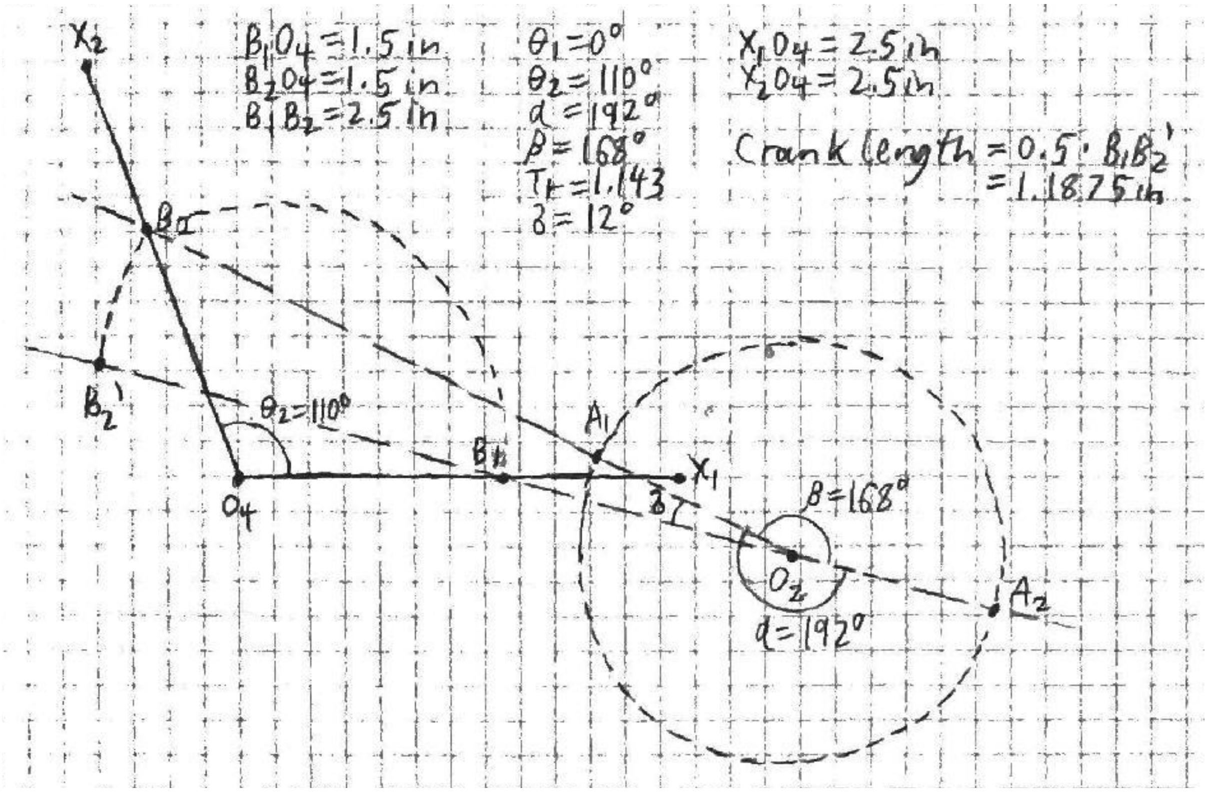
Project 1: Dart Throwing

ME 370 – Mechanical Design

Lab Group 14



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Section BL1 – Aimy Wissa

15 October 2020

Abstract

Our overall goal for this project was to create a mechanism that can throw a dart at a target while taking into account internal and external concerns of the system. In order to achieve this goal our first step was to create smaller and more attainable goals. After breaking down our ultimate goal into sub-steps we defined each sub-step into two categories, quantitative and qualitative goals. For the qualitative steps of the system, we analyzed the different movements the robot needed to take to achieve its ultimate goal. These movements consisted of the motions of the different mechanisms in the robot needed to locate, pick up, prepare, and finally shoot the dart which were all. For the quantitative steps of the system, we identified the specific values and mathematical calculations needed to make a working linkage system that would follow the previously mentioned mechanical motions. After carrying out each of these quantitative and qualitative steps we were able to form a respective operational scenario and sketched diagrams for the system. This led to the building of a working low-fidelity prototype that could be referred to when creating a real-life robot that shoots a dart.

Design process

With the goal of making a robot capable of shooting a dart, the design process began with taking into account the internal concerns of the system such as its functions, and the external factors such as the environment the system was in. For our internal concerns, we emphasized the importance of our robot being large enough to hold a dart, and powerful enough to throw the dart, as well as being cost-effective to build as the users were assumed to be students. For our external concerns, we took into account where the robot would be placed, how it would be used, and who would use it, leading to the conclusion that the robot should be built to be compact, easily transported, and made with items readily available and economical. When initially designing the system, our robot consisted of a four-bar linkage with a rocker connected to the coupler and ground at the center and one end of the link. This caused the rocker to be grounded in the loading position, but not when shooting the dart. Due to this contradiction, we made iterations on the linkage to fully ground the rocker on one end and connect it to the coupler on the other end so that it was grounded in both shooting and loading positions. In addition to this, rather than making the system a basic 4 bar-linkage with a rocker moving in an arcing motion, we decided to make the linkage into a quick-return mechanism. With this modification, the rocker arm returned back to its loading position at a faster pace than its throwing motion, unlike the initial design that had the mechanism move at the same pace when shooting the dart and moving the loading position.

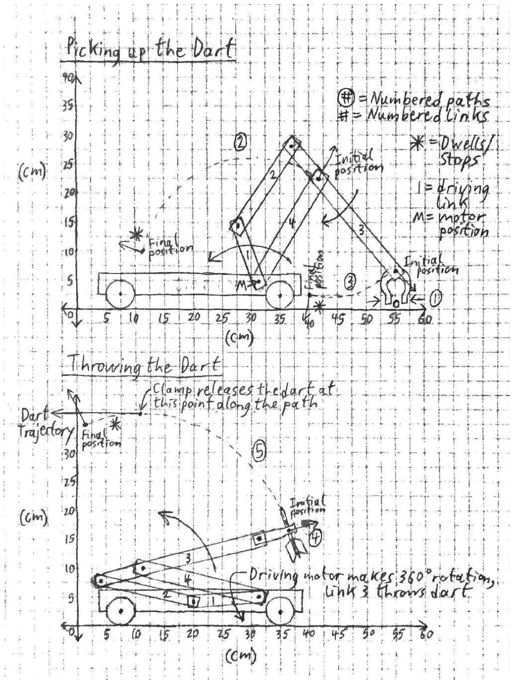


Figure 1: System Initial Design

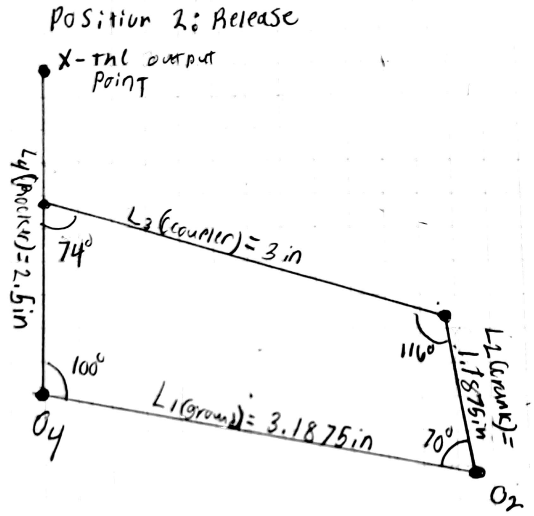


Figure 2: System Final Design

Finally, we reduced our system requirements to only shooting the dart, making the user requirements locating the dart, aligning the system with the target, and loading the dart into the mechanism. While the system's requirements were now to throw the dart at the target and return it's arm to the original location in order to be reloaded. This influenced sources and comments in the user/stakeholder requirements by changing the steps with the new user requirements to have the source to be the user rather than producer. In addition to this, the comments for the new user requirement changed. Before this change the comments specified how the different link mechanisms would move in reference to each other or how the robot would move in reference to the target or the dart, but now the comments were adapted to give instructions to the user's on how to prepare and load the dart into the robot.

The goal when building our lo-fidelity prototype was to ensure that the crank was able to make a full rotation and that the rocker followed the correct path. In our mechanism, the rocker is acting as the arm that throws the dart; therefore the top end of the rocker is the path that we traced. We made our mechanism out of cardboard for our linkages and paper clips as our connecting joints. Although this worked for our lo-fidelity prototype this is not sustainable for a final design, for it did not hold our mechanism together well. After assembling we found that our rocker was not able to make an arc of 110 degrees, and that every time we attempted to rotate the crank it would not make a full rotation. After playing around with the mechanism we then realized that our ground was not long enough. We then made adjustments to both our physical and theoretical designs to get to our final lo-fidelity prototype. After making these adjustments, the rocker then followed the correct path and the crank was able to make the full rotation. An important lesson we learned was that "doing is the best kind of thinking"-Tom Chi. If we had not built our lo-fidelity prototype we would not have had a mechanism that completed the goal at hand.

We created a four bar linkage using a three point synthesis. For our mechanism we focused on path synthesis because we felt that to attain our goal we needed to ensure that the path trace was correct. We believe that we have achieved our goal because the mechanism that we built was run through two different tests and came back with the same results. Our two tests were to trace the correct path with both our physical and simulated (creo) models. The path that has been traced is an arc that covers 110 degrees, which we determine was the correct arc in order to accurately throw a dart at a target. Additionally, due to the specific link lengths, our mechanism will have a quick return meaning that it can be continuously reloaded. Finally, our design is large enough to hold a dart, but compact enough to be able to be transported. We believe that given the tests that we put our design through it meets the requirements of our goal.

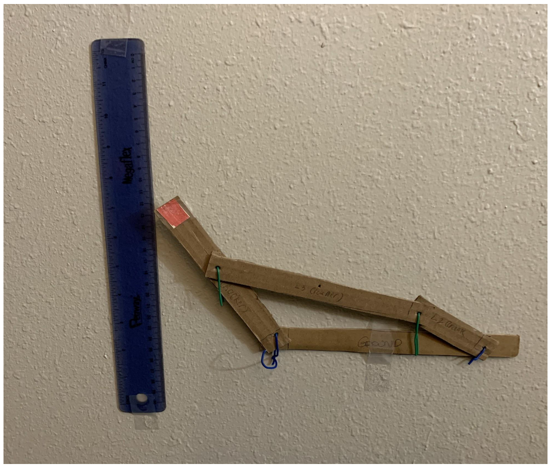


Figure 3: Final linkage in environment

<u>Mechanism Analysis and Results</u>

When designing a mechanism to trace a desired arc, the ratio of link lengths is more important for the arc shape than the final links. If the ratio of link lengths is known then they can be multiplied by any factor to get a linkage of desired size that traces an arc of the desired shape. This property allows for the graphical linkage synthesis, done on a standard size piece of paper to be scaled up to size more appropriate for the scenario. Our graphical linkage synthesis produced the following link lengths, which were then used to find the link ratios.

L1 (ground) = 3.1875 in, L2 (crank) = 1.1875 in, L3 (coupler) = 3 in, L4 (rocker) = 1.5 in,
Throwing Arm: 1 in

$$L\_2\ /L\_1\ = 0.37,\ L\_3/L\_1\ = 0.94,\ L\_4/L\_1\ = 0.47,\ (Throwing\ Extension)/L\_1\ = 0.3137$$

In order to get a mechanism large enough for our users' needs, our link lengths were scaled up by a factor of 4 from the original synthesis. Engineering drawings depicting these lengths can be found in appendix A.

L1 (ground) = 318.75 mm =12.55 in, L2 (crank) = 118.75 mmn = 4.68,
L3 (coupler) = 300 mm = 11.81 in, L4 (rocker) = 150 mm = 5.91 in,
Throwing Arm: 100 mm = 3.94 in

These lengths give us the ability to classify this four bar linkage through a grashof classification method. This classification provides information about the motion of the mechanism based on the lengths of the linkages. Three scenarios's exist they are as follows:

$$Class\ One: S + L < P + Q,\ Special\ Case: S + L = P + Q,\ Non\ Grashof: S + L > P + Q$$

Where S is the shortest link, L the longest, and P and Q the intermediate.

Applying this classification to our linkage:

$$S = 1.1875\ in\ L = 3.1875\ in\ Q = 3\ in\ P = 1.5\ in$$
$$3.1875 + 1.1875 < 3 + 1.5$$
$$4.375 < 4.5$$

This indicates a Grashof class one linkage. This means that at least one link will do a full rotation. Specifically our linkage is known as a "Crank Rocker" this means that one link, the crank does a full 360 degree rotation and one link rocks back and forth between two positions with a coupler in between. This design allows the crank to be driven by a constant output motor since there will be no point where the crank needs to switch directions. In this manner the rocker output can oscillate continuously through its full range of motion. This allows the mechanism to throw a dart, and return to the load position without requiring a directional change to the input. This reduces cost and complexity of the mechanism's manufacture.

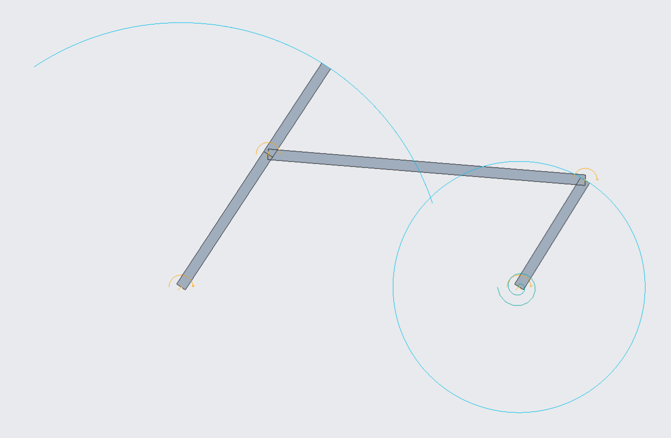


Figure 4: Final Linkage and Traced Path

The arcs traced by the crank and the rocker are seen below in figure (4) above. The crank and rocker are clearly visible. Note the limited motion of the rocker corresponding to a full rotation by the crank. This brings the rocker through all four positions of note: loading, release, follow through, and return. In the following figures the exact position of the rocker can be seen at any given moment in time. An animation of the rocker motion can be found here: https://youtu.be/FamBBKRFbHs

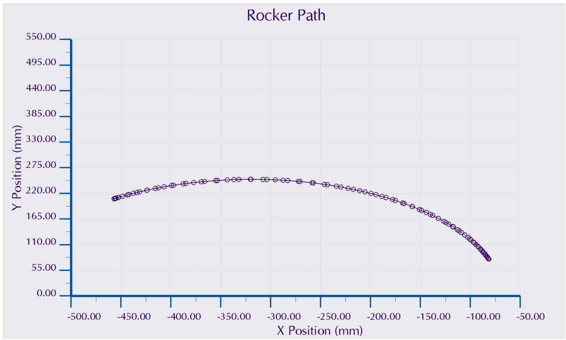


Figure 5: Final Linkage Rocker Output

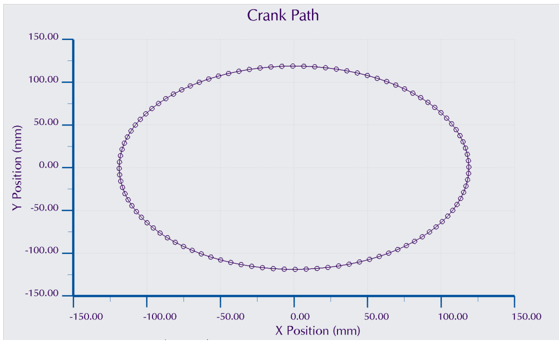


Figure 6: Final Linkage Couple Output

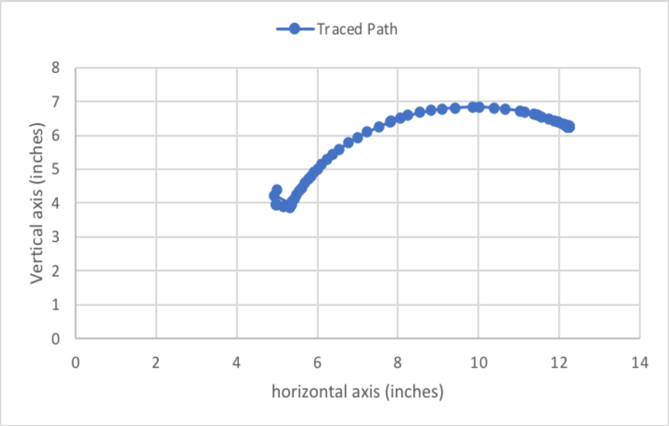
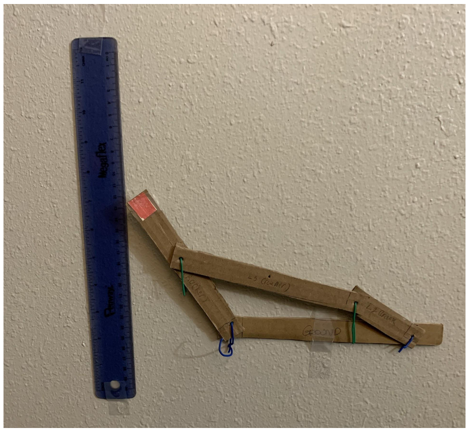
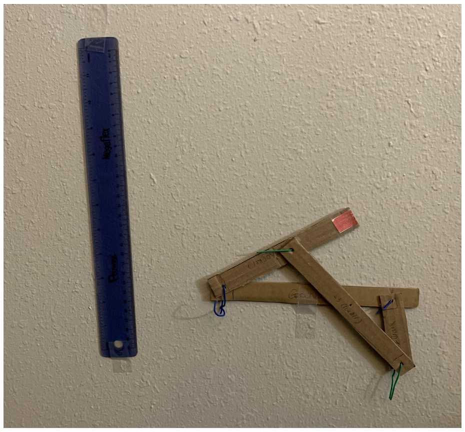


Figure 7: Traced path of Rocker linkage in lo-fidelity prototype





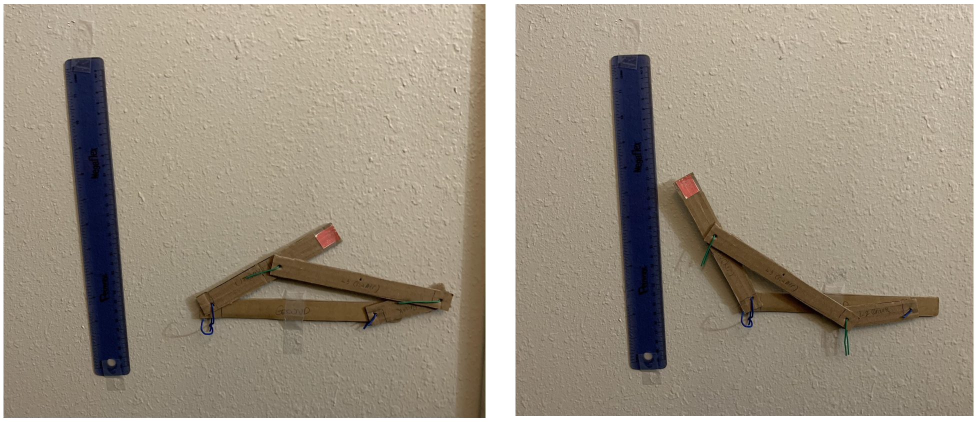


Figure #8: Lo-fidelity Prototype in Starting, Throwing, Toggle, and Return positions

The curves traced by our physical prototype (figure 7) and our simulated prototype (figure 5) are similar. They follow the path we designed, as they both span the appropriate 110 degrees between their initial and final positions. The simulated curve starts at approximately 0 degrees in relation to the horizontal and travels to 110 degrees, and the physical curve is the same yet the mechanism is inverted. The physical curve, however, has an abnormal motion at the start of the curve that shows unexpected movement. This unexpected movement is likely due to environmental factors such as shifting components, joints, or friction.

The figure below shows the instant centers of our linkage at 4 different positions.
1 = Starting position, 2 = throwing position, 3 = fully extended, 4 = return position
The further an instant center is from the two links, the larger the mechanical advantage one link has over the other. This applies to our linkage when we observe the changing position of the instant center I_24 between the crank and the rocker link as the linkage operates. In the first position, I_24 lies on the linkage because links 2 and 3 are in a toggle position. In position 2, I_24 is located far from the linkage, resulting in the greatest mechanical advantage when the linkage throws the dart. I_24 is again on the linkage due to a toggle position in position 3, and on the linkage due to the links crossing in position 4.

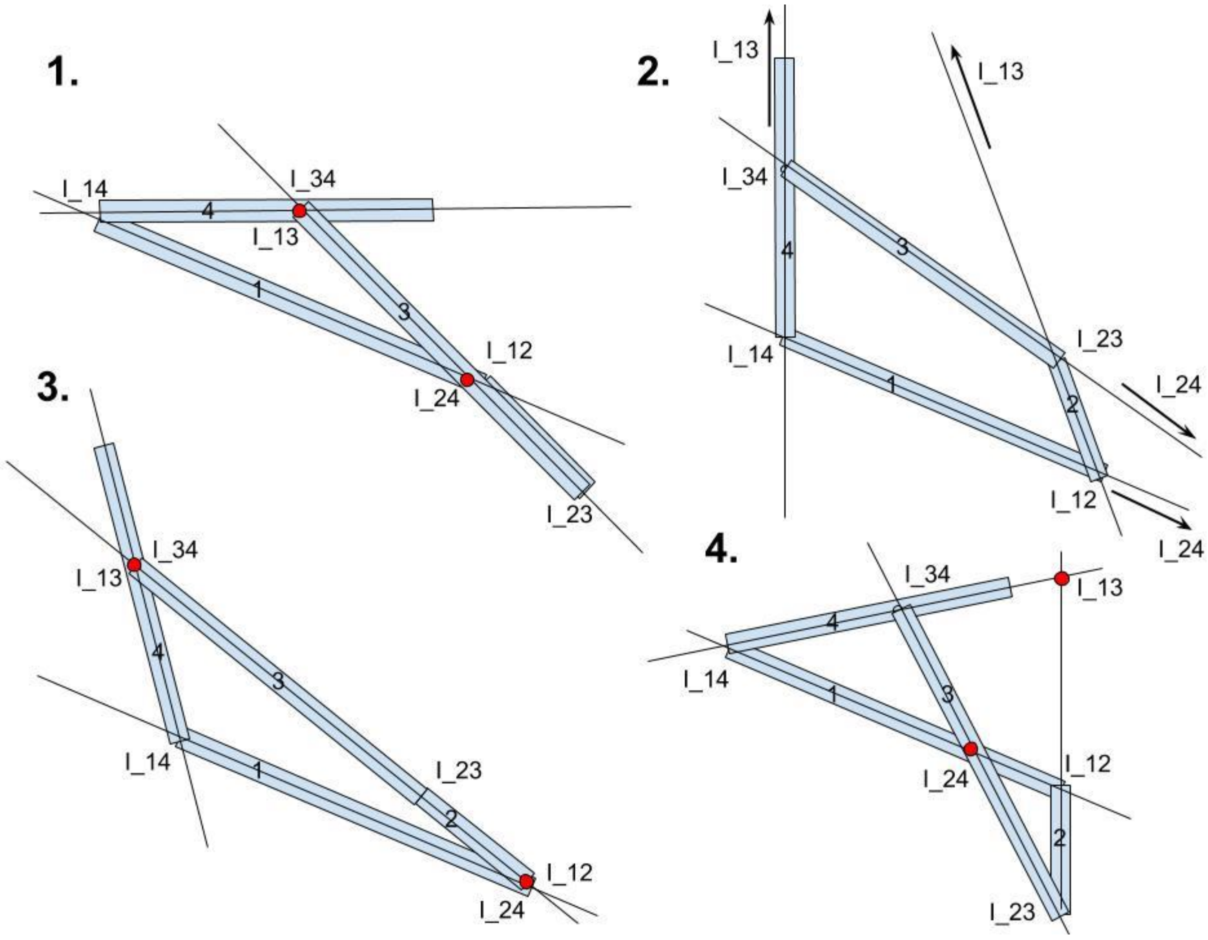


Figure 9: Instant centers of mechanism in the Starting, Throwing, Toggle, and Return positions

Appendix A

On tolerance; when manufacturing linkages of a specific length what matters more than anything else is the distance between the joints. The linkage can be longer than the specified length, but the pins must be exact in location.

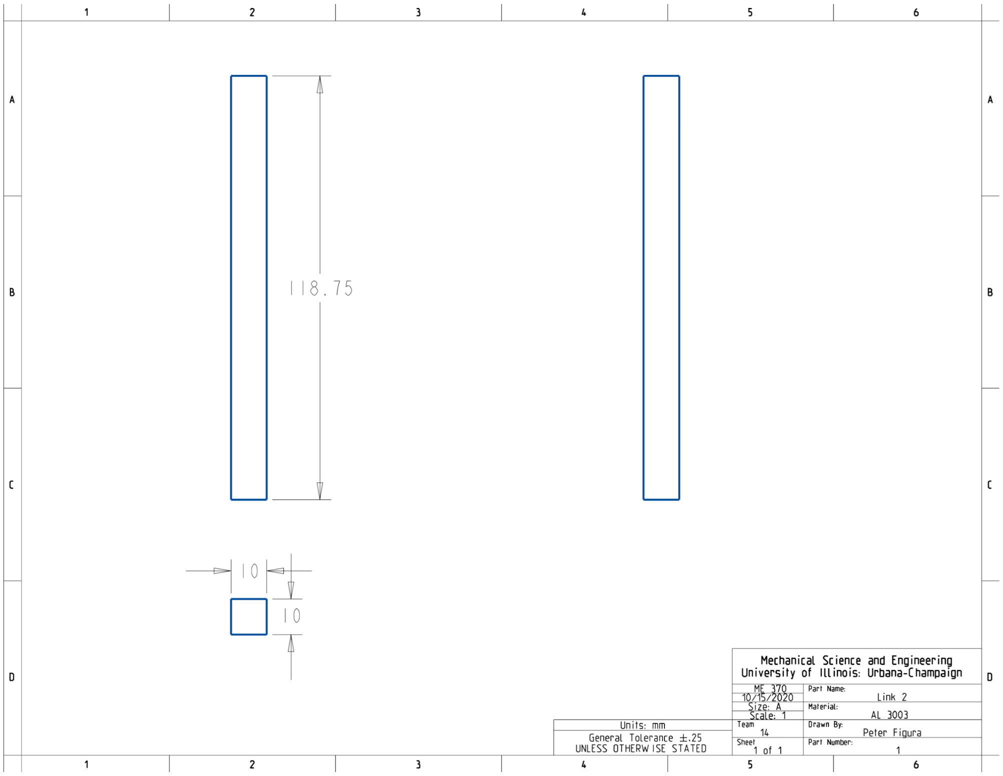


Figure 10: Engineering Drawing of Link 2

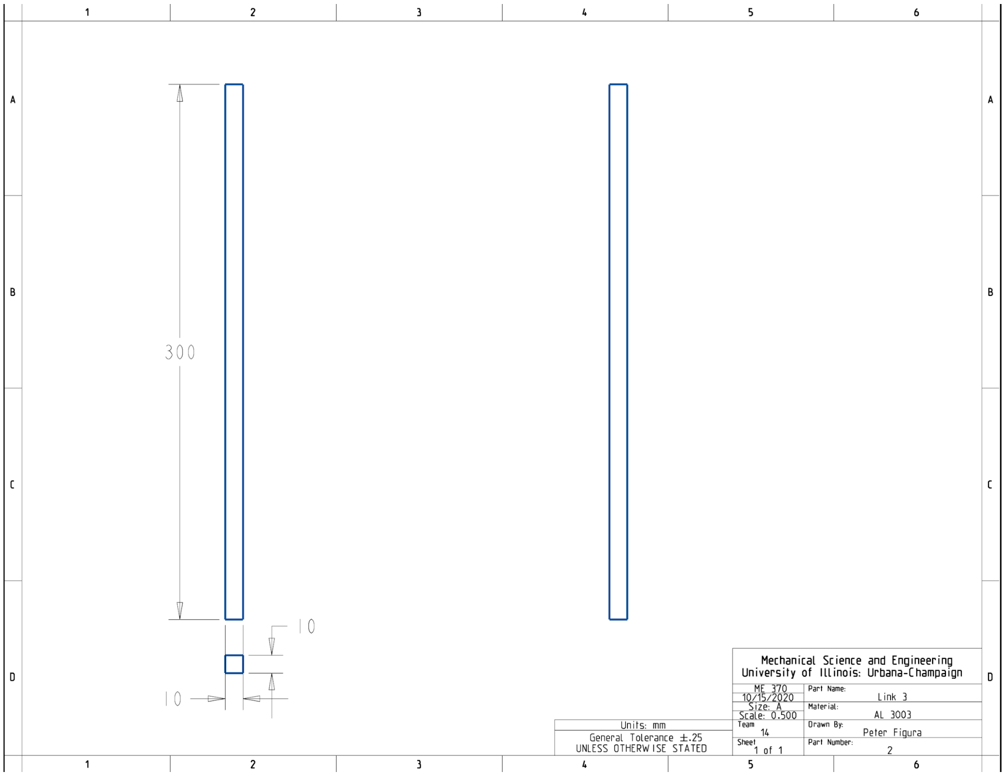


Figure11: Engineering Drawing of Link 3

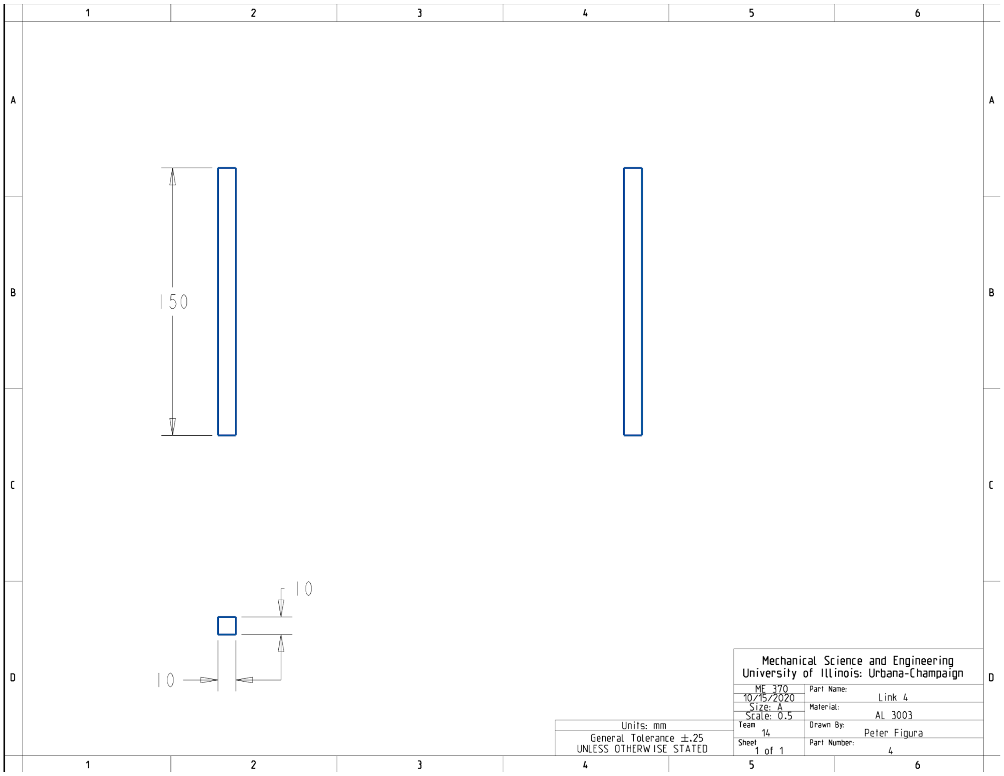
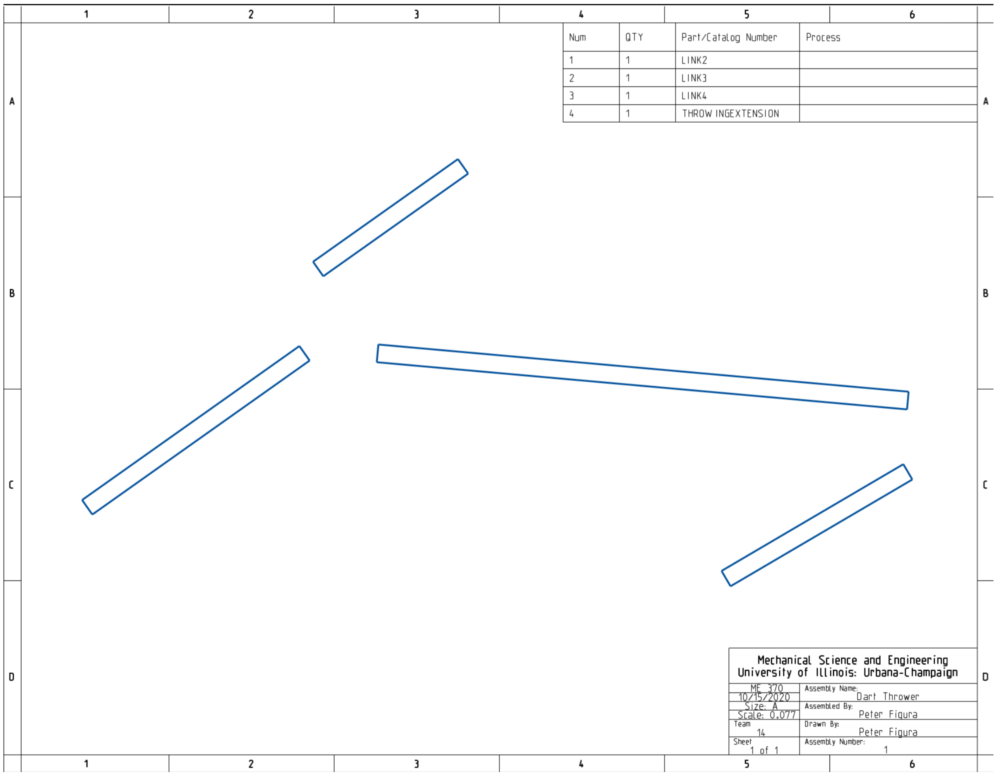


Figure 12: Engineering Drawing of Link 4



Num	QTY	Part/Catalog Number	Process
1	1	LINK2	
2	1	LINK3	
3	1	LINK4	
4	1	THROWINGEXTENSION	

Mechanical Science and Engineering
University of Illinois: Urbana-Champaign

ME 370 10/15/2020	Assembly Name: Dart Thrower
Size: A Scale: 0.077	Assembled By: Peter Figura
Team 14	Drawn By: Peter Figura
Sheet 1 of 1	Assembly Number: 1

Figure 13: Engineering Drawing of The Exploded View

Appendix B

Team Contributions

I, _______ Peter Figura ________________, hereby agree to follow all academic integrity policies while producing this report. In addition to my original contributions, I have read through this entire report and certify that all materials are correct and unplagiarized.

Signature: Peter Figura

Date: ___12-19-20______

I, _______ Jessica Nicholson _______ __, hereby agree to follow all academic integrity policies while producing this report. In addition to my original contributions, I have read through this entire report and certify that all materials are correct and unplagiarized.

Signature: _______Jessica Nicholson_________________________________

Date: ____12-19-20______

I, _______ Jasmine Lee ________________, hereby agree to follow all academic integrity policies while producing this report. In addition to my original contributions, I have read through this entire report and certify that all materials are correct and unplagiarized.

Signature: _______Jasmine Lee______________________________

Date: __12-19-20______________________

I, _______ Lauren Mah ________________, hereby agree to follow all academic integrity policies while producing this report. In addition to my original contributions, I have read through this entire report and certify that all materials are correct and unplagiarized.

Signature:____________ __________________________

Date:___________12-19-20____________