

# Dunagan Marchman

## Design Portfolio

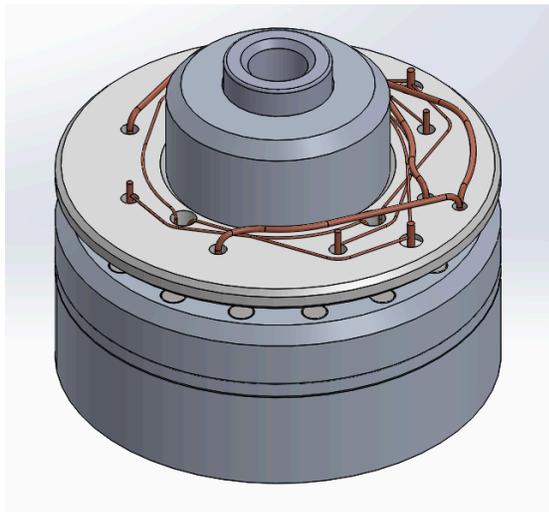
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Hi there! I love all things engineering, with a special interest in structures and mechanisms. I love learning new things about this wonderful field, which means I'm always working on something! These are some of my recent projects.

## Force Based Joystick

Jan 2026 - Present

### Version 1 Model



### Motivation

Improve user control for robotics and drone applications by leveraging the human ability to control force better than displacement.

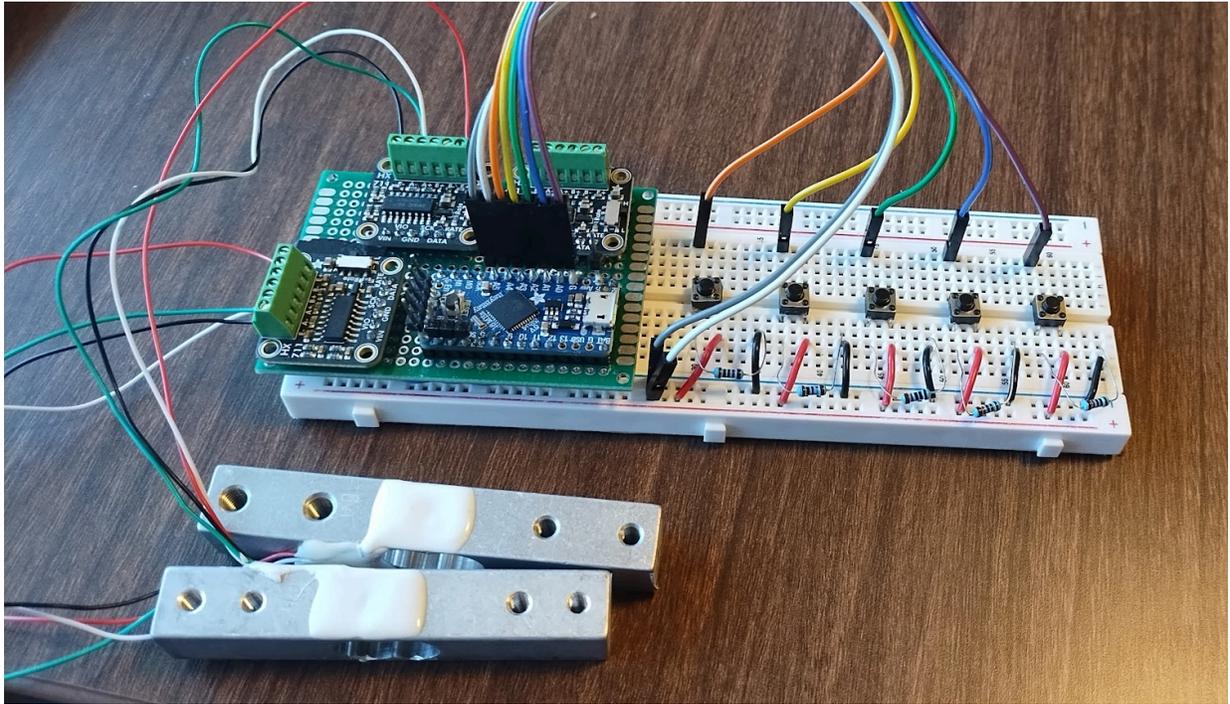
### Goals

1. Learn about strain gauges
2. Explore force input as an alternative to displacement input for applications where precision is key.

### Requirements

- Package into a gamepad joystick form factor
- Be robust to impacts and overloading of axes
- Maximize signal-to-noise of strain gauge sensors

## Initial System Prototype



The initial stage of the project was dedicated to solving the biggest unknowns, with a minimum viable system. The prototype shown above was designed to answer three questions

1. How can I use a microcontroller to interface with Windows as a HID device?
2. What is the noise, and return to zero accuracy of cheap strain gauge setups, and how much filtering will be required?
3. How easy is it for a user to control the system and give precise inputs?

The prototype uses an ItsyBitsy microcontroller, and several HX711 ADC amplifiers to take strain gauge input and emulate an Xbox controller's joystick output with an open source HID library. This prototype proved the viability of a strain gauge input system, and proved to be extremely easy to control when tested in video games.

## Geometry Iteration

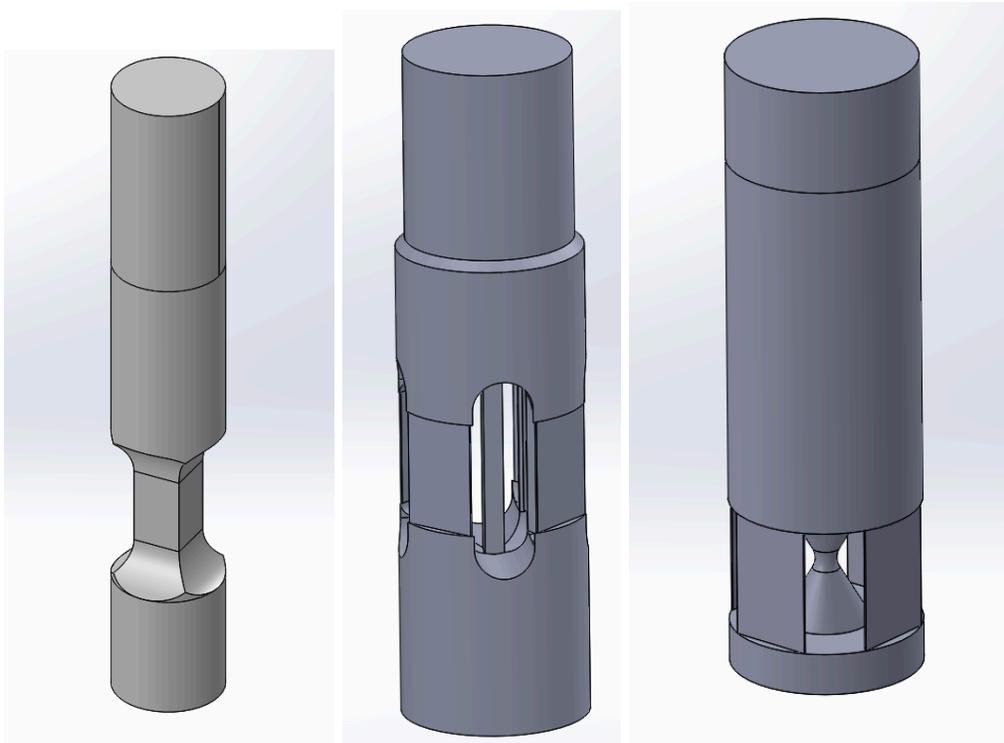
The next design iteration was aimed at integrating the X and Y axes into one joystick unit. Each axis would consist of two strain gauges in a wheatstone bridge to minimize thermal drift effects. To maximize signal to noise of the axes, it is important to maximize strain at the gauge locations, while maintaining adequate factor of safety with respect to material yield strength. This means the material selected should have a high fatigue stress, and a low elastic modulus. The strain at fatigue can be determined with the simple equation:

$$\epsilon_{fatigue} = \frac{\sigma_{fatigue}}{E}$$

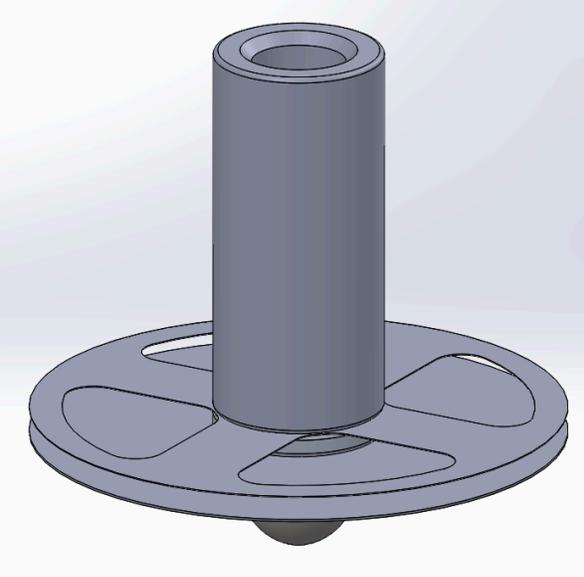
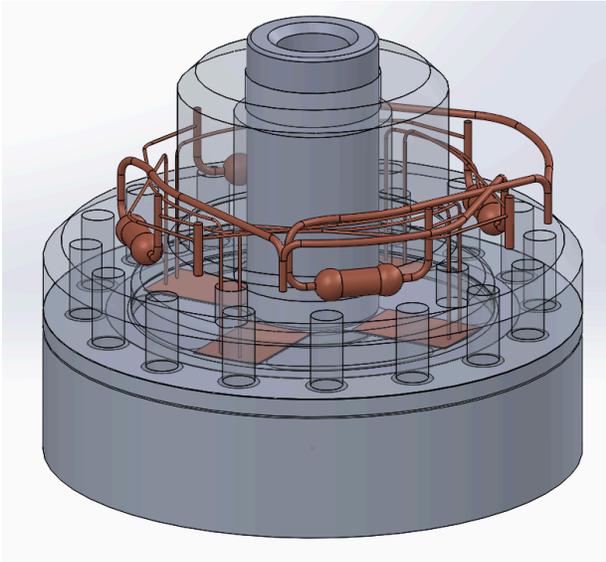
This number can be used to compare materials.

Strong aluminum alloys such as 6061 and 7075 stand out in this comparison as well as titanium, and hardened steels. 6061 aluminum was chosen as a starting point for its good performance and wide availability, and a target of 1000 micro-strain was set.

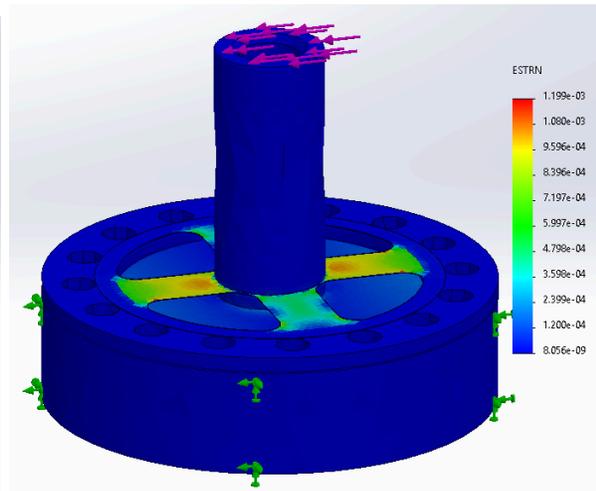
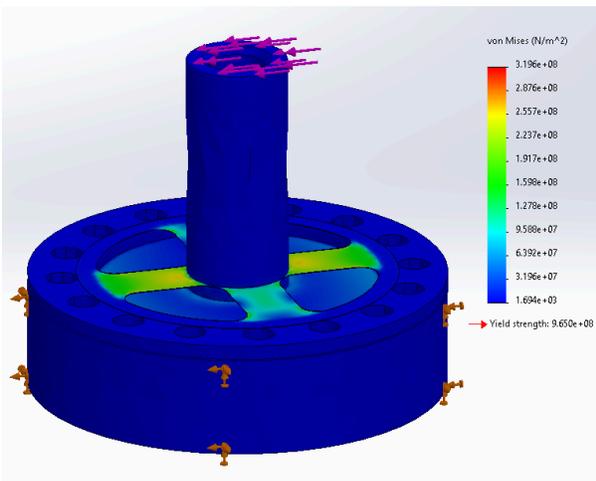
Testing of the initial prototype revealed that across a number of users, a 2lbf applied load represented a good upper limit before muscle strain became an issue. This presented a significant design challenge; a large internal stress must be developed in the joystick in a small volume, with only a 2lbf applied load.



Several joystick geometries were rejected due to overall size or manufacturability issues. The accepted design shown below uses thin stainless steel flexures made from shim stock, and closely spaces them which achieves a large force multiplication at the strain gauges.



The bottom sheet is 0.005" thick and acts as a pivot point to form a second class lever which increases the force applied to the 0.002" top sheet. The assembly is clamped by a ring of 4-40 bolts, and strain gauges are glued in four places to the top sheet. Hard stops constrain the rotation and axial movement to prevent sheet failure when excessive force is applied.



This design achieves the 1000 micro-strain target, which keeps the stress at 3x under yield, and just below the fatigue stress for the selected 304 full hard stainless steel material.

## V1 Manufacturing

Manufacturing began with the creation of a number of custom ground High Speed Steel tools.



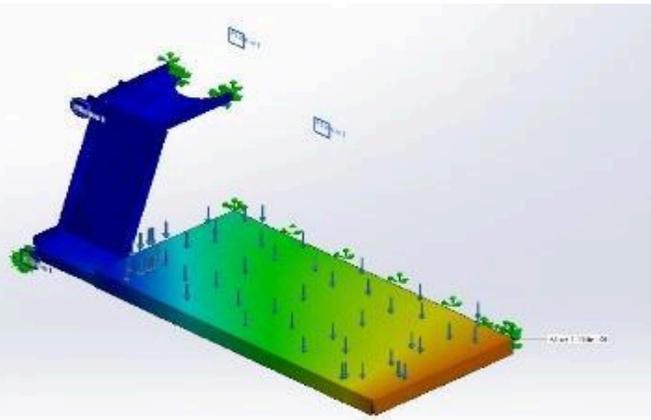
These tools allowed for a specific order of operations where the 20-hole pattern on the parts of the outer body were drilled once, in one setup. Individual parts could then be machined off of this blank of prepared material saving significant time.

This is an ongoing project that will continue as I have time.

# Whiteboard to Trade Show

## Production Prototype: Package Safe

Jan-Aug 2022



### Motivation

I was hired by Evermore Systems Inc. to design a prototype package safe system, using readily scalable manufacturing methods. The idea was to create a system that could be installed in homes to prevent porch piracy by safely storing packages away, without requiring a key or code for the delivery worker to operate the safe.

### Goals

1. Utilize commercial solutions and scalable manufacturing techniques to maximize cost efficiency and allow high volume production
2. Store packages in an automated and secure manner such that the outside door can remain unlocked without compromising security

### Requirements

- Accommodate packages of up to 154lbs and 2ft x 2ft wide
- Nest 3 shelves in a tight space, no taller than 24in to allow for multiple package deliveries
- Optimize for high volume production

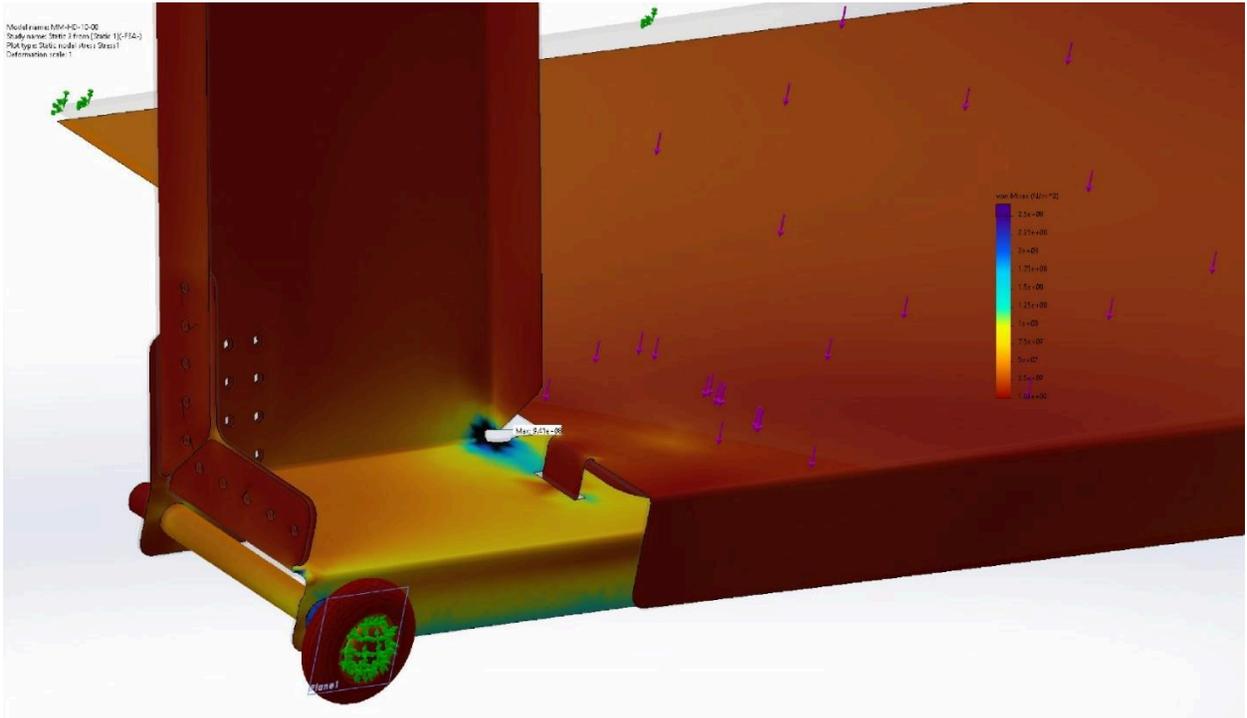
### Contribution

At the start of the product development, I was given a whiteboard drawing of the basic idea. I designed a sheet-metal shelf system that could be laser cut in high volume and utilized garage door rollers and track to leverage commercial solutions. I used SOLIDWORKS to model and analyze a solution that met the requirements, then saw the product through manufacturing, assembly, and real-world load testing to validate the simulation model.



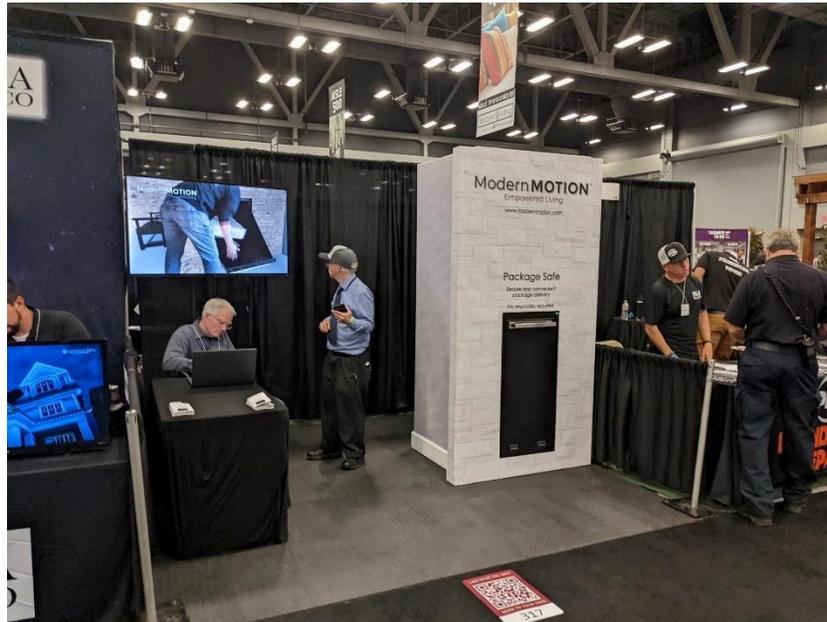
### Iteration

During the first analysis run, I identified a significant stress riser in the design that resulted in stress 4 times greater than the yield strength of the material. This stress was also across a significant section of the mesh. The simulation data informed an iteration to the structure of the shelf to eliminate this issue before production.



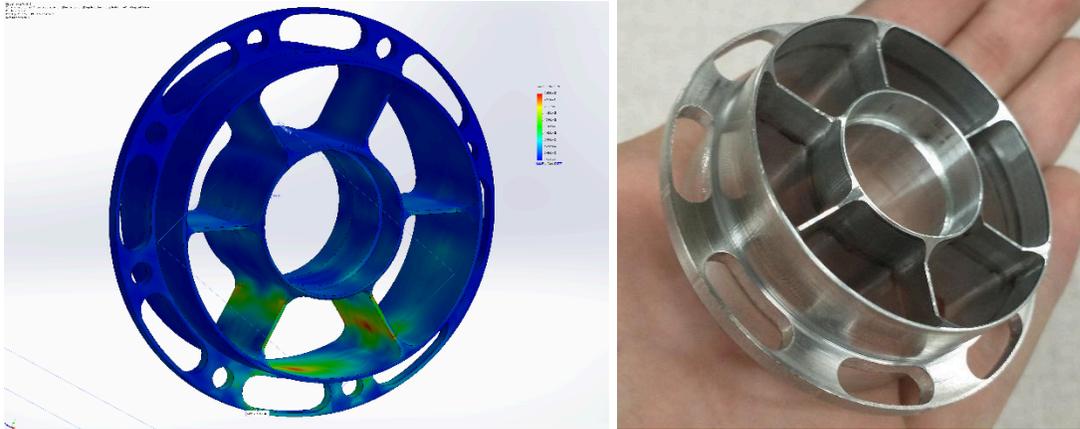
## Outcome

- Delivered a functional prototype that met all requirements
- Proved viability of the concept
- Product demonstrated at trade shows



# Analysis-Driven Design

Summer 2022



## Motivation

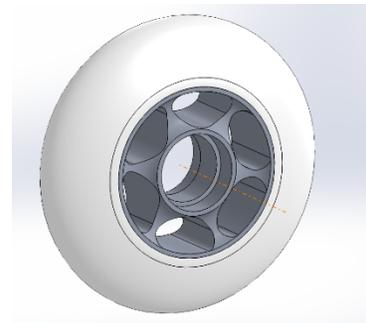
As an avid outdoor inline skater, I wear through wheels quickly on the rough asphalt of city roads. Replacement wheel sets range in cost from \$70-120, so I began looking for a cheaper alternative. The idea to manufacture more durable aluminum hubs that could be re-over-molded to extend their life turned out to be the perfect opportunity to dive deeper into simulation analysis and CNC manufacturing.

## Goals

1. Become more proficient in optimizing structures based on SOLIDWORKS simulation data
2. Develop CAM skills in FUSION 360 and manufacture parts using CNC milling
3. Develop a more cost-effective solution to wheel life problems associated with skating on asphalt

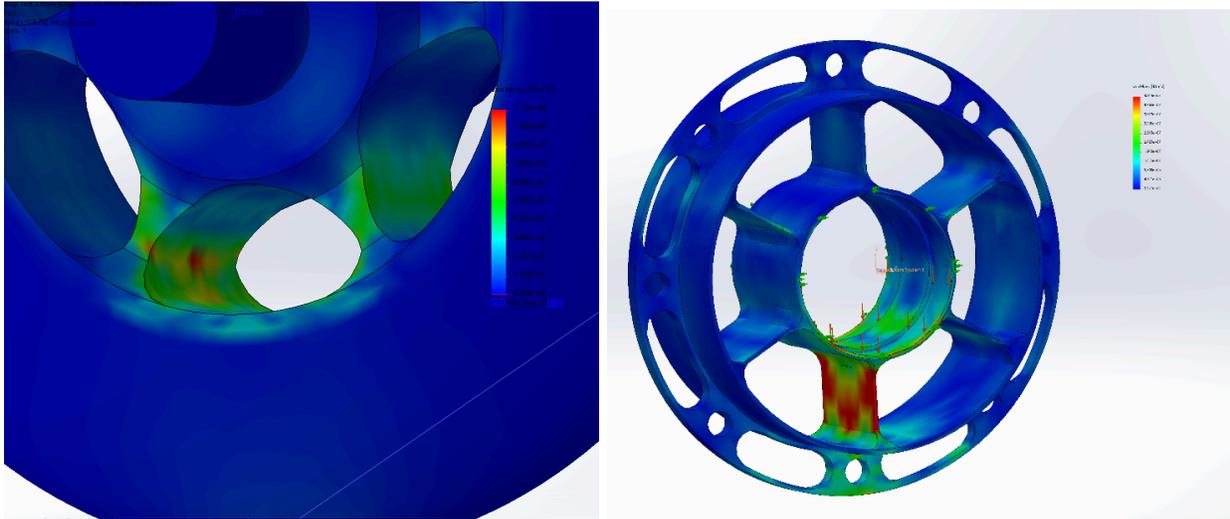
## Requirements

- Minimize weight to increase maneuverability
- Withstand a worst case 2m drop impact, assuming a 160lb skater



## Process

Two load cases were analyzed: impact on a spoke, and impact between spokes. An impact simulation in SOLIDWORKS was used to optimize the design over eight iterations. The heavier wheel (left) was optimized until the much lighter version (right) was achieved. Analysis ended when the minimum factor of safety of 1.5 was reached.



The wheel molds and hub were then tool pathed and manufactured on a Haas 3-axis and manual lathe. After over-molding, the final wheel weighed only 0.192lbs.



In testing, the wheel appeared to perform very well. Upon closer inspection after testing, two issues were identified. Firstly, the only easily accessible urethane rubbers I could find were suited for casting and mold making, and the chosen urethane had degraded rapidly in the short duration of the test. Second, a buckling failure around the rim of the wheel that the analysis had not predicted was found (image right).

## Outcome

While not entirely successful, the project yielded:

- A functional prototype that skated smoothly
- Great learning opportunities in Simulation, CAM, Machining, and real-world applications of engineering principles



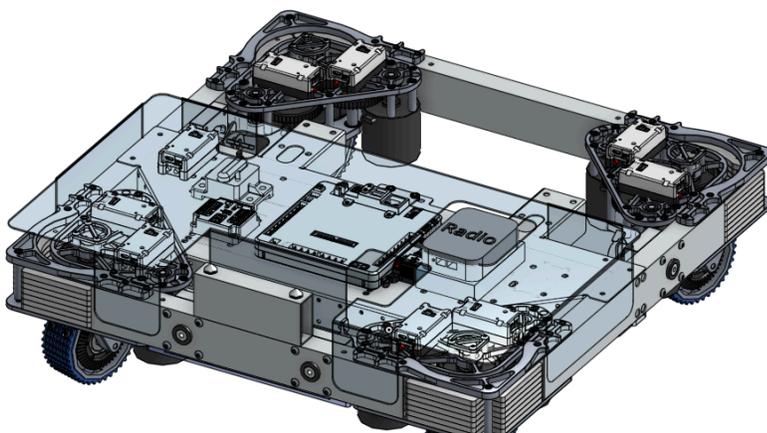
# Integrated Arm System

Spring 2023



This award-winning design is a set of systems developed for an FRC robot to compete in the 2023 game *Charged Up*. The robot consists of four integrated assemblies: the Chassis, Shoulder, Arm, and Intake. The goal of the design is to acquire game elements, traffic cones, and inflated cubes, and score them on multiple levels of a “grid.” The robot was designed to cross the field in a stable and low configuration, but be able to extend to reach all levels of the grid in order to outscore opponents. To accomplish this, during the design phase, I took responsibility for the design and integration of the Chassis, Shoulder and Arm.

## Chassis



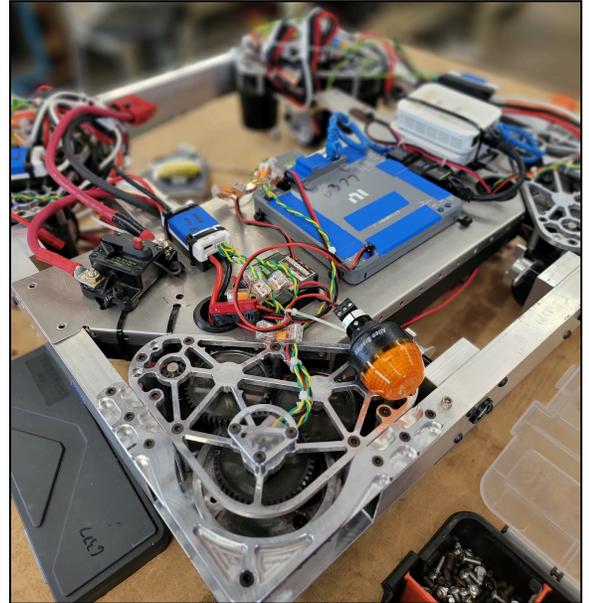
Designed for maximum maneuverability both on the field and over the charging station, the chassis is powered by SDS MK4i swerve drive pods. High ground clearance ensures the robot will never bottom out on the charging station.

A small frame allows for best maneuverability through tight spaces and balancing with three robots, while also staying stable enough to score on the high nodes.

Onshape Design File: [Link](#)

#### Features:

- **23" x 23" frame perimeter** keeps us out of the way of alliance partners
- **3.5 inches of ground clearance** prevents high centering on the charge station
- **Custom quarter turn bumper mounts** allow lightning-fast sub 30 second bumper changes
- **Back-to-back electronics layout** houses all major components in a highly compact yet easy to service format
- **Adjustable steel corner ballast plates** counterweight the motion of the arm and can be tuned to create good stability without sacrificing acceleration
- **Spike pin shear interface** interlocks with arm in the low position and transfers impact loads into the chassis, protecting the arm



#### Shoulder

Designed for speed, precision, and stiffness, the shoulder integrates the battery, shoulder gear reduction, and pivot structure into one tight and integrated package, ensuring controllable motion through superior stiffness and smooth low friction interfaces.

Onshape Design File: [Link](#)

#### Features:

- **Integrated bottom loaded battery mount** for optimal arm counterweight
- **3 stage 90:1 reduction** strikes a balance between speed, holding current, and efficiency
- **Single piece billet construction** for excellent precision, stiffness, robustness and serviceability



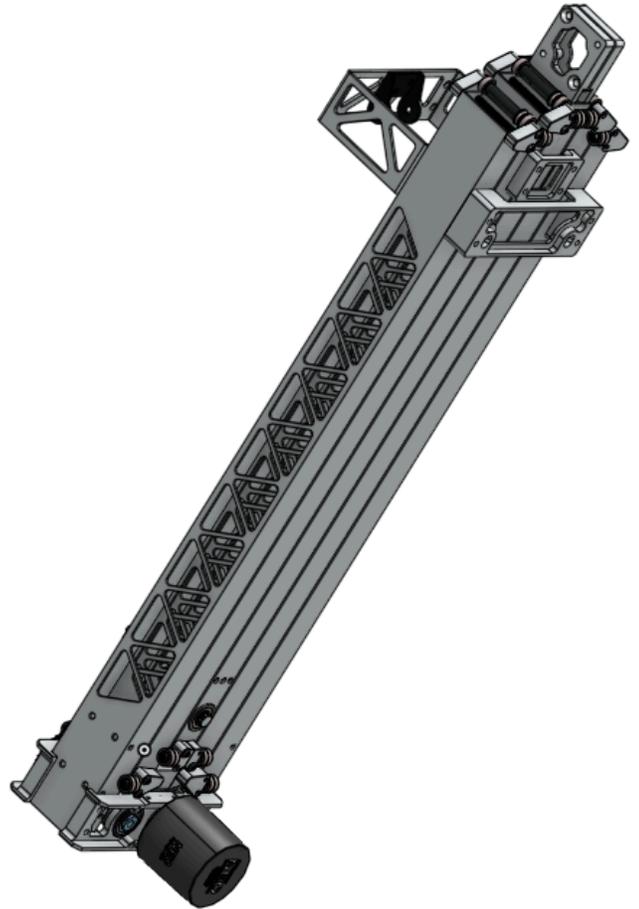
## Arm

Designed for maximum speed and minimum weight, the 2-stage extension allows the robot to reach the highest nodes and collapse into a very nimble and stable configuration when crossing the field. This completely custom design allows for minimal weight, in an extremely tight package.

Onshape Design File: [Link](#)

### Features:

- **Pocketed 1/16" wall 1x2 tubing** for very light and stiff structure
- **Custom 2 piece bearing blocks** pivot to provide excellent serviceability and very small volume
- **1:1 capstan driven rigging** run through the tubes for very light and simple rigging



## Outcome

- World Championship Excellence in Engineering award for the Arm and shoulder subsystems
- Ranked in the top three at district level
- World Championship Division Finalists

### Additional Links:

- [Behind the Bumpers](#) interview in which I describe the above design elements
- Video of the [Robot In Action](#).
- The *Charged Up* [Game Manual](#) gives full details of the game challenge