GIOVANNI CORDOVA
ENGINEERING PORTFOLIO

121 Calle Sol Se Mete NW, Albuquerque, New Mexico USA

505.373.9649 giovanni.d.cordova@gmail.com

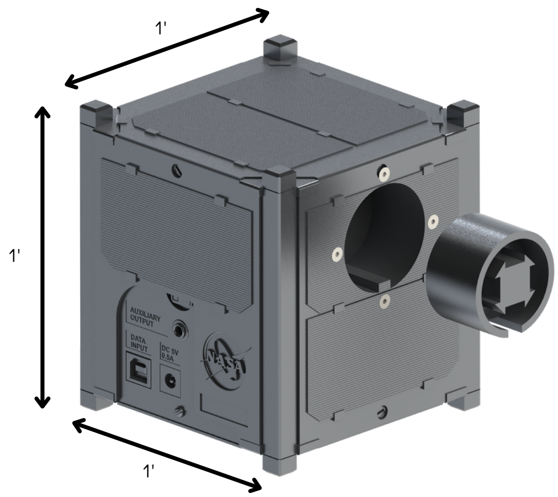
giovannicordovadesign.com

Updated 11.27.2023

Table of Contents

Smart Satellite Orbital Replacement Unit Module

Summer 2023 — UNM Agile Manufacturing Laboratory



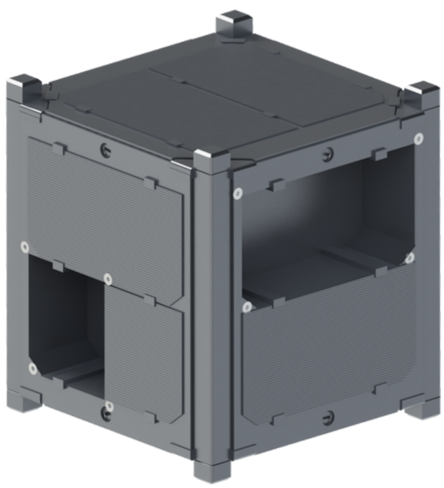
Smart Satellite Front Isometric with Circular ORU

The Orbital Replacement Unit (ORU) module developed for the UNM Agile Manufacturing Laboratory's Smart Satellite test bed serves **as a research platform for validating autonomous in-orbit robotic satellite servicing tasks** in a controlled laboratory setting.

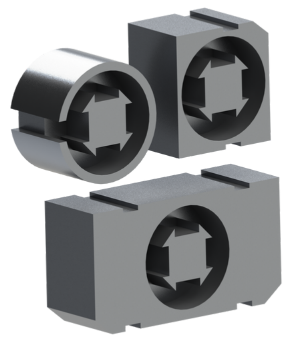
Our satellite module design was inspired by the iBLOCK module from the Intelligent Building Blocks for On-Orbit Satellite Servicing (iBOSS) project.

The satellite was created to have **three keyed and unique ORU shapes**, with a **tolerance of 3mm** so the robotic system must learn how to perform the insertion based off of this tolerance.

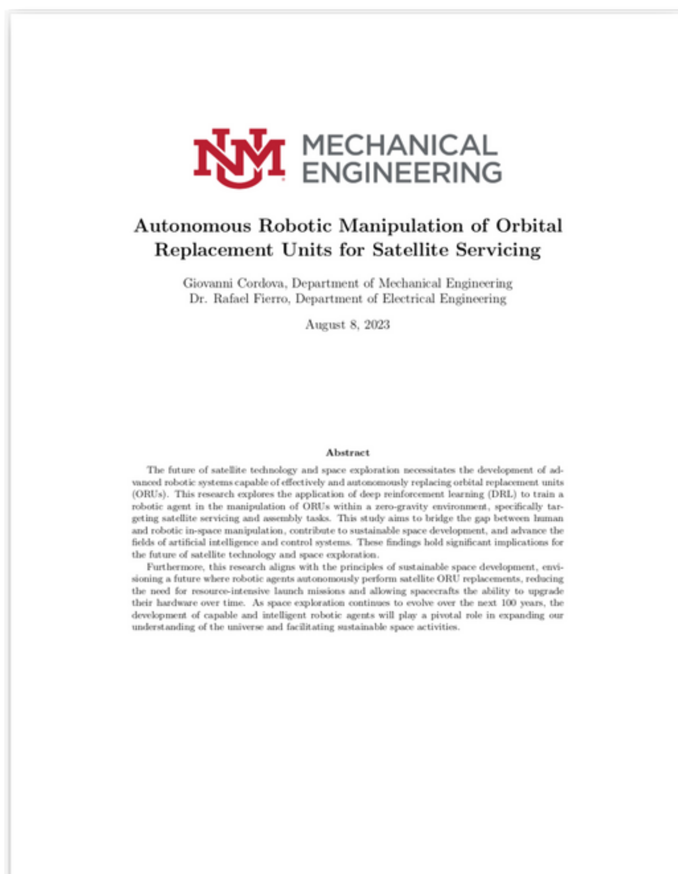
To create the satellite in our laboratory, we utilized 1" t-slotted aluminum extrusion to build the frame. We then 3-D printed the ORUs using PLA filament. The ORUs were **designed to be easily manipulated by our UR5e robotic arm that is equipped with a RobotIQ 2F-85 gripper.**



Smart Satellite Rear Isometric



ORUs of Various Size



MECHANICAL ENGINEERING

Autonomous Robotic Manipulation of Orbital Replacement Units for Satellite Servicing

Giovanni Cordova, Department of Mechanical Engineering
Dr. Rafael Fierro, Department of Electrical Engineering

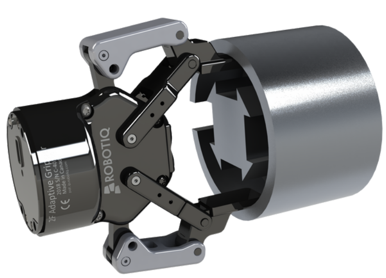
August 8, 2023

Abstract

The future of satellite technology and space exploration necessitates the development of advanced robotic systems capable of effectively and autonomously replacing orbital replacement units (ORUs). This research explores the application of deep reinforcement learning (DRL) to train a robotic agent in the manipulation of ORUs within a zero-gravity environment, specifically targeting satellite servicing and assembly tasks. This study aims to bridge the gap between human and robotic in-space manipulation, contribute to sustainable space development, and advance the fields of artificial intelligence and control systems. These findings hold significant implications for the future of satellite technology and space exploration.

Furthermore, this research aligns with the principles of sustainable space development, envisioning a future where robotic agents autonomously perform satellite ORU replacements, reducing the need for resource-intensive launch missions and allowing spacecrafts the ability to upgrade their hardware over time. As space exploration continues to evolve over the next 100 years, the development of capable and intelligent robotic agents will play a pivotal role in expanding our understanding of the universe and facilitating sustainable space activities.

Summer Research Paper: Autonomous Manipulation of Orbital Replacement Units for Satellite Servicing



Robotiq 2F-85 Gripper with Circular ORU

Photo of Smart Satellite Test Bed v.1.0

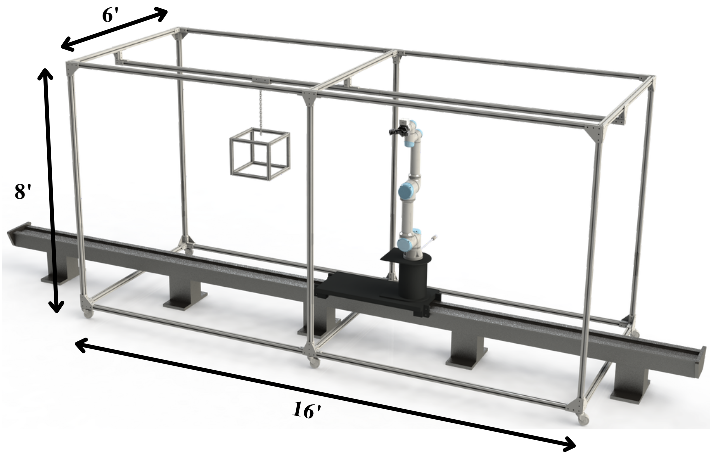
The results of this summer research project were documented in a **18-page academic paper**, documenting the literature review, design, simulation, and manufacturing processes.

Smart Satellite Test Bed Linear Rail

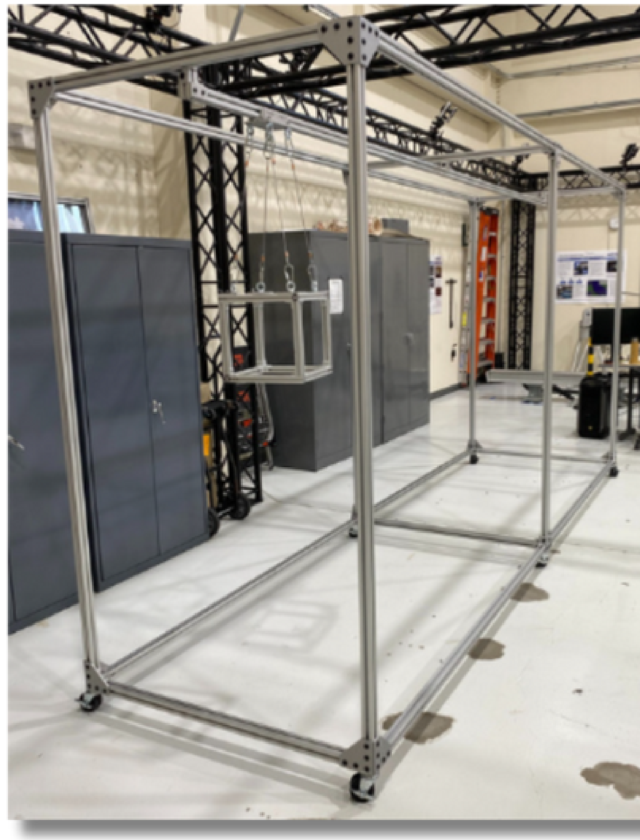
Summer 2023 — UNM Agile Manufacturing Laboratory

To expand the capability of our lab to recreate robotic satellite servicing tasks, I designed a **linear rail to transport our Smart Satellite test bench.** The rail was designed to fit over our 7th axis track housing our UR5e robotic arm.

This was **designed within a single workday,** then was later fabricated and assembled over the course of two days by myself and an additional research assistant, Jacob Jackson.



Rendering of Smart Satellite test bed's linear rail with UR5e robotic manipulator on 7th axis rail.



Isometric photo of Smart Satellite test bed's linear rail.

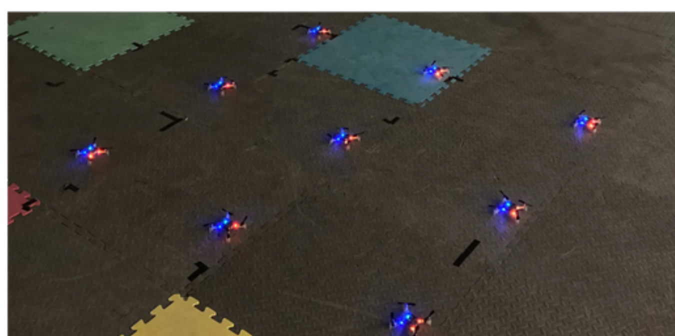
Crazyflie UAV Swarm Deployment

Summer 2023 — UNM Multi-Agent, Robotics, and Heterogeneous Systems Lab

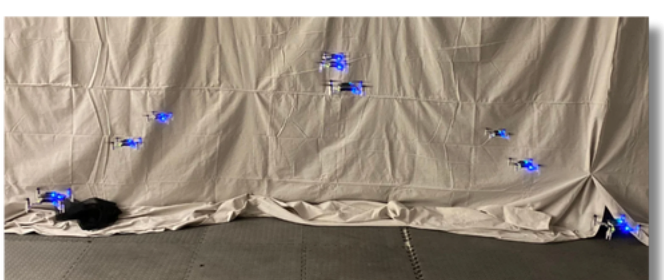
During the Summer of 2023 I collaborated with another intern, Emely Sheron, in the UNM Multi-Agent, Robotics, and Heterogeneous Systems (MARHES) Laboratory to **deploy a swarm of nine Crazyflie drones in various aerial shapes** using the Crazyflie Python API and their Lighthouse positioning system.

We assembled the drones, flashed them with the most recent firmware, set up and calibrated the Lighthouse positioning system, then deployed the drones via Python 3.7.

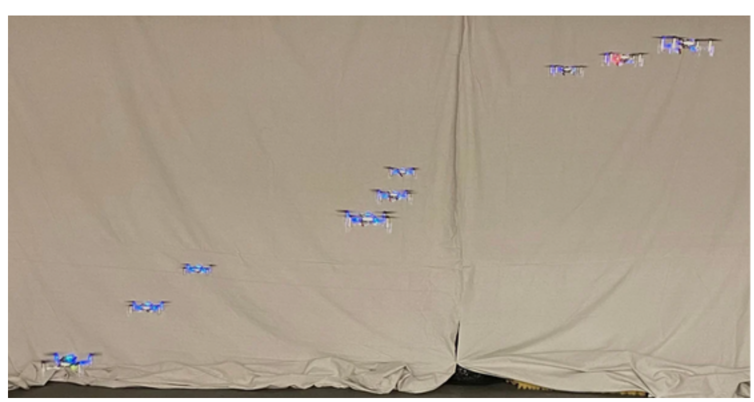
We created the following shapes: flat plane, pyramid, inverse pyramid, diagonal line.



Crazyflie Swarm in their undeployed state.



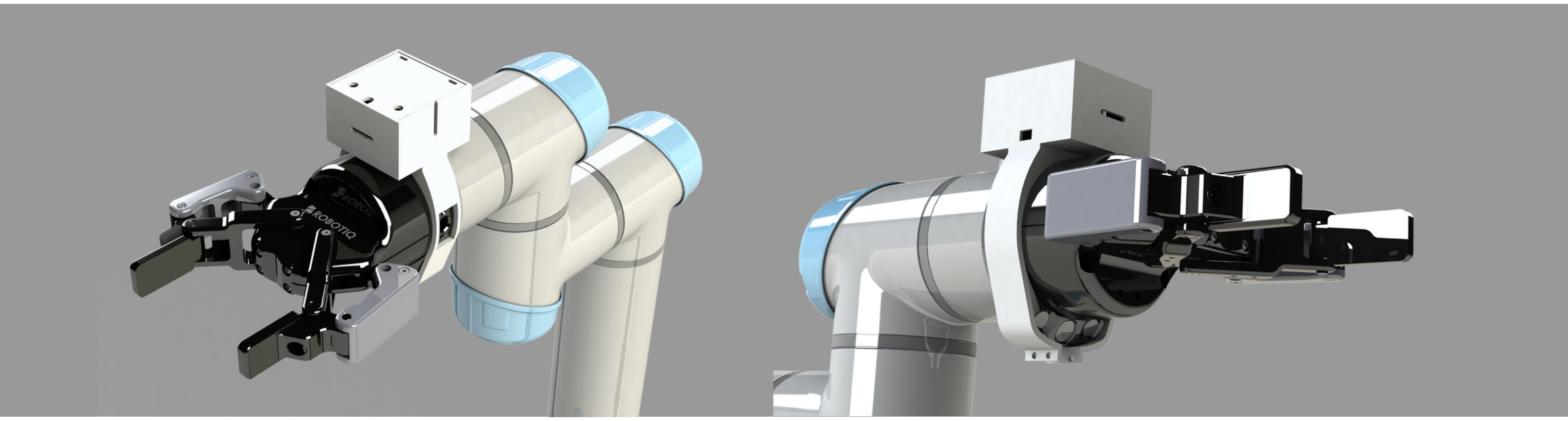
Crazyflie Swarm arranged in a pyramid configuration.

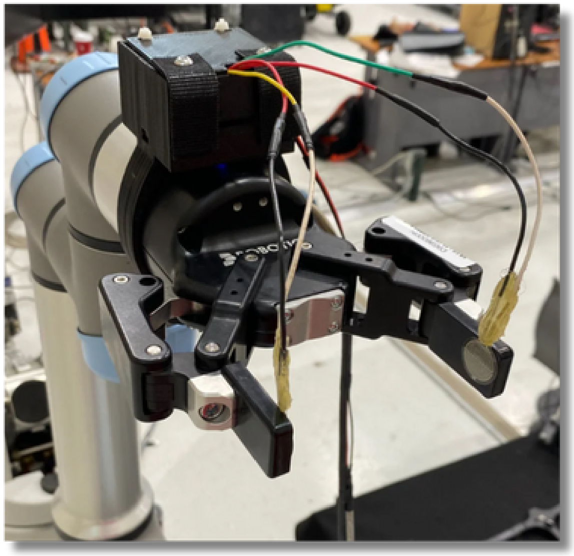


Crazyflie Swarm arranged in a diagonal line configuration.

UR5e Wireless Force Sensor Housing

Spring 2023 — UNM Agile Manufacturing Laboratory





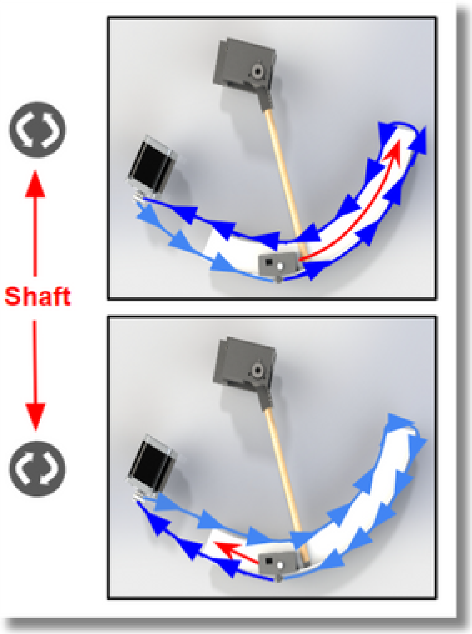
During my collaboration with Longsen Gao, a Ph.D. student in the Electrical Engineering Department at the University of New Mexico, **I developed a housing solution for a tactile sensor integrated into the wrist of a UR5e robotic manipulator.**

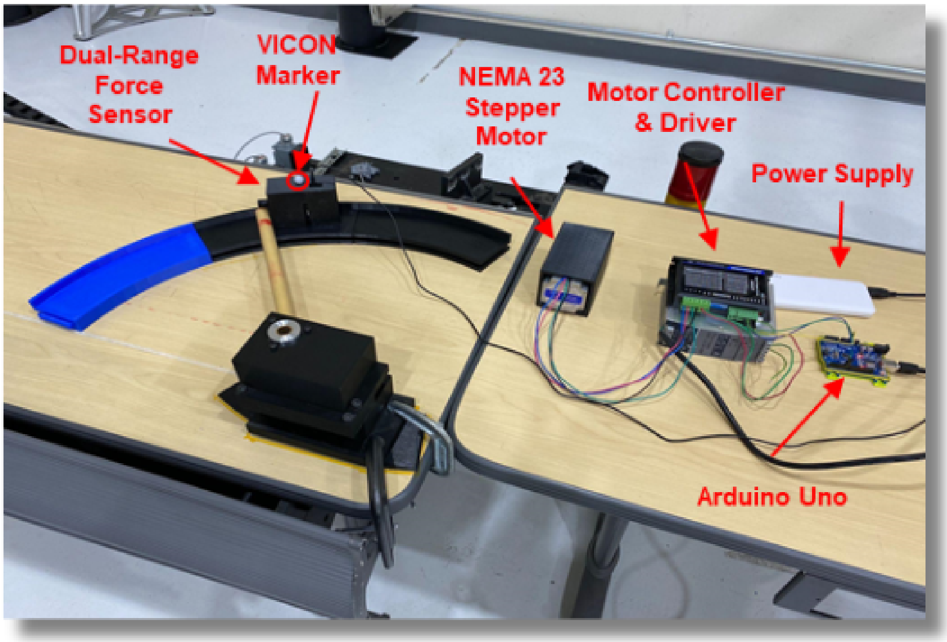
Using SOLIDWORKS, I designed a comprehensive model, which was subsequently 3D printed in carbon-fiber PLA to accommodate the wireless tactile sensor module created by Longsen. Through our concerted teamwork, **we accomplished this project within a single day,** enabling our team to successfully capture and wirelessly acquire valuable tactile feedback from the UR5e.

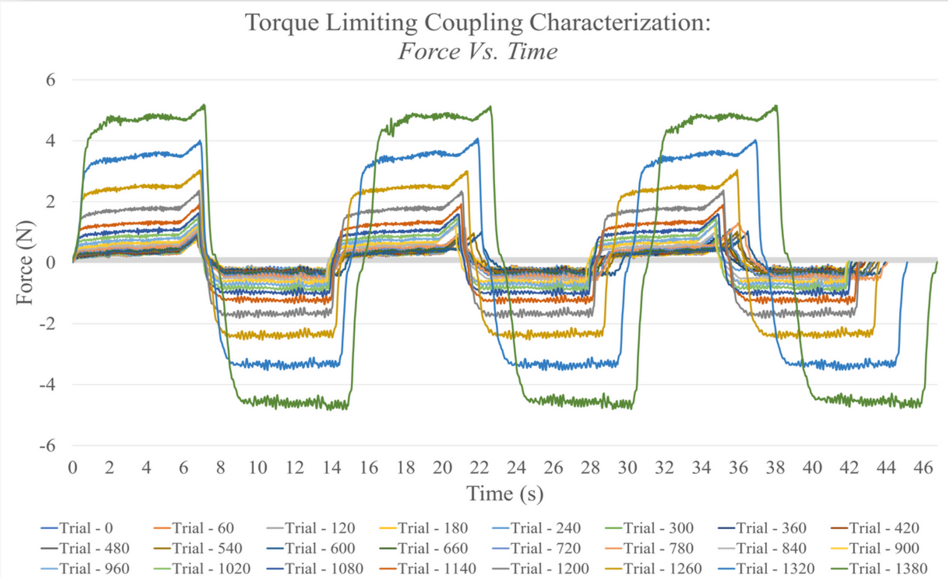
This endeavor presented an invaluable opportunity to gather tactile data that would have otherwise been unattainable.

Torque Limiting Coupling System Identification

Fall 2022 - Spring 2023 — UNM Agile Manufacturing Laboratory







This work presents an **experimental study characterizing the dynamic parameters** of a test bench comprising a torque-limiting coupling with a 1/2" diameter keyed shaft capable of delivering a maximum torque of 75 in.-lbs. at 50 rpm, a tapered roller bearing, and a rod with a length of 0.354 m.

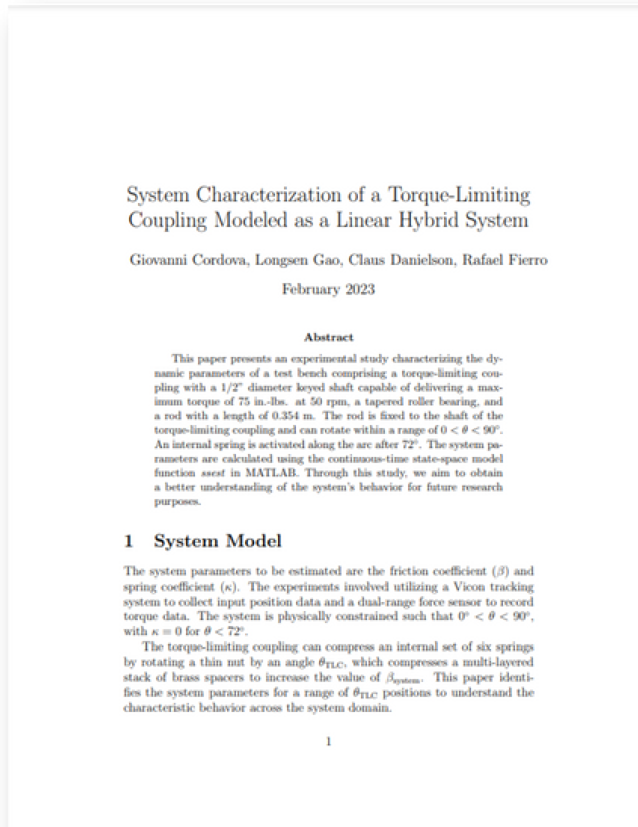
The rod is fixed to the shaft of the torque-limiting coupling and can rotate within a range of 0°<θ<90°.

An **internal spring is activated along the arc after 72°, meaning the system can be modeled as a linear hybrid system.** Through this study, we aimed to obtain a better understanding of the system's behavior for future research purposes

The system parameters are calculated using the **continuous-time state-space model function, ssest, in MATLAB.**

The system parameters estimated were the friction coefficient (β) and spring coefficient (K). The experiments involved utilizing a **Vicon tracking system to collect input position data and a dual-range force sensor to record torque data.** The data collection processed involved connecting the dual-range force sensor to the tip of the rod which was then moved via a stepper motor all while collecting position data from a the Vicon system.

The torque-limiting coupling can compress an internal set of six springs by rotating a thin nut by an angle θ^{tlc}, which compresses a multi-layered stack of brass spacers to increase the value of β.



System Characterization of a Torque-Limiting Coupling Modeled as a Linear Hybrid System

Giovanni Cordova, Longsen Gao, Claus Danielson, Rafael Fierro

February 2023

Abstract

This paper presents an experimental study characterizing the dynamic parameters of a test bench comprising a torque-limiting coupling with a 1/2" diameter keyed shaft capable of delivering a maximum torque of 75 in.-lbs. at 50 rpm, a tapered roller bearing, and a rod with a length of 0.354 m. The rod is fixed to the shaft of the torque-limiting coupling and can rotate within a range of $0 < \theta < 90°$. An internal spring is activated along the arc after 72°. The system parameters are calculated using the continuous-time state-space model function *ssest* in MATLAB. Through this study, we aim to obtain a better understanding of the system's behavior for future research purposes.

1 System Model

The system parameters to be estimated are the friction coefficient (β) and spring coefficient (κ). The experiments involved utilizing a Vicon tracking system to collect input position data and a dual-range force sensor to record torque data. The system is physically constrained such that $0° < \theta < 90°$, with $\kappa = 0$ for $\theta < 72°$.

The torque-limiting coupling can compress an internal set of six springs by rotating a thin nut by an angle θ_{TLC}, which compresses a multi-layered stack of brass spacers to increase the value of β_{system}. This paper identifies the system parameters for a range of θ_{TLC} positions to understand the characteristic behavior across the system domain.

1

The system model was implemented in Matlab, with the **matrix elements A(1,1), A(1,2), B(1), and C held constant during the identification process.** The identification was carried out at various values of θ^{tlc}, and the resulting **output vector A was used to calculate the values of β and K.**

The **rotational inertia J of the system was determined using the function J=mL², ** where m is the mass in kilograms and L is the length of the rod in meters.

Measurements yielded **m=0.167kg** and **L=0.354m,** resulting in **J=0.021kg*m².** This value was held constant during the system identification process.

System Dynamics Model:

$$\tau(t) = J\ddot{\theta} + \beta\dot{\theta} + k\theta$$

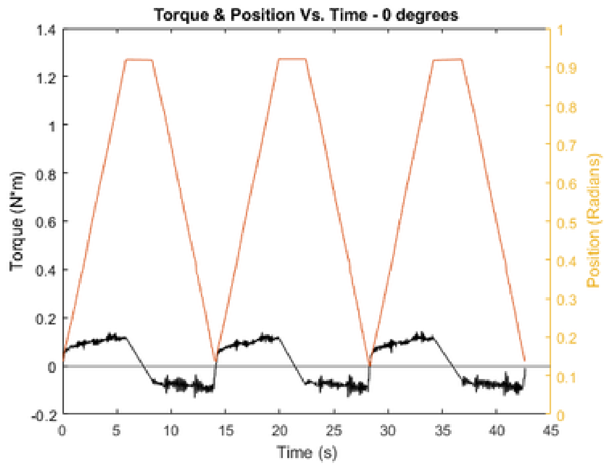
State Space Model:

$$\dot{x} = A * x(t) + B * \tau(t)$$

$$\theta = C * x(t)$$

$$x(t) = \begin{bmatrix} \theta \\ \dot{\theta} \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ \frac{1}{J} \end{bmatrix}$$

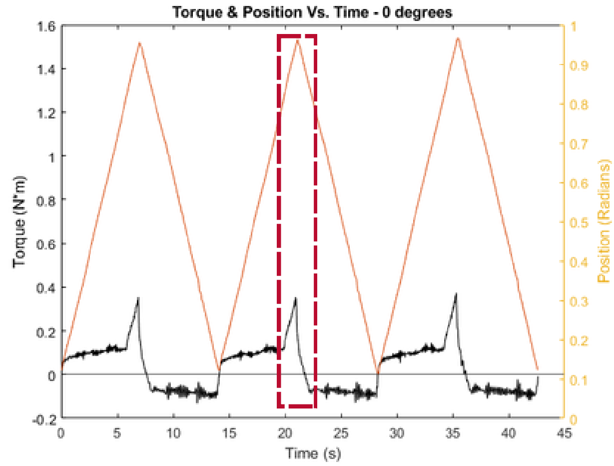
$$A = \begin{bmatrix} 0 & 1 \\ -\frac{k}{J} & -\frac{\beta}{J} \end{bmatrix} \qquad C = \begin{bmatrix} 1 & 0 \end{bmatrix}$$



System Parameter Values: $\kappa = 0$		
θ_{TLC}	A	β [N*m*s/rad]
0°	[0,1;0,-0.932]	0.019509
300°	[0,1;0,-0.919]	0.019225
600°	[0,1;0,-0.933]	0.019535
900°	[0,1;0,-0.935]	0.019564
1200°	[0,1;0,-0.941]	0.019713
1380°	[0,1;0,-0.943]	0.019753

Figure 1: Estimated system parameters in $0° < \theta < 72°$ region.

$$0.019509 < \beta < 0.019753$$



System Parameter Values: $\kappa \neq 0$			
θ_{TLC}	A	β [N*m*s/rad]	κ [N*m/rad]
0°	[0,1;-0.929,-0.932]	0.019509	0.019446
300°	[0,1;-0.935,-0.919]	0.019225	0.019565
600°	[0,1;-0.943,-0.933]	0.019535	0.019733
900°	[0,1;-0.948,-0.935]	0.019564	0.019849
1200°	[0,1;-0.978,-0.941]	0.019713	0.020464
1380°	[0,1;-0.981,-0.943]	0.019753	0.020537

Figure 2: Estimated system parameters in $72° < \theta < 90°$ region.

The averaged value of $\overline{\kappa}$ is 0.020 [N*m/rad].

First, **to calculate the value of β, we isolated the data to the linear region when K=0.** From Figure 1, we can identify β_{min} to be 0.01951N*m*s/rad and β_{max} to be 0.01973N*m*s/rad.

Next, **to determine the value of K, the system identification was performed in the 72°<θ<90° region** highlighted in Figure 2 by a dashed red box, while holding the β value calculated in Figure 1 constant. The averaged value of K was determined to be 0.020N*m/rad.

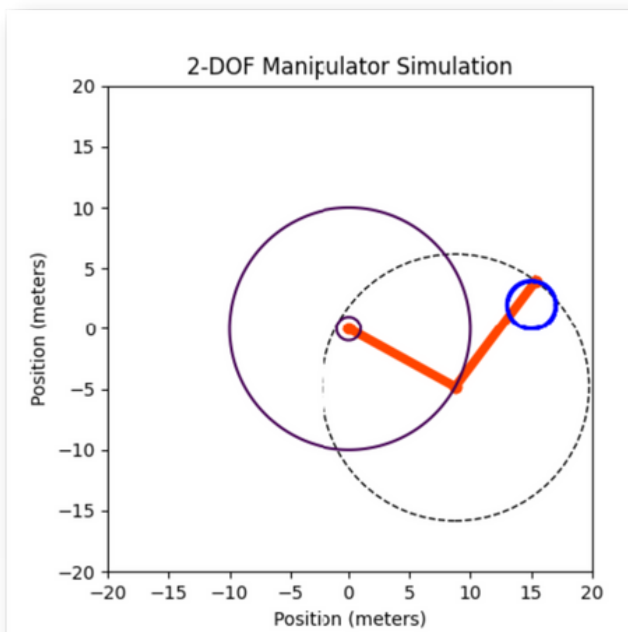
2-DOF Manipulator FK/IK Simulator

Fall 2022 — UNM Agile Manufacturing Laboratory

Under the guidance of Dr. Rafael Fierro and Longsen Gao, I undertook the creation of a **Python 3.9-based planar, two-link robotic manipulator simulator.** The simulator's primary objective was to enable circular motion, **showcasing both inverse and forward kinematic manipulation prowess without external Python libraries.**

I engineered the simulator to execute a precise circular trajectory, visually depicted in the accompanying Figure. The simulator's had the capacity to translate mathematical principles into tangible motion.

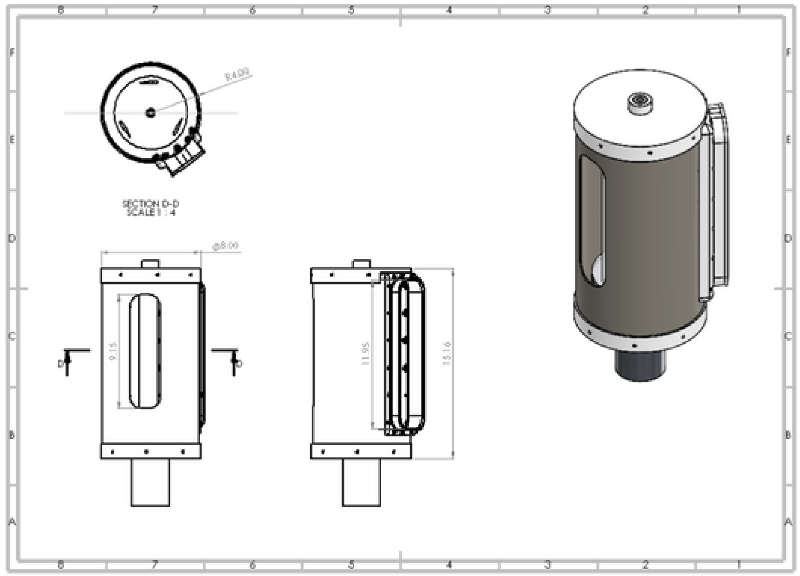
This project served a dual purpose. It allowed me the **opportunity to delve into the core mechanics of robotic manipulators,** enhancing my grasp of the subject matter. Simultaneously, it sharpened my Python programming skills, aligning theoretical understanding with practical coding experience.



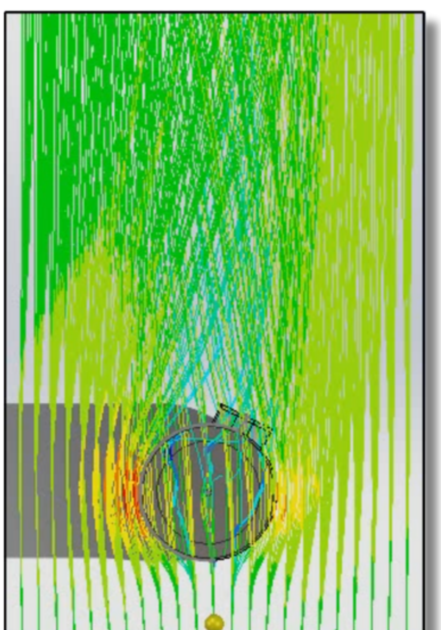
Deployable Vertical-Axis Wind Turbine

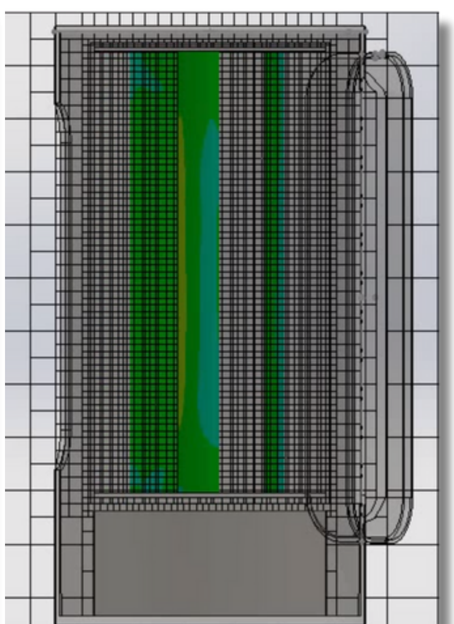
Summer 2022 — WHY Laboratory

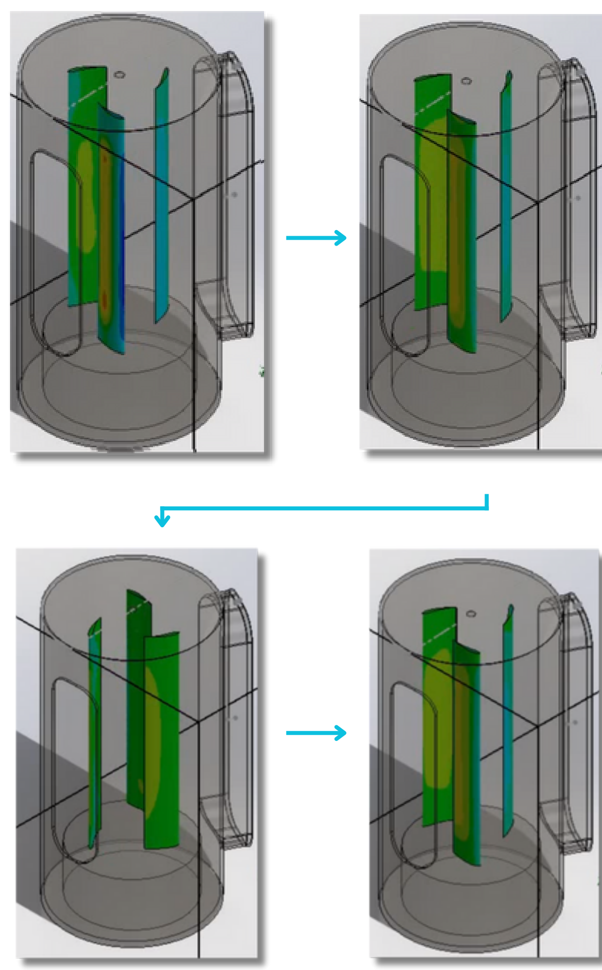
This project design focus was on creating an **efficient, small-scale energy system to be used in emergency response situations** to power communication and medical devices. A small-scale, low-windspeed, deployable wind turbine seemed to be a viable option for emergency responders to utilize in the field to power their medical and communication devices.



The prototype was designed and fabricated by myself using 3D printed parts and off the shelf components. A prototype was developed based off of the most up-to-date research being conducted on low-windspeed wind turbines. We opted for a vertical axis wind turbine with an enclosure, as this type of turbine has been shown to be efficient at low wind speeds. **A novel contribution to this design was the inclusion of a diffused located at the enclosure outlet to increase wind velocity.**

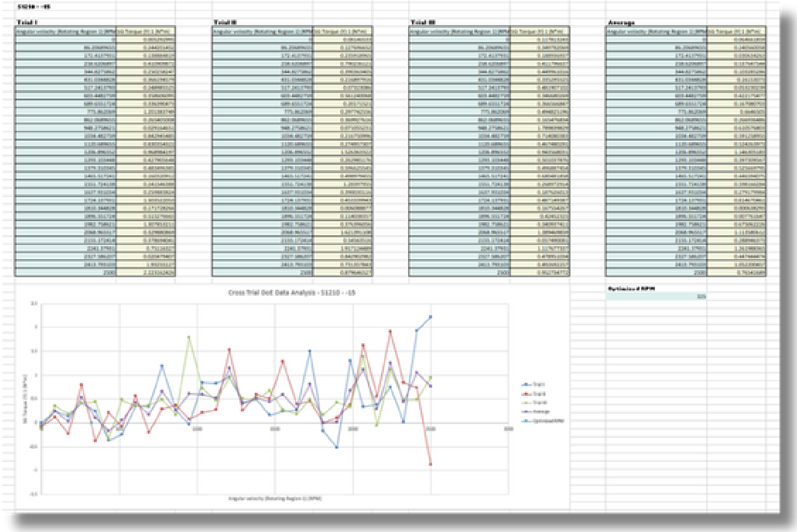






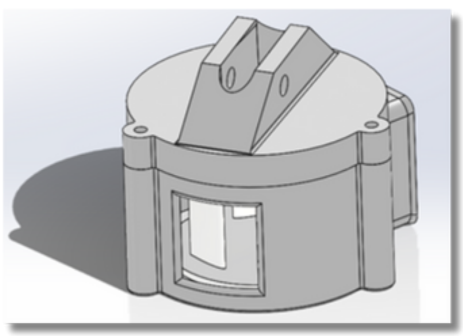
The CFD performed was done through SOLIDWORKS Flow Simulation. This was utilized as a way for us to preemptively determine what airfoil and orientation of the blades that would operate most efficiently given our turbine design. **A full sliding mesh analysis was conducted for the NACA 0015 airfoil.**

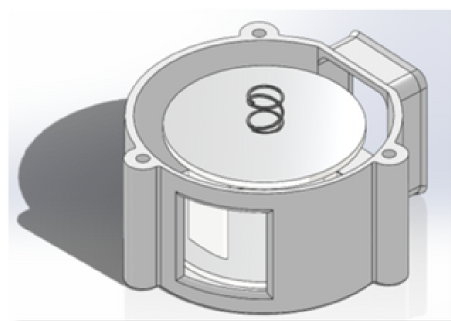
The CFD is performed in three operations. The first being a Design of Experiments (DoE), the second being a Goal Optimization, and the third being the Sliding Mesh Analysis.

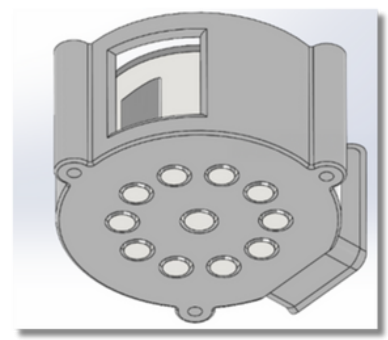


The CFD performed was done through SOLIDWORKS Flow Simulation. This was utilized as a way for us to preemptively determine what airfoil and orientation of the blades that would operate most efficiently given our turbine design. **A full sliding mesh analysis was conducted for the NACA 0015 airfoil.** The CFD model was simplified to accommodate the simulation and reduce computation time.

The CFD is performed in three operations. The first being a Design of Experiments (DoE), the second being a Goal Optimization, and the third being the Sliding Mesh Analysis.







To further validate our simulation results, I designed a **wind tunnel model with a frontal area of the model only blocking 5% of the airflow in the wind tunnel.** The mounting bracket is oriented so that the inlet of the turbine is facing towards the incoming air in the wind tunnel. The system is set-up to be **spring loaded to allow for one to easily change the orientation of the blades.** There are ten holes on the bottom of the model to allow for reorienting the blades during the experiment.

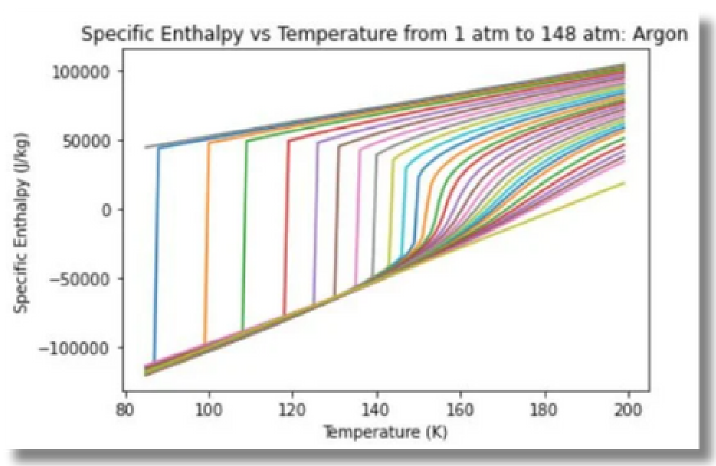
Specific Enthalpy Graphical Analysis

Fall 2021 — Thermodynamic Fluids Under Extreme Conditions Lab

Generated **enthalpy vs temperature graphs for Argon at varying pressures** through Python programming on a Jupyter Notebook.

This project was completed during my freshman year as a Research Assistant in the Thermodynamic Fluids Under Extreme Conditions (TFX) Laboratory to **analyze the different behaviors of Argon during its super critical phase.**

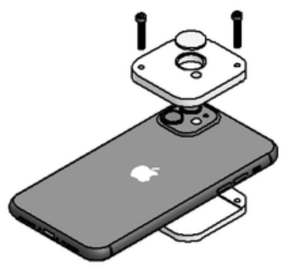
This project enhanced my Python programming skills while also introducing me to academic research.



Derma-seek

Summer 2022 — Personal Project

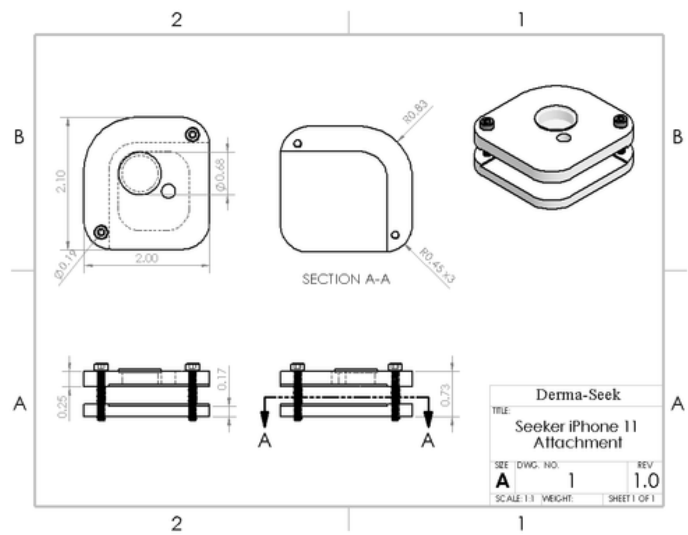
DERMA-SEEK
A I HEALTH SOLUTIONS



I worked alongside John Cooper, a senior in the undergraduate computer science program at UNM, to develop an **at-home diagnostics app aimed at facilitating the diagnosis of melanoma.**

Recognizing the **unprecedented imaging capabilities and computational power of modern smartphones,** I conceived the idea of harnessing this technology to support the diagnostic process of melanoma.

Currently, dermatologists rely on dermascopes, which are well-lit, 10x magnifiers, to aid in the visual assessment of skin lesions.



To **transform a smartphone into a dermascope,** we devised a compact attachment housing a 10x magnification lens.

In our project, John Cooper led the machine learning components.

Meanwhile, my responsibilities encompassed **designing the user interface (UI)** for the mobile application, and **developing and manufacturing the dermascope attachment.**

Micro-Grid Project Manager

Summer 2021 — Focused Sun

Led a team of five engineering interns to develop a reduced-size prototype of a shipping container with **solar concentrators, thermal storage, and power generation.** The shipping container measures 20' in length.

Coordinated with the founder and **presented progress to executive staff weekly.**

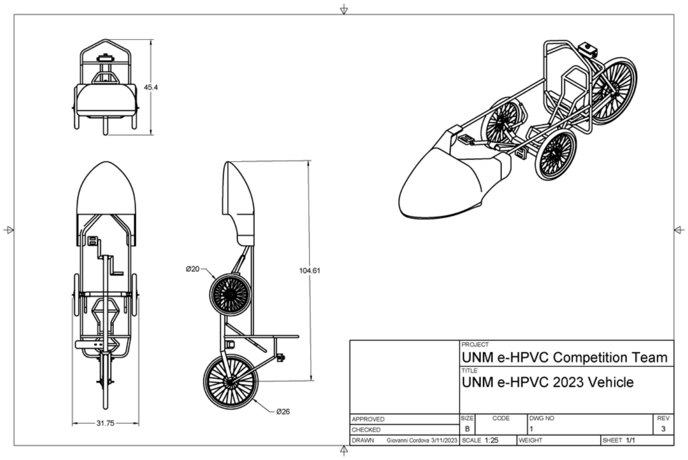
Managed **product development, R&D testing, and material sourcing.**

Manufactured stack press, mirror assembly, frame, thermal storage tank, and absorber arms.

Operated various heavy-duty tools, including **MIG welders, plasma torches, sheet metal shears, rollers, and brakes.**

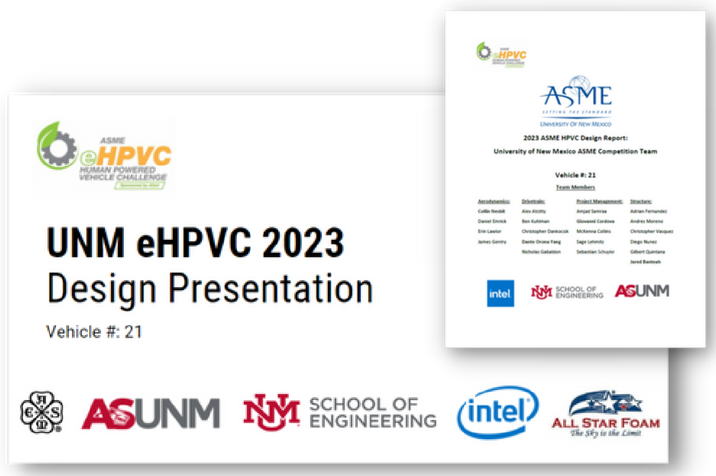
UNM ASME 2022 e-HPVC Competition Vehicle

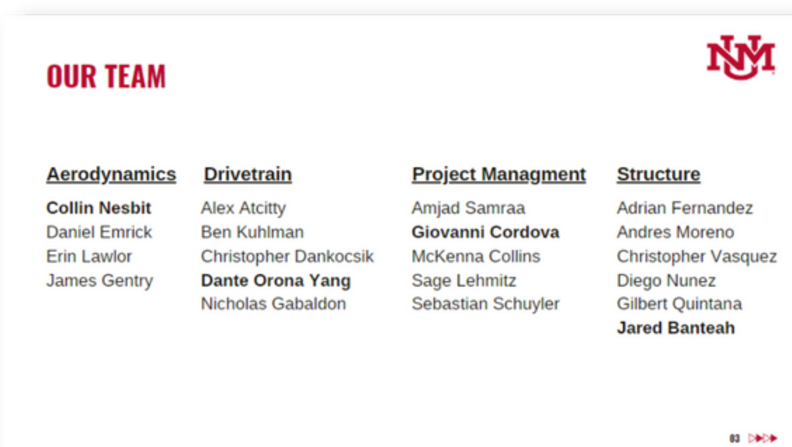
Spring 2023 — ASME 2022 e-HPVC Competition



As the lead Project Manager for the University of New Mexico's American Society of Mechanical Engineering Student Chapter, **I successfully led a diverse team of 20 undergraduate and graduate students** during the Spring 2023 semester in the 2023 ASME e-Human Powered Vehicle Competition (eHPVC).

Our comprehensive participation in the competition involved **designing, fabricating, and presenting our competition vehicle by delivering a 15-page design presentation and a 13-page technical design report,** which were prepared and presented to a national panel of judges.





Despite the logistical challenges posed by the distant location of the competition, we persevered by **completing a fully functional electric-powered vehicle within a single semester,** a task that typically spans an entire year for other teams.

Throughout the project, I played a pivotal role in **securing essential funding amounting to $12,000** for materials and travel expenses. Furthermore, I actively contributed to the fabrication process, specifically in the carbon fiber fairing mold creation and layup procedures. To ensure cohesive progress, **I led weekly meetings to facilitate effective coordination among the sub-teams** specializing in Aerodynamics, Structure, and Drivetrain.

NSF Scholar Community Service Project

Spring 2023 — South Valley Economic Development Center

As participants of the NSF UNM School of Engineering Fellowship, **our team of three engaged in a community service project** aimed at enhancing the local community through the application of our practical engineering skills. Our focus was directed towards the South Valley Economic Development Center (SVEDC), a community center with whom we collaborated closely.

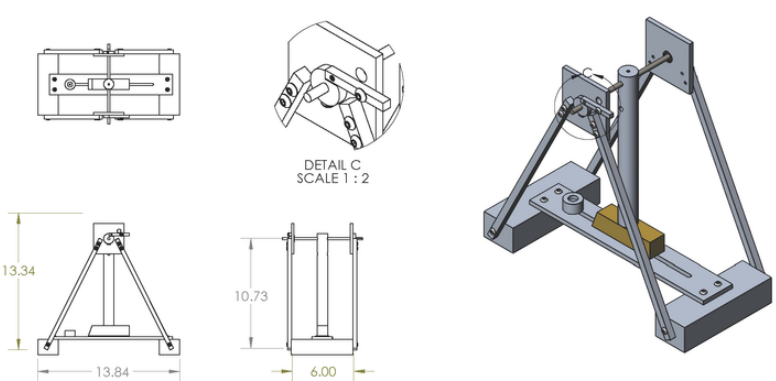
In this project, our team achieved three key objectives. Firstly, we produced a detailed **40+ page kitchen safety video,** which was displayed on SVEDC's televisions in the lobby and kitchen areas, covering food handling techniques, foodborne illness risks, equipment usage, and chemical safety. Secondly, we **created a precise 30:1 scale model of SVEDC's storage area,** enabling us to devise an optimized floor plan for efficient space utilization. Finally, we successfully **repaired SVEDC's malfunctioning jarring machine** by addressing a misaligned shaft and leakage issues, employing shimming techniques and TIG welding to restore its functionality.

30:1 scale model of storage room (current).

30:1 scale model of storage room (proposed).

Mechanical Engineering Design II Final Project

Spring 2022 — Coursework



CAD of our final competition ball launching mechanism.

Left to Right: Kenneth Armijo, Emma White, Giovanni Cordova, Melachi Sanchez, Jared Banteah, Dionicio Maestas.

Collaborated with **five mechanical engineering students to design and fabricate a ball launching system for a final project.**

I designed and machined a reliable and variable trigger mechanism that operated with a **95% accuracy** shooting a ping-pong ball and golf ball 10 feet away into a 10 inch target.

Highest rated by a panel of judges

First Place in Launch Competition

In addition to assisting in the design, machining, assembly, and testing of the project, I also **calculated the minimum angle our hammer head would need** to have under idea conditions to reach over the barrier, was the **sole designer of the project poster,** and made **major contributions to the project report.**

Competed against 9 other teams and were the **only team to operate with a 100% accuracy during the launch competition.**

Mechanical Engineering Design I Final Project

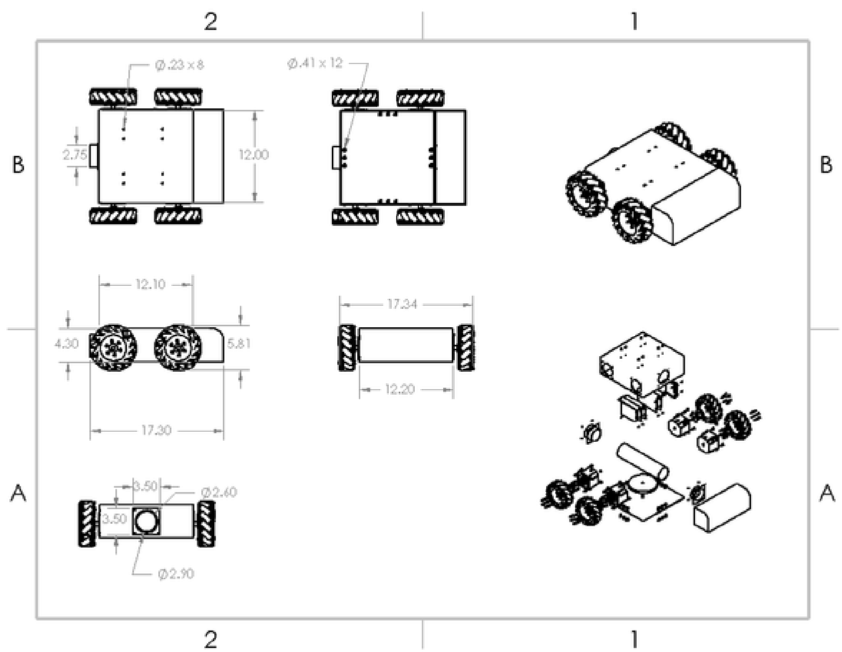
Fall 2021 — Coursework

Worked alongside four mechanical engineering students to **design a novel commercial product and brand.**

Today, cities have to do multiple passes with a street-sweepers to clean a single road, because often times there are obstructions blocking the gutter, such as parked cars.

Our robot solves this by being able to fit underneath the chassis of most automobiles and clean the debris being blocked by parked vehicles.

Made **significant contributions to final design decisions and 3D modeling of prototype.**



Linear Fresnel Lens Solar Concentrator

Spring 2019 — Personal Project

Designed and **built a concentrating solar collector with a 3' x 3' linear Fresnel lens.**

Created a prototype using a **single-axis tracking frame, data collector, and stop-motion camera.**

Achieved a **peak temperature of 470°F** and analyzed the collected data.

Filed a provisional patent for a novel use of an omni-directional solar tracker.