**OBJECTIVE**

As part of my Stress Analysis class, my group and I were tasked with designing and building a mechanism powered by a servomotor which could lift a cylindrical weight. Our mechanism was fixed in a given starting position and had to pass through an obstacle as it moved towards the weight which placed constraints on its shape and size.

Additionally, we were required to keep our crane design under 20 ounces and left the weight a minimum of 2 inches. Our design competed in two categories: lifting the weight the highest or having the lightest crane to achieve the minimum lift of 2 inches.

**TEAMMATES**

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 [Samantha Ho](http://saho.studio)

At our first design review we assumed that the arm itself was massless. This is neither practical nor possible; however, we chose to assume this because the center of mass of the arm was so close to the axis of rotation-- thus the moment caused by the arm itself was negligible compared to the torque of the servo, the weight of the counterweight, and the force due to the weight.

Additionally, we assumed that the arm would lift a max of 60 degrees. Although the servo was capable of rotating further, the change in x position of the counterweight as the arm increased in angle would cause the arm to no longer be able to lift the weight. As a result, a 60% lift angle would be a safe assumption for the actual max lift angle.

Lastly, we assumed that the max torque by the servo was 57 oz-in as stated by the manufacturer. After some prototyping, we discovered that we weren't getting anywhere near that torque despite that was what the manufacturer rated the servo for. We suspect that this is due to the fact that these servos were reused for several years.

Manufacturing

After coming up with our design and running simulations, we took our materials into the shop and began working. The main body of our crane was constructed out of aluminum cylinders. We used rods rather than rectangular extrusion to resist torsion while still preventing buckling and bending. Additionally, we minimized weight and material use by hollowing out our 1 inch aluminum stock on the lathe.

Design Review 1:

We were essentially achieving 2 inches of height up until the night before the first design review. The main source of error that we encountered was the fact that the servo we were using was not consistent. Not only did we see different capabilities between different controllers, but also when we began the design review, we realized that the servo was performing at a reduced level compared to the night before. Our suspicions were confirmed when we switched servos and our crane performed better. There was also a slight source of error due to the assumption that the arm was massless as the arm in practice was not.

The actual output of our crane was much worse than the calculations that we did to find our theoretical servo torque as well as our theoretical lift height. Initially we calculated that using a counterweight that had its center of mass six inches from the axis of rotation would provide plenty of torque to allow for the servo to easily lift the weight. Unfortunately, when we placed our design on the field, we quickly found that the arm could barely lift the weight and that the crane was nowhere near the 2 inches that we needed to achieve.

Final Design

After the first design review, we added a 45 degree bend in the lever arm and improved our counterweight so it would no longer hit our crane arm. Additionally, we milled a smaller base that allowed for more adjustability when it came to iterating for our final version.

Our final crane design was extremely adjustable in terms of rotation as well as adjusting our servo mount to get the arm to interact with the weight at the correct angle. Hollowed rods allowed for us to minimize weight without sacrificing structural integrity, especially in respect to bending. The tension strips that were used were instrumental in preventing further bending as it prevented bending for the first 60% of the crane arm length. The angled arm allowed for the weight to be lifted at a larger distance from the servo. It also allowed the counterweight to not overpower the servo at the beginning, but apply enough counter torque for the arm to lift the weight completely.

In the end, our design lifted the weight a height of 4.875 inches, which was the second highest in the class.

Overall I have been rather dissatisfied with the makerspace. Seeing how it is defined as the MechE makerspace, it would be nice if there were some slight accommodations for mechanical engineers seeing how we rely on these resources for our core classes’ grades. For example, during the bracket assignment in Design 1 it would have been very helpful to have at least one laser cutter reserved for our use as one iteration of our brackets took about 3 minuets to set up and cut while others using the laser cutters were learning how to set it up and doing large engraving which took much longer and caused many of us to have to wait in line for extended periods.

Additionally, more computers with Solidworks capability, if not in the makerspace exactly but in the nearby area, would be amazing. Often due to a class or just many people working on projects at the same time, I have had to walk all the way to IDeATe where there is about 3 times the computers so I am always able to find a computer even if a class is going on. The old MechE computer lab had a much larger capacity and dual monitors if I remember correctly which was actually really useful. Additionally, it served as our lounge of sorts as only MechEs had key card access. Ideally it would be nice if there were a smaller MechE only computer cluster nearby to both serve as a lounge where MechEs can go to work and have better odds of finding an open computer during the makerspace's peak times or during a class.

I have also heard rumor that the CMR and other teams with machine shops will soon be forced to use the makerspace machine shop instead of their own machine shops. I am very concerned about this. As I mentioned above currently the machine shop is decently busy but I am still usually able to get on a machine I need in a timely manner. I think that even suggesting this shows a lack of understanding of just how much work these teams constantly do. If these teams were moved into the makerspace general use of the machines would decline due to use by these teams and I would be much less likely to use it due to the difficulty of finding an open machine.

Also, it generally feels like the makerspace is seeking to make a profit rather than genuinely helping the students. For example, they are currently charging 40 cents per milliliter to print on the form2s while, when buying it from formlabs directly is only 15 cents a milliliter. The same goes with printing on the ultimakers where you can get if from one of their preferred resellers for 2 cents a gram which is a lot less than the 30cents per gram which they charge. Their acrylic also costs much more than IDeATe’s but I do not have the numbers on that.

Finally, in terms of staff I feel like there is a general lack of training. Often I see that only a few people are qualified to handle some of the more technical aspects in the space. There have been times that I have spotted something going wrong in the space, such as an obviously failed form2 print where the part never adhered to the plate and it is airprinting or an ultimaker with the tension screw placed on the outside, and I have had to explain to a staff member why this was wrong so that they could fix it or at least stop a failed print and try it again. I think more oversight of these by a nonstudent staff member would be very helpful as more of these issues simply require a mere glace with an experienced eye. Additionally, their staff scheduling seems really off balance as sometimes there are 3 students on shift during non peak times when nothing is happening and then later there is one poor staff member working all alone during peak hours. Being in contact with MechE classes and knowing when their projects are due so that they can adjust for these sudden spikes would also be helpful.

Thank you very much and sorry for the long read. If you need more information feel free to contact me at mmong@andrew.cmu.edu

Have you been able to easily gain access to and use your necessary tools and technology? If no, any recommendations MechE should consider?

Overall, it seems like there are many redundancies in their safeguards to using the computers. On the lasercutters for instance, it already won’t let you log in if you don’t pass their certifications; however, they then put an additional key card reader on it which takes more time to the monitor to turn back on and then adds the complication of people leaving their ID cards inside the reader.

At one point a staff member wanted to me to sign into a machine and then sign out with another staff member when I was done to ensure the machine was clean(which is a very real issue when people leave them uncleaned). However, when I wanted to leave I couldn't find anyone to sign out with so I just had to leave. I think some system like this would be nice but they dont have a good system in place for it. I think it might be better to match time logs from inserting into the machine with camera footage to catch people leaving messes as it seems to be the minority vs the majority.