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Portfolio Introduction

My name is Adam Libert and I've been an engineer from my earliest years – that's me above, crouching, with my hand on the launch controller at the age of 6. This photo captures the first test of a complicated homemade multiple-stage rocket that I designed and built from scratch. It was a miserable failure that nearly took out the neighbor's window, and one that taught me: the best systems are simple ones.

Since then, I have made it my profession to identify simple and elegant solutions to complex problems.

My focus on machine design in both my UPenn Bachelor's and MIT Master's degree programs has equipped me with a powerful quiver of mechanical, electrical, software, and controls tools to evaluate problems and determine the best path forward for success. In my five years at SpaceX, I have leveraged these tools and successfully integrated them as the Responsible Engineer and Lead Engineer for numerous hydraulic, pneumatic, and electromechanical actuation systems.

My greatest successes have always been from simplification of any hardware, software, or operations. Still, complex problems sometimes require complex solutions – and I have found that a well-concerted multi-disciplinary approach spanning across teams is often critical to system success in these cases. I have experience in both engineering these myself and leading diverse engineering teams to success when faced with such problems.

I find it most fulfilling to provide guidance and help small teams achieve success in their audacious goals to achieve new feats, and I intend to support passionate mission-driven companies in their efforts.

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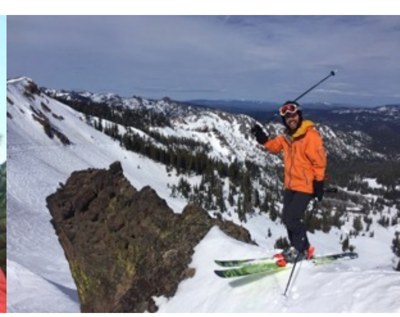
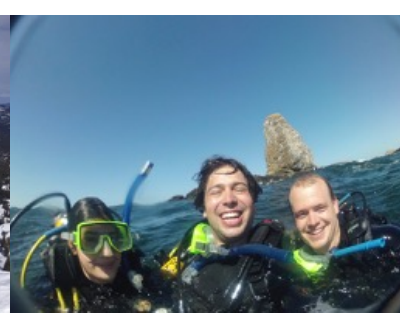
Outside of engineering, I love photography, and am an avid rock and ice climber, skier, mountaineer, sailor, free diver, and scuba diver. Not only are these sports immensely fun, but they're also incredibly interesting from an engineering and physics perspective. My engineering background helps me to be better at these sports and to appreciate their natural beauty.

In addition, I try to be as engaged and involved in my community as possible, so I led the recruitment effort of the Graduate Association of Mechanical Engineers at MIT, and have been heavily involved in the SpaceX recruiting effort as well. At SpaceX, I created a group to bring people together to improve information exchange on best practices and lessons learned regarding motor and electromechanical actuator design, which has proven to be both fun and educational.

This portfolio contains a small selection of the many awesome projects I've worked on. These photos and descriptions are meant to serve as a window into my world and to share with you my passion for engineering.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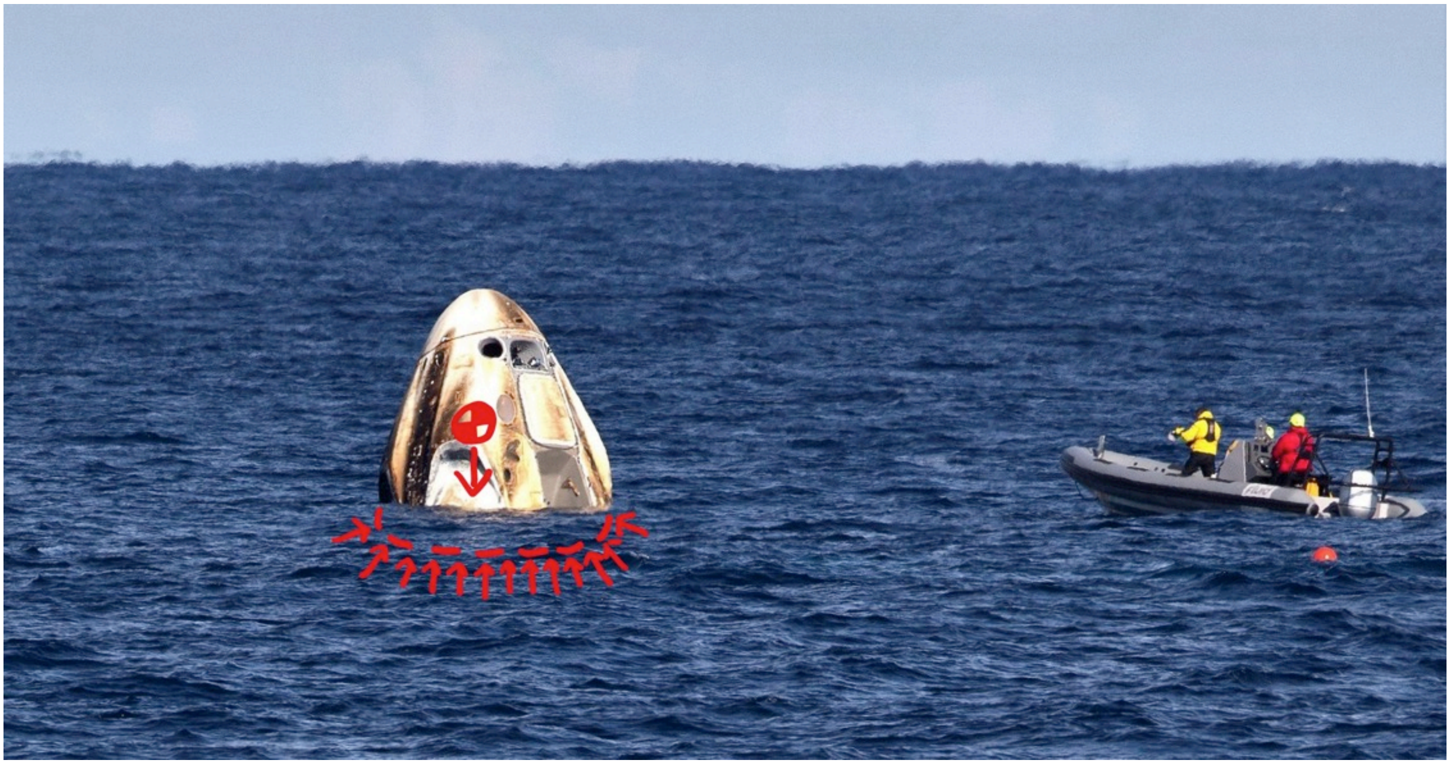

Caption: The Crew Dragon capsule floats in the ocean after successful Demo Mission 1. An approximate center of mass of the capsule is marked in red, with the gravity force acting downwards on it. Additionally, the buoyant forces are represented by the arrows acting on the underwater portion of the capsule. The relative location of the center of mass to the center of buoyancy defines the attitude at which the capsule sits in the water.

Dragon Water Ballast System

Lead Engineer – SpaceX

Objective: Ensure capsule remains in the upright Stable-1 position after splashdown, such that the crew inside is kept at a healthy angle with respect to gravity given their deconditioned state after being on orbit for months.

Project Details: After multiple previous methods of post-splashdown capsule stabilization had failed qualification, this project was one of the top combined technical and schedule risks for the Dragon program. The Director put me in charge of four engineers to solve the critical-path ocean stability problem on an aggressive timeline. We built models of the capsule stability points in the ocean, brainstormed from first principles ways to improve stability, and development-tested various solutions to retire risk and down-select to the final concept. Although we identified an unconventional system, it was based on simple physics principles and we quickly proved out each component of the system. Using scrappy test setups, we continued on to sub-system and ultimately full-scale system level tests to validate our models and ensure proper operation.

Results: We aggressively developed, qualified, certified, and integrated the system on schedule. I feel particularly proud of the system because of how successfully it combined components from multiple disciplines: fluid systems, specialized valving, non-explosive actuators, electromechanical pumps, soft goods, structure, and thermal protection – all uniquely designed and qualified by my team to the satisfaction of both in-house and customer requirements. This was the first system of its kind in many regards and has already served as an example for following development programs.

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Caption: One of the seats in the Crew Dragon capsule interior is shown above. One Seat Actuator is circled in red. The extension or retraction of this actuator results in the forwards or backwards tilting of the seat. Tilting the seat to the proper angle for any given phase of flight is critical to crew health and safety.

Dragon Seat Actuation System

Responsible Engineer – SpaceX

Objective: Ensure that the Dragon spacecraft's crew is kept at an appropriate angle with respect to the accelerations they will experience in flight, such that they do not experience any harmful health impacts of the sustained acceleration.

Project Details: Upon completion of my work on Falcon, I was pulled into the Dragon program by its new Director. He reassigned ownership of the troublesome Seat Actuation System to me in order to get it to the finish line. It became clear to me, immediately upon diving into the project, that it had not been set up for success. For example, I immediately performed CT Scan of a critical black-box vendor component and proactively identified an internal failure mode that would indeed result in qualification failure weeks later. This allowed me to start my redesign effort weeks early and get ahead of the problem. Similarly, through my identification of the project's critical path, I was able to pull schedule to the left by more than two months. In parallel, I worked across teams with Human Factors, Flight Software, Avionics Systems, and Space Operations to define the concept of operations (CONOPS) for the system, as well as the Fault Detection, Isolation, and Recovery (FDIR) strategy that had been previously neglected. Throughout this whole process, I worked closely with our NASA customer to ensure that their requirements were met and that the system would be easily certified.

Results: Since I took over the project and pulled in schedule, the Seat Actuation System remained off the critical path of the Dragon program. I have fully defined, developed, and validated both component-level and system-level characteristics to ensure robust operation in flight. In the process, I've built up a wealth of knowledge regarding actuation system design and component-level best practices, which I have shared with colleagues through the Motor Mongers group I started to ensure the success of similar programs.

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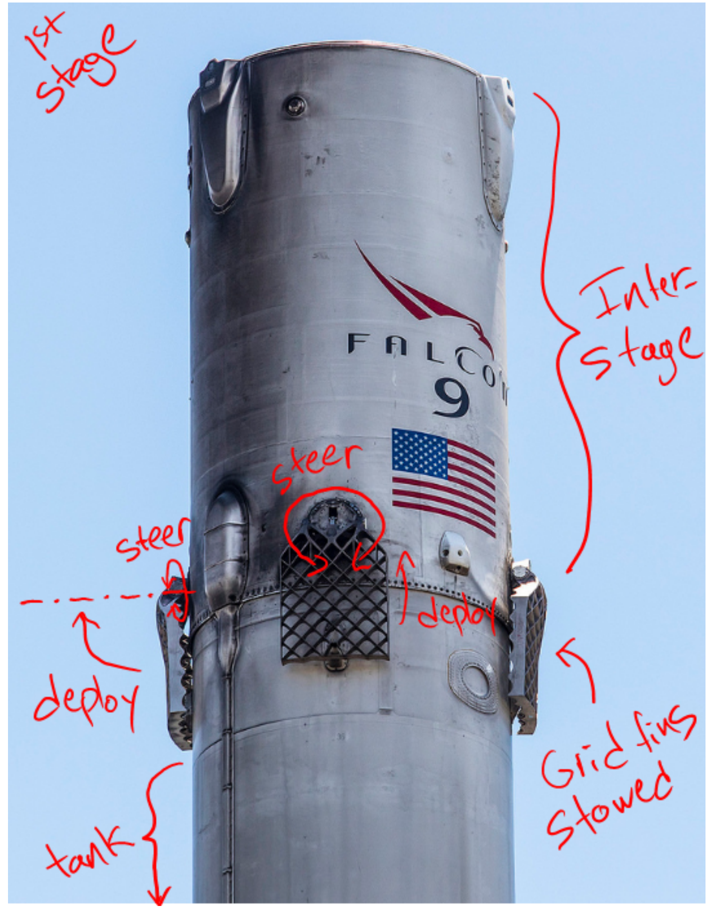


Caption: Gwynne Shotwell, the President of SpaceX, can be seen in the above left photo looking into the interstage of the Falcon 9 rocket. My four Grid Fin Actuators can be seen circled in red. These actuators connect with the Grid Fin Shafts and are used to steer the rocket's Grid Fins for landing. This is shown at right.

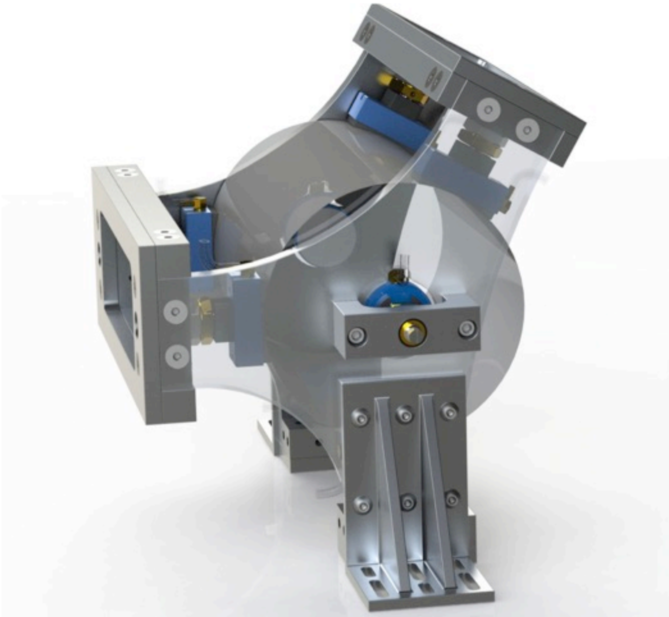
Falcon Grid Fin Actuators

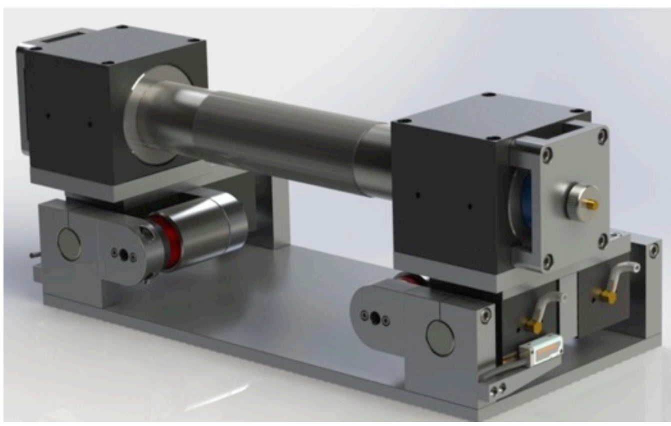
Responsible Engineer – SpaceX

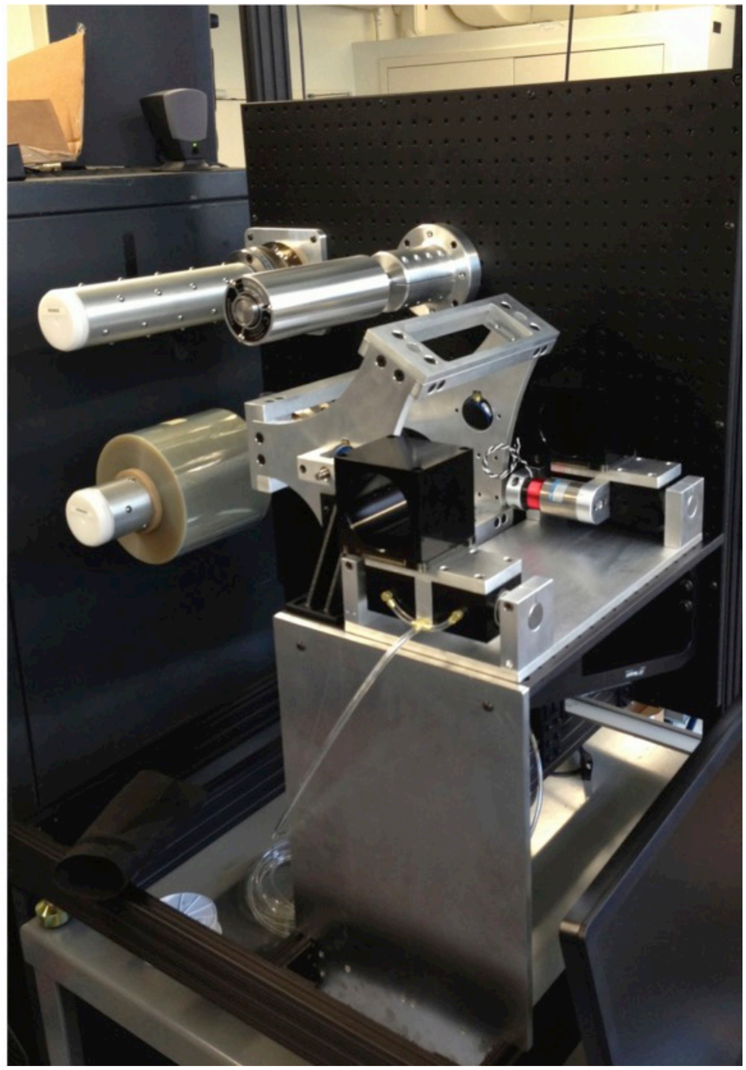
Objective: Design the highest-pressure hydraulic actuator ever made at SpaceX, used to control the Grid Fins that enable the Falcon 9 rocket to successfully land and be reused for future flights.

Project Details: To improve both reuse and reliability, I took on the project of designing a new Grid Fin Actuator to be implemented with a block change of the rocket. First, I worked with the Combined Loads Analysis and the Guidance, Navigation, and Control groups to understand what the load and speed requirements were for the actuator. Then, I worked with the Stage Fluids team to understand how to best integrate with the booster's hydraulic system. Once I gathered all the inputs, I used a combination of hand calculations, Excel workbooks, Matlab models, CAD, and ANSYS to design the actuator, then worked closely with Production and Test teams to build and qualify it.

Results: I successfully designed, developed, qualified, certified, and proactively built up a safety stock of Grid Fin Actuators all within one year of starting the project, staying well ahead of the demand schedule. The actuator met all requirements and has had a flawless flight track record. Additionally, the actuator saved $40k and 20 lbm per booster. Due to its immense capability, low cost, compact packaging, extreme simplicity, and proven reliability, the actuator has gone on to be used for other vehicle projects, and has served as a model for future actuator design.







µFLEX Microcontact Printing Machine

Research Work in the Lab for Manufacturing and Productivity – Massachusetts Institute of Technology (2014)

Objective: The goal was to design a machine that will demonstrate scale-up feasibility of a novel manufacturing process applicable to printed electronics and large-area surface modification.

Project Details: Microcontact printing is a process that uses a custom casted silicone stamp to print micron-scale features onto a substrate. It has been demonstrated in a variety of lab-scale settings, but my work was to design a machine to investigate how the process can be scaled up in a way that would enable large area, high rate manufacturing of engineered surfaces. Applications of this technology include flexible electronics displays, transparent conductors, distributed sensor systems, and bio-inspired surfaces. I designed the machine to print silver nanoparticle inks and self-assembling monolayers onto a 6” wide, clear, PET plastic film at a web speed of up to one meter per second. In order to accomplish this goal, I worked closely with two lab mates who were investigating electronics and cylindrical stamp casting.

Results: The machine served as the platform for my Master’s thesis, which was on the modeling of the continuous roll-to-roll print contact mechanics and the control algorithm used to give a robust process window. Due to the progress on the machine and the promise that it showed, the research grant funding was renewed and increased to allow for more researchers, who will then used the machine I designed as the platform for their continued research.

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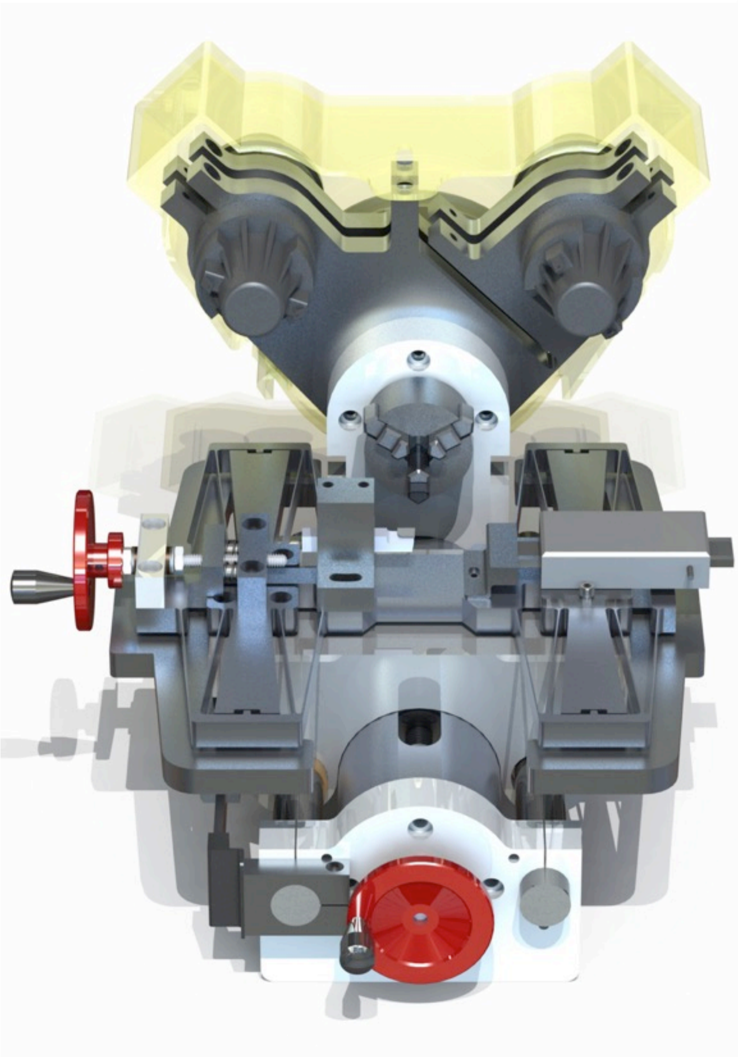

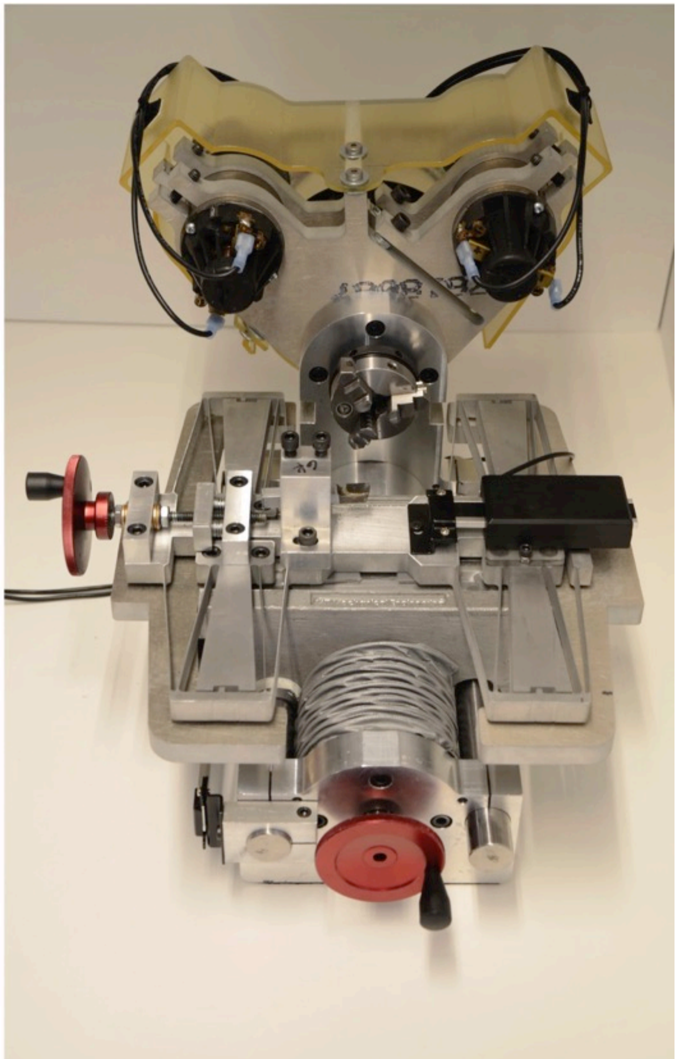

Precision Desktop Lathe

Elements of Mechanical Design Course Project - Massachusetts Institute of Technology (2013)

Objective: Our goal was to design and fabricate a desktop metal lathe capable of turning aluminum with high precision.

Project Details: I was appointed the "Machining Guru" of our group of seven students, so I took charge of most of the CAD/CAM work and oversaw the fabrication of every part in the lathe. For this project, we had to think critically about every parameter of the machine, as we needed to be careful to design for a given safety factor, but also not overdesign. The project was rooted heavily in analysis and FEA simulation, with every design decision needing to be backed up by calculations showing the expected stress, deformation, fatigue life, and thermal expansion. I learned a lot about power transmission, bearing selection, bolted joints, flexure design, and a variety of other elements of machine design.

Results: Our lathe was driven by dual 1/4 horsepower DC motors, had DRO position readouts, and was capable of turning aluminum and steel to a tolerance of 0.002". After demonstrating our lathe, it was put through the "death test" wherein the professor stood on top of it, dropped it from desk height, and hit it with a sledgehammer. Even after all that, it still continued to turn pieces to the same tight tolerance!

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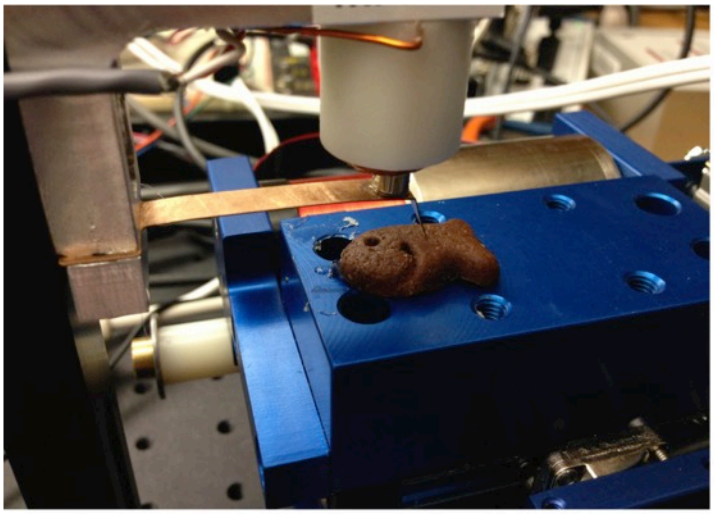

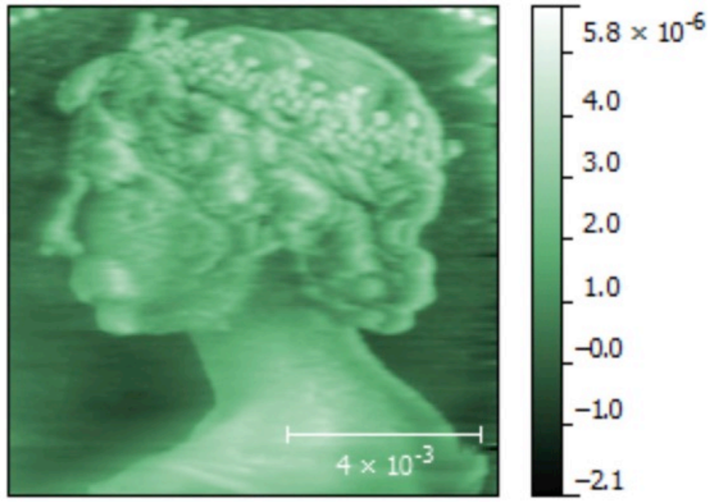

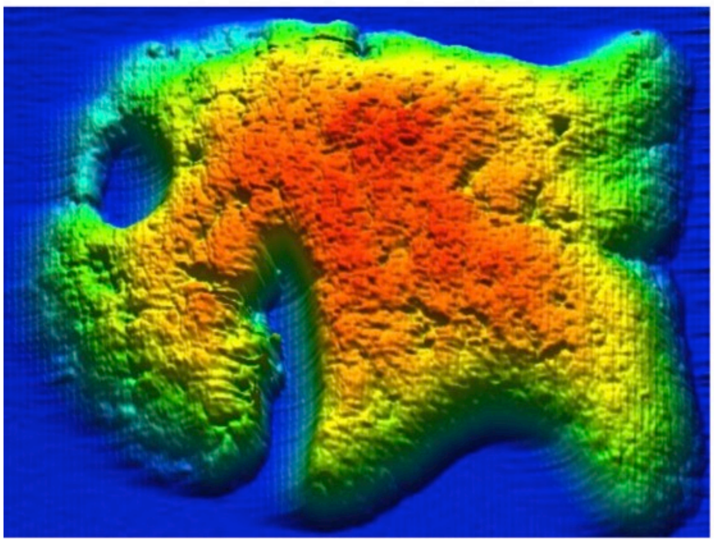

Macro-Scale Atomic Force Microscope (AFM) Profiler

Mechatronics Course Project – Massachusetts Institute of Technology (2012)

Objective: We each had to develop a control algorithm for an AFM to take a high-resolution 3D scan of the face of a coin.

Project Details: Using hardware developed for a mechatronics course, I coded a LabVIEW program and control algorithm for a macro-scale atomic force microscope (AFM) profiler. This project required interfacing with rotary and optical linear encoders, voice coils, a stepper motor, and various existing and self-made amplifiers. We did this with a National Instruments Real-Time Computer and FPGA. The AFM used an inch-long copper cantilever as the scanning probe, which was excited at its resonant frequency by a magnet and miniature voice coil. While the y-axis of the positioning stage was simply driven by a stepper motor open loop, the x-axis used a voice coil with an interpolating optical encoder for position sensing. We modeled the voice coil stage and used the loop-shaping method to create a suitable position controller for it.

Results: Using my control algorithm, the AFM was able to record the surface topology of various objects with micron resolution. Though scanning the faces of coins gave beautiful results, I also decided to try something a little different and scanned an Oreo cookie and a Goldfish cracker for my final report.

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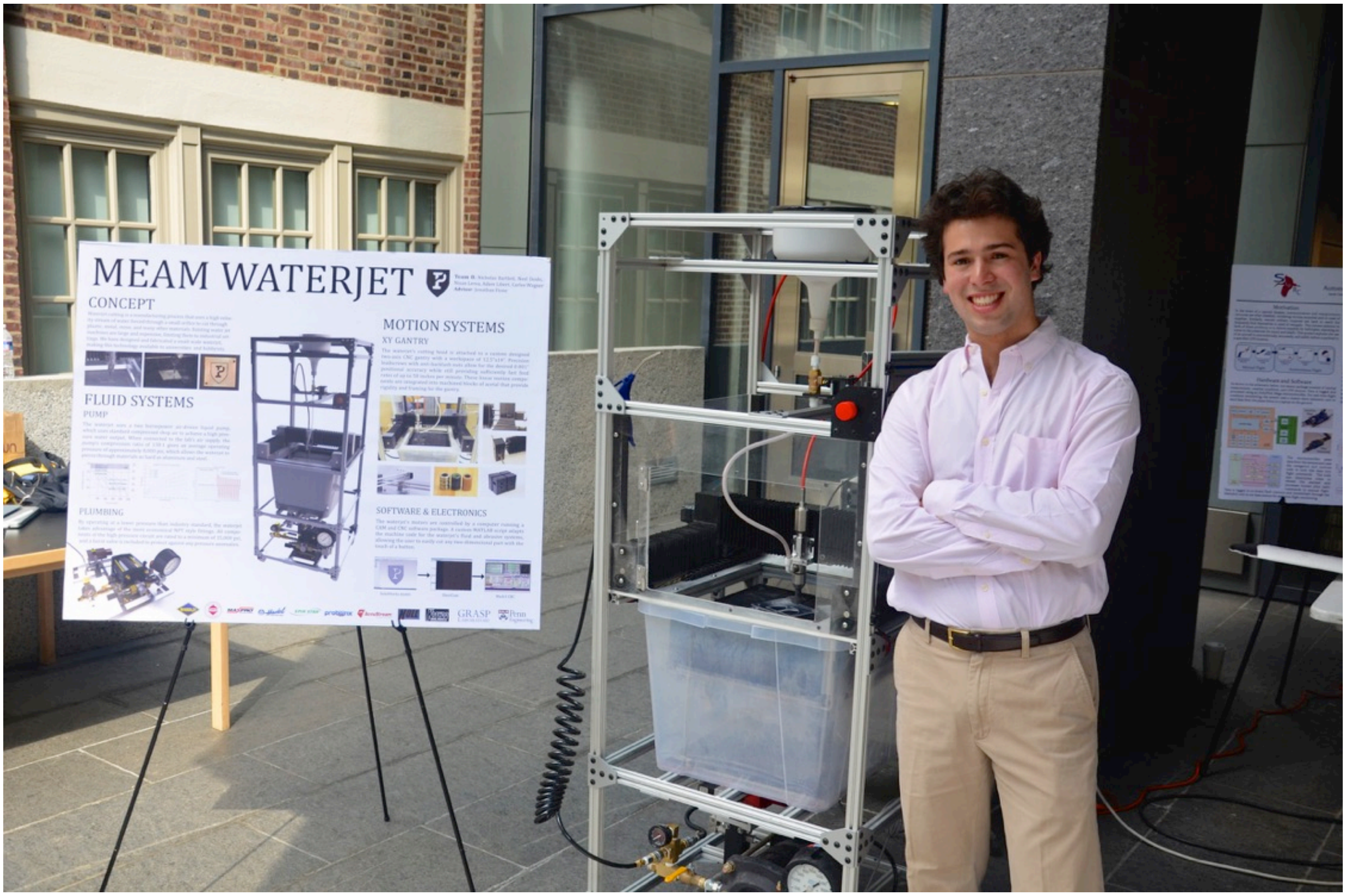

Hydro: The First Low Cost Waterjet

Senior Design Project – University of Pennsylvania (2012)

Objective: My team of five decided to create the first ever, small-scale, low-cost, and easy-to-use waterjet cutter, finally making this great technology available to hobbyists and small businesses on a budget.

Project Details: I was the lead mechanical designer on this project and custom designed a fully waterproof and environmentally sealed XY gantry that would be able to withstand the water and abrasive from the waterjet. The waterjet has a cutting work space of 12”x14” and yet the machine is entirely self-contained to a footprint of only 2 feet by 2 feet, meaning that it can be easily rolled through a doorway and fit in the corner of any room. As well, it requires only a typical electrical outlet and shop air supply to run, making it a feasible option for universities, hobbyists, and small businesses with a budget of $5000 or less. The waterjet is low maintenance, requires only minimal training to run, and is able to cut through 1/4” aluminum and 1/8” steel to a tolerance of 0.005”.

Results: This project won the Mechanical Engineering Senior Design competition, and each of us on the team was presented with the Gemmill Award for Outstanding Creativity. The project has since been successfully Kickstarted to raise $1.5MM of funding and become the company WAZER (www.WAZER.com).

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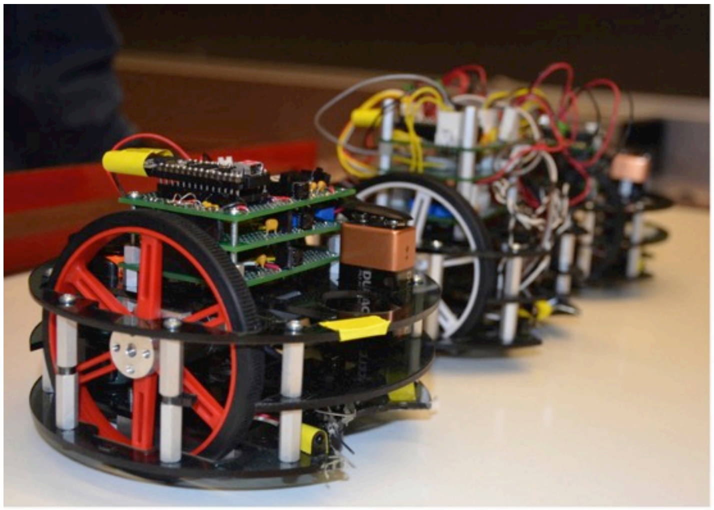

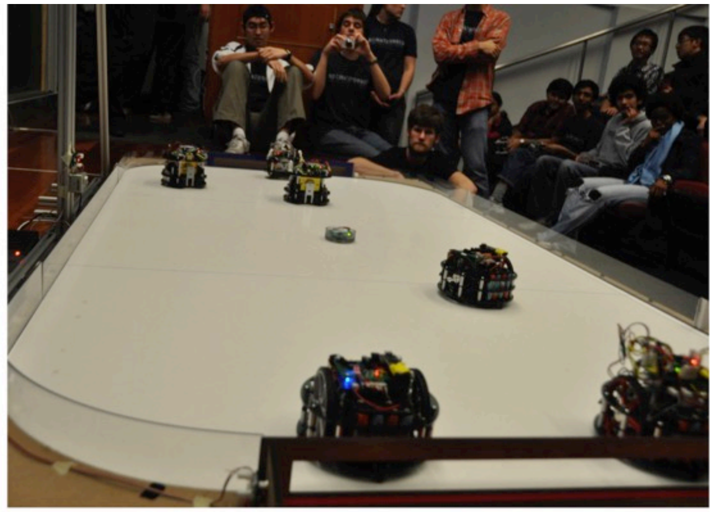

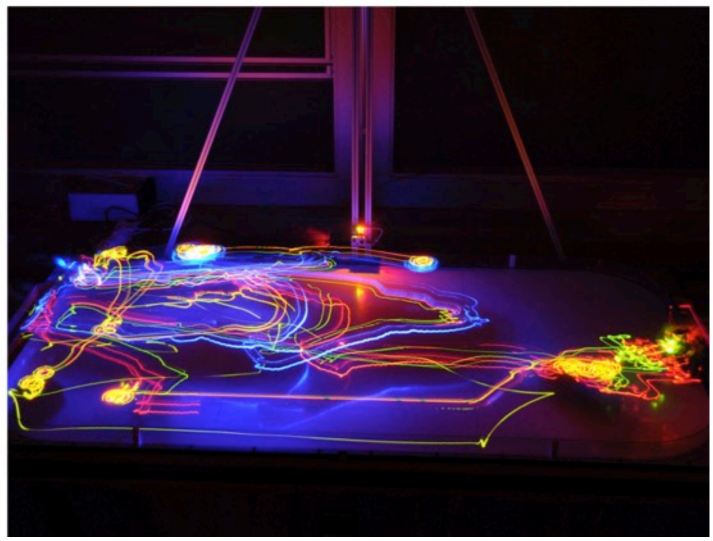

Robockey

Mechatronics Final Project – University of Pennsylvania (2011)

Objective: For the final project of this course, we created a team of three fully autonomous hockey-playing robots meant to compete against other groups' robots in the annual Robockey Cup.

Project Details: I led the mechanical design and did the coding for the robots. We used hacked Wii controller sensors aimed at the ceiling to compute each robot's position from a constellation of infrared LEDs overhead. As well, I positioned a variety of IR sensors around the circumference of each robot that gave them the ability to track the IR-emitting puck. Using just an Atmel microcontroller to process all this data, our three robots then wirelessly coordinated with each other to find the puck and escort it to the opposing team's goal. We built in an electronic solenoid to shoot the puck when the robots were close enough to the goal. Our most effective design choice, however, was to simply mount heavy steel blocks to the bottom of each robot, which gave them increased traction on the slippery plastic rink surface and allowed them to push through defending robots on the other team.

Results: My team's robots placed in the top four of the tournament bracket, beating out 20 other teams in the class. As well, the Robockey Cup was more exciting than most hockey games I've been to, with an entire auditorium of people sitting on the edge of their seats, screaming and cheering for their robots. After the tournament, we turned the lights off and I took some beautiful long-exposure photographs of the robots playing in the dark.

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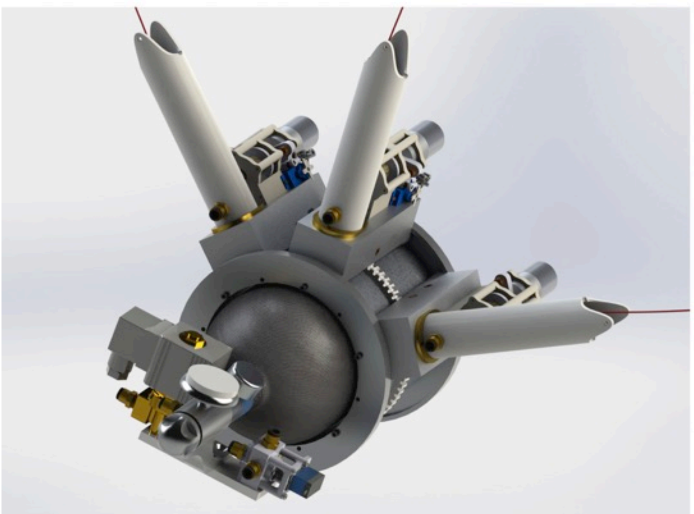

Spideybot

Research Work for the Modular Robotics Lab – University of Pennsylvania (2011)

Objective: The goal was to create a robot that could explore disaster sites that have too much rubble on the ground for wheeled or legged robots. For example, in a collapsed parking garage, this robot would be able to winch itself through, using exposed rebar, pipes, and conduits as it relays video back to a search and rescue team.

Project Details: I designed and prototyped the Spideybot, a spiderman-like robot that had the ability to pneumatically launch grippers at the ceiling and swing from one object to the next. Since the robot had to carry its own weight, the project forced me to think critically about factors such as material selection, power sources, and actuation methods. For example, instead of launching the grippers mechanically or electromagnetically, the robot was designed around a carbon fiber 4500psi compressed air tank, which was chosen for its high energy density and ability to easily launch the grippers. I also had to come up with a gait pattern that would allow the robot to swing from object to object while employing the least number of necessary grippers to keep the weight of the robot down. The design I came up with was inspired by my experience that summer at Six Flags. I designed a rollercoaster-like track to be circumferentially wrapped around the air tank for the three gripper-launchers to crawl along.

Results: I was able to get most of the sub-systems to work by the end of the summer, and I continued to serve as the team leader when new lab members were brought on to continue my work. After another semester's work, the Spideybot could successfully launch a gripper at pipes on the ceiling, grab on, support its own weight, and release from them.

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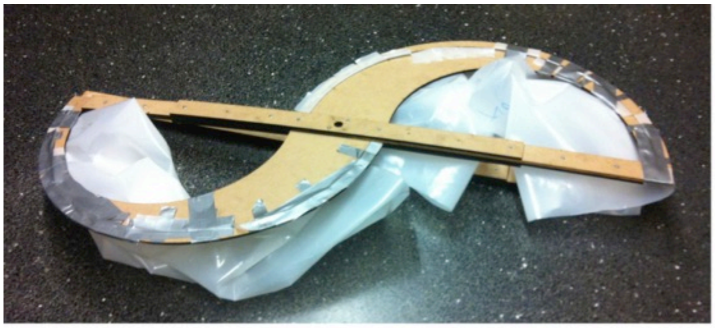

Shopping Cart Wind Turbine Contest

Design Lab Project – University of Pennsylvania (2011)

Objective: For a lab course project, teams of three were to design vertical-axis wind turbines that could be mounted in a shopping cart. The objective of the project was to compete with other groups in the goal to generate the most electricity when run down the length of a hallway, as measured by a microcontroller connected to the electrical generator.

Project Details: For this project, I created and tested various scale models in a 12” wind tunnel before the final two-scoop Savonius design was selected. We chose the Savonius design over the Darrieus design because it is self-starting and easier to construct, especially on such a limited budget. The final turbine that we used in the competition was made entirely from laser-cut MDF, plastic sheeting, and duct tape. The most difficult part of the lab was to determine the optimal gear ratio to maximize total power output from the system, which involved making an aerodynamic model of the turbine and comparing its efficiency curve to that of the motor for the expected shopping cart running speed. The determined gear ratio was too high for a single pair of spur gears. Most groups in the class had this same issue, but I was the only one to design a compound gear set that allowed us to achieve the gear ratio we wanted without an intermediate gear axis.

Results: The competition day was a lot of fun. The whole class crammed into a narrow hallway to watch each team push their shopping cart turbine down the hall as fast as they could. Our turbine placed fourth against more than 20 teams.

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Check: Custom CNC Chess Set

Advanced CAD/CAM Course Project – University of Pennsylvania (2010)

Objective: The motivation behind the project was to gain hands-on experience with the UPenn machine shop's new Haas TL-1 CNC lathe by designing and fabricating a custom chess set.

Project Details: I designed and fabricated this chess set with three friends for a course on advanced CAD/CAM techniques. Our team chose to give the set an abstract feel by distilling the pieces down to simple curves, while retaining the most essential elements of each piece so that they could be immediately recognized in gameplay. We machined the pieces primarily on the TL-1, with all secondary operations being done on a ProtoTRAK 3-Axis CNC mill. They were then sandblasted and sent out for clear and black hardcoat anodization. The chessboard was made from a milled plate of aluminum with inlaid press-fit black acrylic squares.

Results: The set was chosen to be in the 2012 Philly Works design show and is still out in the mechanical engineering display case in the engineering building at UPenn.

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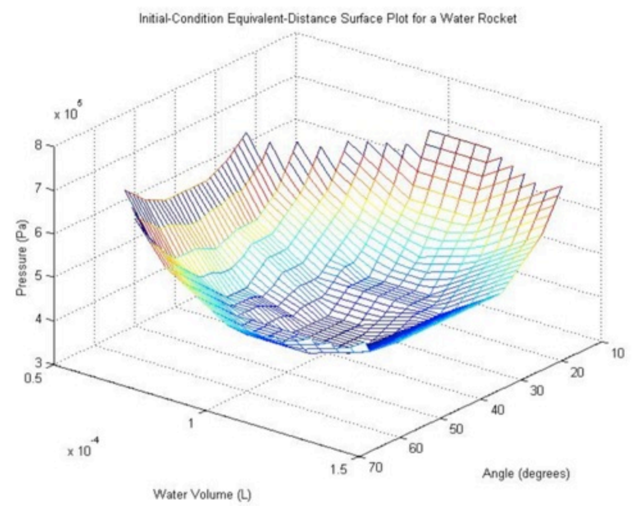

Launch! Water Rocket Contest

Engineering Lab – University of Pennsylvania (2010)

Objective: For this lab, we had to design a rocket body for a custom-made water-rocket engine, and we had to compute the initial launch conditions such that the rocket would hit a target located on the ground a specified distance away.

Project Details: I led a team of three in the design and construction of a simple body for the high-pressure carbon-fiber rocket engine. The launch variables we had control over were the amount of water in the engine, the pressure of the air in the engine, and the initial launch angle. However, the distance of the target was not given until the morning of the launch, and we were not allowed to test our rockets beforehand, meaning that I had to use MATLAB to create a full model of the rocket's dynamics, thrust curve, and flight path for any given launch variables. I noticed that, for any given target distance, there were a plurality of different launch parameters that worked. In order to determine which set of parameters was best, I used response surface methodology to find the specific launch conditions that would give us the least variation for any given target distance. This meant that, on the launch day, all we had to do was input a given target distance, and my script would quickly output the optimal launch angle, water volume, and air pressure.

Results: On launch day, we were given a target distance of 62 feet and our rocket landed less then 6 feet away from it, meaning that my rocket model was accurate to within 10%!

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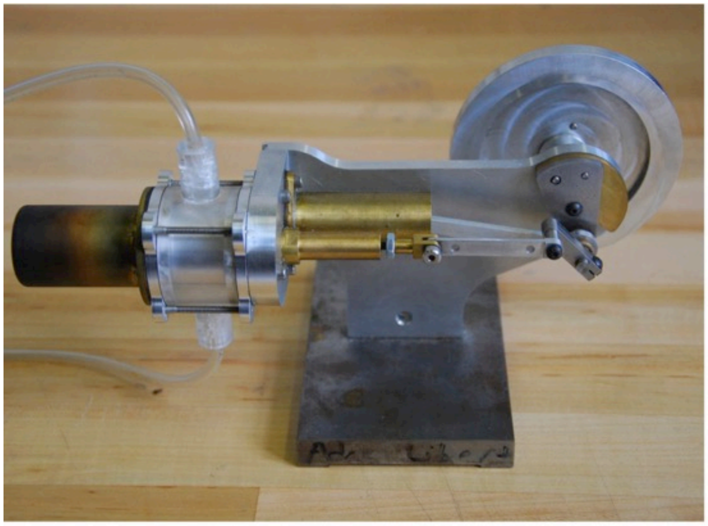

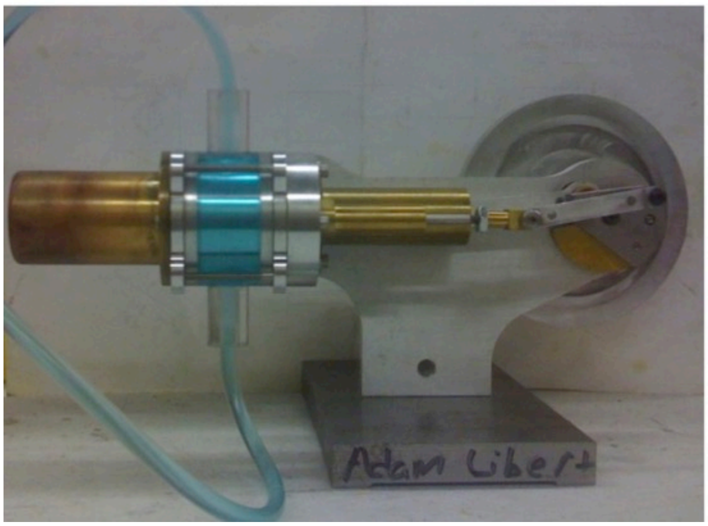

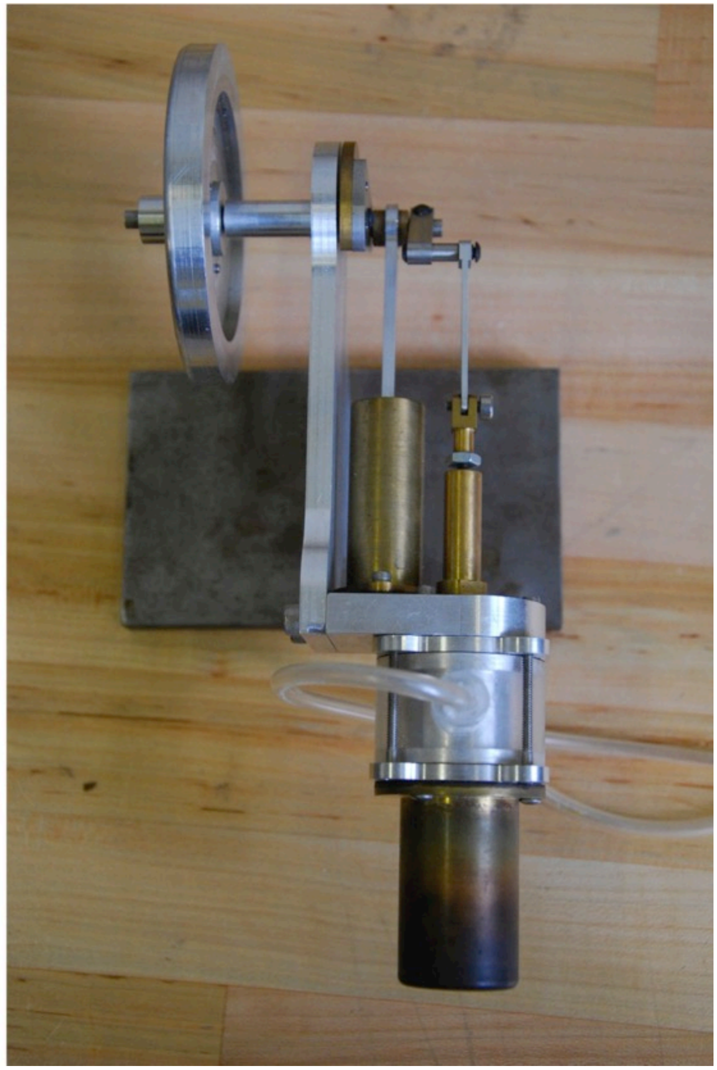

Stirling Engine

Mechanical Prototyping Course Project – University of Pennsylvania (2009)

Objective: The goal of this project was to fabricate a working Stirling heat engine from scratch.

Project Details: Stirling engines are neat devices, as all you need to do is place a little candle underneath them to make them run. The temperature difference between the flame-heated front part of the chamber and the air-cooled heat sink at the back of the chamber allows for an expansion and compression cycle to do work on the piston, which turns the flywheel. Because we were required to make nearly every part of the engine from stock material, I learned how to use manual mills and lathes, as well as CNC ProtoTRAK mills. Additionally, I gained an understanding of other, more specific manufacturing techniques, such as lapping and brazing.

Results: Using a butane torch, my engine reached 1037 RPM, and using a candle it was able to run at 600 RPM. In order to increase its speed, I decided to replace the air-cooled heat sink with a custom designed waterjacket that increased the temperature difference in the engine. Using a basic siphon to flow water through the jacket, I ran the engine again and it maxed out above 1200 RPM. Because of my strong performance in the course, the professor asked me to be the TA for it starting the next semester, my sophomore fall. As a TA, I helped the professor to redesign the course in such a way that the students could customize their engines in countless different ways, and we started to get some really creative and beautiful results.