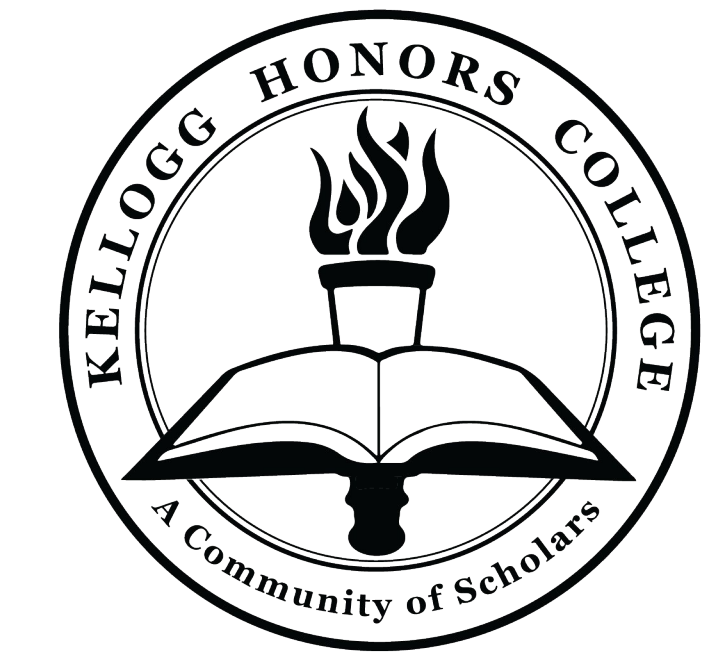




# Design of a Hydraulically Powered Robotic Arm



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## Introduction

This project aims to design and fabricate a function hydraulically powered robotic arm for use in demonstration and education purposes. The system is designed to function at tabling events with no power and minimal space. The resulting robotic arm includes a small scale hydraulics system and simplistic mechanism design to fit within a portable envelope for transport and operation. The arm is actuated by a combination of hydraulic cylinders and electronic actuators. It has a work volume of a 3 ft diameter sphere and has the ability to pick up light objects. The hydraulic system is run by a small hydraulic power unit connected to a proportional valve manifold assembly, pressure relief, check, and dump valves. The design of the electrical and arduino based control system allows for simple operation without the need for an outlet. Sensor feedback is provided through string potentiometers and fed into a closed loop control system with PID and inverse kinematic modeling.

## Mechanical Design

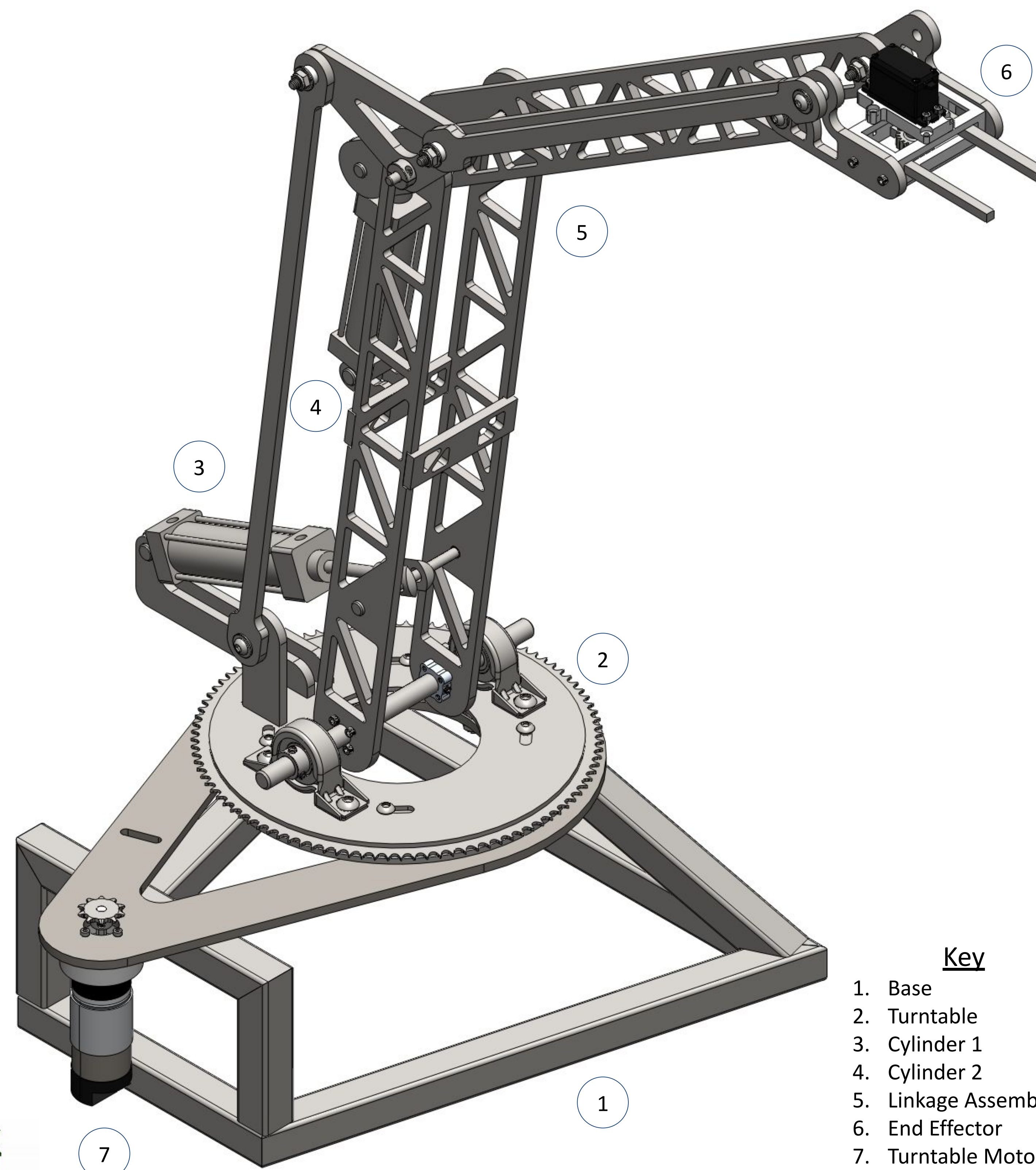
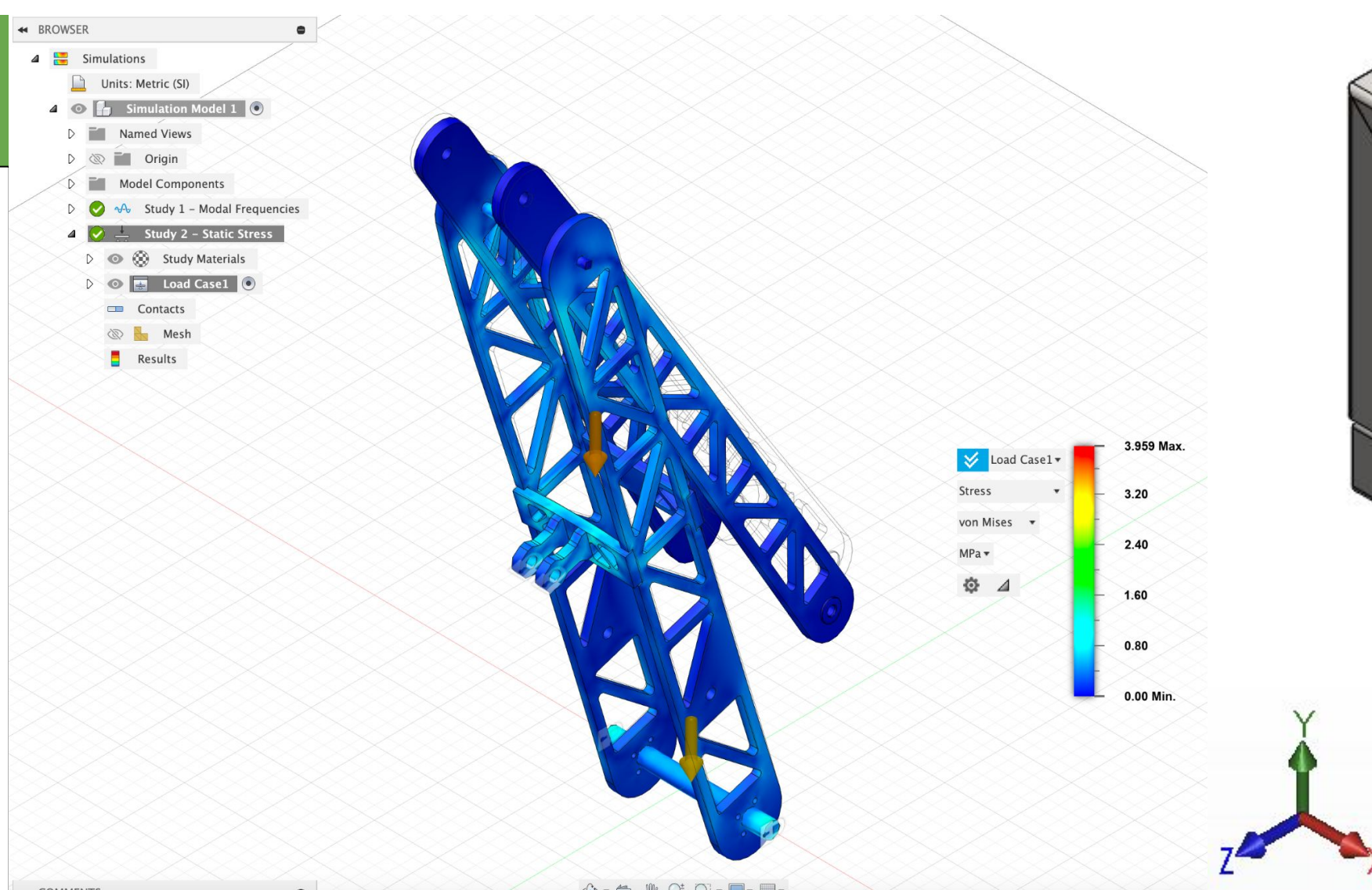
The robotic arm is designed for demonstrations, transport, and rough handling. As a result simplicity, reparability, toughness, and cost were key derived requirements. The arm design has two main links with a four bar system that keeps the end effector parallel to the floor. It is a simple 3 DOF system that is easy to understand and repair while still providing the educational aspect the team aimed for.

Structural parts are plasma cut from 1008 mild steel plates. Holes in the plates allow for wires and hoses to be zip tied and run through the structure. Hardware and more complex parts are COTS. The two cylinders are both 1.5" bore 5" stroke double acting that change the joint angles of the arm. A NeveRest Orbital 20 BDC gear motor controls the rotation of the arm assembly. A MG996R servo actuates the claw on the end effector.

## Simulation

Von Mises stress and strain simulations were run on the structure under 20 m/s<sup>2</sup> acceleration (max measured accel when driving over bumps on road in a truck bed). The steel structure was observed to have a high factor of safety from the simulations. The shafts sized according to the expected stresses from the simulation. Performed in Fusion 360.

Max stress: ~90 Mpa; located at cylinder clevis  
Max strain: ~0.015 mm; located at end effector



### Key

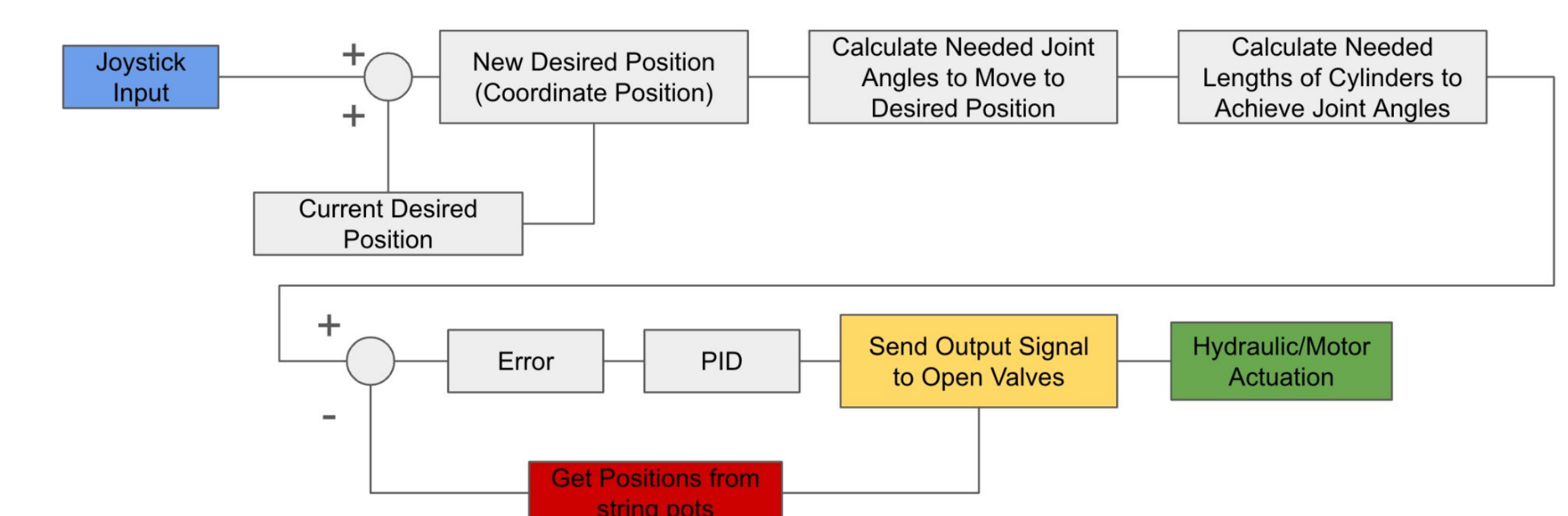
1. Base
2. Turntable
3. Cylinder 1
4. Cylinder 2
5. Linkage Assembly
6. End Effector
7. Turntable Motor

## Control

The robot is controlled with a inverse kinematics model. The arm has 2 DOF, 2 on the arm and 1 on the turntable. As the arm has 2 DOF in the XY plane, the inverse kinematic model was able to be solved as a system of equations with 2 unknowns in MATLAB. The 3rd DOF is rotation about the turntable's axis and is handled by a DC motor. Combining these three axis allows for end-effector centered control in a spherical working volume of about 3 ft.

Inputs are taken from 2 joysticks and fed into a control loop, adding or subtracting from the arm's old target position. The new target is inputted into the derived kinematic equations to find the target angles of each arm joint relative to the floor. The hydraulic cylinders are then extended to achieve the target joint angles. PID is used to smooth cylinder extension velocity curves. Feedback is provided by string potentiometers attached to each cylinder that measures length and encoder in the motor

### Block Diagram



## Hydraulic and Hardware Design

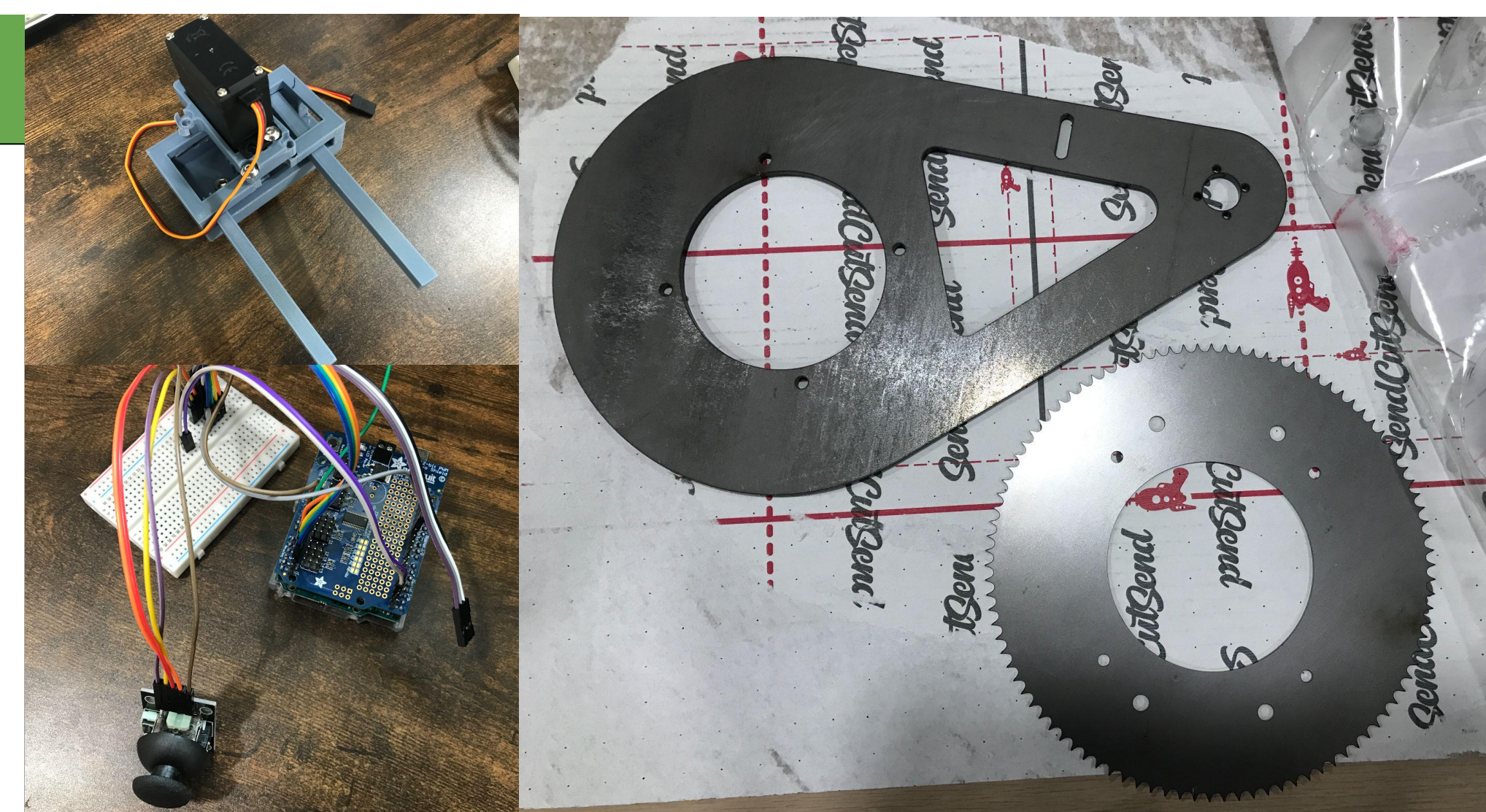
The electronic hardware is Arduino based and is programmed in C++. The team chose this as the basis as it is similar to the control system the team uses in the Rose Float Program. There are two main power lines. A 5V line for arduino and sensor power and a 12V line for motor and pump power. Fuses and cut off switches are positioned in the 12V lines where amp draw can be > 2A and damage the motor drivers. A DAC and op-amp in series provide analog output at 12V to the proportional valves for the hydraulic system to control fluid flow in the system.

The hydraulic system uses a 12V DC pump at 500 psi. A check valve and dump valve allow for the pump to be shut off and for both cylinders to hold positions while reducing back pressure effects. A temperature sensor on the pump is also used to shut off power in case of overheat.

## Manufacturing

The manufacturing process was centered around the team's technical skill and machine shop access. The team had access to the Rose Float Program's machine shop and mainly utilized the CNC Plasma Table and Miller Mark VIII Welding machines. Parts with difficult geometry were made via SendCutSend. Cut plates were welded together to provide a strong bond between them. Bushing holes were bored out to transitional fits. Hand tools were utilized to fasten the rest of the hardware together

Processes used: Plasma cutting, FDM Printing (PETG), Stick Welding (7014 rod)



## Future Work

The project has currently completed its design phase and is now in its production phase. Parts have been ordered and the team plans to continue assembling the system over the course of Spring semester. Additionally due to time constraints, a pre-programmed show might not be achievable within the scheduled time frame. This would be a programming project through the summer.

