MECHANISMS ■ POWER SYSTEMS ■ ROBOTICS

RAPID PROTOTYPING ■ PRECISION DESIGN

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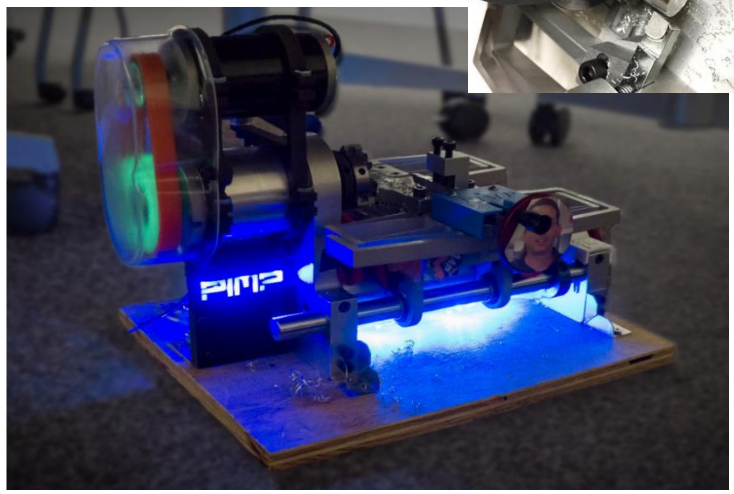
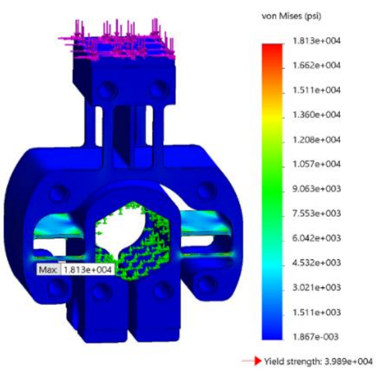
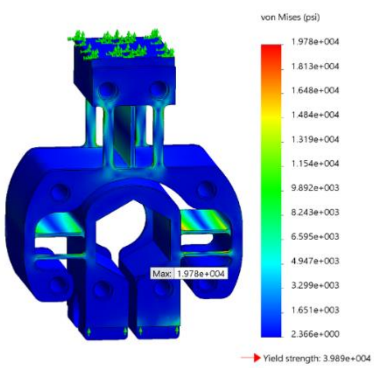
2.72 Elements of Mechanical Design: Desktop Lathe

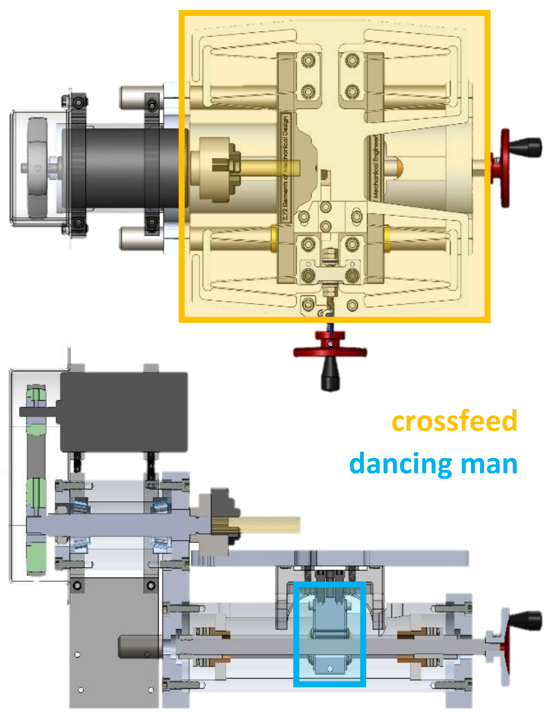


Over a semester, my team* modelled, designed, fabricated, and characterized a desktop lathe that reached 10-15 micron tolerances in taper, diameter, and runout/eccentricity.

I was the FEA Guru, so I optimized our lathe's flexures. The crossfeed flexure gives the tool x-axis freedom, so it was designed for range of motion. The dancing man flexure absorbs cutting forces (left figure) and assembly misalignment (right figure) to allow translation only in the z direction without binding. All components were made by waterjet, so directional tolerances impacted the design and manufacture.







As Modeling Deputy Guru, I also helped develop a MATLAB model of errors/deflections in each component of the lathe using Homogeneous Transformation Matrices (HTMs). We followed the load path from the tool and the chuck/part down to the base, also accounting for thermal effects. This model helped us confirm what dimensions and stiffness were enough to reach our initial goal of 50 micron tolerance.

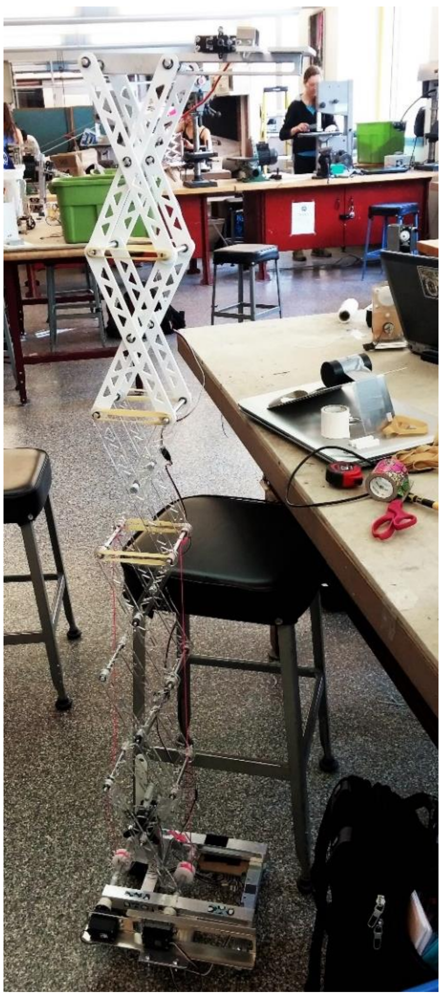
* My team started off as two separate teams that each lost half its members throughout the semester. To help relieve some stress, our professor gave us an unlimited "pimp budget" to deck out our lathe.

2.007 Hack to the Future: Scissor Lift

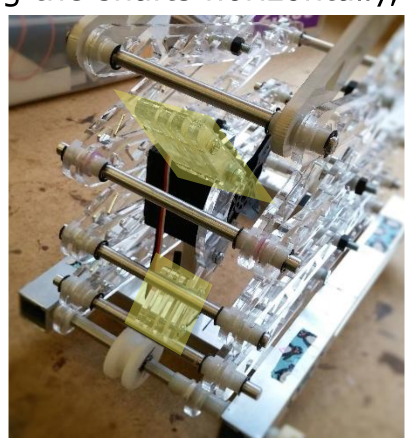
In a Back to the Future themed game, my goal was to cross a ditch via hoverboard (see-saw), grab plutonium rods, and dump the rods into a flux capacitor on the shelf above. In the end, I built a scissor lift that could lift 0.5kg from 1' to 5.5' high.

A functional scissor lift requires very high power and tolerance. After several prototypes, I decided to preload the shafts with rubber bands and use rotating fingers for the initial upwards force. A pulley & string on each side controlled vertical position. Unfortunately, this was impossible to control and would often bind.

However, in the process I learned several key things about designing mechanisms:



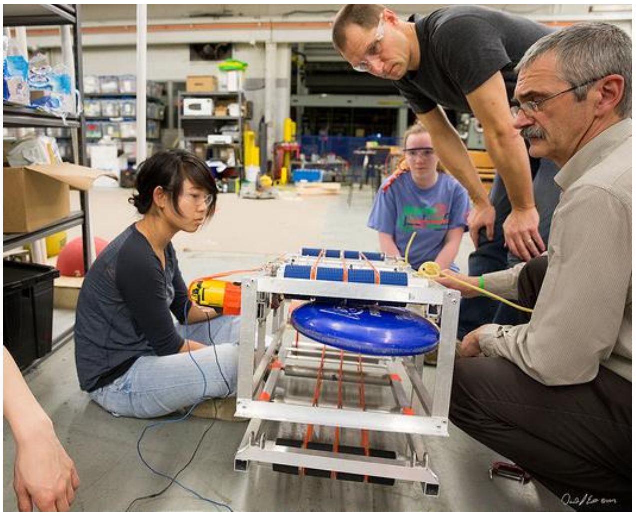
- Stiffness – even though it's easy to get nice holes by laser cutting acrylic, it is actually lighter and stiffer to bend waterjetted sheet aluminum. Ultimately, assembly tolerance & deflection was the death of the scissor lift, not component tolerance.
- Careful assembly – fix things immediately if they are not aligned well. Similarly, design things to be easy to disassemble & reassemble.
- Power transfer – it is very quick & easy to 3D print flexible couplings for motors, and they improve the efficiency a LOT.
- Actuation – it requires an absurd amount of force to initiate the lift by pulling the shafts horizontally, but it's really easy to flick them upward. So with some crazy sliding mechanism and controls work, the first stage could be actuated using flickers, then a leadscrew could be engaged to control the upper range of motion.



FIRST Robotics Competition

Team 469: Las Guerrillas

I like making crazy mechanisms. In my senior year of high school, I designed a floating, flexible roller system to suck up Frisbees and load them to the shooter. With the extra design freedom we got from our floor pickup being so compact, we created one of the most versatile shooters that year.

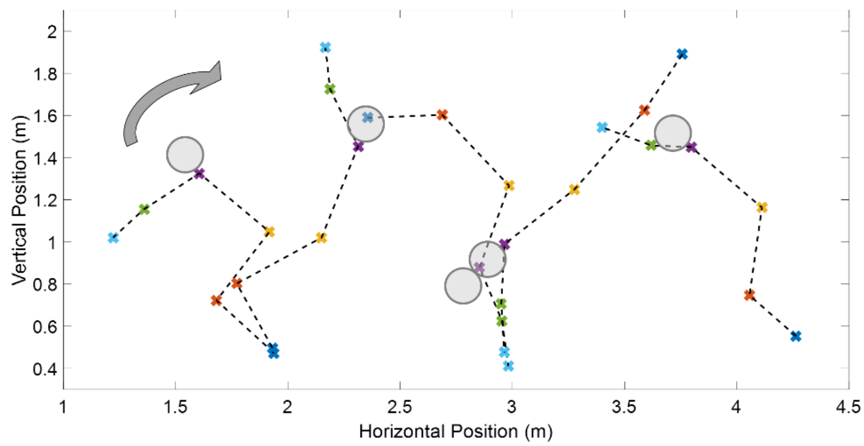


Throughout my time on my high school's robotics team, I learned the basics of design, prototyping, machining, assembly, and testing. On the left, we took apart a conveyor from the robot the year before and reconfigured it for the 2013 Frisbee game. With the new completed system on the right, we tested the conditions under which we could load successfully. We could load driving forwards or backwards and load multiple Frisbees simultaneously without problems. We went on to become Michigan State Champions and World Finalists this year.

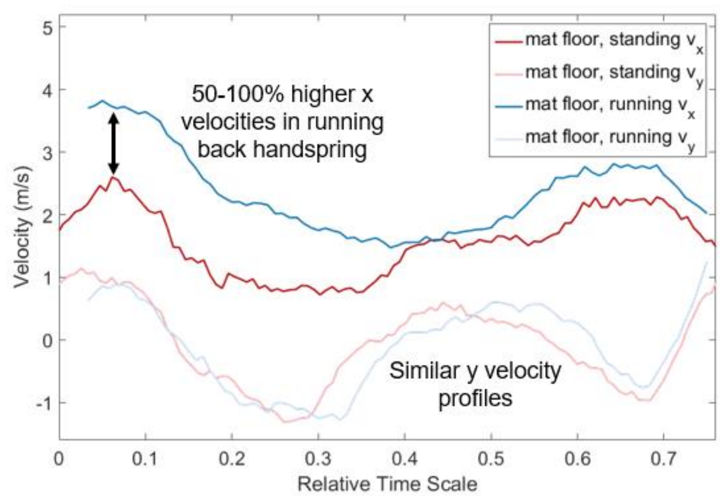
2.671 Measurement and Instrumentation

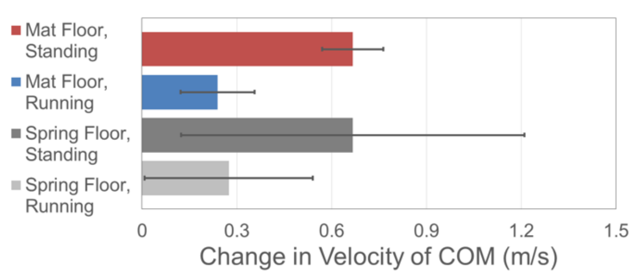
Measuring the momentum in a back handspring

I was on the MIT Cheer Team for two years, and while we picked up stunts quickly, everyone really struggled with tumbling. Because of this, I was very invested in understanding what makes a back handspring difficult. I used video analysis in MATLAB to track how the elasticity of the mat and the entry method (running vs. standing) into the back handspring affected parameters of Jasmin's (my test subject) back handspring.



Due to the low resolution of high speed videos, the marks that I placed on Jasmin's body sometimes warped or got obscured, so in order to get stable measurements of her center of mass, I had to play with many filtering techniques. I found that though the body position parameters of a back handspring do not change significantly across different conditions, a running back handspring is significantly less demanding on the arms than a standing back handspring.





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A few other fun projects...

Gifts & Crafts

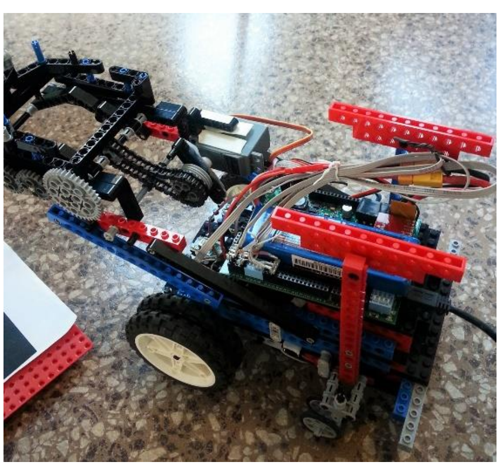
My machine of choice is almost always the laser cutter – I love making both toys and robots in my free time.

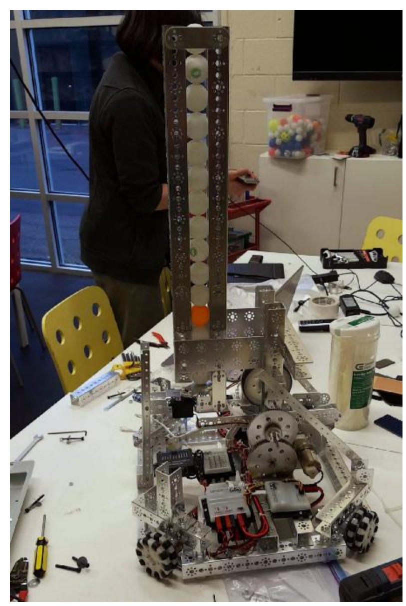
2.008 Design & Manufacturing

We used injection molding, thermoforming, and 3D printing to create our own “mass-produced” (qty 50) yoyos.

Autonomous Robot Competition

I developed navigation code based on drive train sensors and provided GPS data. This was my first exposure to a huge controls project.





VEX Ping Pong Shooter

I have a lot of friends involved in The Robot Garage, a store that helps inspire students to explore engineering. We built this for fun after work one week as a demo.