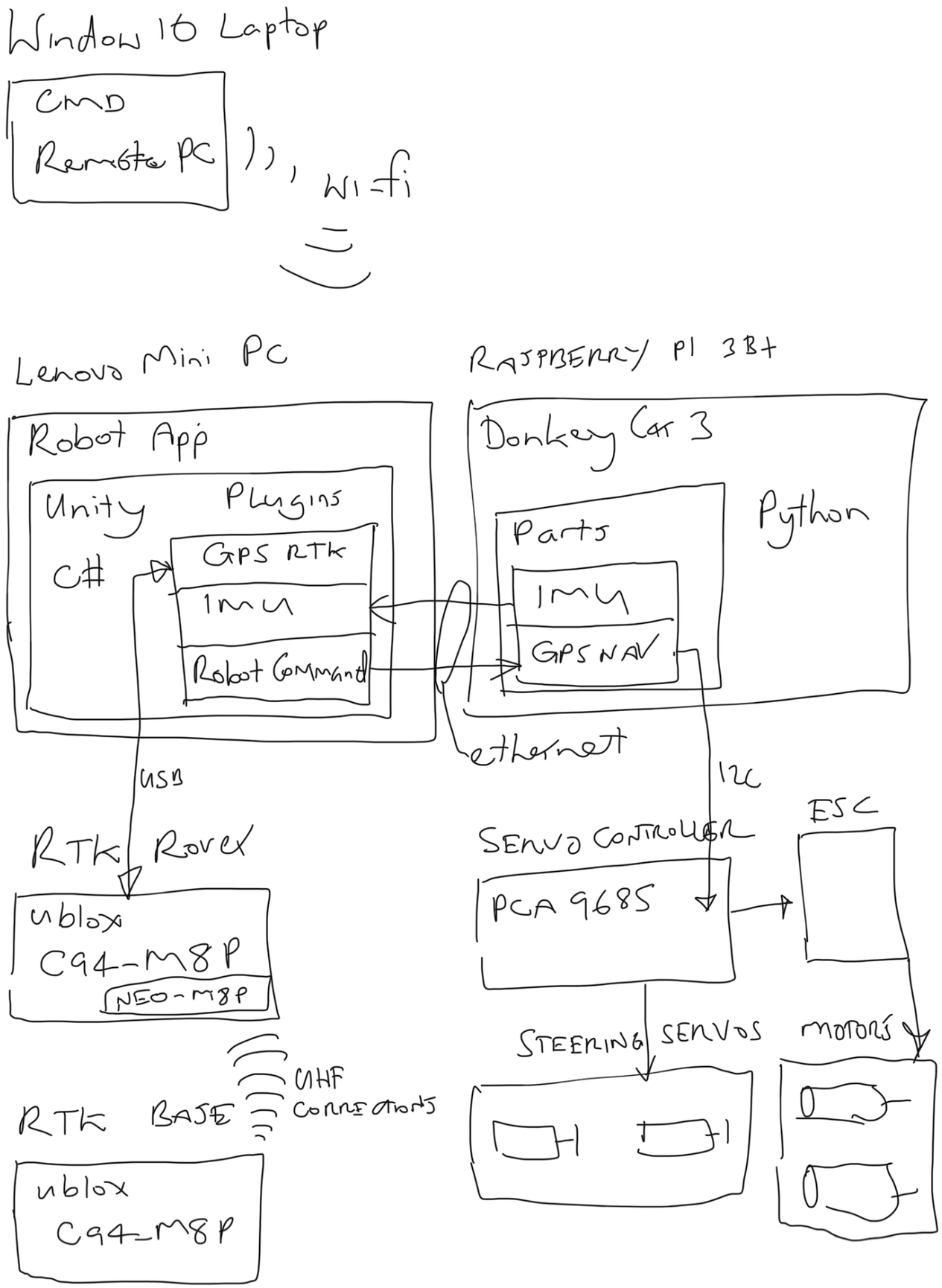

Scene
Console
Asset Store
Shaded
2D
Gizmos
Hierarchy
Create
Telemetry Log entry
Inspector
Navigation
Services
Telemetry Log entry
Static
Tag Log
Layer Default
Transform
Position X 8.296125 Y 1.5 Z 2.490849
Rotation X 0 Y 0 Z 0
Scale X 0.2 Y 0.2 Z 0.2
Sphere (Mesh Filter)
Mesh Sphere
Mesh Renderer
G0_Telemetry (Script)
Script GO_Telemetry
Lon -97.16097
Lat 32.9626392
Distance To Waypoint 0.7597433
IMU Heading 350.75
Calibrated_IMU_heading 297.373
RTK Heading 295.0674
Calc Heading 283.0228
Target Heading 303.5273
Ground Speed_Mper S 0.0317
Waypoint_lon -97.1609740185719
Waypoint_lat 32.9626418815548
UBX_Rate 0.1000061
Steering Code 3
Direction Difference 6.154358
Calc Normalized Angle 0.1367635
Throttle 0.225
Status Msg turning right with an angle delta: 6.154358
Close Enough To Waypoin 0.2
Angle Threshold 1
Max Turning Angle 45
Max Throttle 0.3
Slow Throttle Factor 0.75
Start Slowing Distance 3
Robot Heading 297.373
RTK_Carrier_fix float
Heading Type 3
Project
Create
Assets > MAPNAV
Poly2Mesh
Accuracy
FixPlaneAspect
FixQuadAspect
GetDistance
GetGeolocation
GetTapLocation
GO_Telemetry
GPS_Status
Game
Display 1
Standalone (1024x768)
Scale
Maximize On Play
Mute Audio
Stats
Gizmos

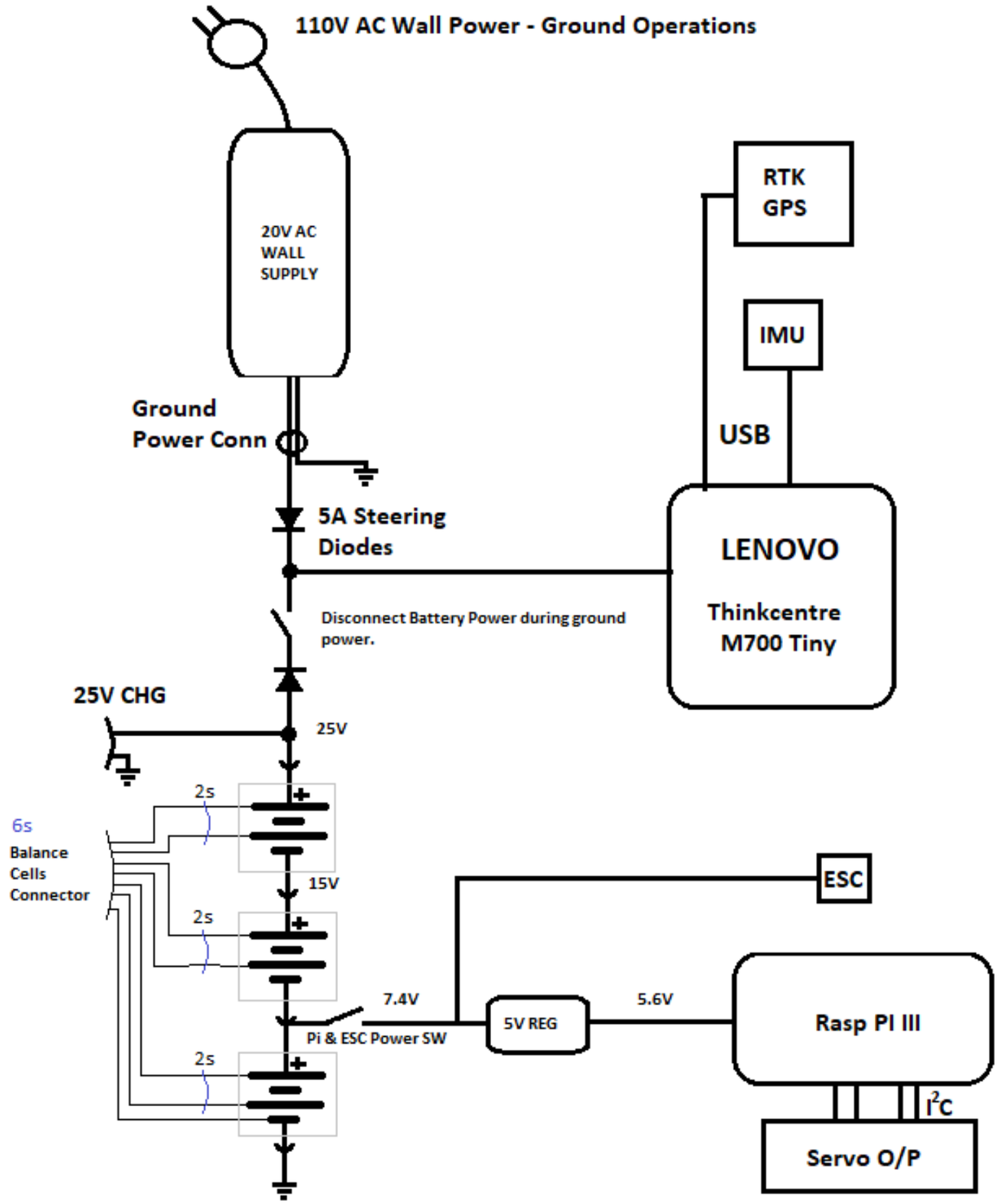
4:1 silver gearboxes added to slow down the robot: GPS RTK required a slower robot



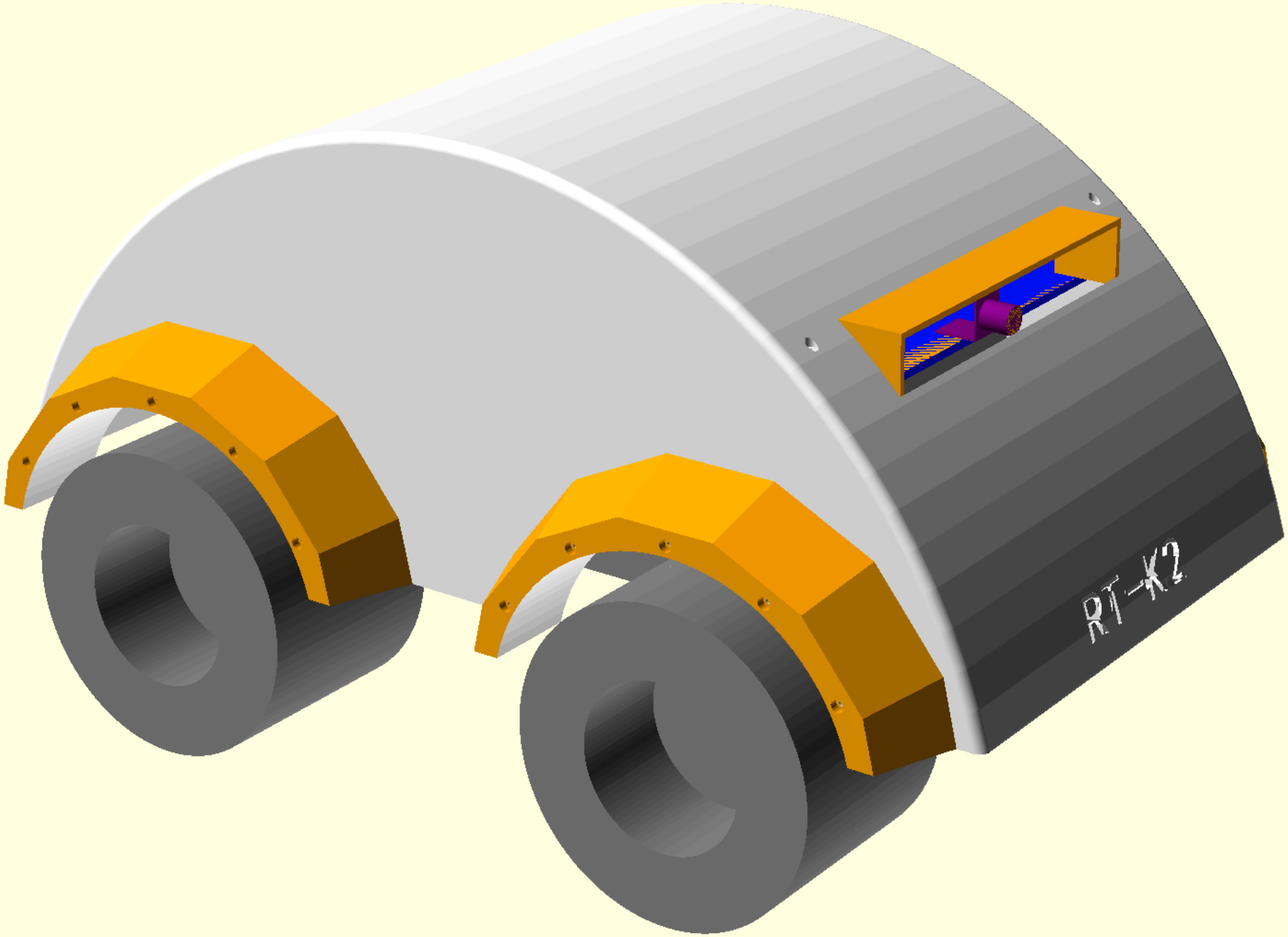

Scene
Console
Asset Store
Shaded
2D
Gizmos
0
1
2
3
4
Hierarchy
Create
Telemetry Log entry
Project
Assets > MAPNAV
Poly2Mesh
Accuracy
FixPlaneAspect
FixQuadAspect
GetDistance
GetGeolocation
GetTapLocation
GO_Telemetry
GPS_Status
InitScreen
InstantVelocity
MapNav
Pathway_Telem
PathwayDefiniti
PlayerPrefsX
SetGeolocation
Telemetry
Triangulator
Materials
NavMesh
Plugins
Standard
Inspector
Navigation
Services
Telemetry Log entry
Static
Tag Log
Layer Default
Transform
Position X 13.8621 Y 1.5 Z -3.1744
Rotation X 0 Y 0 Z 0
Scale X 0.2 Y 0.2 Z 0.2
Sphere (Mesh Filter)
Mesh Sphere
Mesh Renderer
GO_Telemetry (Script)
Script GO_Telemetry
Lon -97.16092
Lat 32.9625965
Distance To Waypoir 0.4743663
IMU Heading 236.25
Calibrated_IMU_hea 201.1489
RTK Heading 192.5233
Calc Heading 192.8614
Target Heading 215.5776
Ground Speed_Mper 0.0367
Waypoint_lon -97.1609221610687
Waypoint_lat 32.9625945332812
UBX_Rate 0.1020508
Steering Code 3
Direction Difference 14.4287
Calc Normalized Ang 0.1603188
Throttle 0.225
Status Msg turning right with an angle de
Close Enough To Wa 0.2
Angle Threshold 1
Max Turning Angle 90
Max Throttle 0.3
Slow Throttle Factor 0.75
Start Slowing Distan 3
Robot Heading 201.1489
RTK_Carrier_fix fixed
Heading Type 3
Pin (Instance)
Shader Standard
Add Component

RTK Robot Architecture





RTK ROVER ONBOARD & GROUND POWER DISTRIBUTION

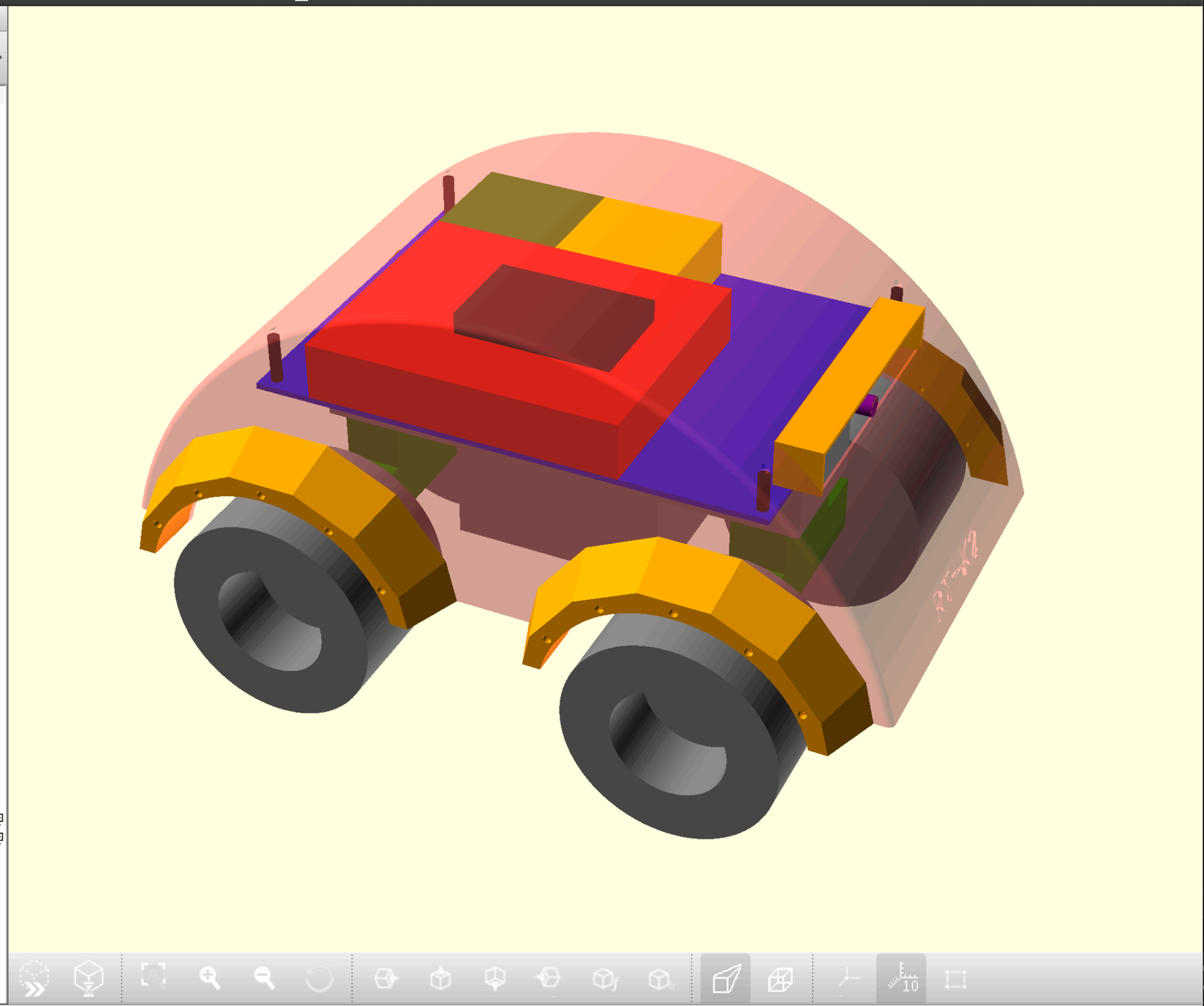

RT-K2

OpenSCAD File Edit Design View Help

RT-K2.scad

Editor

```
/*
 RT-K2 Body Shell CAD
 Copyright Ross Melbourne 2019

*/
$fn=100;  // facets per layer

//Debugging and printing
{
var_debug = false ;

var_just_show_shell = false  ;

var_split_into_parts = false ;

// 1 = Left side front,
// 2 = Right side front,
// 3 = Left side back
// 4 = Right side back
// 5 = top front
// 6 = top back
// 7 = post front
// 8 = post back
// 9 = Camera Bay cover
// 10 = wheel arch left
// 11 = wheel arch right
var_part_number = 8 ;

var_render = 1 ; // unused
}
// variables defined here
{
// Define wheels
var_wheel_width = 150 ;
var_wheel_radius = 150 / 2 ;
var_wheel_depth = 105 ;

var_width_between_wheels = 160 ;
var_wheel_offset_width_from_center = (
    var_width_between_wheels / 2) +
    var_wheel_depth ;
var_inner_wheel_diameter = 80 ;

var_distance_between_axles = 290 ;

// Define Body shell
var_shell_radius = 280 ;
var_shell_width = 270 ; // was 254
```



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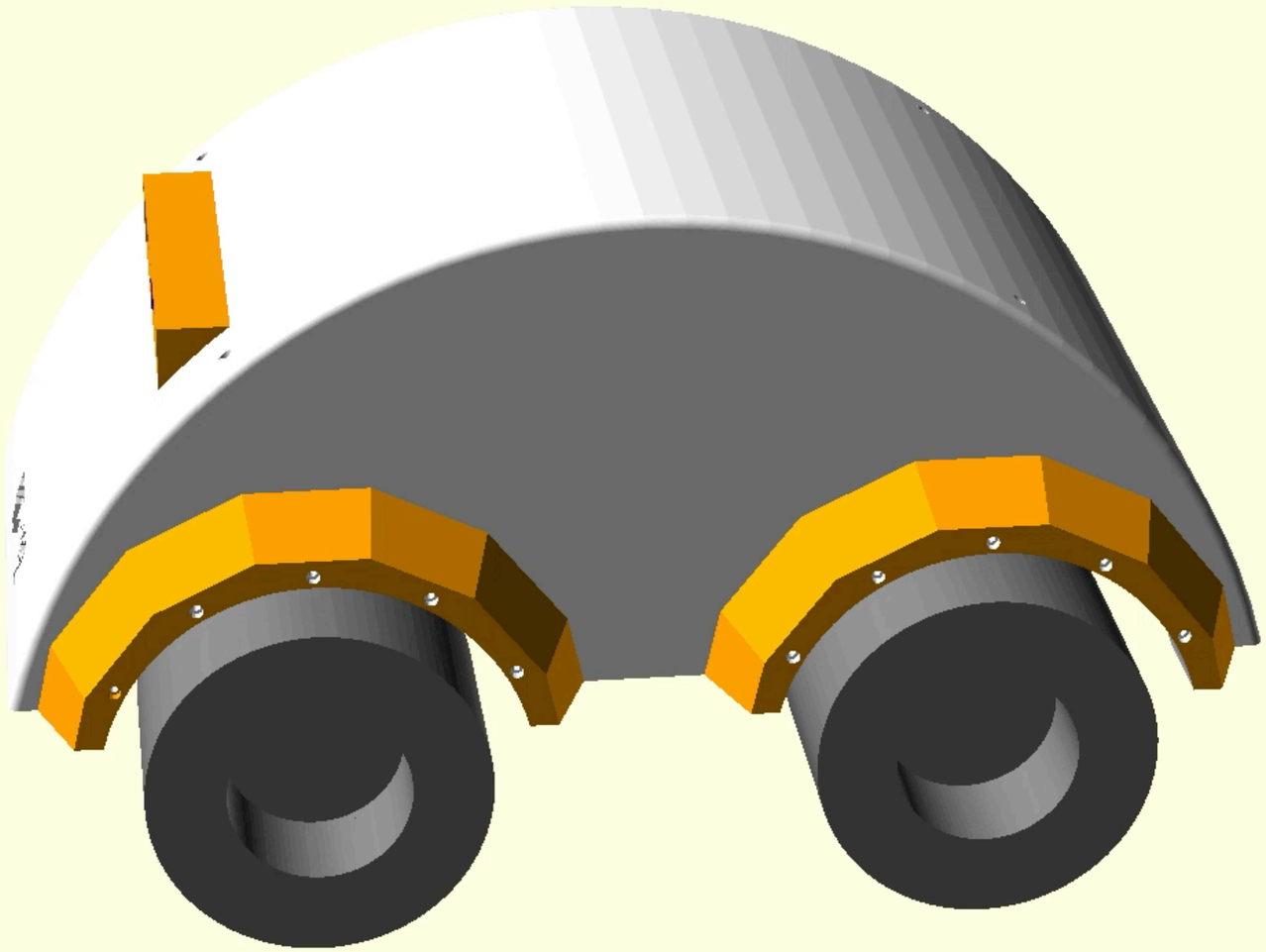
OpenSCAD 2019.05