Chris Magoon

Design Portfolio

My name is Chris Magoon. I grew up in northern Connecticut and the woods of Vermont. I'm an engineer, artist, longboarder, and videographer... Really, I just love to make things, whether I'm working on a CNC lathe to make parts for a new camera rig, hand carving a custom longboard form, or painting a sunset view.

I like to understand how the things that I use work, and to figure out if I can make them better. I won't stop designing, building, and testing until I've created something I'm truly proud of.

This portfolio is a collection of just a few of the design projects I have worked on while a student and instructor at the Thayer School of Engineering. You can find more projects, including my art, videography, and longboard design work on my website at www.ChrisMagoon.com

Chris Magoon

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The TibFinder ™

An Intra-Osseous Needle Placement Guide

Thayer School of Engineering, Winter 2015

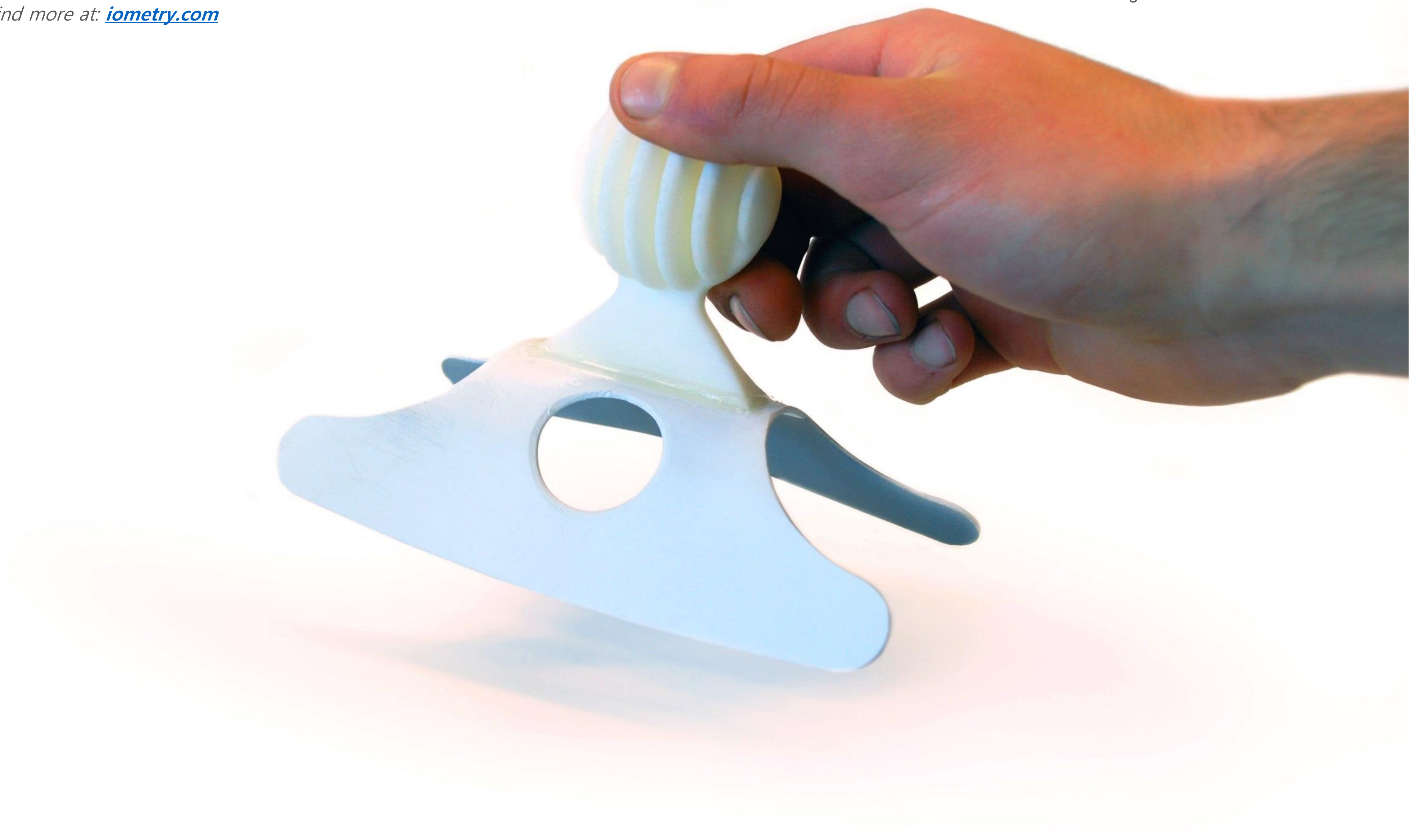
Lead Designer, Cofounder

This product has not been cleared for use by the US FDA

Find more at: ***iometry.com***

Tools and Techniques

Iterative Prototyping
Medical Device Design
Human factors, ergonomics
User manual design
User testing

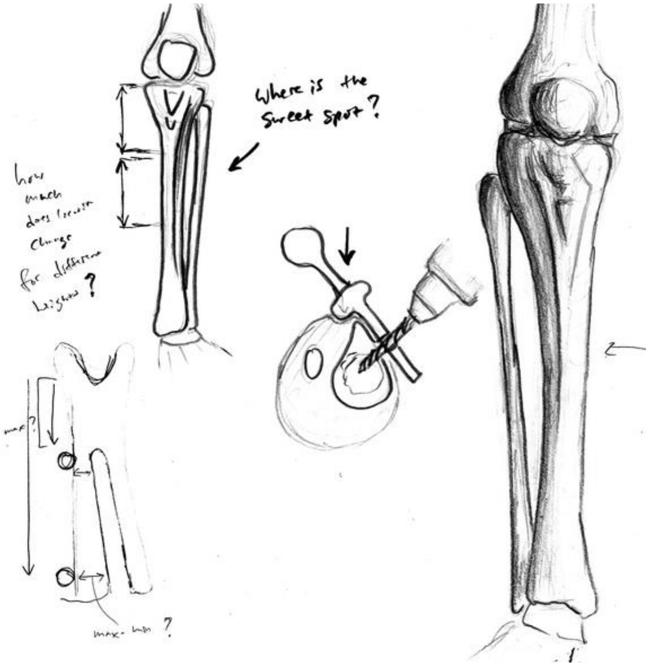


Stage I: The Challenge

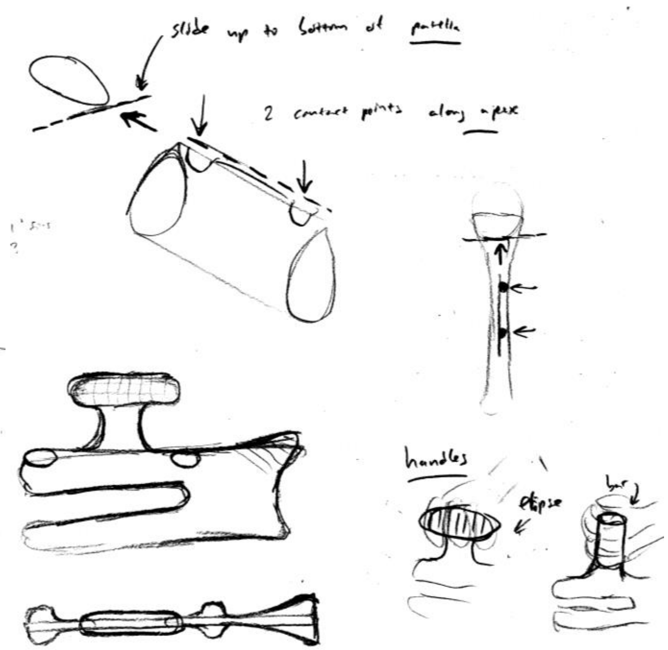
How can we make intra osseous infusion simple enough for anyone?

While working as the Thayer School Design Fellow, I worked in a team of students, graduates, and professors to design a simple guide that would allow a non-medically trained user to safely and reliably place an intra-osseous needle in the tibia. An intra-osseous (IO) infusion allows fluids to be introduced directly into the marrow of a bone, which is a faster and more reliable way to administer life saving fluid to severely dehydrated patients than a standard intra venous (IV) infusion.

In an IO infusion, a unique self drilling needle is drilled into the bone using a handheld drill. Fluid can then be infused directly into the bone marrow. **The critical step in the process is locating the correct insertion site. Our goal was to make a guide to allow this spot to be reliably found by minimally trained users.**

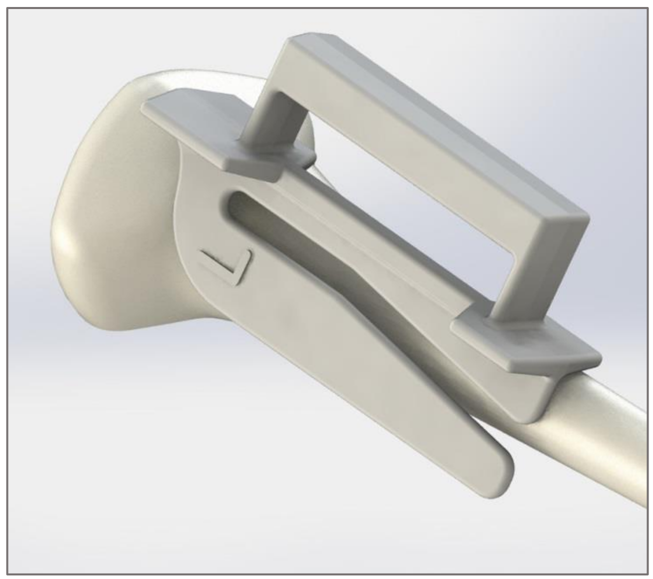


Sketching the bone geometry of the knee to understand where our target zone is



Sketches of an early slotted design

Day 1: First foam core prototypes
Here I'm testing an early design for fit on my leg. I made over a dozen foam core and laser cut acrylic prototypes in the first stage of design iteration.



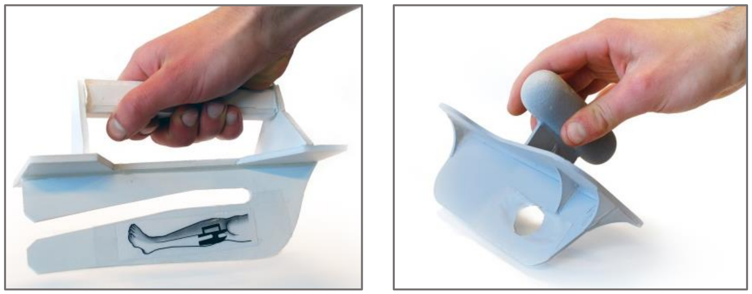
Day 4: Injection Moldable SolidWorks model
I made SolidWorks models of many of our designs to test possibilities for injection moldability and to demonstrate our design progress to potential sponsors. This early concept has a long slot for the potential of different insertion sites

Day 7: Testing in the Simulation Lab
We tested our final 3D printed design in the Simulation Lab at Dartmouth Hitchcock Medical Center. Here, Alex demonstrates using the guide to locate the insertion site on a testing mannequin.

Stage II: Design Iteration

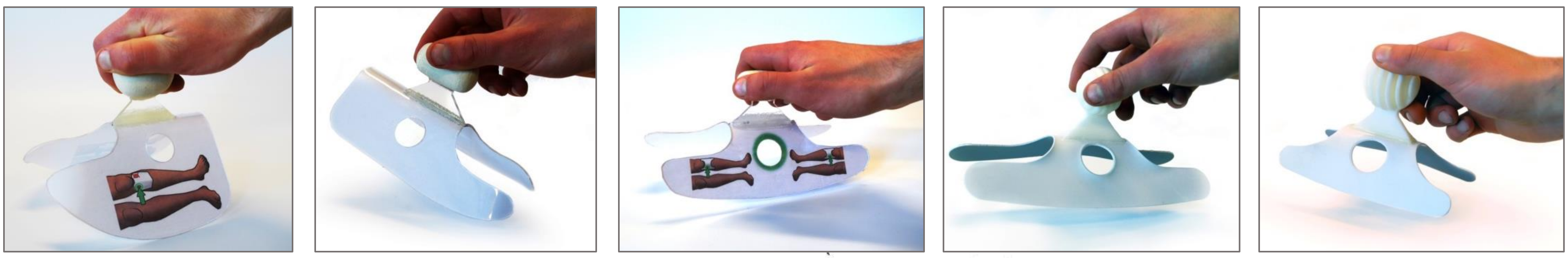
After receiving funding for further development, we entered Stage II of the project. We expanded the team, pulling in several graduate and undergraduate engineers to help with testing and to bring fresh design insights to the table. We began by reopening the design space to explore new design concepts.

After initial brainstorming sessions, I took the lead on fabricating dozens of prototypes, rapidly iterating through designs. In our weekly meetings, we would discuss my new iterations, perform informal testing, and determine areas to improve or modify. In this way, we were able to rapidly advance the evolution of our designs.

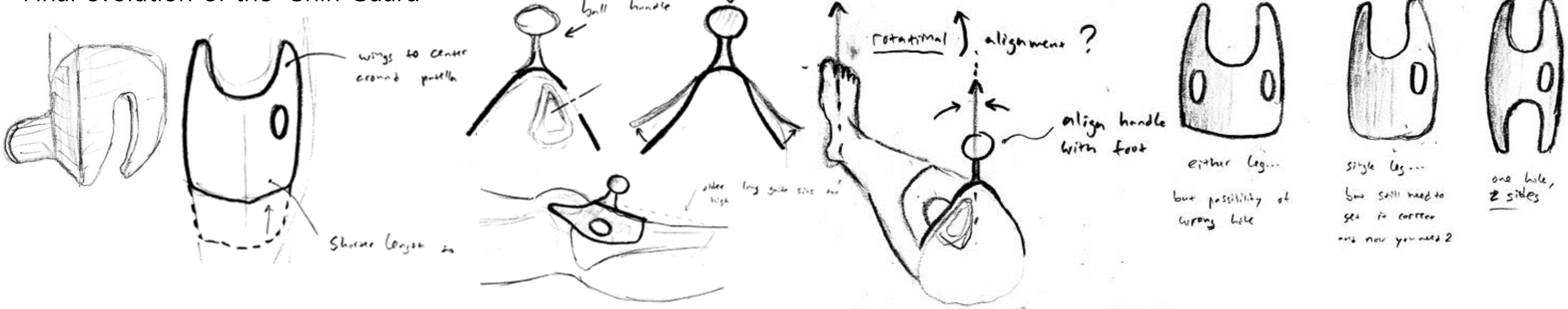


The "Ice Skate" design progressed from its phase I configuration to a much more refined state in phase II, leading to the "shin guard" design

I fabricated dozens of prototypes for testing and analysis on our path to a final design



Final evolution of the "Shin Guard"



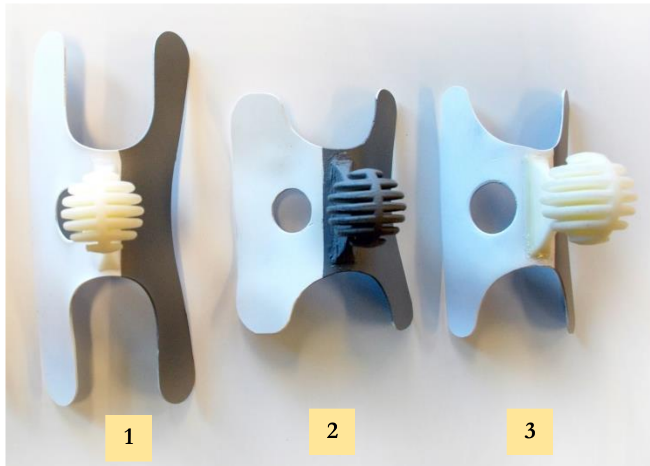
User Testing

Our user testing was conducted to guide us through our final design changes on our prototype and our user manual. I built our test setup using an EZ IO training leg and a mannequin. The training leg has a removable tibia section with realistic skin patch to simulate drilling through tissue into bone. The accuracy of each user's insertion was measured on the target area. Participants were given an IO kit, our guide, and our manual with no other directions given.

Steven Reinitz demonstrates the user testing setup

Progression of final design through iterative user testing:

1. *Long alignment wings*
2. *Widened patella slot and shortened wings and flattened curvature*
3. *Final design with short wings, a slightly reduced patella slot, and tightened curvature*

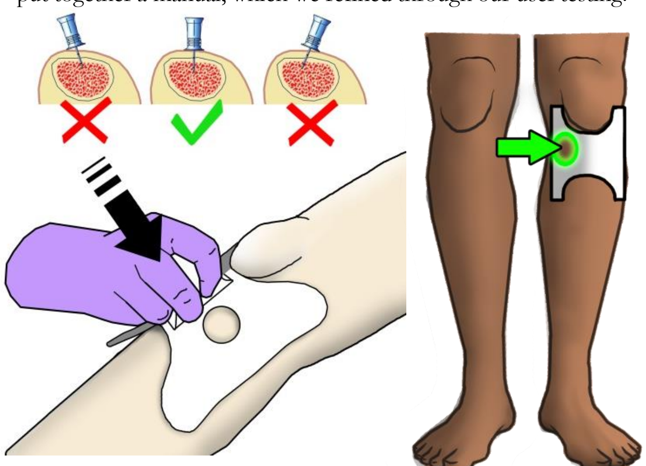


The first design we tested with had long alignment wings, making a snug fit but required firm pressure to flex the guide and properly seat it in place. Users were apprehensive of applying this much force to the device, so we widened and shortened the alignment wings, and opened up the overall curve of the guide. Users were able to properly use the guide, but it was possible to easily rotate the guide on the leg, resulting on improper alignment.

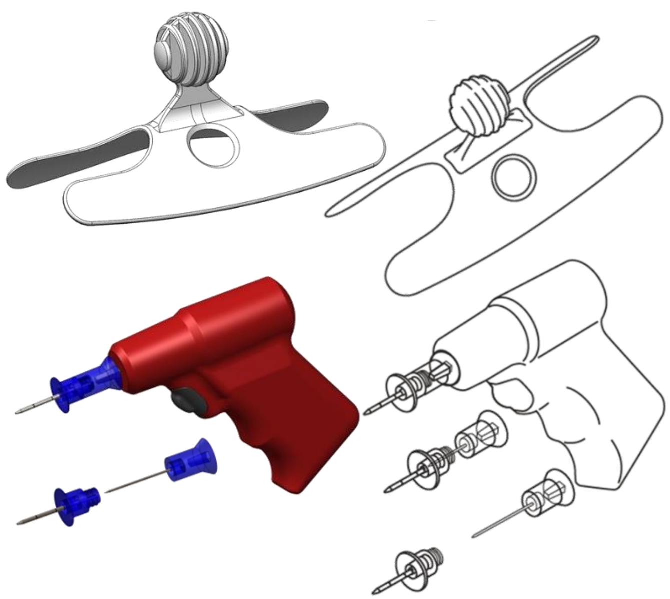
For the final iteration, we kept the short, wide alignment wings, but tightened the curvature of the guide to require some force to seat it against the leg and provide correct alignment. This combination was successful in testing; paired with our revised manual, users showed excellent success in accurately locating the target site and properly inserting the IO needle.

Manual Design

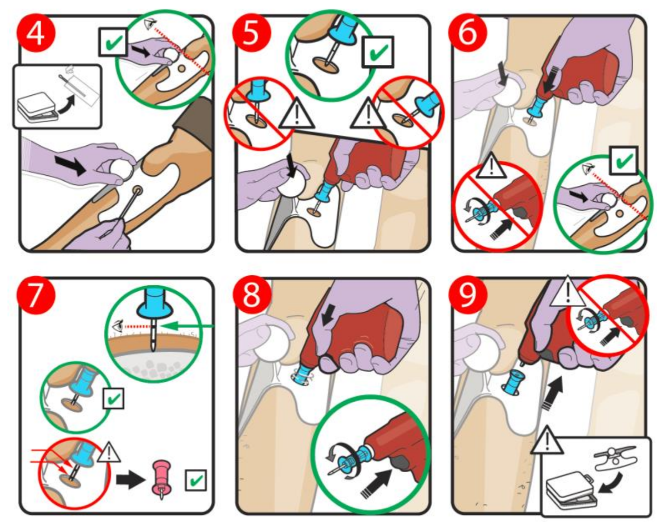
We turned to Funnel Inc., a graphic design firm specializing in manuals and infographics, to design our manual. We provided their designers with photos of the proper use of the guide, detailed SolidWorks models I had made of the guide, IO gun, and needles, as well as my manual concept drawings. Funnel put together a manual, which we refined through our user testing.



Some of my manual concept art



Funnel Inc used my SolidWorks models of our prototype and the IO driver to create accurate pictorial representations



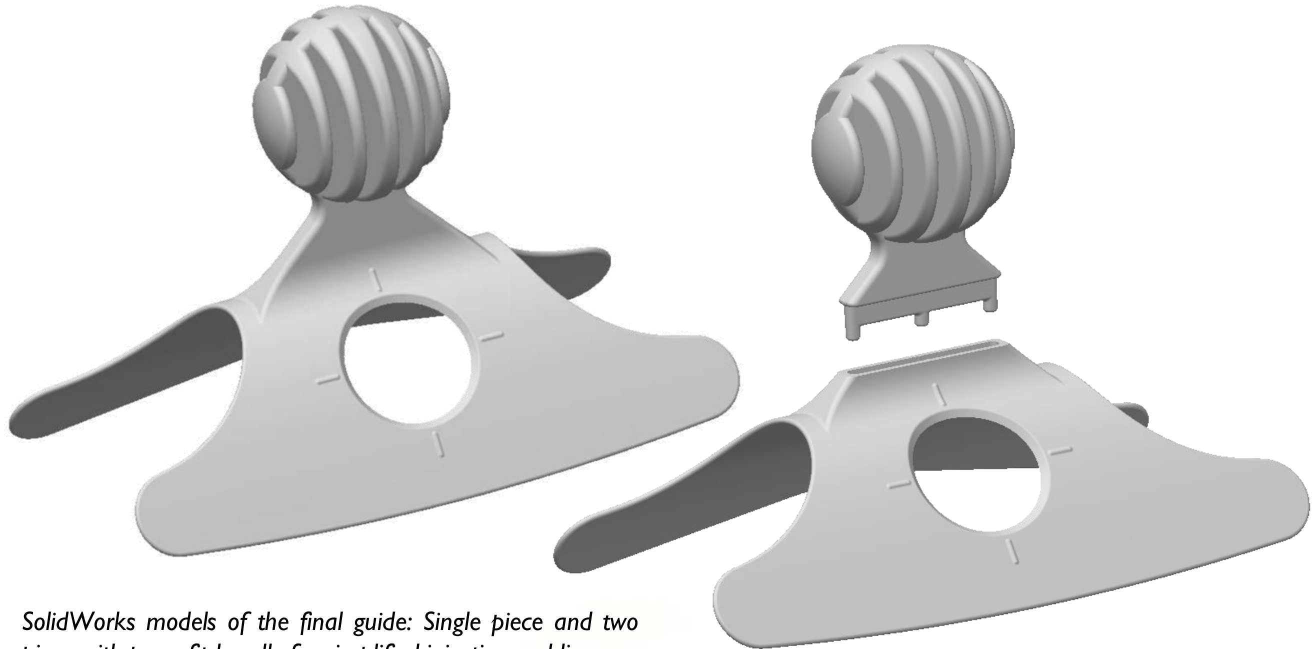
An excerpt of the final manual design. After Funnel Inc gave us their final manual we continued to modify the design, guided by our user testing. The full manual may be found here.

Finished Product

In addition to my handmade prototypes, I worked on modeling the guide in SolidWorks and ensuring the design could be injection molded. I created one version of the guide as a single piece, which would require a 3 part mold. I also made a version with a separate handle that could be made with only a 2 part mold. We worked with ProtoMolds to get feedback on our designs and cost estimates for manufacturing.

I fabricated several identical final prototypes for user testing. The main body of the guide is a sheet of ABS milled to shape on a CNC mill, then thermoformed over an aluminum mold. The 3D printed handle is bonded to the molded sheet with a flexible thermoplastic adhesive, allowing the guide to flex without breaking the glue joint.

My work on the project concluded in March 2015. However, the Tib-Finder project continues today with external funding and is moving through the regulatory and manufacturing pathways.



SolidWorks models of the final guide: Single piece and two piece with press fit handle for simplified injection molding

The TibFinder ™

Round handle for secure, omnidirectional grip

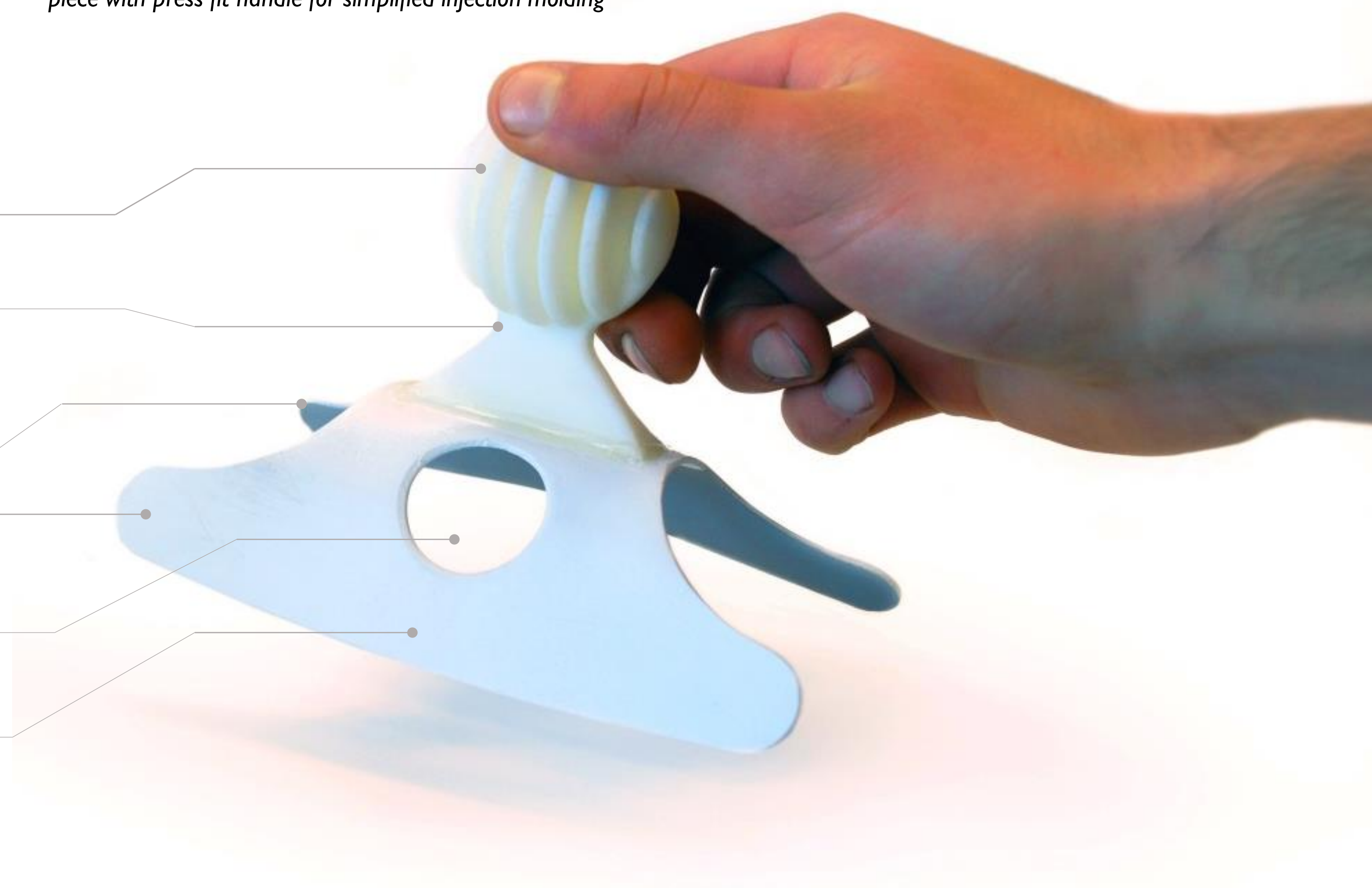
Handle offset from guide to reduce any chance of patient contact

Curved shape flexes to fit snugly on leg

Wings align guide on patella

Target hole sized to accommodate IO needles

Hole placement based on anthropometric measurements



Di-wheel

Unconventional human powered vehicle

Computer Aided Mechanical Engineering Design, Spring 2013

SolidWorks Lead

Tools and Techniques

SolidWorks, FEA analysis
SolidWorks Composer
MIG Welding
CNC Plasma Cutting
Machining

The Challenge

Design and build an unconventional vehicle in only 4 weeks

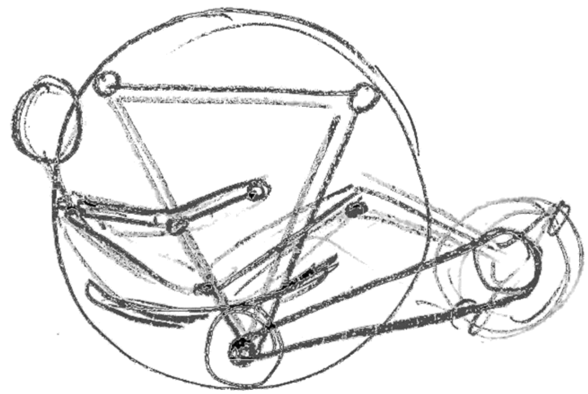
For the final project, we were challenged to design and build a pedal powered diwheel, a wheeled vehicle where the rider sits within a pair of large hoop wheels. This was the first year this project was done; even our professor didn't know how well it would work out. In a team of 4 with nothing more than salvaged bike parts from two bikes, two steel wheels, and limited materials for the frame and other parts we needed to have a functional diwheel ready to compete in a class race in 4 weeks.

We only needed 3 weeks to get rolling. And we won the final race by a longshot. How did we pull it off?

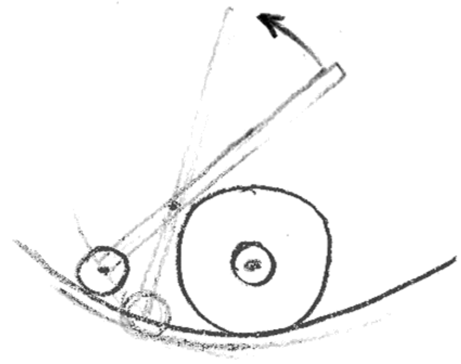
With such limited time, there was no way to develop and build multiple prototypes. We had to do all of our design iteration in SolidWorks. Beyond that, we had to plan on being fast and flexible, adapting to design challenges and overcoming them on the fly.

Getting Started: Keep it simple

The central challenge of controlling a diwheel is steering, which requires differential driving of the wheels. We considered traditional mechanisms of a differential or a pair of disk or belt clutches, but wanted something that was much simpler. In our brainstorming, we came up with the idea of using the drive wheels as a sort of clutch, with a lever on each side to lift them off of the hoop wheels, which would allow the diwheel to pivot around the disengaged side to turn. Once I tested the feasibility of the mechanism in SolidWorks I used a flexible base sketch to create the frame, allowing easy changes to geometry and rapid design iterations.

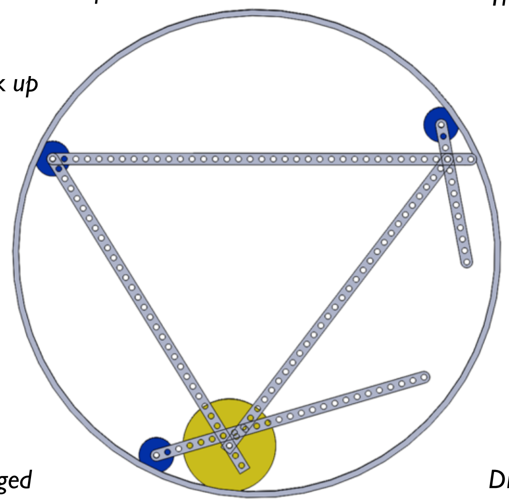


How to fit a rider into the frame

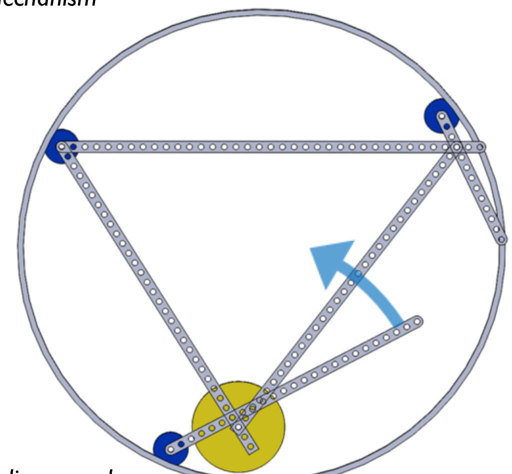


The lever mechanism

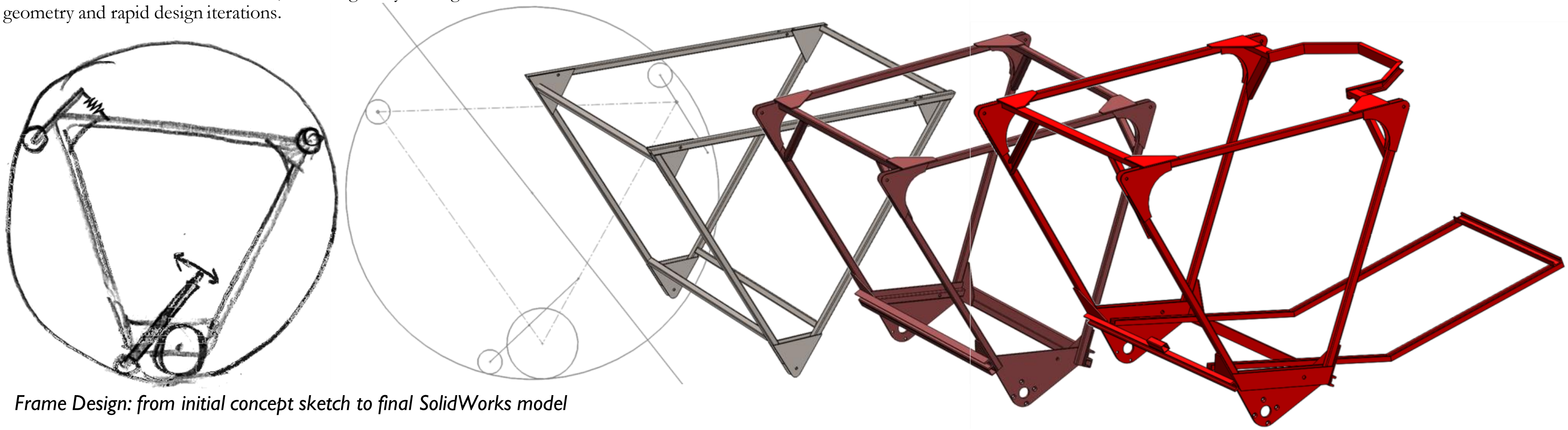
SolidWorks mock up of the simple lever steering mechanism



Drivewheel engaged



Drivewheel disengaged



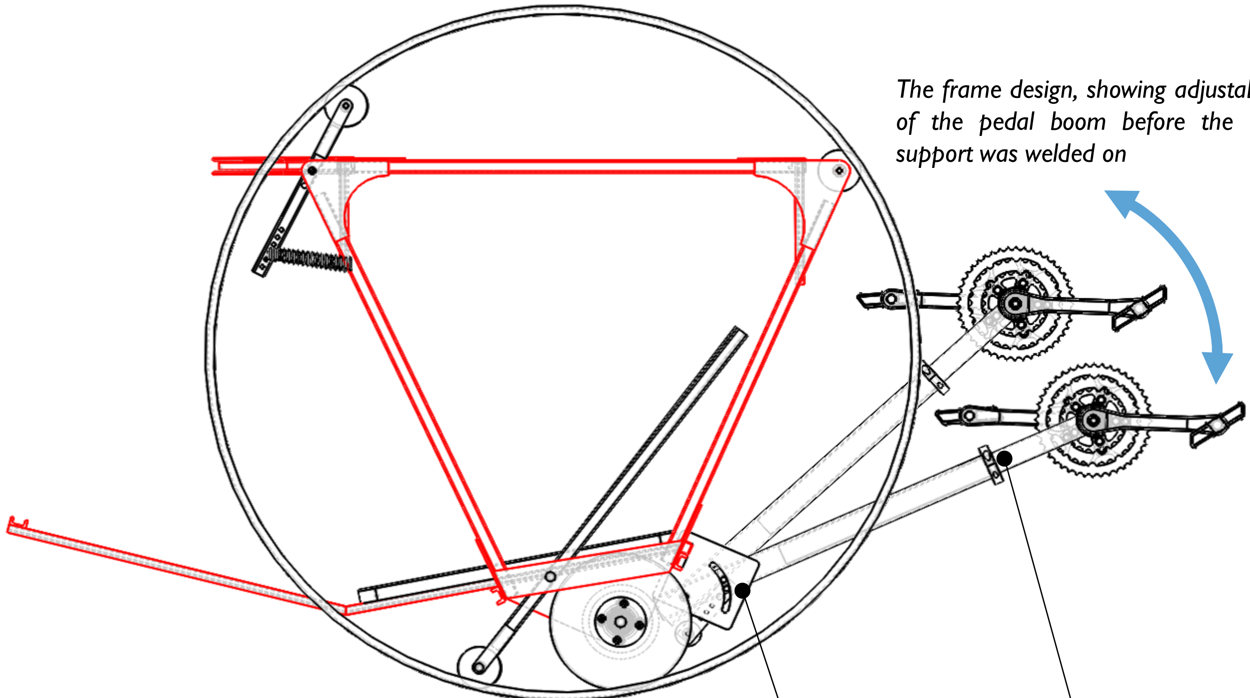
Frame Design: from initial concept sketch to final SolidWorks model

Flexible Design

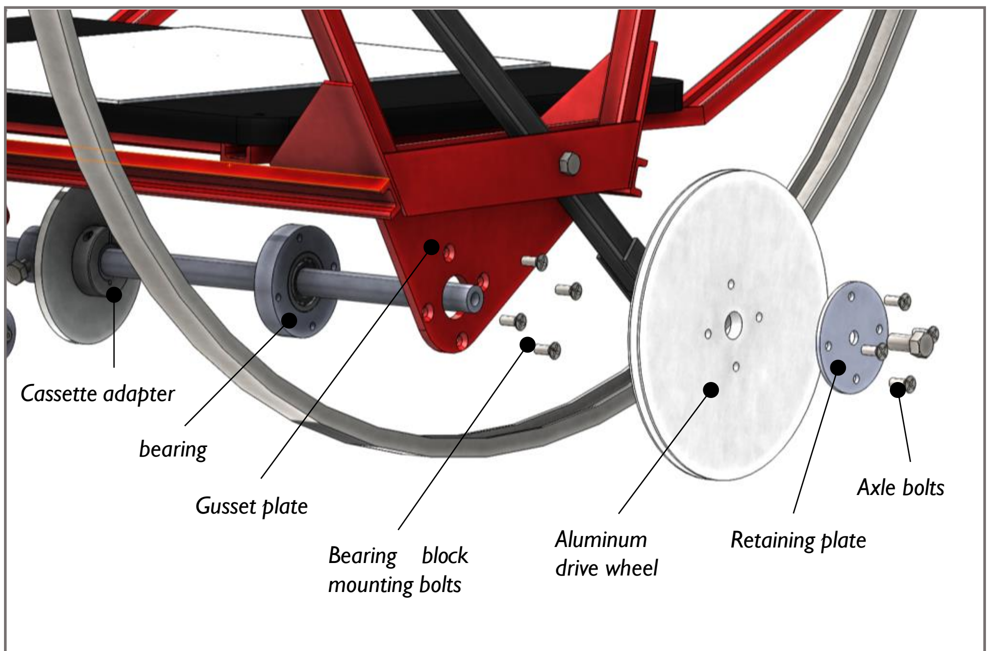
With over a foot of height difference among our team members, we knew getting the right pedal and seat geometry would be a challenge. We designed the frame so we could adjust both the angle and length of the pedal support. Once we found a position that worked for all of us, we welded the support in place with another structural member, forming a sturdy triangle.

Design for Fabrication

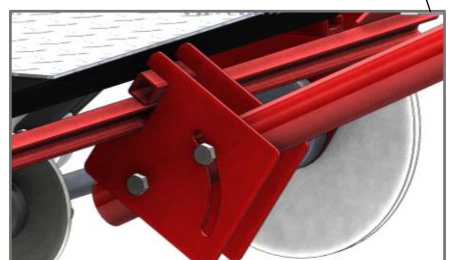
With limited time, we needed to limit the complexity of fabrication and assembly required to get our diwheel rolling. Our design has only 3 different machined parts: the aluminum wheels, bearing blocks, and a cassette hub to attach the bike cassette to our fixed axle. Everything else was CNC plasma cut or cut on a bandsaw. I designed the frame so it could be easily welded without requiring any jigs or measuring, using only the plasma cut gussets for alignment. We managed to get our diwheel to a rideable state in only 5 days of fabrication.



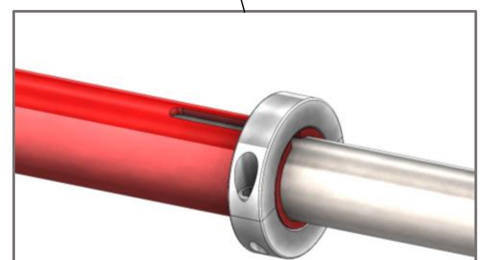
The frame design, showing adjustability of the pedal boom before the final support was welded on



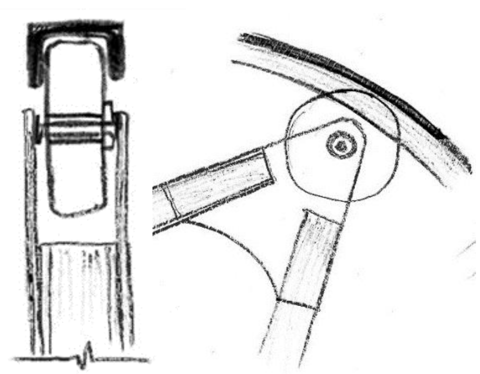
Exploded view of one side of the fixed axle drive line



Pivoting pedal boom base



Adjustable length pedal boom



The plasma cut corner gussets give solid weld points for the structural members, align the members for assembly, and serve as brackets for the idler wheels.

Ready to Roll

We took our mantra of working fast and flexible seriously. With a plywood seat, some hose clamps, and a pair of vice grips we tested riding our frame as soon as we had the main parts together. We realized that the rear cross member was in the way of where the rider's head needed to be while decelerating. We were easily able to cut out and add a new bent member to the frame, which now served as a head rest.

Having our diwheel rolling a full week before the race gave us plenty of time to fine tune the drive system. We tried different gears and adjusted chain tension to get optimum power transfer. **Our simple, rugged design came through; we won the final race and were the only team to not have any mechanical failures during competition**.

A year later my teammate Scott and I worked as teaching assistants for the class, helping another class of students build their own diwheels in addition to developing, testing, and managing the other smaller class projects. Scott joined the class on race day in our diwheel, making second place out of 7 teams. In the third year of diwheels, all teams designed drive systems that relied on a differential for steering. Even against this new generation of highly efficient drive systems, I held my own in the Scorpion which was again the second fastest diwheel on the course.

The diwheel ready for its first test ride.

Year 1: Rob holding the lead in lap 2 of the race

My video of the 2013 race

Year 2: Scott about to take the lead in our second race

My video of the 2014 race

*The Scorpion:
going on 4 years old
and still riding great*

Ballast Mount Solar

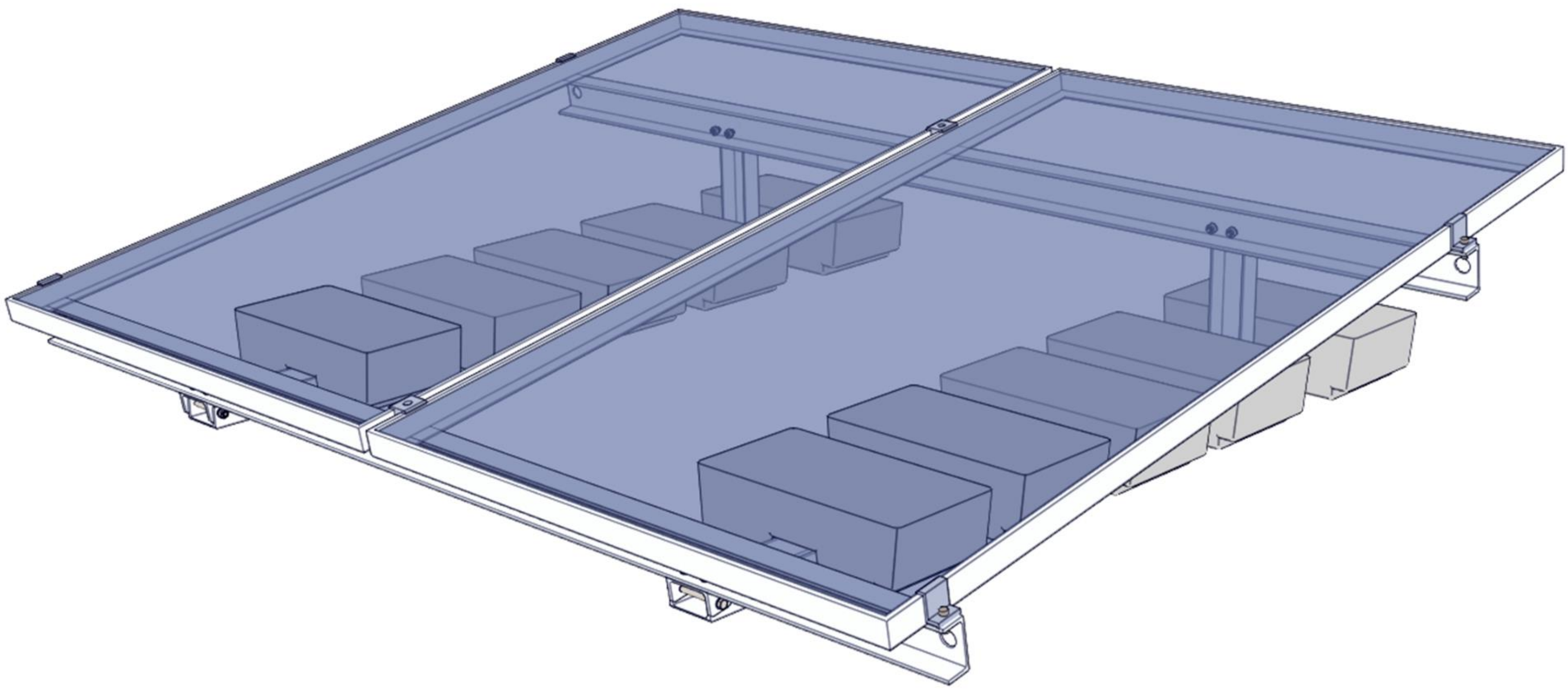
Simplifying the installation of Solar PV on flat roofs

Engineering Design Methodology / Norwich Technologies, Fall 2013-Winter 2014

Project Manager, Lead Designer

Tools and Techniques

SolidWorks, FEA Analysis
SolidWorks Composer
ASCE Building Codes
Machining and Fabrication
Concrete Casting



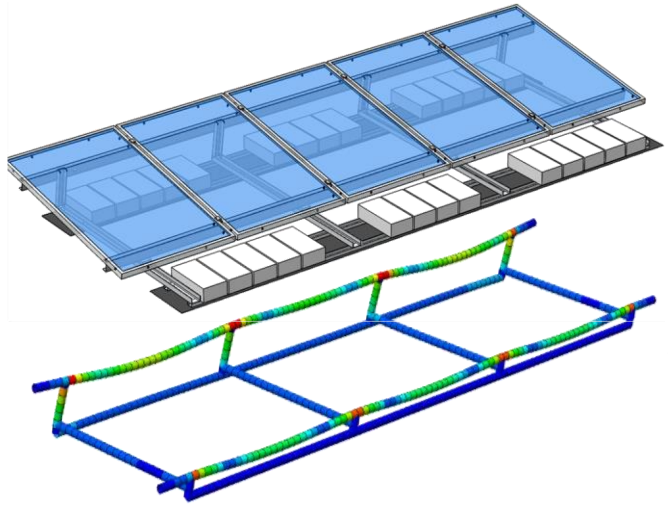
Project Overview

I worked in a team of three to design, build, and test a new low-cost ballast mount system for Norwich technologies, a local solar company. Our project sponsors wanted a mount that was both simple to manufacture and easy to install.

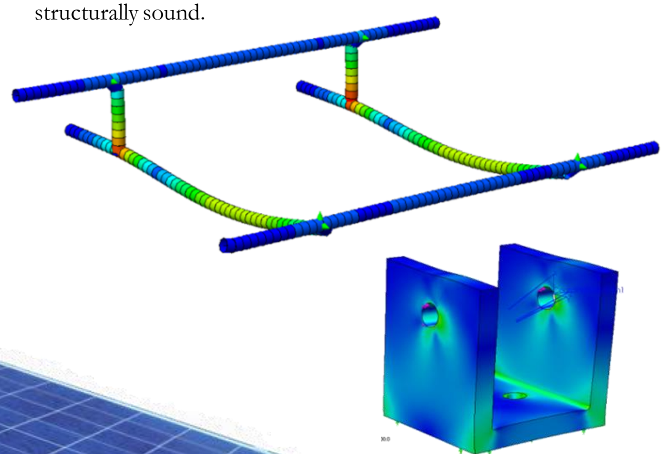
Ballasted Mounts use only weight to hold solar panels on flat roofs. This weight must hold the mount down against wind loads, but not overload the roof structure. The panels are held at an angle to improve efficiency and shed snow.

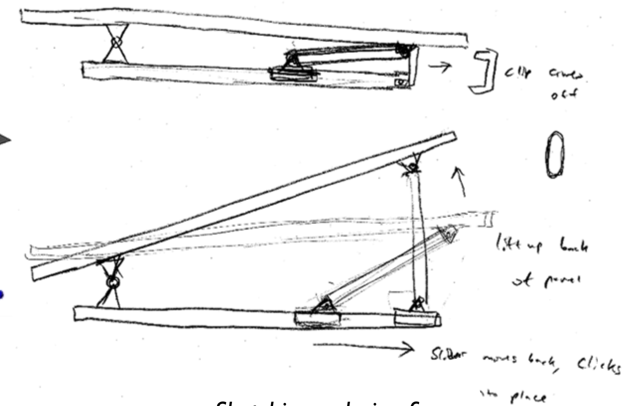
I served as project manager for our team, and was responsible for all our SolidWorks models and FEA analysis. Additionally, I worked with ASCE building codes to develop Excel tables to calculate wind and snow loadings at any tilt angle and exposure.

After determining baseline design loads for wind, snow, and ballast requirements, we got to work brainstorming and fabricating prototypes.

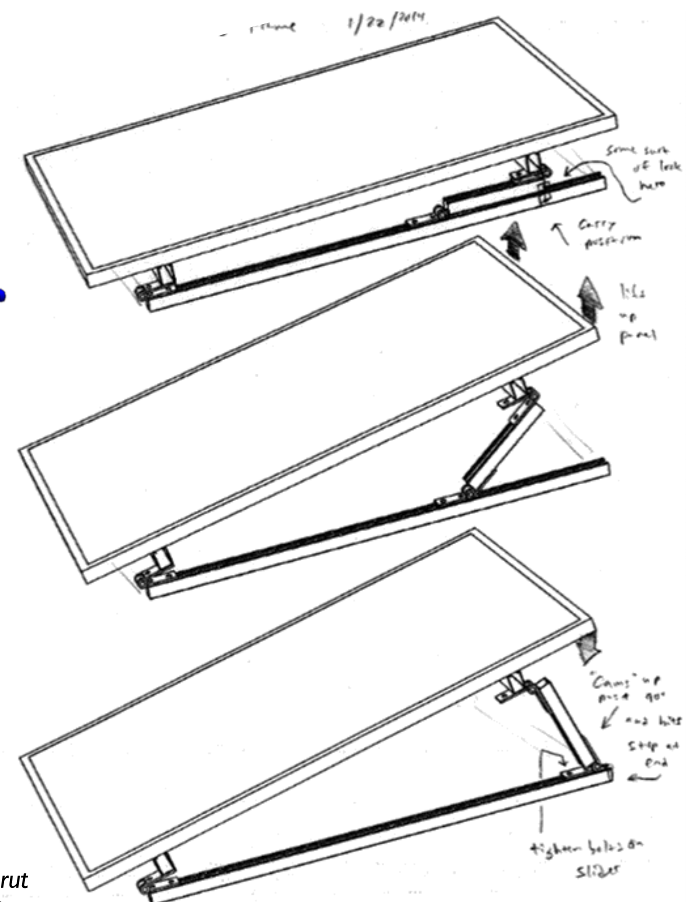


FEA analysis of a mounting bracket and full frame:
I evaluated our physical prototypes for ease of fabrication and installation and conducted FEA analysis and hand calculations on all critical loading conditions to ensure that our designs were structurally sound.





Sketching a design for a sliding folding mechanism

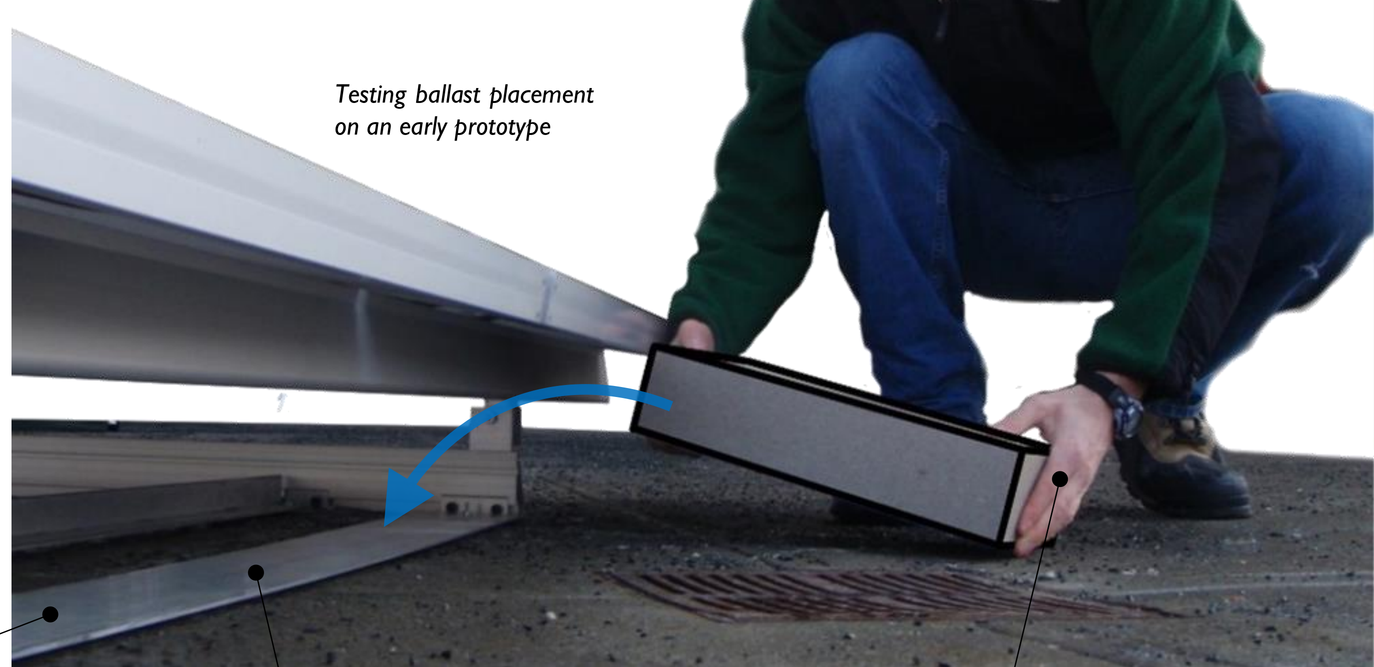


The Sliding Folding Frame using Unistrut demonstrated a promising concept but required expensive hardware

Rethinking Installation

Testing ballast placement on our prototypes exposed some usability problems. We had assumed that there was no room for improvement in the most widely used technique of placing standard concrete blocks in ballast trays. With Norwich Tech's goal of a pre-fabricated mount in mind, we had to figure out a better way to install ballast.

Our "Aha!" moment came when we tilted up the panels on one of our prototypes. That would allow for much easier placement of ballast. Designing a simple custom ballast block solved the ergonomic struggles of gripping a standard block and eliminated the need for any extra ballast trays to hold the ballast. These three design insights came together to become the basis of our final prototype.

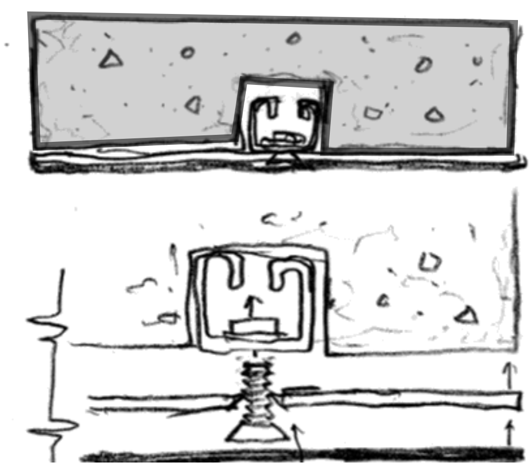


Testing ballast placement on an early prototype

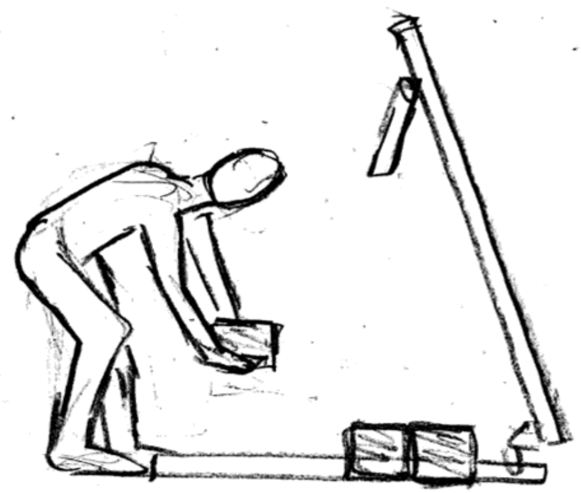
Extra structure to hold ballast adds cost

Placing ballast under panels is difficult

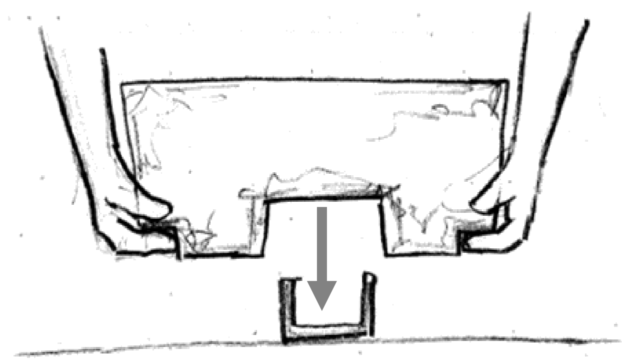
Square blocks are hard to hold on to



Cast ballast to fit over the mount frame:
Most mounts use ballast trays, which adds material, cost, and installation time. We designed a custom cast block that fits over the frame material, eliminating the need for ballast trays.



Install ballast with panels upright:
By lifting the panels up, it is easier to place ballast without awkward reaching or sliding. Additionally, since the ballast is completely under the mount, roof space is conserved



Add grip slots to ballast blocks:
Lifting and placing a concrete block can be made much easier by adding a small lip around the bottom, giving an easy place to grab the block when it is flat on the ground. Our custom block design is easy to grip and place with minimal effort.

Installation Test

After fabricating our final prototype, including casting our custom concrete ballast blocks, we tested installation on Norwich Tech's roof. The un-ballasted mount at only 50 lbs can comfortably be lifted by two people. Placement of ballast was easy, with one person holding the panels up while the other sets ballast on the base rails.

Dan and Misha demonstrate the installation process:

1,2 The prefabricated panels are lifted and positioned on the roof.

3 The rear bolts are removed to allow the panels to lift

4 One person lifts the panels up while another places ballast

5 The angled supports are bolted in to their installed position

6 Installation complete.

The team (from left): Dan, Emil (N-Tech) Misha, Troy (N-Tech), myself


1


2


3

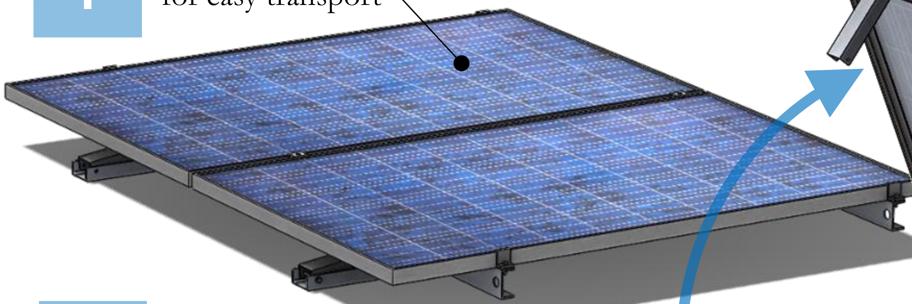

4


5


6

Final Design

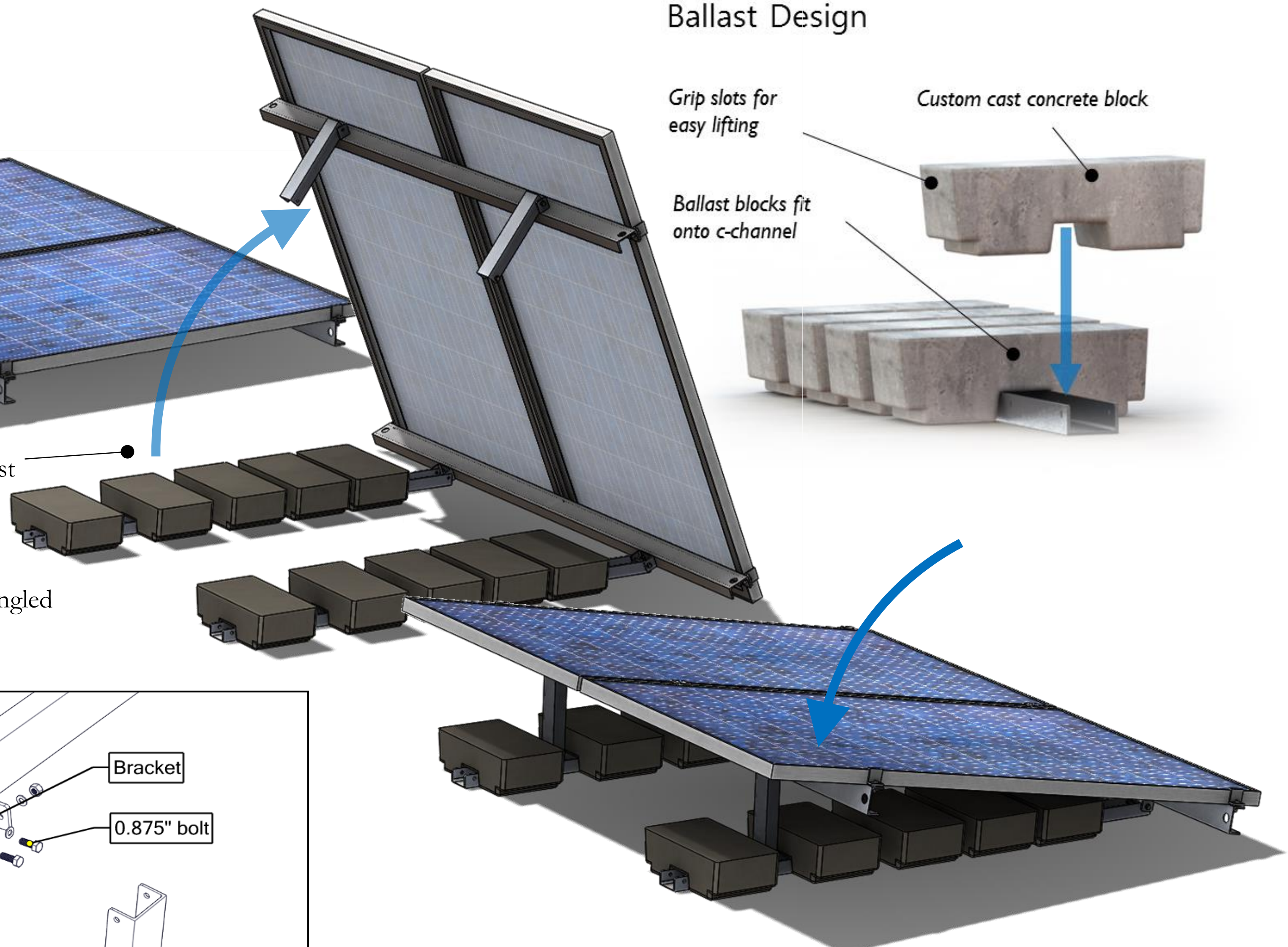
1 Unit arrives folded flat for easy transport



2 Panels release and lift for installation of ballast

3 Panels fold down to final angled position and bolt in place

Ballast Design



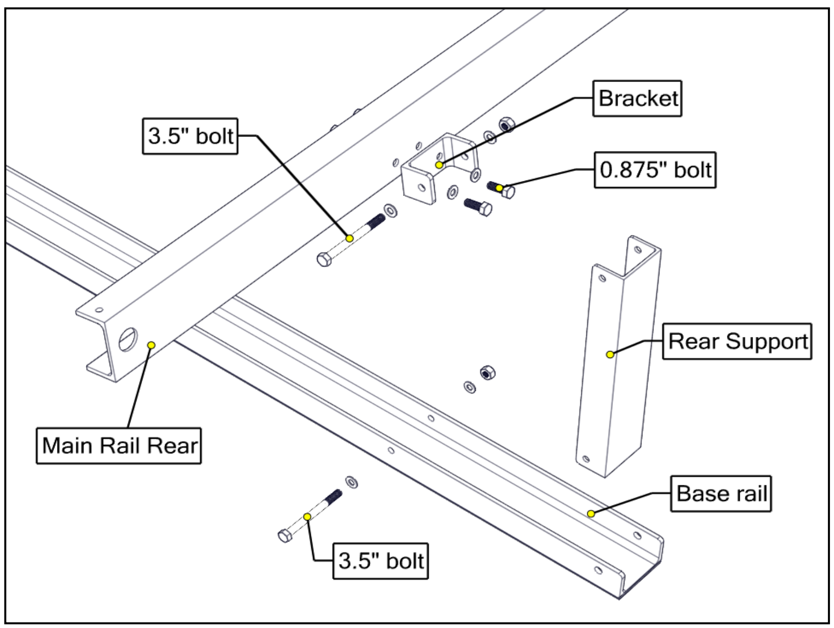


Diagram from our assembly and installation manual

Our final prototype combined a simple and low cost c-channel frame with custom cast concrete ballast blocks for a unique installation scheme. The frame is extremely simple to fabricate and requires no more than a cutoff saw and a drill press, ideal for Norwich Tech's small workshop. With all assembly done in the shop, only two bolts need to be installed on the roof after the ballast is placed.

Our final deliverables to Norwich Tech included engineering drawings of all the parts of the mount as well as a detailed assembly manual I created using SolidWorks Composer. This was in addition to all of our design and calculation tools I developed for wind and snow loading analysis.

Norwich Technologies was very pleased with our work on the project. At the end of the year, our project was awarded the Dartmouth Society of Engineers Prize for outstanding performance.

Cantilever Test Jig

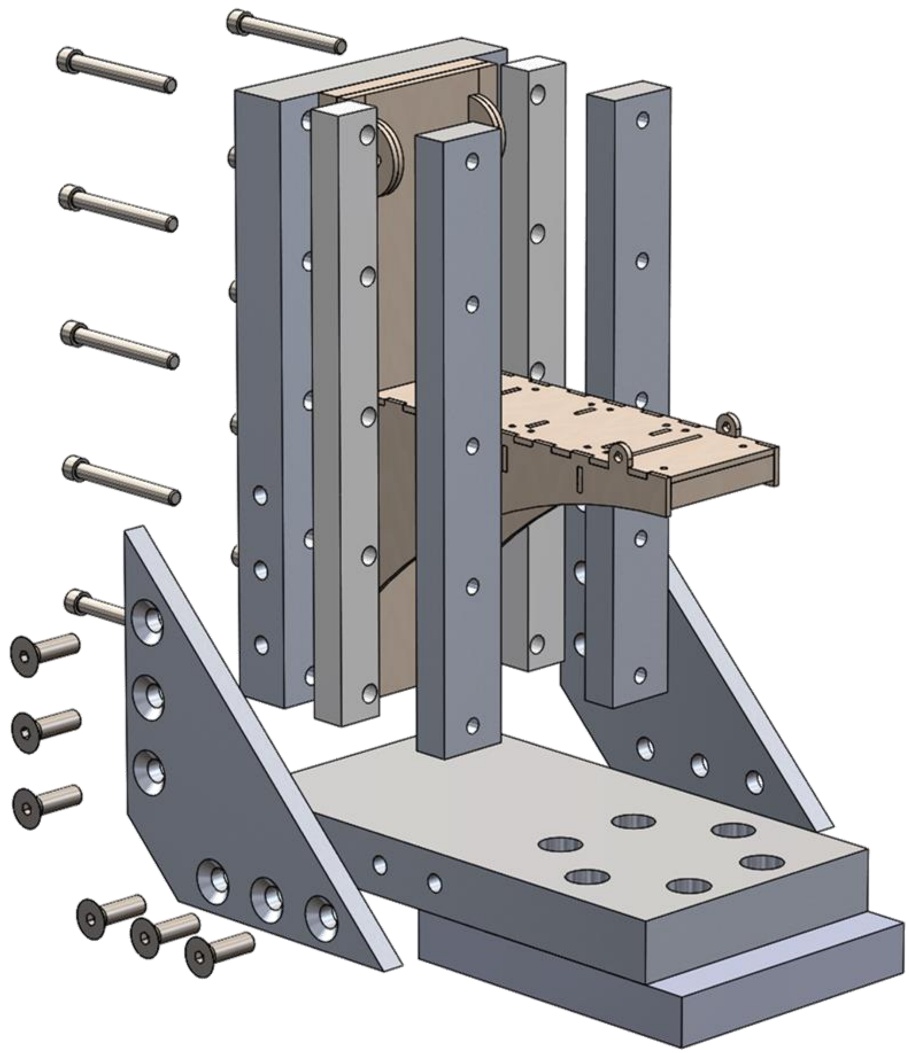
A unique jig to test a cantilever wood structure

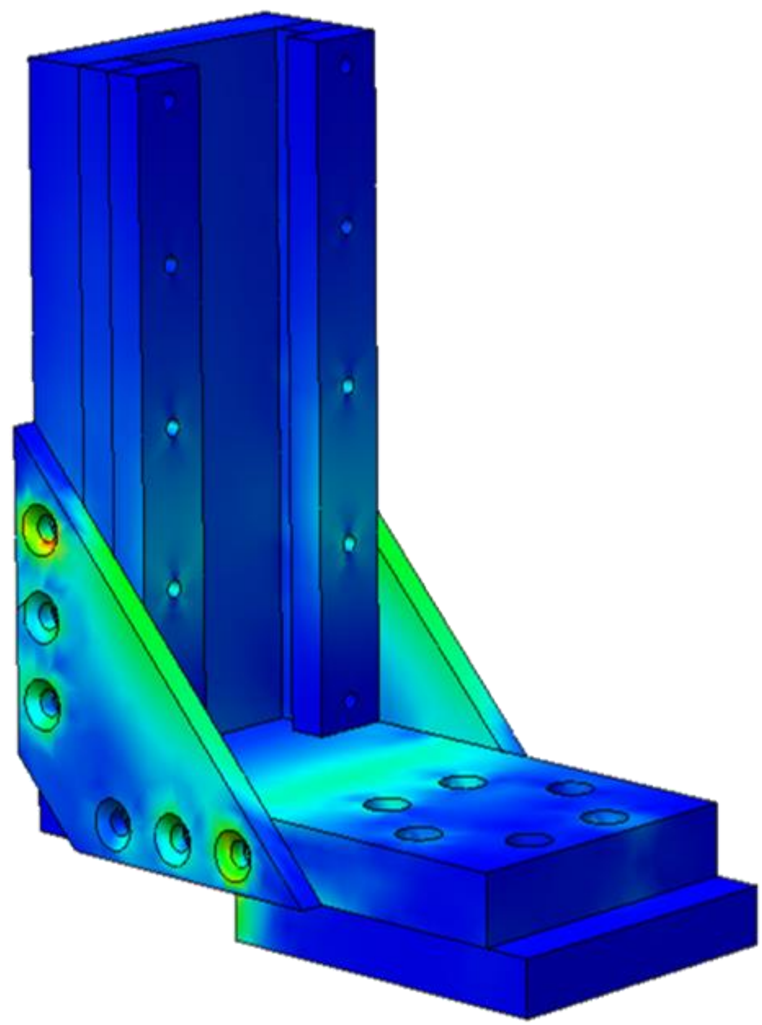
Designed and built for Solid Mechanics, Fall 2015

Machine Shop Instructor

Skills

SolidWorks FEA
Connection Modeling
Machining
Tutorial Design / teaching





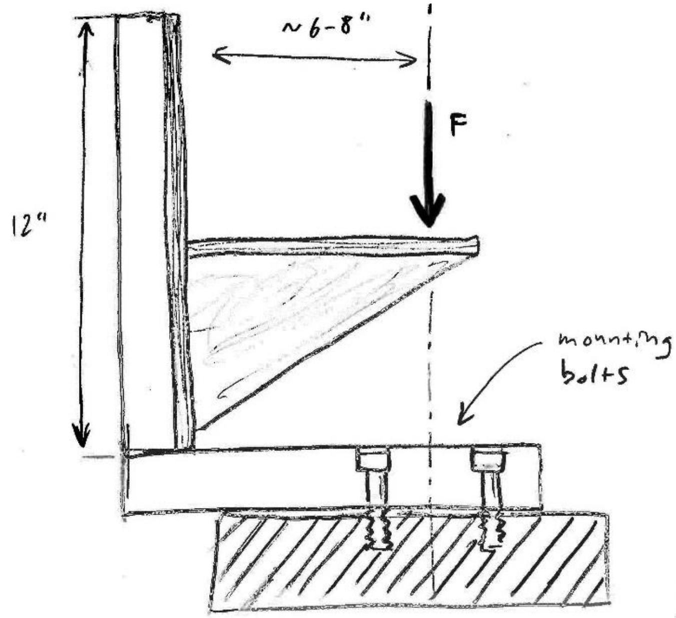
The Challenge

Design and build a fast and stable fixturing system to test wooden structures

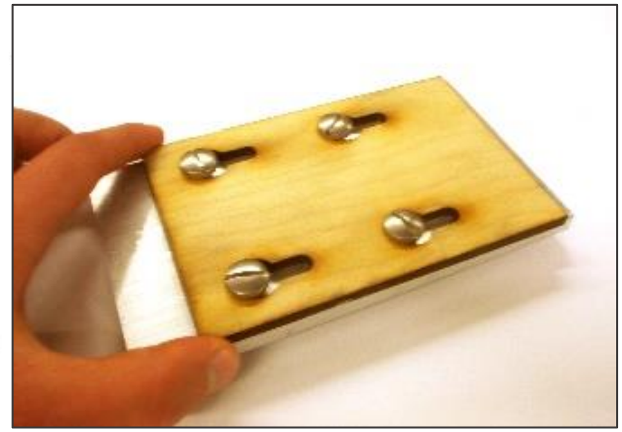
Traditionally, students in Solid Mechanics have designed wooden bridges to test under 3 point bending. Professor Vicki May wanted to try something new: testing a cantilever structure with cable supports. While working as a Technical Instructor in the Machine Shop I designed a system for building and testing a cantilever structure that could include cable supports. The jig would need to mount to the Instron testing machine on a bolt pattern centered under the loading point. It also needed to allow for quick and easy mounting of each structure.

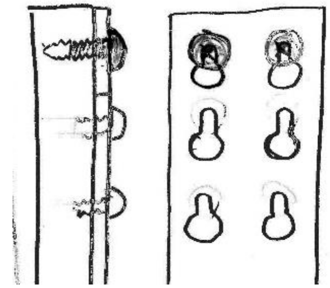
After settling on some rough dimensions and basic design with Professor May, I explored several options in SolidWorks and used FEA analysis to determine potential failure modes in the wooden structure and aluminum fixtures.

The goal was to minimize stress in connections to the jig, and minimize the jig's displacement. We wanted the connections to the jig to be stronger than the rest of the wooden structure so that the students were challenged to optimize their structure's overall design, not worry about how if was attached to the jig.

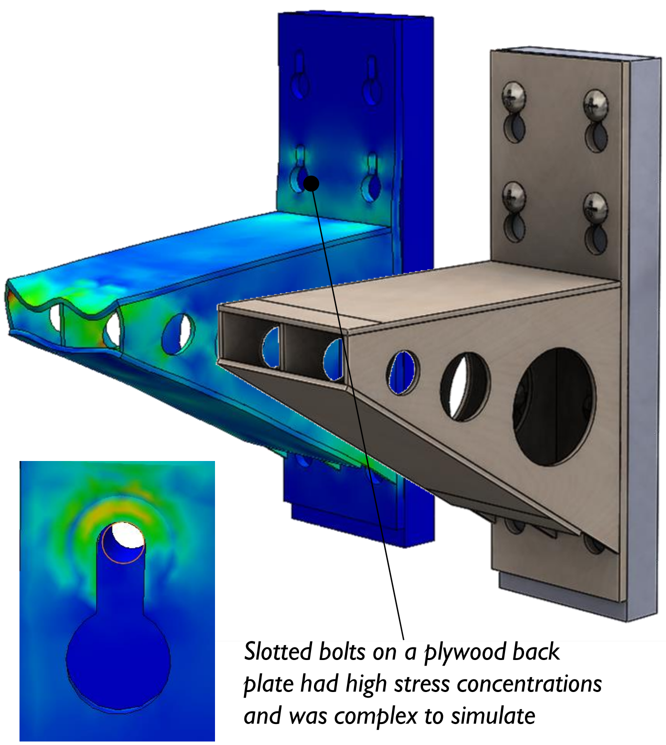


The rough layout and geometry of the jig showing force application and mounting bolts

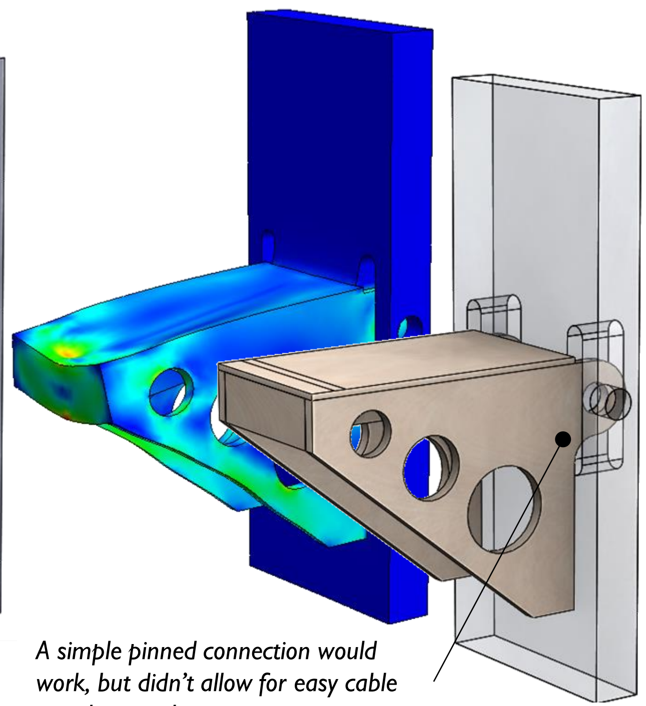




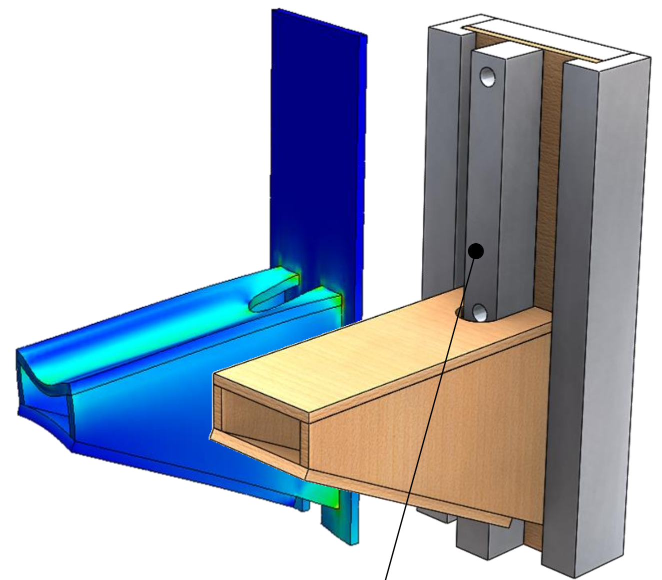
The first concept: slotted bolt holes to distribute the load over the back plate



Slotted bolts on a plywood back plate had high stress concentrations and was complex to simulate



A simple pinned connection would work, but didn't allow for easy cable attachment above

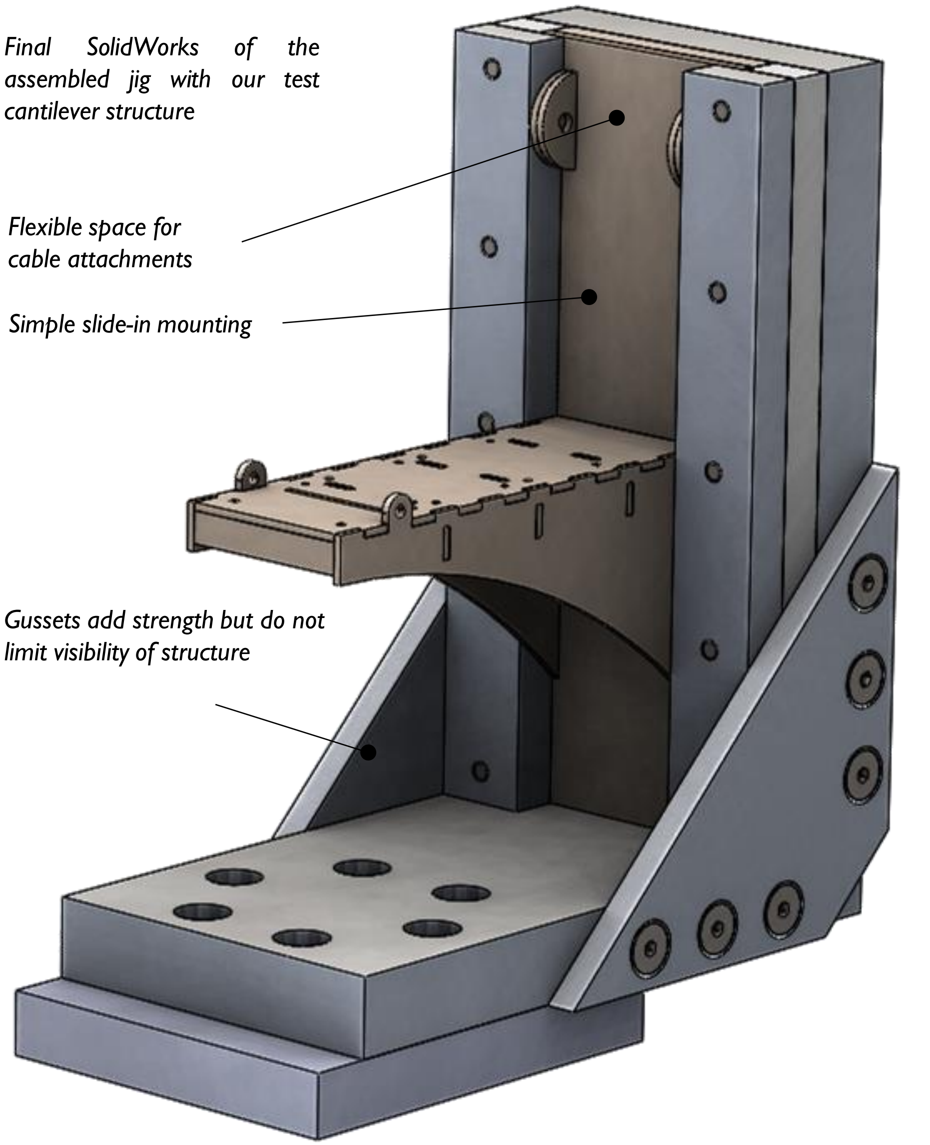


A central clamping bar would support a ¼" plywood back plate, but limited the available surface for attachments and required bolts through the wood back plate

Breakthrough

Our laser cutter can only cut through ¼” plywood, so that limited the back plate thickness. But without a thicker back plate, it was challenging to hold the structure securely without an intrusive or overly complex jig. To reinforce the back plate, I decided that students could glue the laser cut ¼” sheet to a piece of ½” plywood we could pre cut on a table saw. **With that, I could make a simpler jig that gave full flexibility for cables and sufficient space for creative design while having a solidly attached back plate that was easy to mount with no fasteners.**

Assembly scheme the students would follow to attach their structures to the plywood back plate

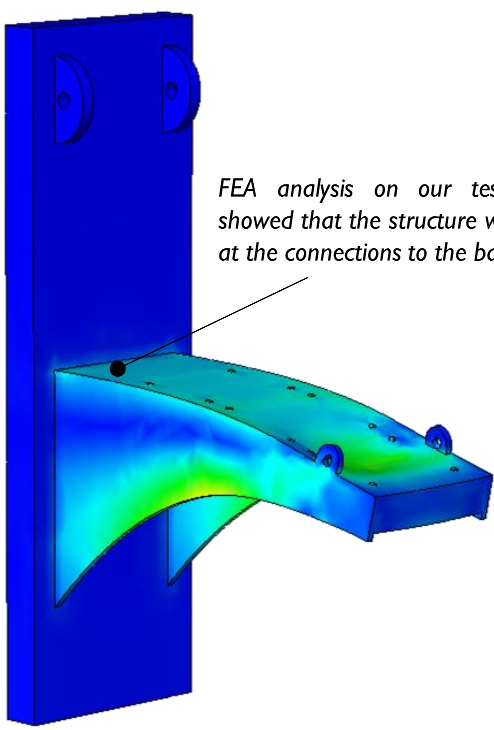


Final SolidWorks of the assembled jig with our test cantilever structure

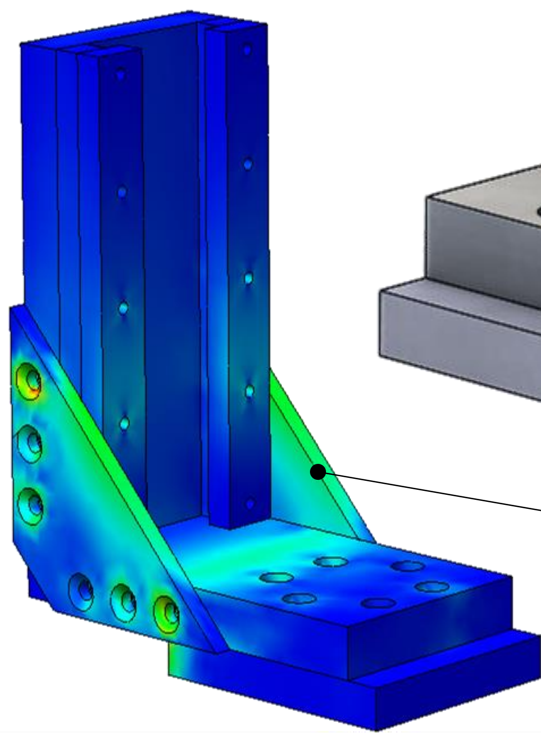
Flexible space for cable attachments

Simple slide-in mounting

Gussets add strength but do not limit visibility of structure

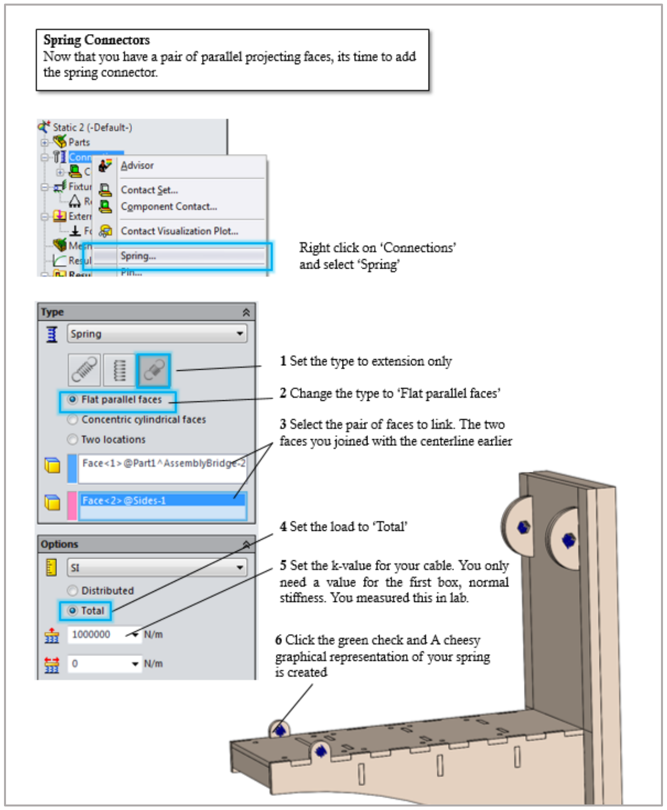


FEA analysis on our test cantilever showed that the structure would not fail at the connections to the back plate



FEA analysis using bolted connections showed that the jig would not deform too much to significantly affect student’s predictions of their structure’s deformation

Final Touches



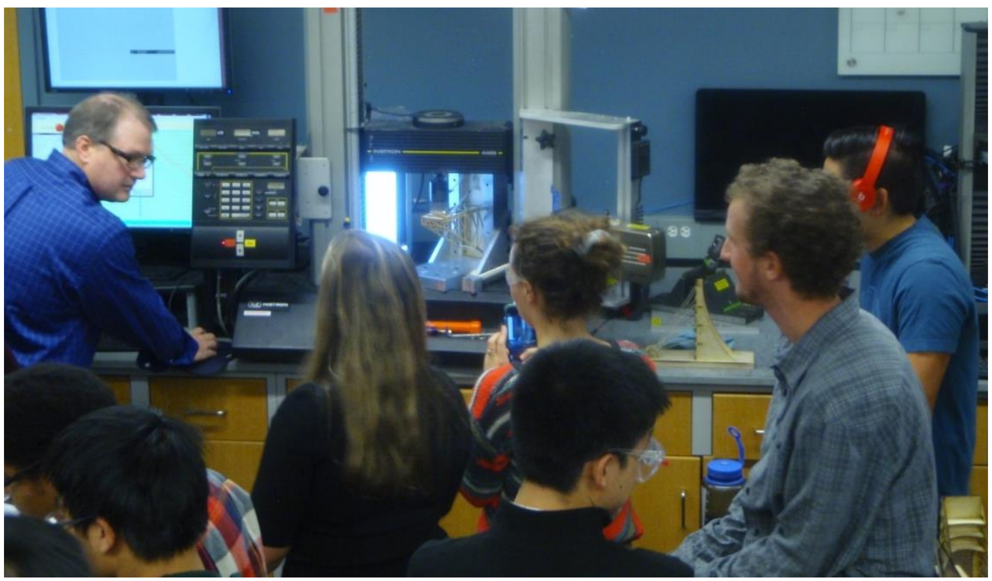
After finalizing the design of the jig, I machined and assembled the pieces. I tested the wooden test structure in the jig on the Instron and compared the results to the FEA analysis in SoldiWorks. I used the data from the testing to evaluate different options for modeling the cables in SolidWorks.

Using what I learned, I prepared a detailed tutorial to teach students how to best use SolidWorks to simulate their structures and predict failure loads. I taught my tutorial to the class as an interactive lecture, with students following along in SolidWorks on their laptops. In the week before final testing, I helped groups one-on-one with any questions they had about making their simulations work properly.

On testing day, the jig worked flawlessly, allowing for rapid mounting and removal of structures. The students had designed a wide variety of structures, fully utilizing the creativity permitted by my jig design.

Left: A page from my tutorial used to show students how to use SolidWorks to model and simulate their structures

Below: Test Day: Students watch as their structures are loaded on the Instron



The completed jig. The wood structure slides into the jig for easy mounting with no tools required