Spring Internship 2018 at the Prototype Development Lab: A place of Dreamers and Makers

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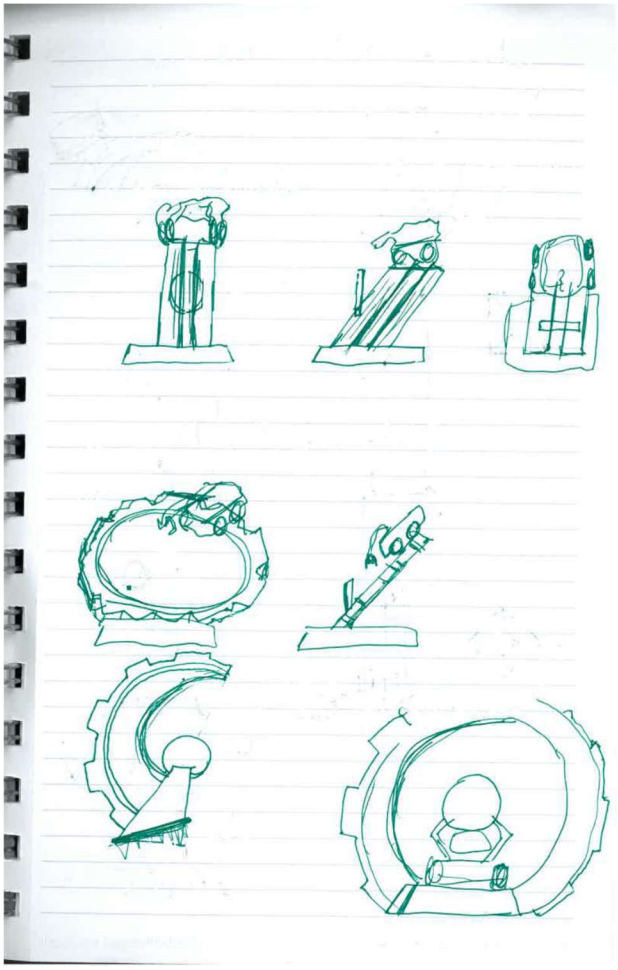
This paper covers the role of the design process and the methodology of creating a trophy during my Spring 2018 Internship at the Prototype Development Laboratory at the Kennedy Space Center. In the course of this project I used many new machines and materials while trying to deliver a professional product for a competition that invites college student teams from across the country. The machines covered in this paper include the wood chop saw, CNC mill, water jet, laser engraver, and the 3D printer. This paper also serves as an assembly guide for the trophy.

A. Introduction

Projects are sent to the Prototype Development Laboratory (PDL) to fabricate unique equipment needed for the Kennedy Space Center. The customers may come from the National Aeronautics and Space Administration (NASA) or its commercial partners such as Space X or Blue Origin seeking parts quickly or a whole project for the research and exploration of space. For this reason, the PDL has a wide assortment of machinery to facilitate the fabrication of the orders brought in by customers. This paper will cover many of the capabilities of the PDL (but not all of them!) by focusing on one such order from the Robotic Mining Competition hosted by Swampworks.

The Robotic Mining Competition (RMC) organizes more than 50 college teams to design a robot that will mine gravel that resembles regolith on the moon the planet Mars. Each year the competition revises its rules to better resemble actual conditions as more discoveries reveal the reality explorers and off world colonist will face. The organizers of the RMC requested from the PDL trophies for the competition's many categories of excellence. This project came to me to design and build each of the 14 copies of the trophy using materials readily available within the shop, be under a theoretical budget, and designed to allow for quick assembly.



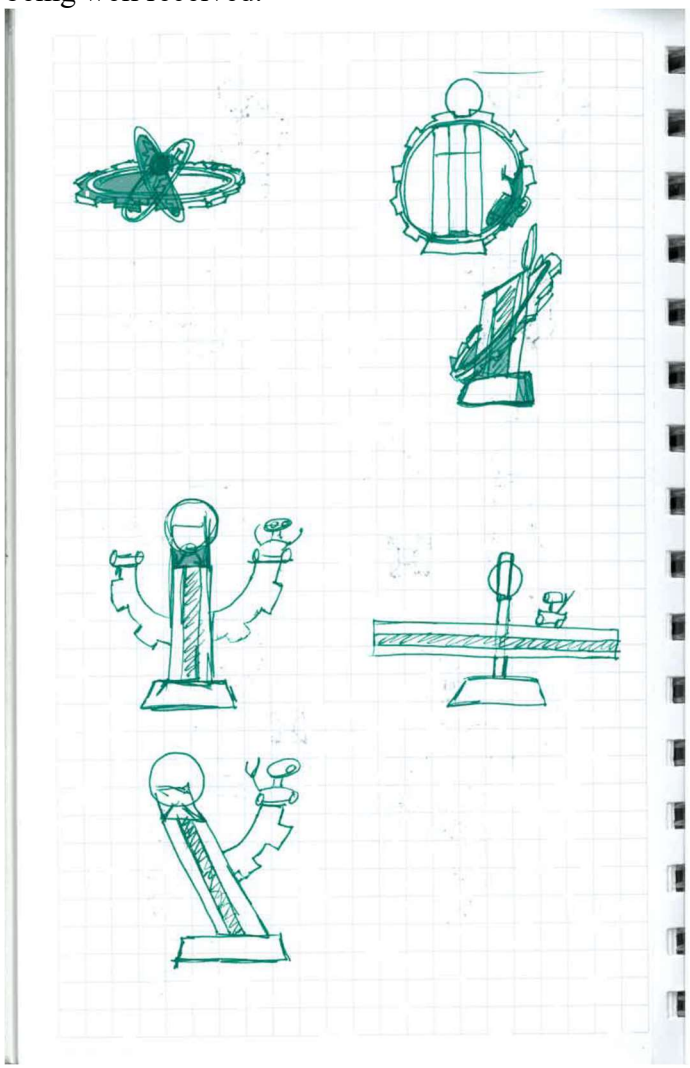
B. Design Phase Formalizing Objectives

The first stage of the project consisted of a design phase and research. To begin the design phase starts with determining the intent of the product. Similar to designing a building, a plane, or a robot, determining what the functionality or desired outcome at an early stage will help bring a cohesive whole to the project. Conditions of success should be stated at this phase to help balance the direction of design and the revisions to accommodate new mandates in functionality or availability of resources. For example, such conditions govern the energy efficiency of a building, the efficiency of an engine of a plane, or the lifting potential of a robot. But for the trophy, numbers do not enter easily to govern the design of the project.

The trophy wanted by the RMC will recognize different accomplishments made during the competition. By understanding the work involved just to make a robot move increases the desire to design a worthy trophy to honor the amazing work. The condition of success the trophy must pass is

based entirely on an emotional wow factor. The trophy will face the expectation of the students as they are recognized for their accomplishment, for this memento summarizes the long process and work involved in getting to the competition and competing. Is the trophy capable of holding that much meaning? In addition, this competition also looks forward by testing designs that will best suit the needs of the future. Does the trophy contribute in encouraging students to compete again next year or to continue in a career in robotics?

Novelty in design will only go so far. Once seen, it has been seen. A design meant to shock and wow will not pass the test of time other than as a memory of a shocking statement. For a successful design to last it must meet its intended functionality and make an emotional connection. This last part is completely reliant on each person. And for the trophy, its functionality also relies on an emotional response. Can this trophy doubly fail? Yes it can. But by having a clean design, it readily accepts meaning without asserting its own. A non-clean design distracts from its intended purpose and seems to add on features not thought of in the beginning, features that could be understood as tacked on meaning. Personal and cultural backgrounds also plays a part of the reception of the trophy, but there are many clean-designed products that have transcended design sensibility barriers, most notably Apple products and Asian design principles. Committing to a clean design increases the odds of the trophy being well received.



C. Design Phase Sketches and Research

The next phase involves two parts that more or less occurred simultaneously, sketching and research. Sketching involves throwing a wide net to grasp as many ideas as possible in a short time. Any and all ideas are jotted down in order to see the breadth of possibilities. Once on paper, a series of sudden idea can have a turn for further development with creating branches of possibilities from the original idea. It takes practice to fully realize an idea entirely in one's mind. By having the idea on paper it will be possible to discover different potential aspects of the design. Otherwise, a person will need to hold in memory every aspect of the idea and be able to hold the variations of ideas and keep track of potential solutions. A good mark of a productive sketch session usually involves discovery possibilities far beyond initial preconceptions. Starting and leaving the sketching phase with a preconceived notion into production usually leads to an uninspired outcome or designed into a corner unable to achieve multiple criteria of the project.

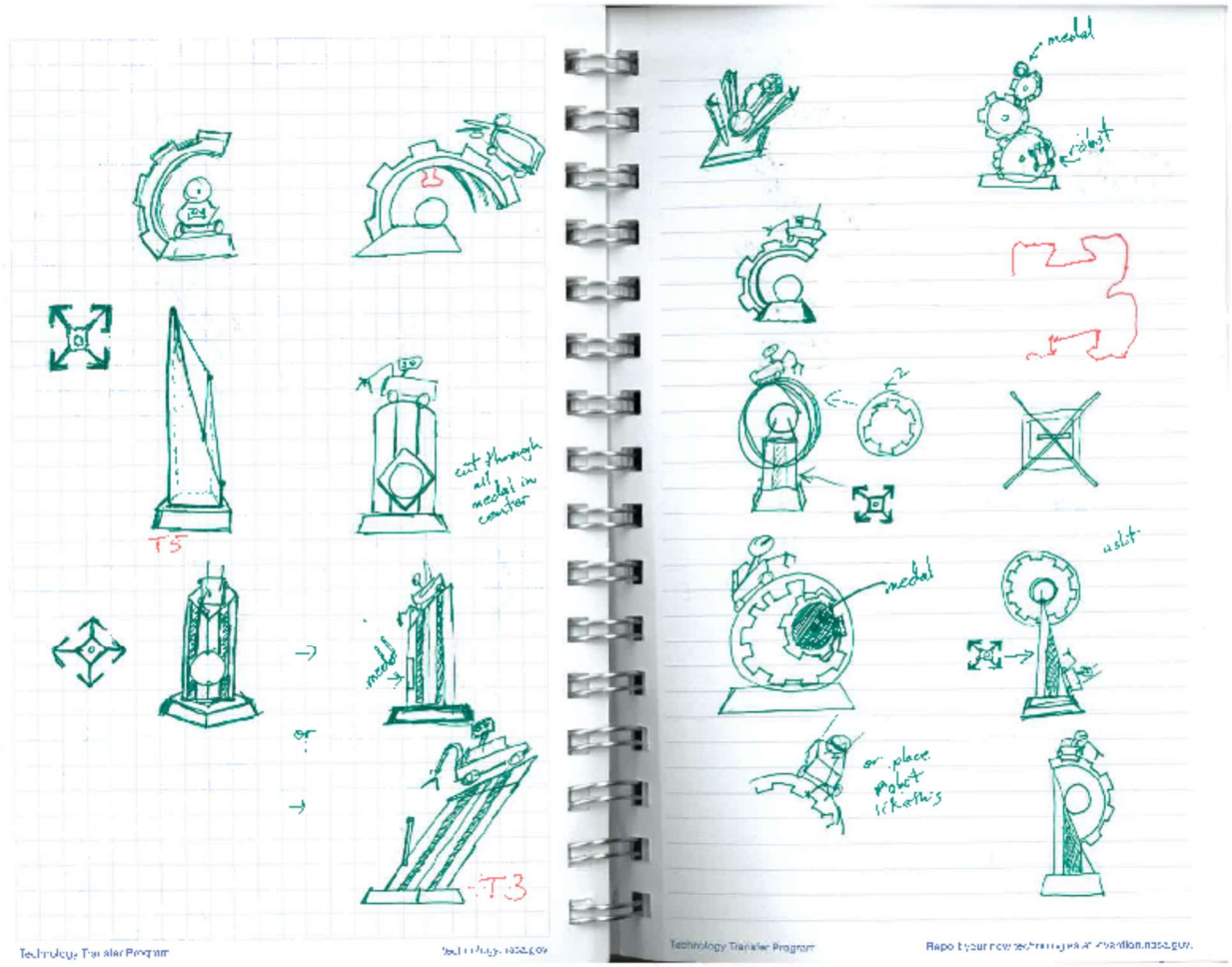
While sketching, I also conducted research to determine the possibilities to achieve physically for the trophy. Sketching a glass blown feature for the trophy may result in an excellent design, it will be useless to continue thinking along these lines for this particular project. The PDL currently does not offer glass blowing services. Even so, a wide variety of resources and machinery offer potential developments along many different avenues of thought. As part of the project conditions to keep it under a theoretical

budget, I will have to perform the majority of work and avoid interrupting the master technicians or welders. Relying on my crafting skills in a professional setting also tests how well I can fabricate using new machines and raw materials, in addition to developing my design skills. In the description of the individual elements I will relate on how I prepared myself to produce the final elements of the trophies.

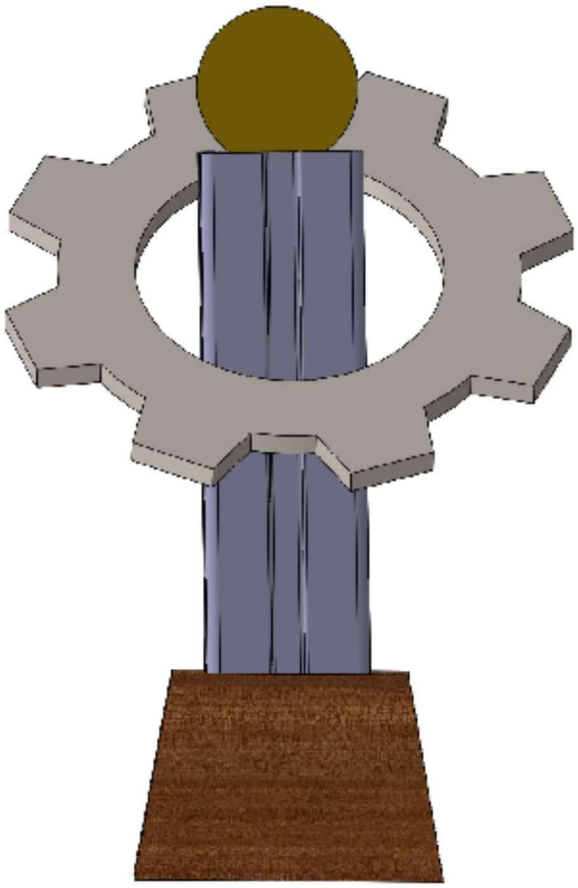
In addition to be familiarized with the machinery in the shop, I was taken through the safety protocols relating to each machine; including the machines I will be using individually, the ones I will have supervision with, and the ones I will not be operating. This instruction also informed the sketching process by avoiding shapes the machines cannot safely create. And by working within the safety parameters of the machines, the machines can produce repeatedly reliably measured parts. Thereby increasing the likelihood of producing quality parts than haphazardly guessing how a machine works to work on material not suited for that machine or configuration.

D. Finalizing the Design

The design process continues on as promising sketches are selected for further development. In the case of the trophy, that means creating a 3D model within software that will enable a pre-visualization of what the sketch could become. In this case, the sketch offered the basic shape and arrangement of elements while hinting at what materials to make those elements out of. In this phase, it becomes necessary to use accurate dimensions to help define the size of each element as well as the proportional relationships between the elements. This can be done with hand drawings but the software provides a quicker route to get this detail and be able to adjust it quickly. In addition, the software makes it possible to view the trophy from any angle which helps with adjusting the sizing of the elements.



If you think of sketching as perceiving a design through a haze, the overall shape slowly becomes apparent but not the details, most notably the details that describe how the elements of the trophy connect to each other. Previsualizing brings the design out of the haze into more concrete terms. In this phase of design, stating how elements connect to each other also states how the trophy will be assembled. While having various metallic pieces connecting may suggest welding, and since I cannot weld, I will need to rely on someone else's welding skills to assemble a key feature on the many copies of the trophy. Since that will counter one of the original parameters given with the assignment I needed another solution. To keep this trophy from falling apart when awarded to the students, and thus counter the intent of the trophy, glue should be avoided as the sole means of attaching elements together. Thinking of other solutions will also help the design move forward and keep the end goal of the solution in mind.



Getting to see the trophy take shape with the digital world is helpful but the trophy is intended to be held and seen in relation to other items. Making temporary parts helped visualize the trophy as it exists. Simple questions such as, is there a comfortable place for a hand to hold the trophy, or does the trophy tip over easily? The answers to these questions will contribute to the overall impression that the trophy will give and affect if the trophy is a failure or a success. Making these temporary parts also provided practice in using the machines I will be using making the final product. Making bases out of glued 2x4s to check for balancing issues allowed me to practice using the wood cutting machines with cheap material. I also used the 3D file to create a template and used the laser engraver to make cardboard parts as stand-ins for metal pieces. Through trying different adjustments in sizing and proportions one design became clearer as the one to base the trophy on.

E. Prototyping

The next phase of the design process involves using actual materials to construct a prototype of the trophies final form. This means using aluminum, walnut wood, and 3D printing to create a trophy to show the organizers and say 'this is the trophy' without asking the organizers to substitute the cardboard with metal. This step also offers a special insight on the final outcome because the final material will have a certain weight and feel that make up the tactile experience of the trophy. In addition to sight, the tactile experience also contributes to the emotional meaning of the trophy. With a large portion of the trophy made of metal, the trophy overall feels heavy and significant. A trophy too heavy to carry will definitely leave an impression on the recipient but the weight of the prototype surprises the bearer due to the density of the metals. This intrinsic characteristics of the metals says 'I am here in your hands because you have won'. In addition, the walnut wood base lineament will give a positive reaction due to its rich colors.

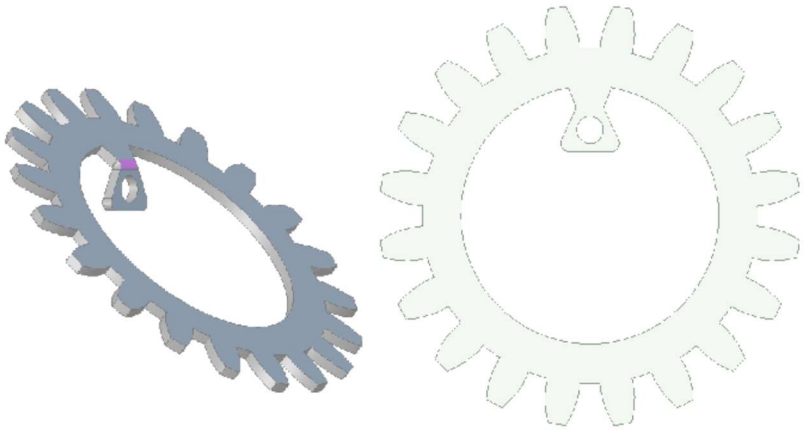
The sizing of each element reaches its final adjustment as elements settle into concrete terms while balancing importance and directing lines of sight. The sizing of the robots took an extra step to keep its visual balance with the rest of the trophy. While the robots play the role of the mascots for the competition, a giant robot figurine on top of the trophy will detract the contribution from the other

elements. And considering the conditions for the assignment for an under budget delivery, a giant robot made from 3D printer resin or plastic would increase the cost per unit to a point beyond the theoretical budget constraints. Testing different sizes of the robot figurines on the 3D software allowed the budget to remain in balance, with a select few trials to confirm the desired size. If for some reason achieving the 'right' size remained elusive, then forming a cross section that best summarizes the silhouette of the robot out of cardboard using the laser engraver can give approximations to the desired dimensions.

F. Construction

The PDL fulfills orders for awards, mementos, or plaques and already stores walnut wood for these uses. And through unique circumstances, PDL also stores a limited supple of purple heart wood. In fact, the base design originally considered using purple heart. The thicker wood naturally provides for a higher base and more area to expose its rich purple color. But the highly dense and hard purple heart wood made it difficult to get clean cuts on a consistent basis. The saw blade left scorched marks on the wood ruining its color appeal. Instead walnut came to the foreground as the wood to use for the base. Since the plank of walnut available had a thinner cross section, the base underwent a redesign to accommodate the new wood. The base design ultimately used a 45 degree chamfer on the front and sides above a 1/8 of an inch border. The grain of the wood also informed the division of the plank so that the grain crosses the base side to side. In addition, a Computer Numerical Controlled (CNC) drilled the central hole and the recess for the bolt. The last step for the base consisted of applying orange beeswax finish to enhance the natural hues of the wood. It will be best to place a narrow strip of masking tape in the place where the tag will go. This will allow the tape to adhere to the wooden base, otherwise, the wood will need scraping to reveal un-waxed wood for the tape to adhere to.

The 80/20 aluminum column first came to my attention through my supervisor. Originally intended for industrial strength erector set, the column offered many appealing features as a key component of a trophy. The form of the column included lines reminiscent of traditional trophies. The weight of the column gave credence to the award. The column felt good in the hand. The column hardly needed modification. A chop saw with a blade made for cutting metal cut the columns to size. Then tapping the central hole will accept a 5/16 bolt through the base and join the two elements. Afterwards, a wash and a scrub with simple green to ensure the metal column presented itself in the best possible light, free of dirt and grime.



Since the trophy existed in the digital world, translating the components into other software to print the components decreased design and production time. Without having to resize or measure new proportions, the software created a flat pattern of the gear for the water jet to cut out of an aluminum sheet. At the same time, the software could instead print to a 3D printer to create the component. But the resulted component will need a metallic finish, otherwise the trophy will have a potentially breakable plastic white gear. For quicker production rates, a gear made of metal needs fewer steps than a plastic gear needing coats of spray paint. As the water jet cuts the gears it leaves sharp burrs along the edges. The tumbler efficiently removes these as it cycles through aggregate meant for polishing metal. Once done and after a rinse, the gear is placed in a table vise to bend the angle needed for a bolt hole to attach to the column.

The coin of the RMC also holds a prominent place on the trophy. From the beginning, the design included a feature holding the coin. Part of the challenge of this feature relied solely attaching the component to the trophy. The form of the 80/20 column makes itself readily available to multiple uses. The design of the component includes a solid insert to the columns void. Due to the minute differences of sizes from column to column, within a thousandths of an inch, finding the right size of the insert was a challenge. Since this component came from a 3D printer, it needed golden spray paint to fit with the rest of the design. That extra layer of paint also affected how well the insert fitted within the column's slot. Several trials tested on different sizes and also to help strengthen the insert so that it can withstand increased pressure when it needs force to slide in the insert. When it comes time to paint the coin holder, place masking tape on the back side of the insert to avoid placing a thin layer on it that may cause problems during assembly.

The visual focus of the trophy belongs to the robot figurine at the top of the trophy because of its role as the mascot of the competition. After finalizing the optimal size for the robot, I designed a capital for the robot to stand on, and in turn the capital connects to the 80/20 capital. The overall effect transformed the robot figurine to a golden statue on a pedestal. The capital attaches to the column through its molded underside that slides into the groves of the column's section. This approach also encountered the same issues as with the coin holder, so the openings were deliberately made wider and double sided extra strength tape both adhered and increased the friction to keep the capital in place. The process for printing usually requires support material for the plastic to rest on as the printer lays out the layers. The support material, in this case, is removed with a sodium hydroxide bath. After a few hours the support material dissolves leaving behind the intended 3D printed part. After rinsing and drying the capital, it waits its turn to be spray painted, which can take several days. It depends on how fast the paint dries. The robot shines best with several light coats, each building on the one before.

Lastly, the final element discussed in this paper, plays a critical role in the overall finished design. The tag states what this trophy is (The Golden Bot) and for what (RMC 2018). The special coated metal first comes as solid black, until the laser engraver burns away the coat to reveal solid white. At first this process seemed straight forward, careful cutting of the metal and deburring followed by precise positioning for the laser. Until the assembly of the trophy I did not realize the importance of the tag and not for its conveyance of information but its color. The trophy's gravitas increases because of the black on the label. The color of the wood appears more dramatic as the black of the tag calls out to the darker shades. The column will always have shadows due to its unique shape and the tag highlight's its shadows. The robot capitals appear brilliant gold but the tag reminds the eye to look for shadows and gives weight to the light gold. The gear casts a shadow over the trophy and within its 20 teeth also in balance with the tag. It is fortunate that his overlooked detail worked out to the benefit of the design. Given the chance, since at this moment, the competition is more than a month away, I would find a way to darken the coin, so that its contours are more readable and takes part with the overall design.

This concludes the design discussion and in general how I made the trophy. I used many machines in the process that I had not used before. I consider myself very fortunate for this assignment and reign in design and execution of the trophy. However, there is an additional section I will like to include that will be part of the PDL archive; instructions for the assembly of the trophy. Putting something together today does not guarantee remembering how to assemble it tomorrow. In the event the organizers of the RMC request this trophy design in the future, it will be important to have a record on how to assemble it. This will include tips discovered along the way that will increase the quality of the product. In addition, this paper not only serves as a memoir of the internship thus far, but as an inside perspective for those interested in the design process, even if it is for an 8" trophy.

Appendix A:
The following are the directions for the assembly of the trophy.

First step is to ensure your hands are clean and the work station is free of oil and debris. Cleaning the trophy after assembly may be difficult since the combined elements can pose as obstructions. The wood may be permanently stained with if in contact with oil and may also affect the gold spray paint elements.

Pass the 5/16 – 18 -1 bolt through the bottom of the base.

Start screwing the column's tapped hole to the exposed bolt. Be careful to avoid scratching the wood.

Finishing attaching the column to the base by placing the base and column as shown. By having the edge of the base and the column lie flat on the surface, they will be parallel to each other. Tighten the bolt while avoiding splitting the wood.

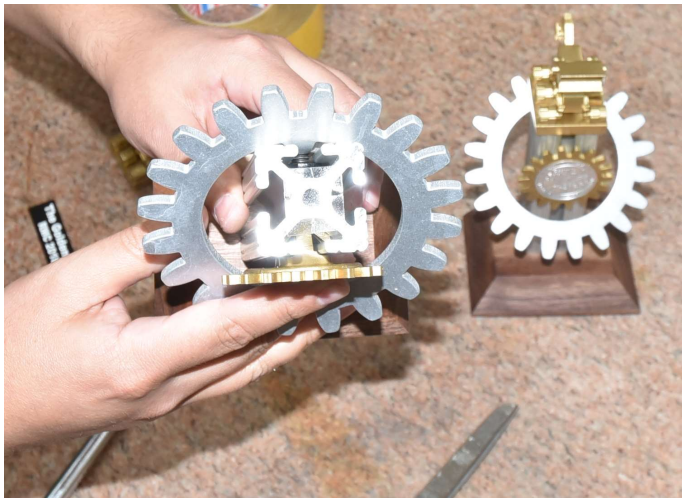
Great care is needed in this step. The gear will be balancing in your hand and if dropped it could impact the wood leaving a dent. Pass the 5/16-18 x .687” (part# 3330) bolt through the gear’s bolt hole and into the T-nut (part # 3278).

Generally slide the gear down the column. Place the nut on the inside groove of the column, taking care of where the front is. Slowly tighten the bolt to keep the gear in place.

If this is not your first trophy you can place the trophies side by side to compare the height of the gear. Tighten the bolt until secure.

Next, slide the coin holder into place. Depending on the spray paint, there may be resistance. Either sand paper or an X-acto blade to scrape away the paint.

Next, cut a piece of industrial strength double sided tape to fit on the central square of the column. The edges of the tape can exceed this size, but if it is too much it will be visible from the bottom of the capital.



Place the capital on top of the column. Make sure it is all the way down and evenly placed.

Next, cut a piece of industrial strength double sided tape to fit on the back of the tag.

Place the tag on the central face of the base.

Keep the trophies clean until delivery.

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