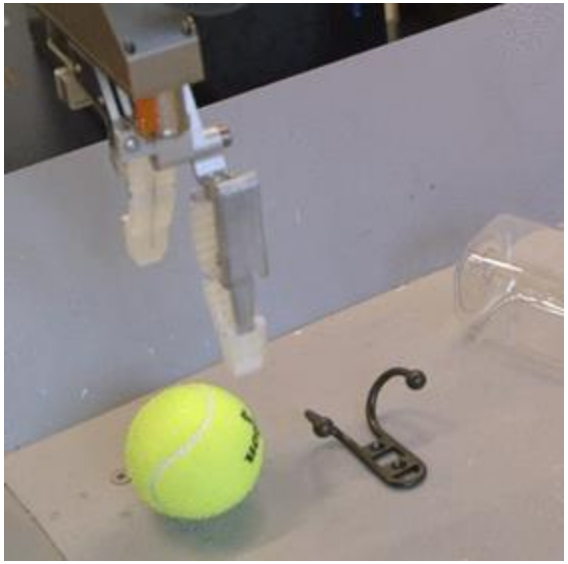
Case Study of Everyday Robot Project

- Everyday Robotics Project
  - Published QT-OPT
  - Robotic Grasping
    - Closed Loop
    - Repositioning

- Robot will perform variety of tasks
  - Sorting trash from bins
  - Interact with humans safely
  - Use Computer Vision and RGBD cameras to avoid obstacles



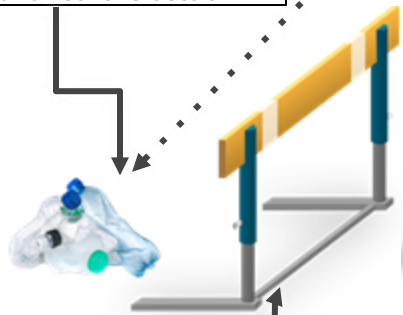
Autonomously Identify, Retrieve, and Recycle Trash

4) Autonomously identify a trashcan randomly placed in the SJSU environment

5) Effectively navigate to trashcan and dispose of the bottle

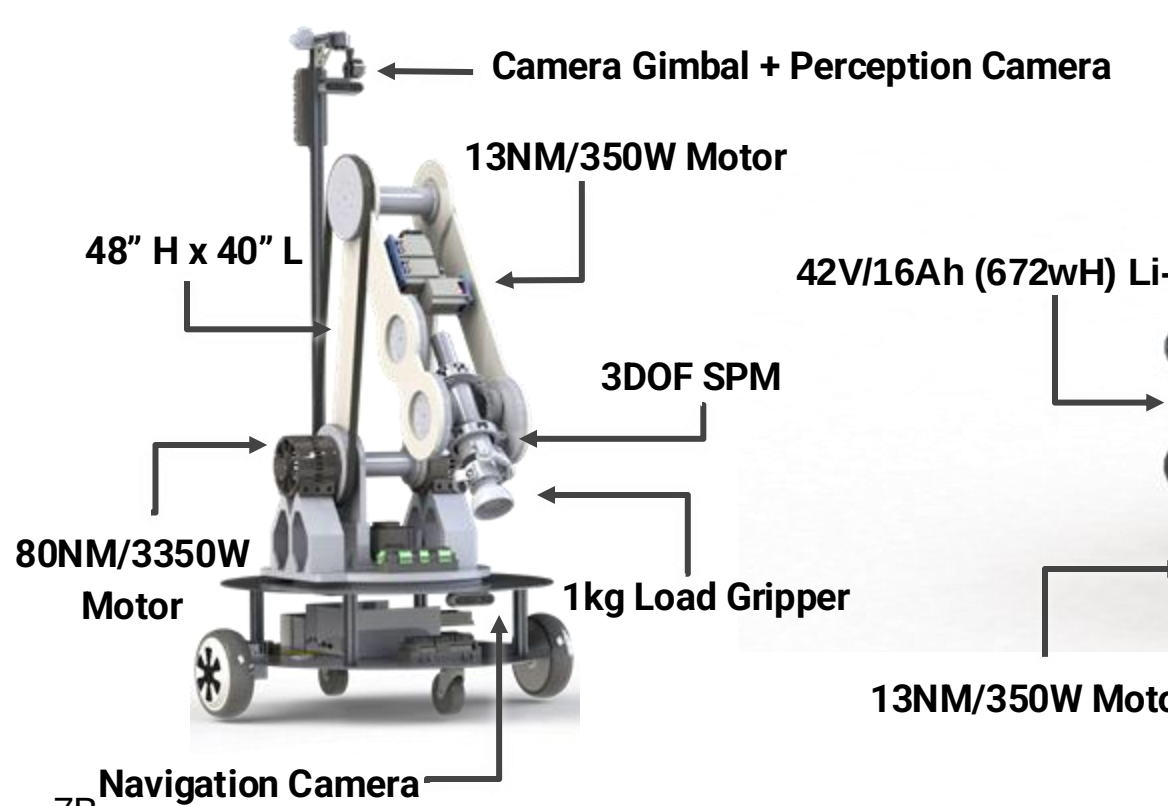
1) Autonomously identify plastic bottle randomly placed in the SJSU environment

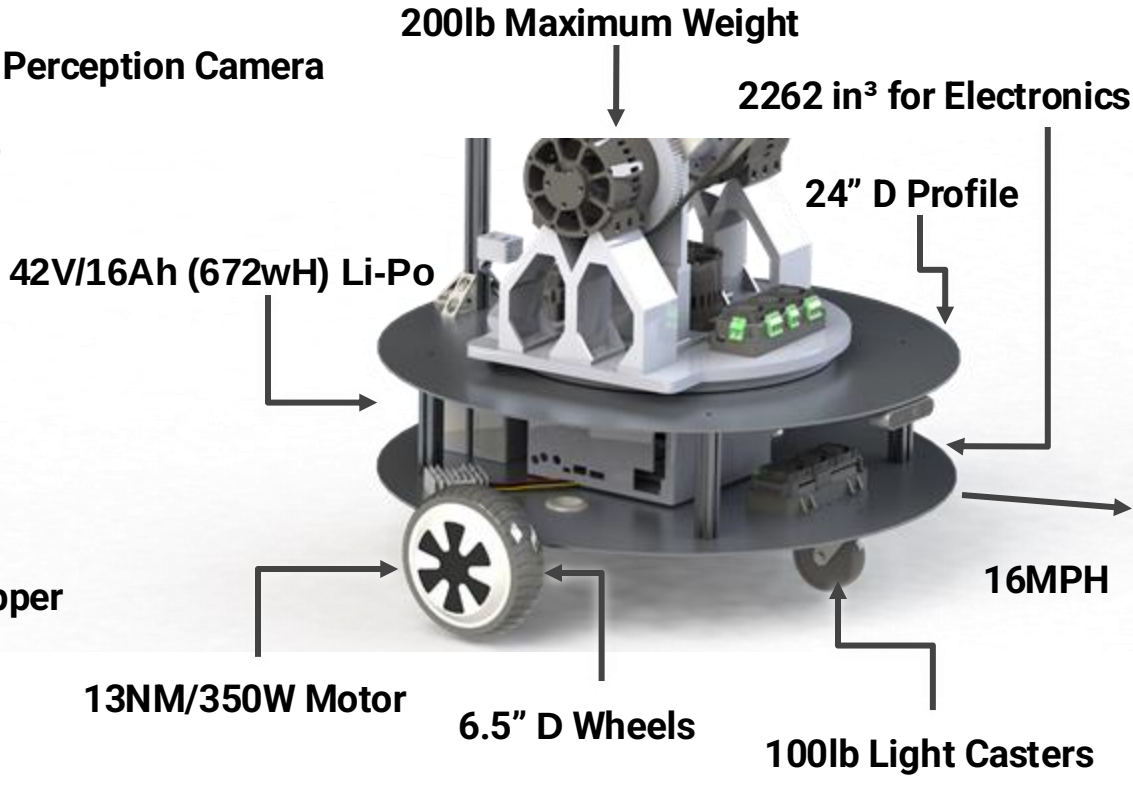
2) Effectively navigate to position nearby bottle and retrieve bottle



3) Avoid all obstacles without losing target and maintain constant locational awareness

Functional specifications and dimensions

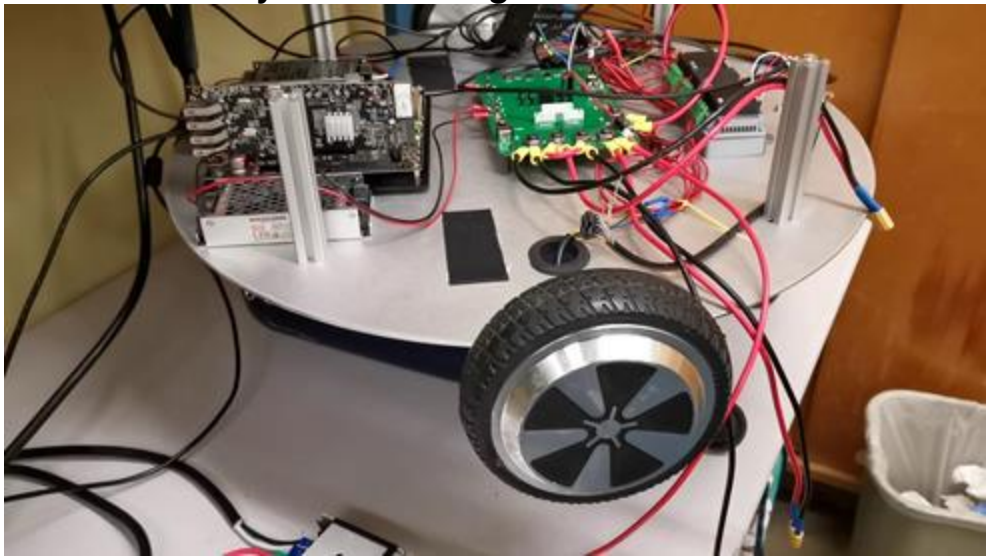




Differential drivetrain design for low cost mobility

3D Printed Forced Convection Odrive

Velocity Control using Hall Sensors on ROS



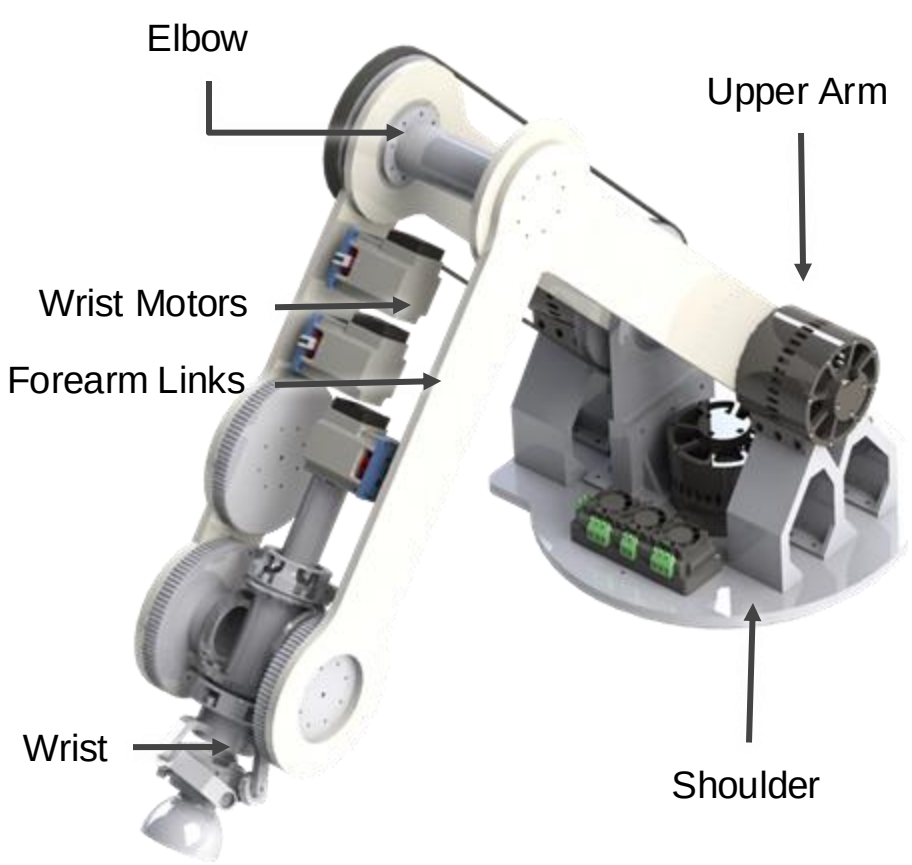
3D Printed Polycarbonate Mounts

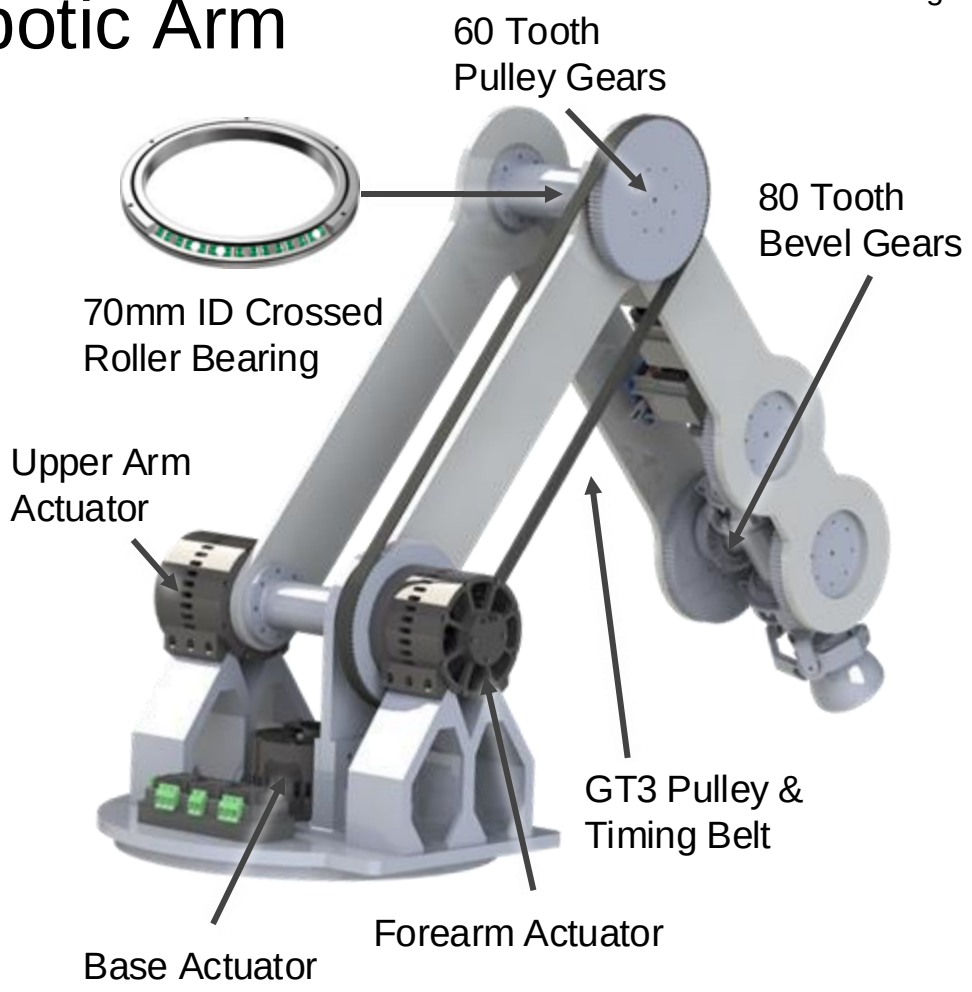
4 x 2020 T-Slot Supports on 11ga Aluminum Plates

4lb mass (counterweight)

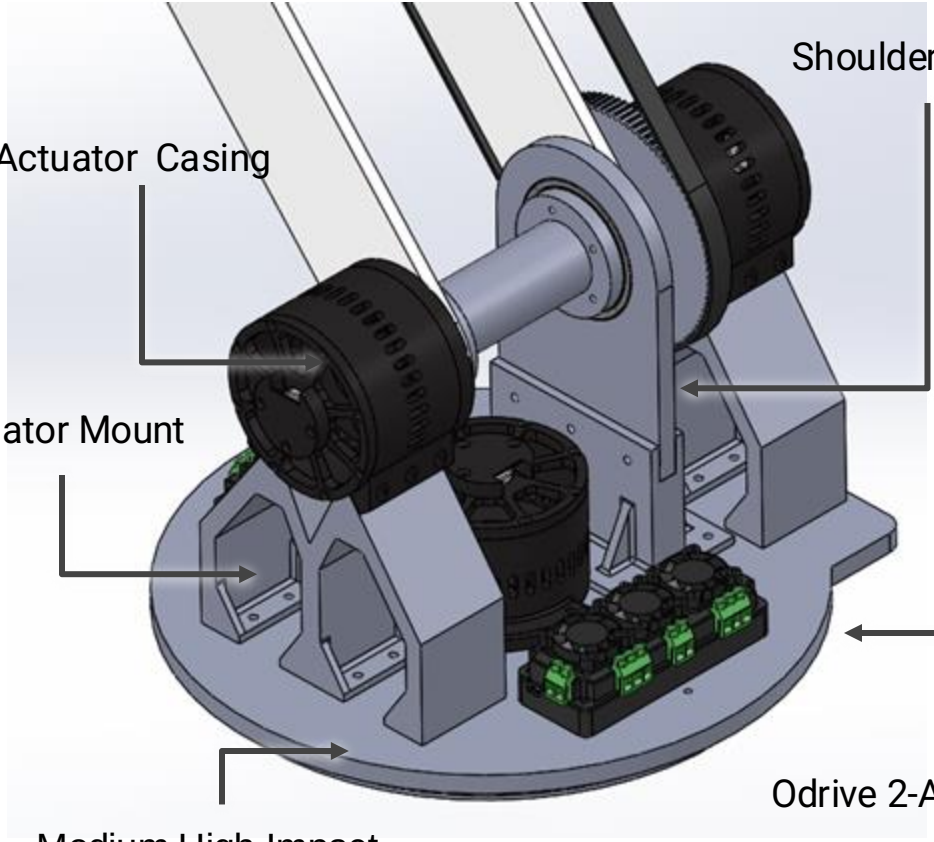
42V, 10A, 1000RPM

3DOF Laser Cut Acrylic Robotic Arm

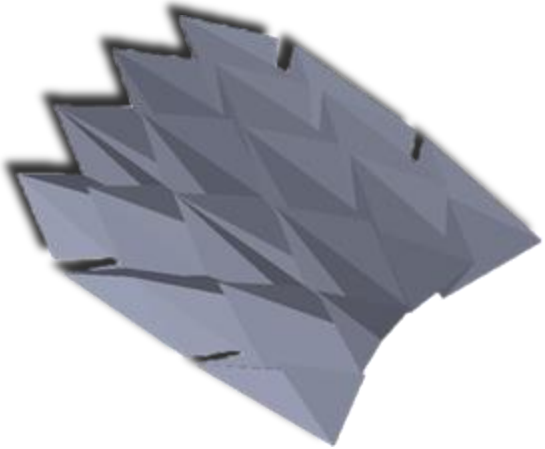




Rotating Turntable Robotic Shoulder



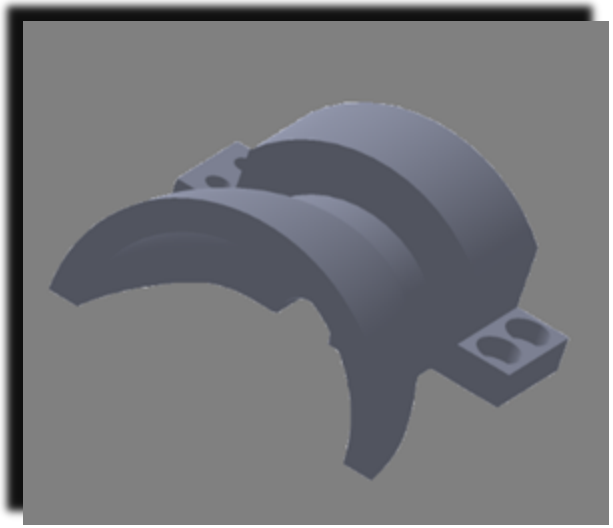
Universal Suction Gripper Design



Rev. 1

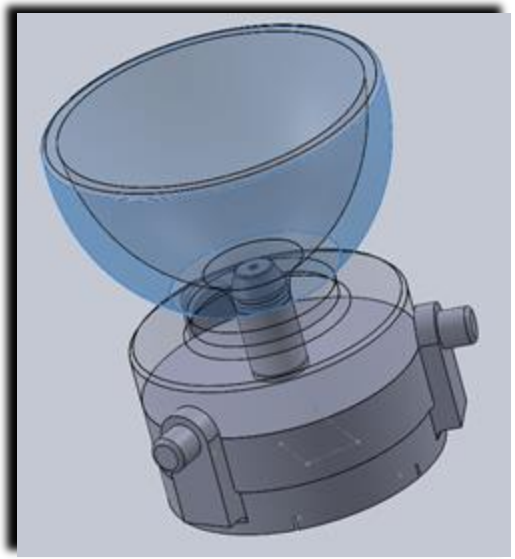
- Functional credibility PoC

7B



Rev. 2

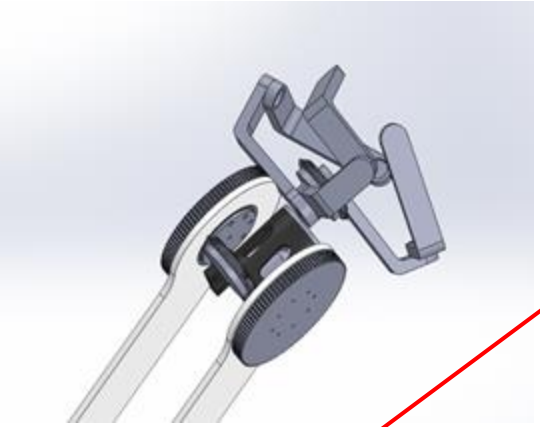
- Increase weight limit
- Structured gripper ➤ coffee ground gripper

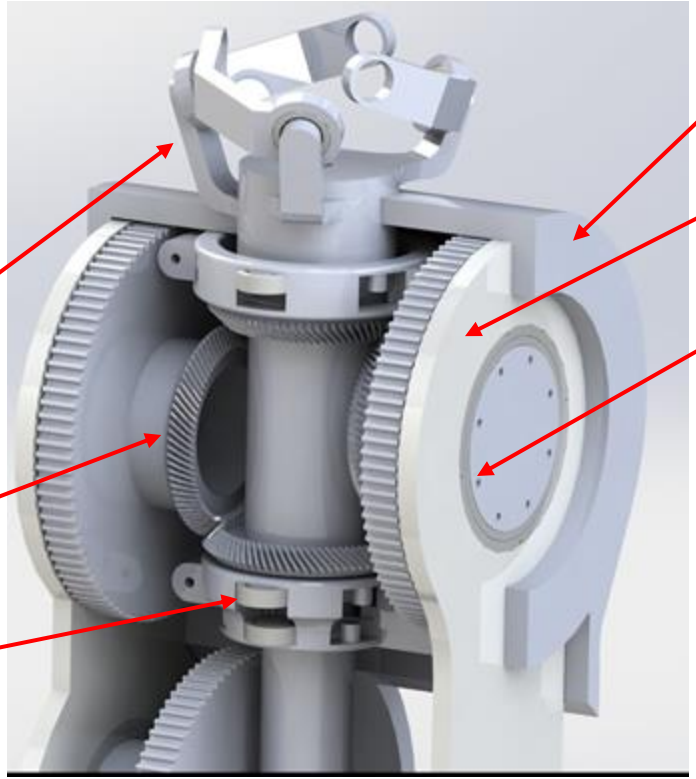


Rev 3.

- Increase weight limit
- Improve manufacturability
- Correct errors & mating

3DOF Spherical Parallel Manipulator Wrist





3DOF Wrist

Nylon Bevel Gear

Custom Ball Bearing

Polycarbonate Wrist Housing

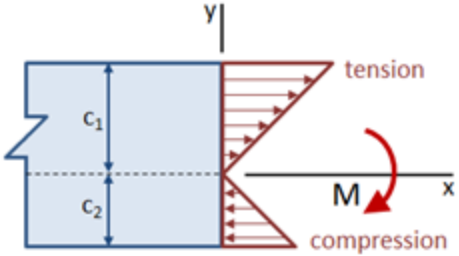
.31” Impact Resistance Acrylic

THK Crossed Roller Bearings

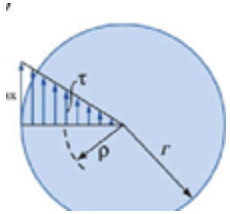
Theory and Principles used for Arm Design

Bending and Shearing Stress

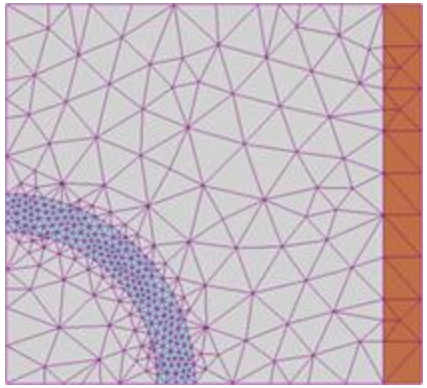
$$\sigma_b = \frac{My}{I}$$



$$\tau = \frac{QV}{Ib}$$

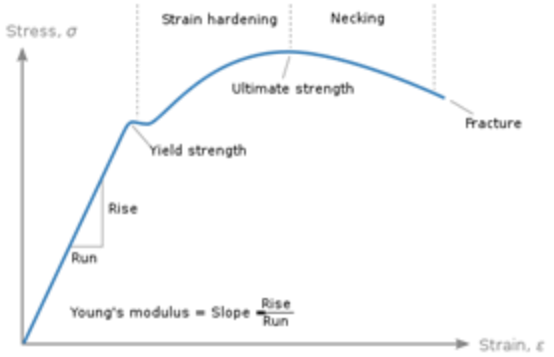


Finite Element Analysis



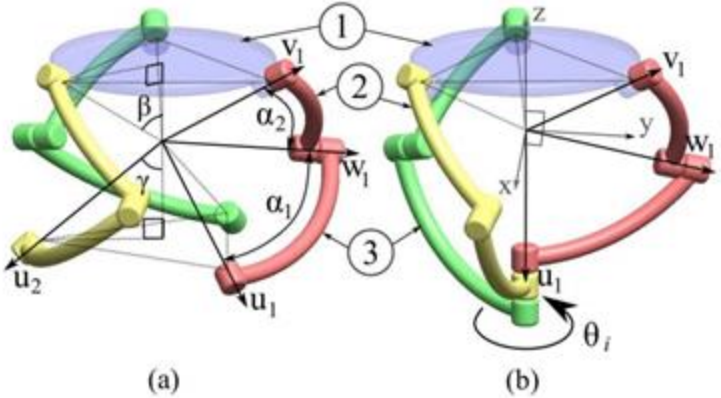
Solidworks Simulations

Stress Strain Curve & Material Properties



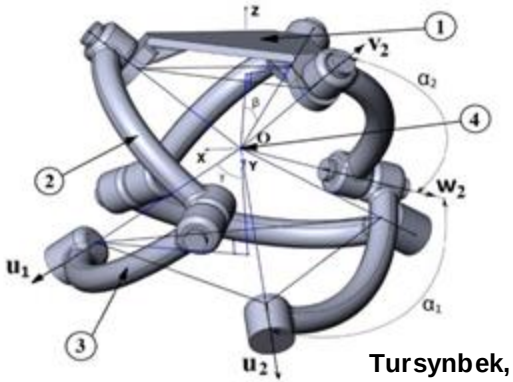
Property	Value	Units
Elastic Modulus	3000000000	N/m^2
Poisson's Ratio	0.35	N/A
Shear Modulus	890000000	N/m^2
Mass Density	1200	kg/m^3
Tensile Strength	73000000	N/m^2
Compressive Strength		N/m^2
Yield Strength	45000000	N/m^2
Thermal Expansion Coefficient	5.2e-05	/K
Thermal Conductivity	0.21	W/(m-K)

Theory and Principle of the Spherical Parallel Manipulator



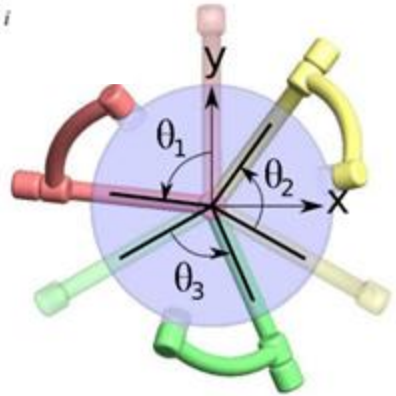
Tuanyazov, 2017

$$\boldsymbol{\theta} = [0, 0, 0]^T.$$



Tursynbek, 2019

$$\mathbf{u}_i = [0, 0, -1]^T.$$



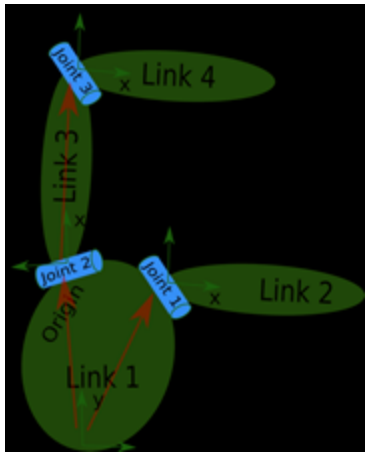
Tuanyazov, 2017

$$\mathbf{w}_i = \begin{bmatrix} \sin(\eta_i - \theta_i)\sin\alpha_1 \\ \cos(\eta_i - \theta_i)\sin\alpha_1 \\ -\cos\alpha_1 \end{bmatrix},$$

Controlling the robot arm and base

Pose Estimation

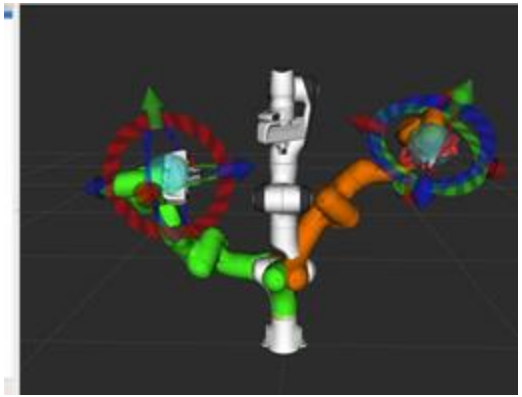
- Created URDF(Unified Robot Description Format) from Solid Model
- Modeled Camera Poses
- ROS Moveit Package

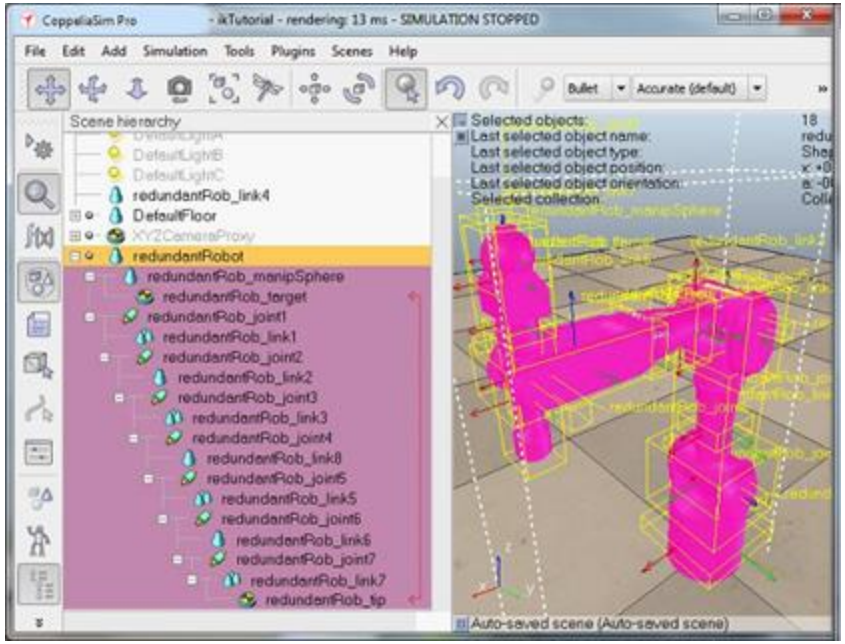


Determining location with optimal end effector position

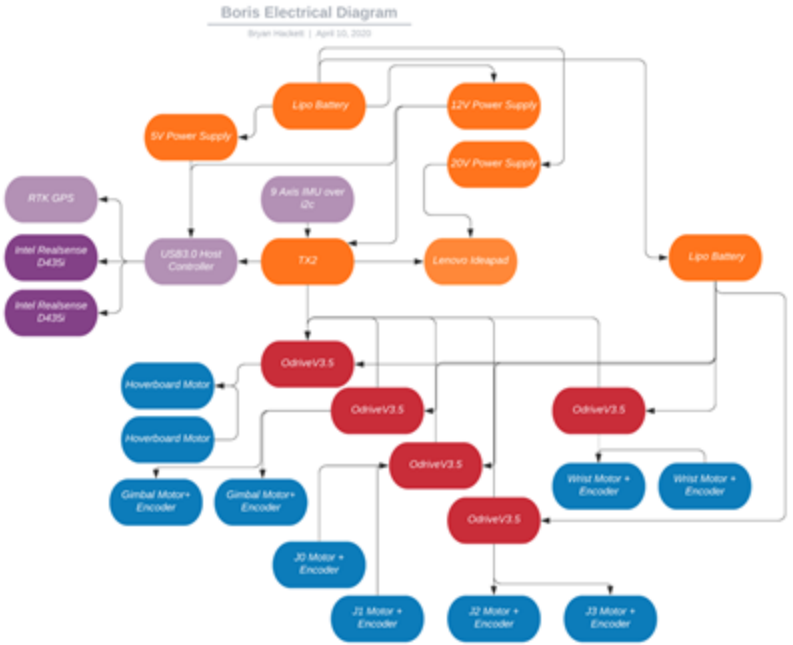
Inverse Kinematics

- Determine End Effector State
- Optimal Grasp Position
- Estimate Object Position
- Determine best grasp pose

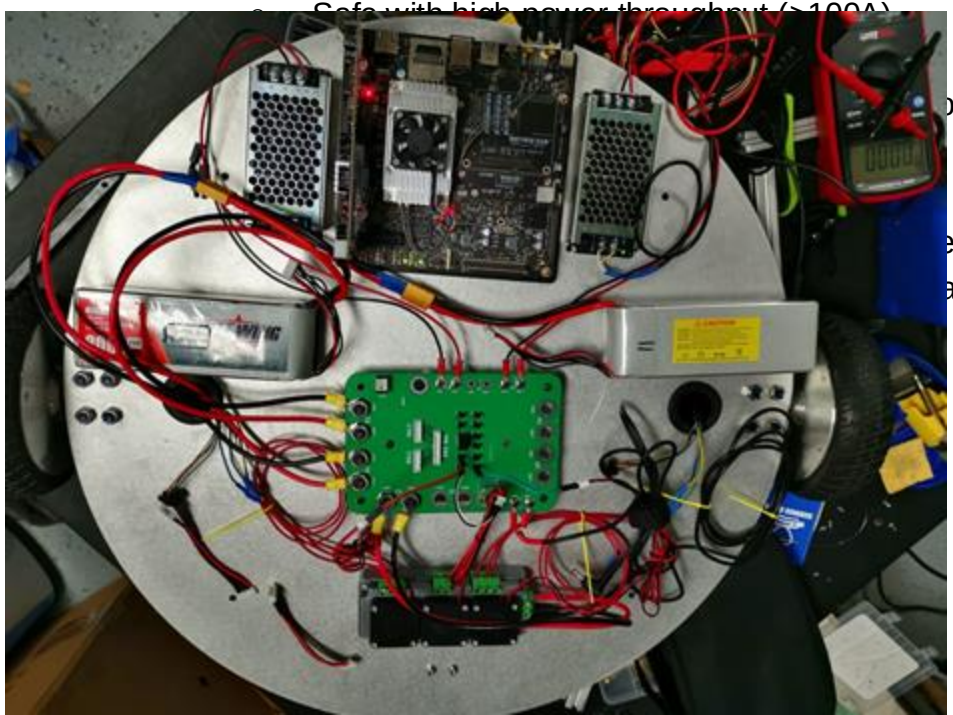




High-level electrical system overview



- **Design Criteria**
  - High accuracy/precision motor control
  - Safe with high power throughput (>100A)



7B

Analysis and selection of electrical components

ROS Master

ROS Slave

USB 3.1 Hub

USB 2 Hub

USB Cables

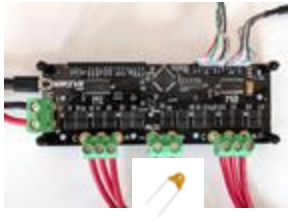
STP Cable

RTK-GPS

9DOF IMU

UART to USB

Motor Controller



Depth Camera

Magnetic Encoder

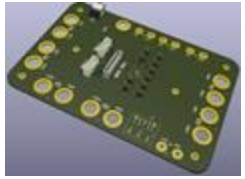
2-Axis Gimbal

LiPo Batteries

BMS

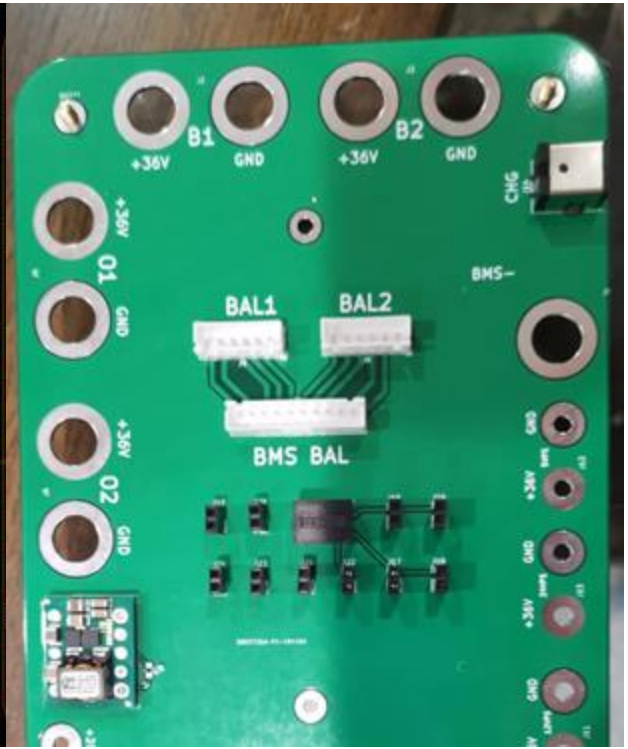
Isolated 12V/5V Regulator

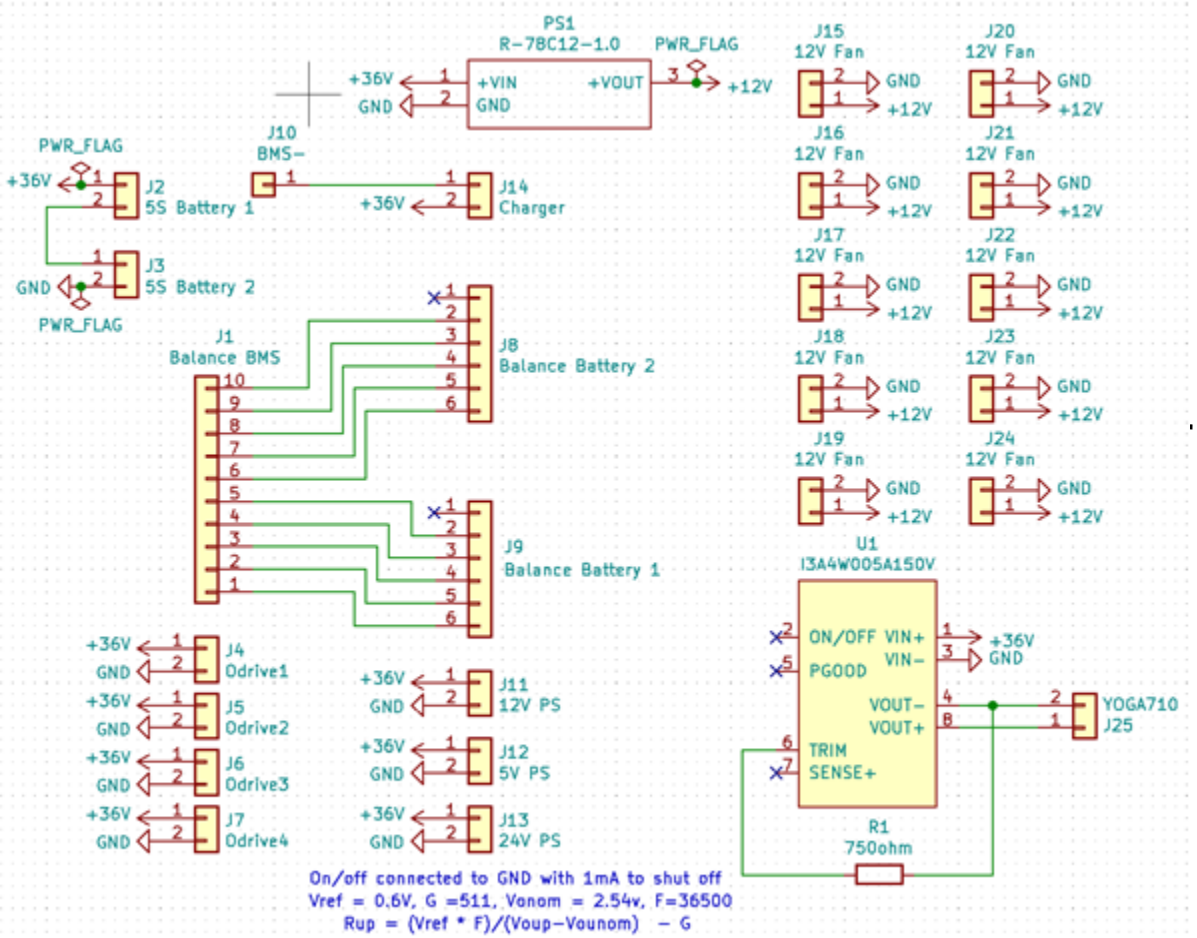
Custom PDB PCB



18/16/12GA Wire

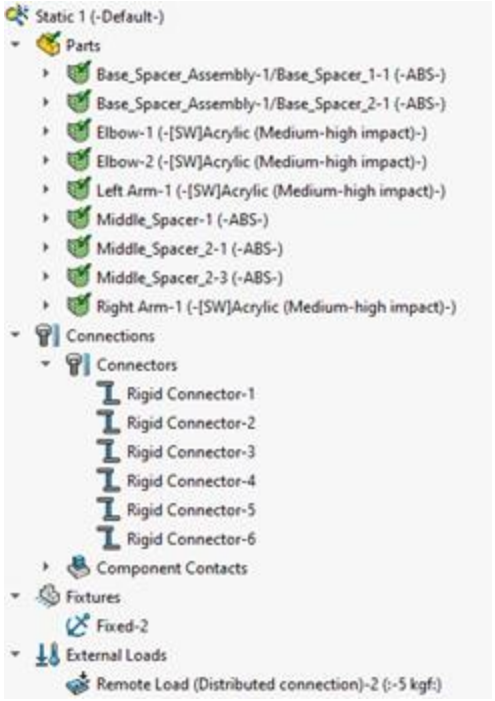
2-Layer PDB PCB Design for system harnessing



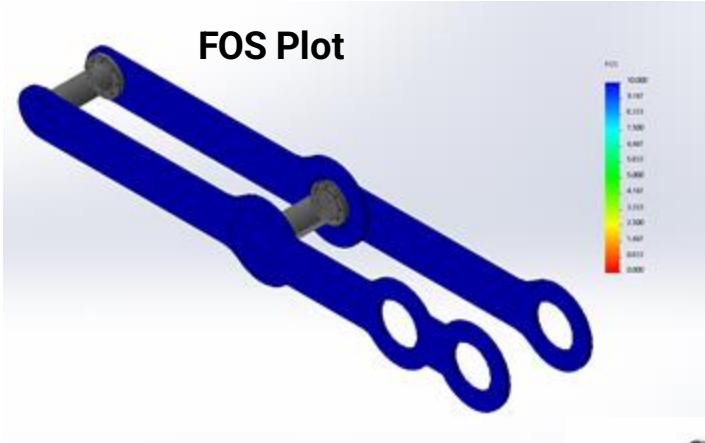


Arm Static Stress Analysis

Boundary Conditions

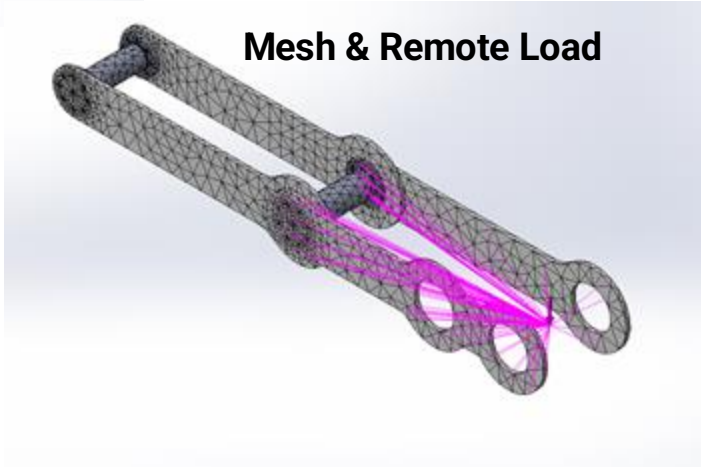


FOS Plot



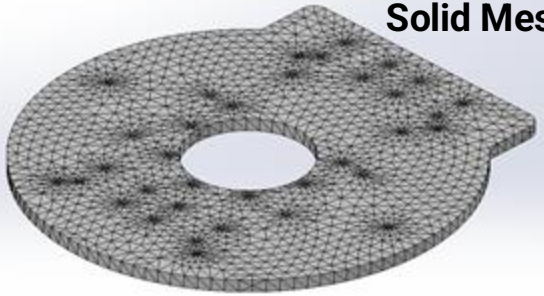
Minimum FOS > 10

Mesh & Remote Load

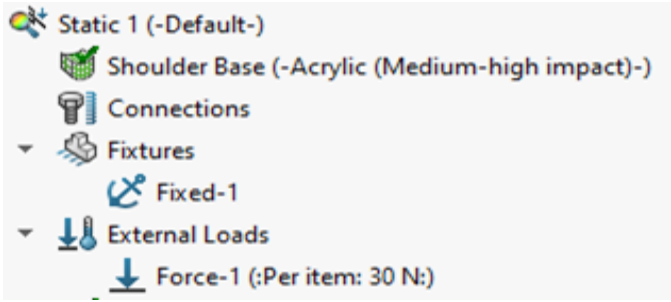


Simulation - Shoulder Base Stress Analysis

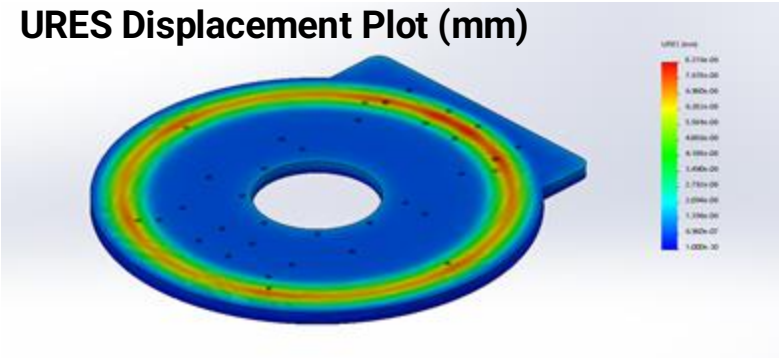
Solid Mesh



Boundary Conditions



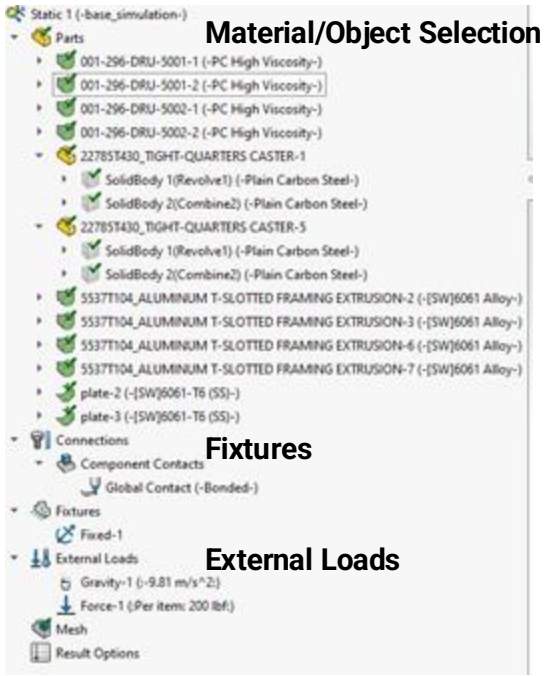
URES Displacement Plot (mm)



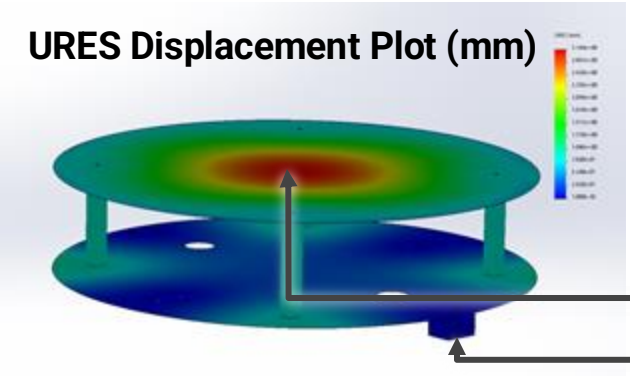
Maximum Displacement < 1mm

Simulation - Static Drivetrain Stress Analysis

Boundary Conditions



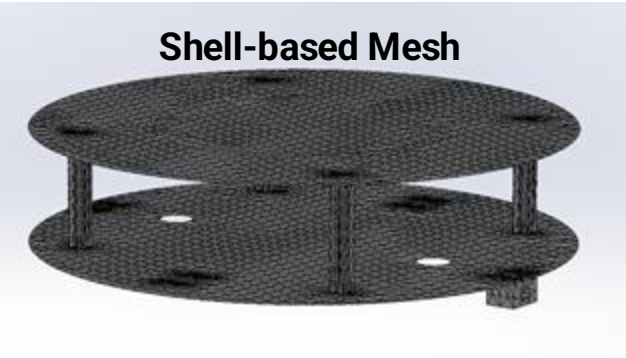
URES Displacement Plot (mm)



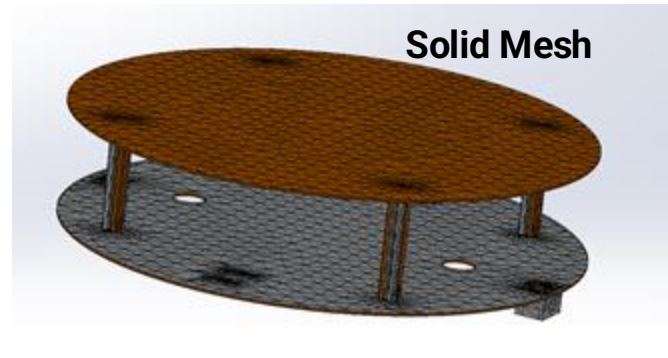
Minimum FOS = 1.8

Maximum Displacement = 3mm~

Shell-based Mesh

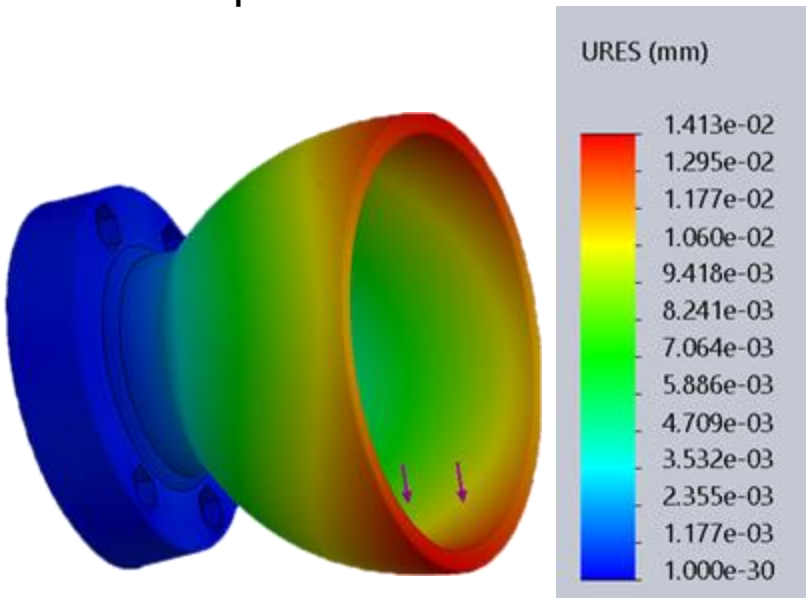


Solid Mesh

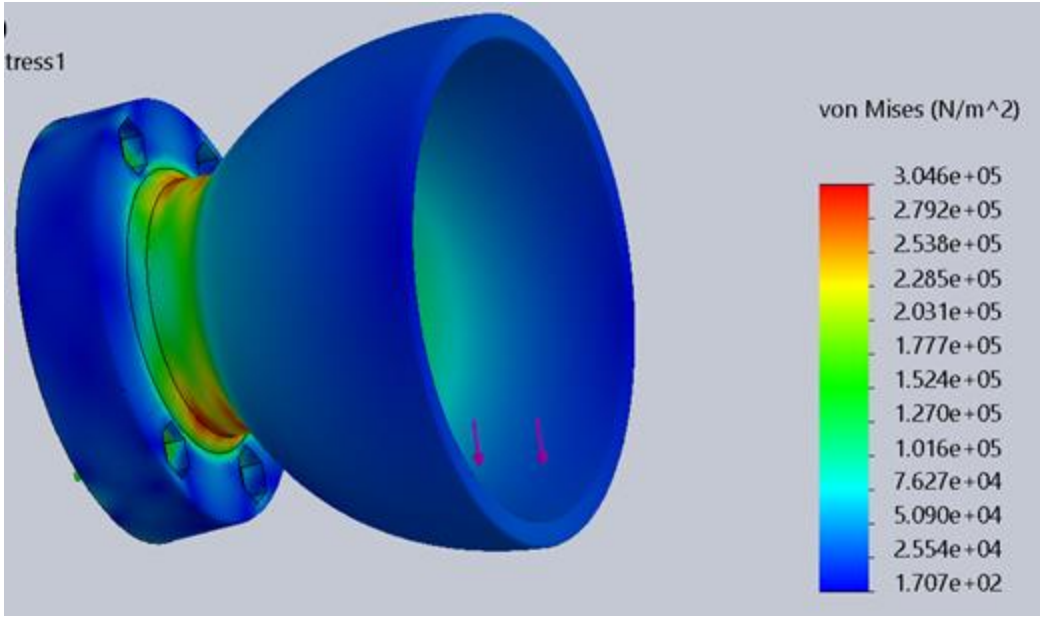


Simulations - Gripper Stress Analysis

Force on internal cup surface adjusted for SF 2.0 at most extreme position

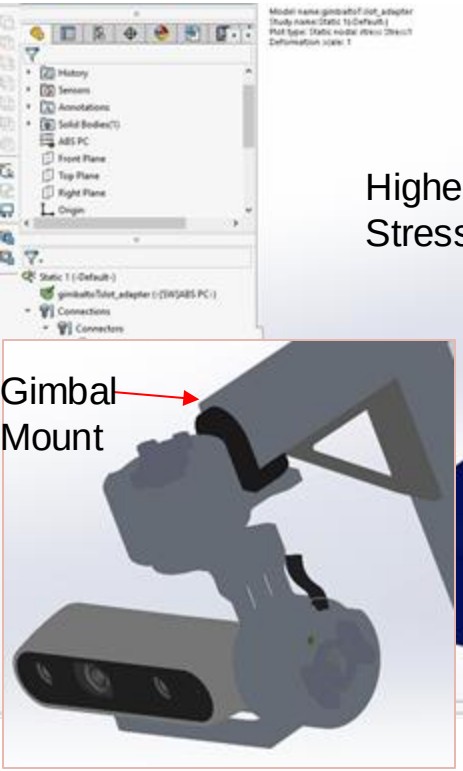


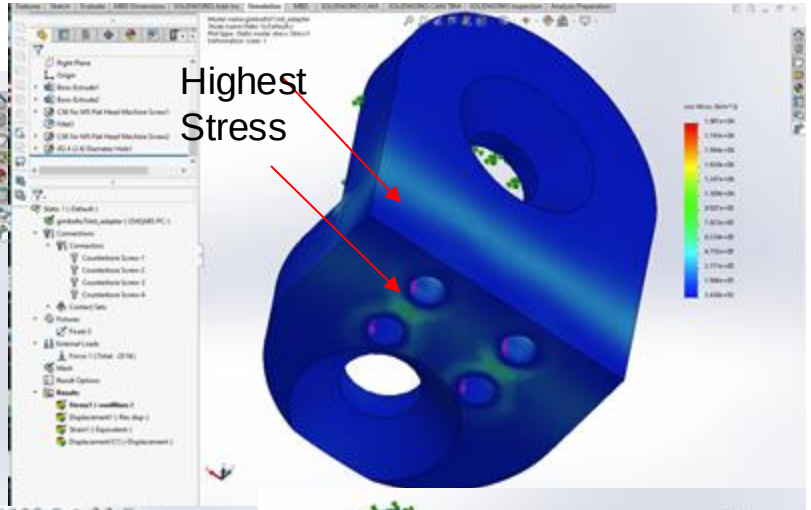
Displacement

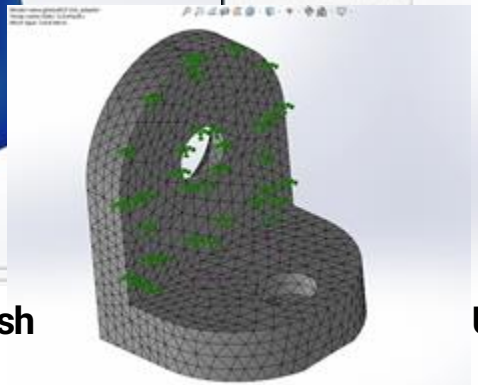


Stress

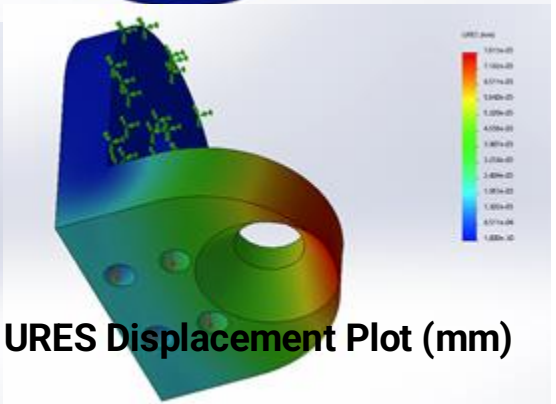
Additive Manufacturing Polycarbonate Gimbal Mount Stress Analysis







Solid Mesh

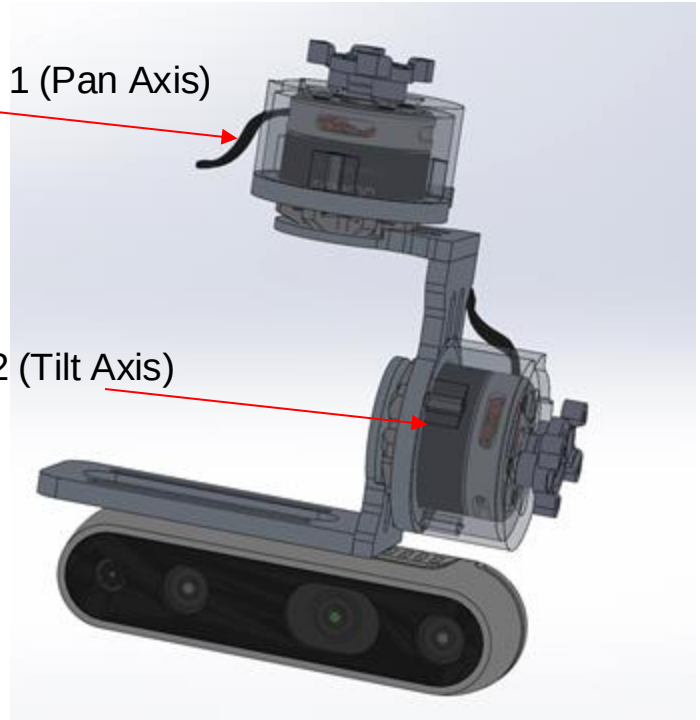


URES Displacement Plot (mm)

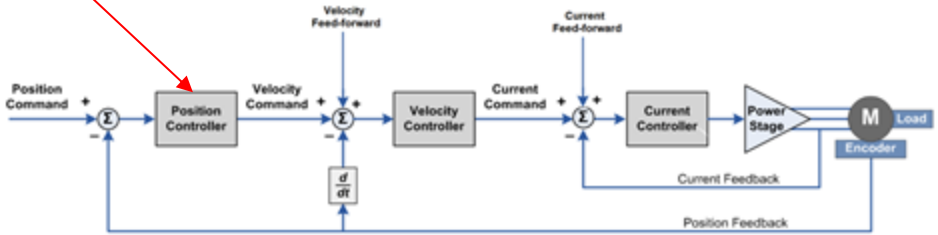
Bryan

Tuning Gimbal Motors for Intel Realsense D435i

- Proportional tuning required for Gimbal
  - Tested at 12V burned out motor
  - 4V driven, without d435i to test
- Position Controller ODrive
  - Proportional controller for gimbal
  - Uses position feedback
  - Voltage Control
  - Tuned position controller gain

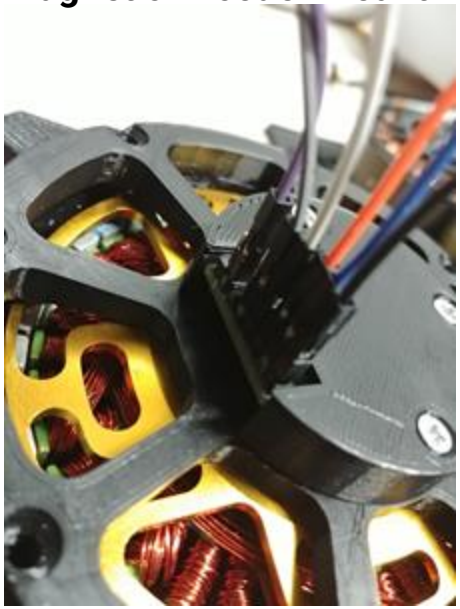


Odrive Controller Block Diagram

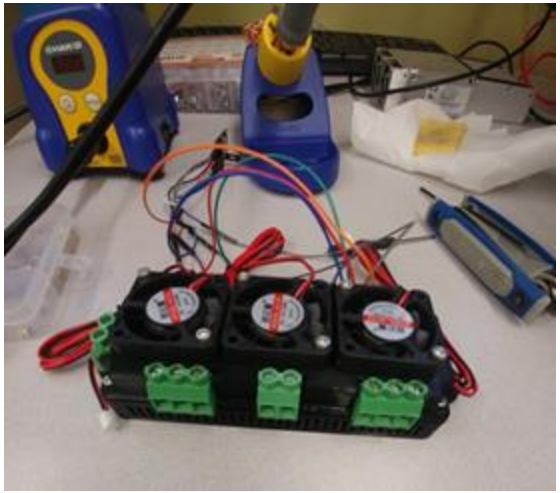


Fabricated Parts

Magnetic Encoder Mount

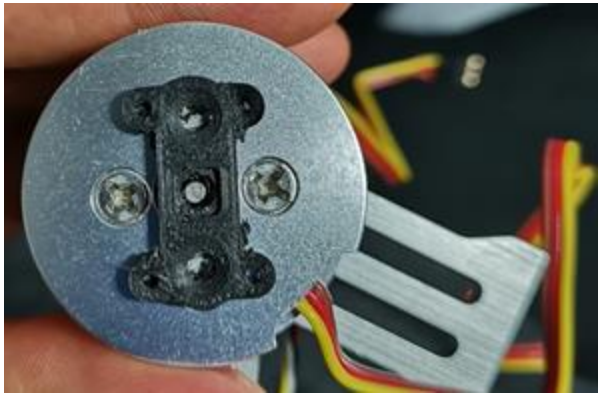


Odrive Enclosure w/Fans

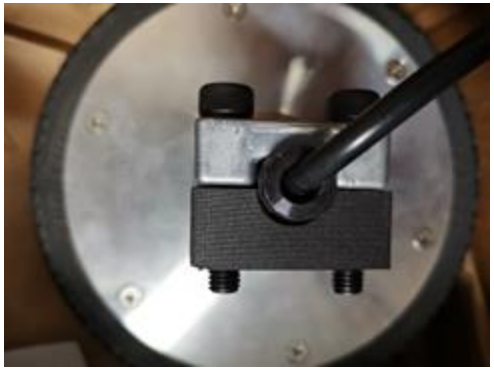


PLA Odrive Lid

Custom Gimbal Encoder Mount



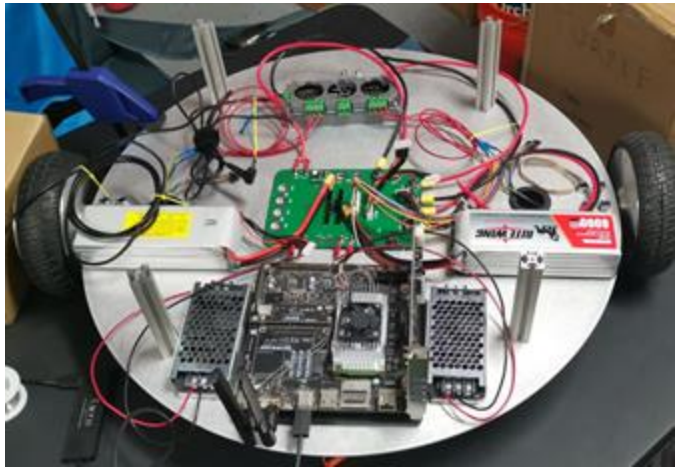
Custom Motor Fixtures



Fabricated Parts

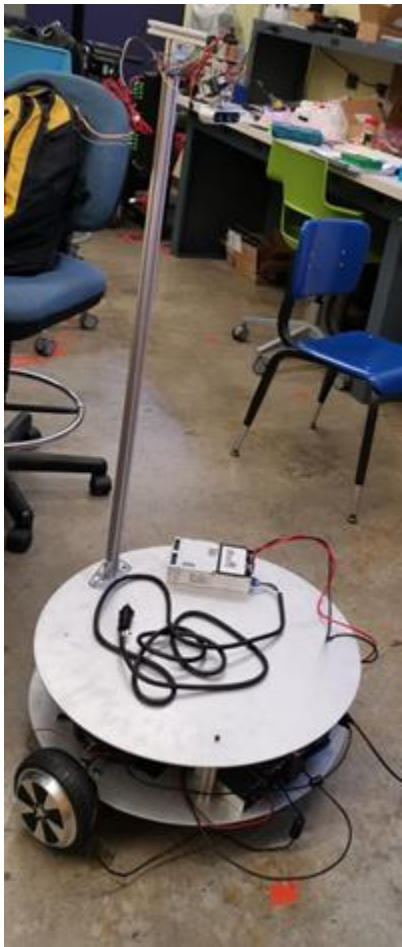
Power Distribution PCB

Drivetrain Electronics



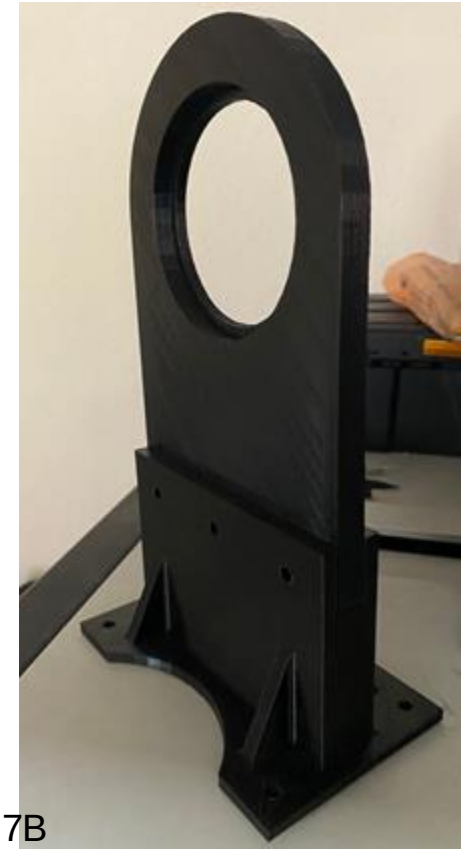
Gimbal Motor Assembly

Base Assembly

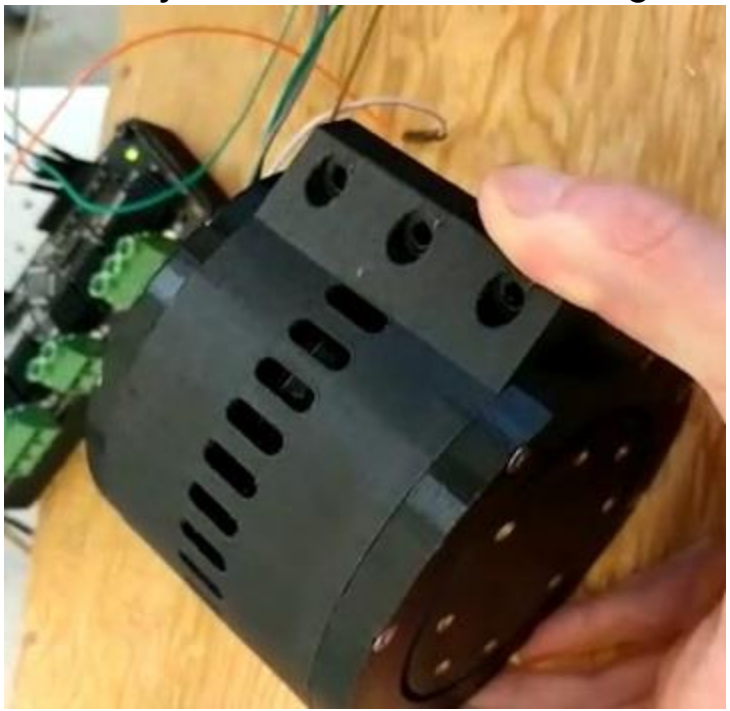


Fabricated Parts

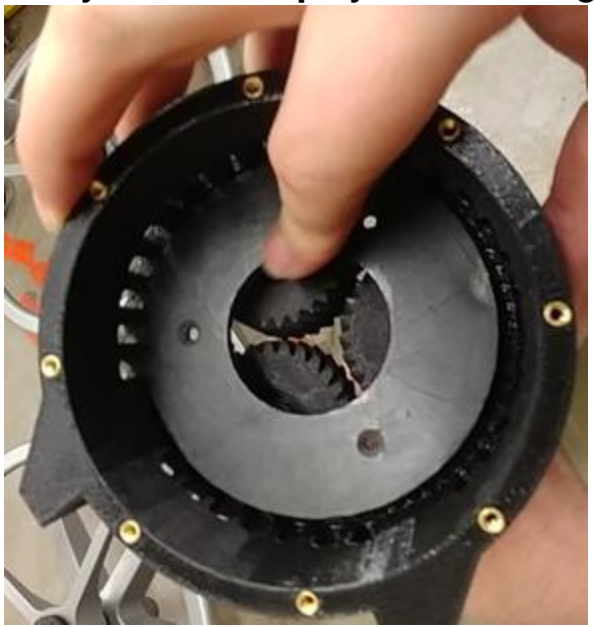
ABS Shoulder Mount



Polycarbonate Actuator Housing

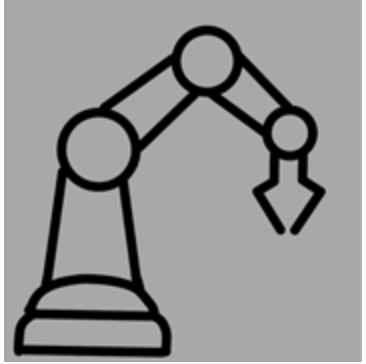


Polycarbonate Epicyclical Gearing



https://hackaday.io/project/159404-opentorque-actuator

Conclusions



- Design of the arm was challenging
  - Changing design made prototyping and testing challenging
  - 3D printing and laser cutting took longer than initially thought
- Drivetrain tested and validated
- Spherical manipulator mechanism
- Navigation started working before Shelter In Place
  - Tested in Hallway in engineering building
  - Was unable to test outside due to lack of GPS and 4G modem

Valuable experience gained from ME195A&B

- Geometric Dimensioning and Tolerancing (GD&T)
- Learning to communicate with a variety of vendors
- Project Planning
  - Gantt Charts
  - Time Management
  - Risk vs Reward Evaluation
- Teamwork & Communication
- Integrating electronics/control with mechanical design
- Manufacturing
  - 3D Printing
  - Laser Cutting

Future Work/Improvement

- Finish manufacturing and qualifying Arm and Wrist
- Complete testing and integration of Gripper
- Develop and test trash retrieval in outdoors environment
- ISO 100 Compliance

Future work can be found here: *https://github.com/itsmomito/boris*

*Our arm would've been finished right now, however due to COVID-19 the lab was closed and our group couldn't finish building our prototype.

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