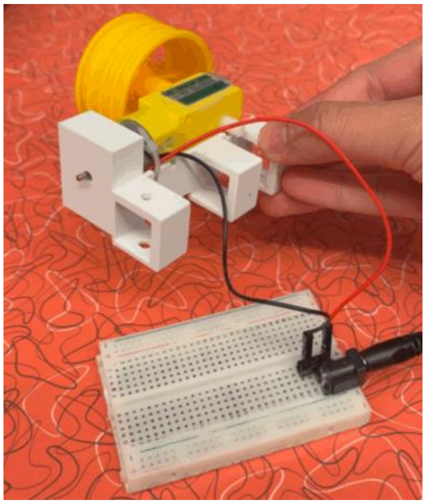

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ME100 PROJECT: DESIGN OF TT DC MOTOR MOUNTING BRACKET FOR TETRIX® BEAMS

A Report Composed For:
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Andrew J B Milne,

I have prepared a report, entitled ME100 PROJECT: DESIGN OF TT DC MOTOR MOUNTING BRACKET FOR TETRIX® BEAMS, to submit as my design project for ME100: Introduction to Mechanical Engineering Practice I. This report details one of many solutions to a problem from the 2022 fall term's Dynamometer Project: 1A Mechanical Engineering students assembled a Prony Brake or Rope Brake using a TETRIX® Kit. This report demonstrates the applied knowledge and skills gained throughout the, ME100: Introduction to Mechanical Engineering Practise I, course to solve an engineering problem. The ME100 course is an introduction to the concepts of engineering, specifically a typical design process of an engineer and its applications. There is an emphasis on the use of AutoCAD and SOLIDWORKS, applying the engineering skills (e.g., dimensioning rules for 2D technical drawings) learned from ME100 Engineering, Graphics and Design. It also elaborates on the design process of each prototype—I used the design method of layered functionality to improve the prototypes—learned from ME100 Design, Communication and Professionalism, that resulted to the final product. This report was written entirely by the undersigned and has not received any previous academic credit at this or any other institution. Thank you for taking the time to review my work. Please do not hesitate to contact me with questions or concerns.

Best Regards,

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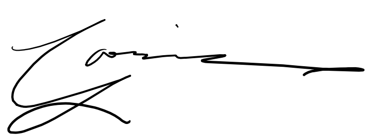

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Summary

This report details a solution to a problem originating from the 2022 fall term's Dynamometer Project. The stream 8 Mechanical Engineering cohort had to assemble a Prony Brake or Rope Brake using a TETRIX® Kit provided. Each group had a common problem: they had trouble attaching the TT DC motor to the TETRIX® beams.

This report proposes a custom mounting bracket to mate the TT motor to standard TETRIX® beams. This problem formulated the following main functions: this mounting bracket is required to seat the TT motor in 6 orientations onto the TETRIX® beams, holding its weight of 30.6-grams without breaking.

From the main function, constraints and criteria were derived to optimize the prototype design. Those main constraints and criteria include applying the concept of tolerances so that the mounting bracket does not get stuck on the TETRIX® beam while mating it but is also durable long-term, and minimizing the cost of manufacturing this product.

Before 3D printing the model, a copy of the SOLIDWORKS file of the TT motor was imported into SOLIDWORKS to determine if the component fits onto the TT motor. This increases the probability of success when progressing to the 3D print.

Research was conducted on the chosen material: use of different filaments and its corresponding tolerances that will work best in producing a viable product. This research of the filament types used to 3D print the prototypes apply the constraints and criteria which include its price, heat-resistance, resilience, and tolerance.

Using that research, potential solutions were brainstormed to build the prototypes, and experimental trials were executed to verify its feasibility. The potential solutions that were considered was 3D printing a bracket that will hang due to gravity, mount from holes, and clamped to the TETRIX® beam.

The final product is a mounting bracket that hangs to the TETRIX® beams where a screw goes through the holes of the mounting mechanism to secure the TETRIX® beam. Though this was the final prototype, there are recommendations to subsequently improve this product.

1.0 Introduction

The ME100 course is an introduction to the concepts of engineering, specifically a typical design process of an engineer and its applications. The idea for this project emerges from the Fall 2022 ME100 Dynamometer Project where the class had to assemble a Prony Brake or Rope Brake using the TETRIX® Kit provided. Most groups had a similar predicament when building the dynamometer: "how can we attach the TT motor to the TETRIX® beams?" Some groups assumed the silver cylinder-shaped part at the head of the TT motor will attach the motor onto some object; however, the diameter was too small to fit perfectly into the TETRIX® beams and rotated so if it was attached to something tightly the motor would stop operating. Observing other groups, several had taped their TT motor to the TETRIX® beams, while others had wrapped around string or rubber bands (e.g., shown in Figure 1) to hold it onto the TETRIX® beams. In this report, the problem is identified, research is conducted to distinguish the constraints and criteria, solutions are formulated, then the design is prototyped to subsequently determine whether the design is feasible and effective.

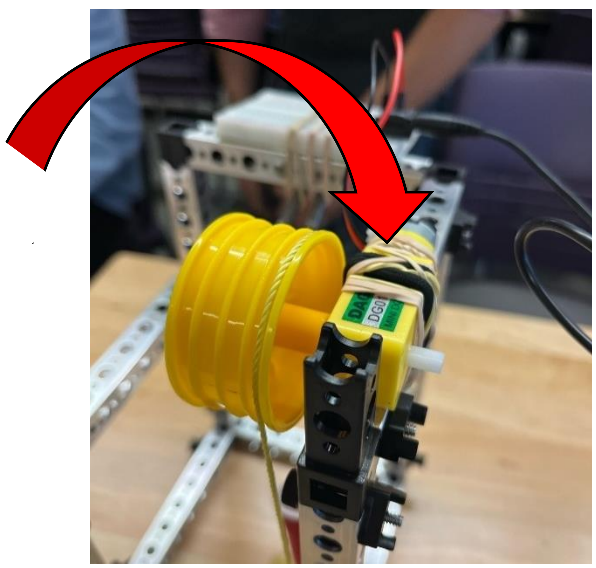


Figure 1 Close up of TT motor secured using rubber bands

A TT DC motor is a type of motor that is frequently used in battery-powered toys (as shown in Figure 2). You can connect something to the white, plastic motor shaft, such as a wheel or pulley, and it will rotate given that the motor body accelerates a mechanical shaft at a certain rate of speed. The motors sometimes require a motor mount (brackets of some kind used to hold the motor in place) which tend to be composed of aluminum or plastic [1]. Figure 3 depicts a 2D technical drawing of the TT DC motor where the measurements are used to aid the measurements of the prototype’s frame.

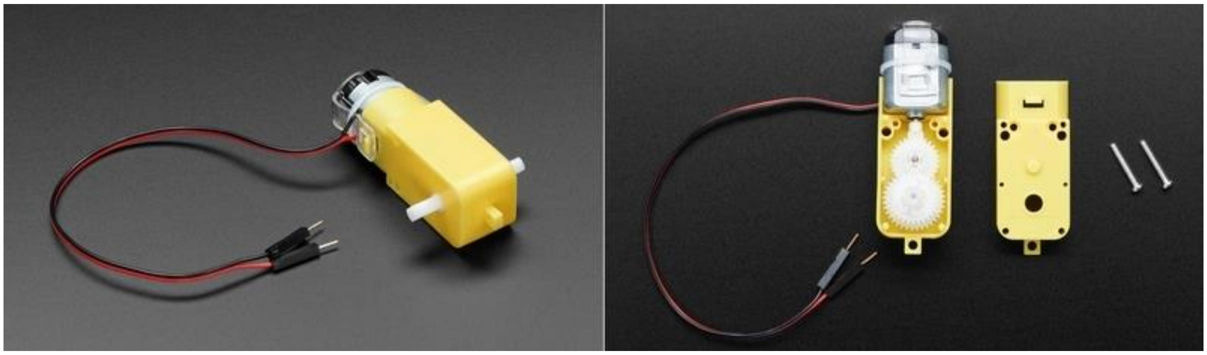


Figure 2 On the left, a yellow motor called a TT motor. On the right, a fully plastic gearbox [2].

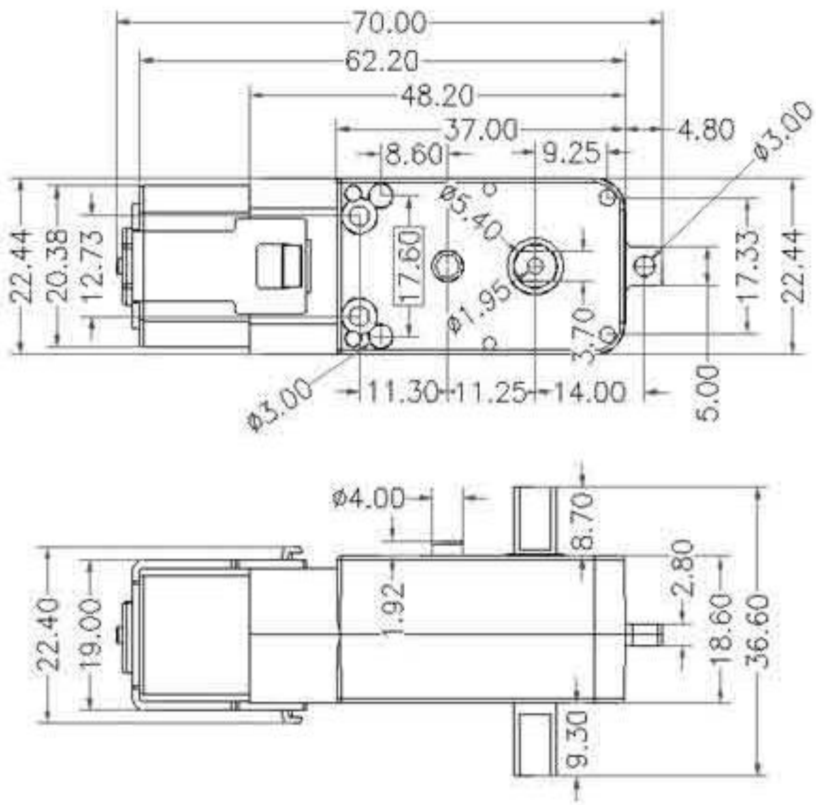


Figure 3 2D technical drawing of the TT motor [2]

The TETRIX® Kit, specifically the TETRIX® PRIME Robotics Set for EV3 (shown in Figure 4), provides pieces allowing an individual to build, for example, a dynamometer. This kit contains more than 290 aluminum and plastic pieces including structural elements (e.g., beams that have 4/5/6/7/8/13/15 holes with measurements of 16 mm by 16 mm), connectors, hubs, brackets, wheels, and gears plus a gripper kit; rechargeable battery pack and charger; two standard servo motors and two TETRIX® PRIME DC Motors; 4-in-1 and 2-in-1 screwdrivers, and a hex nut driver; a sturdy storage bin; four balls and cups each for robot course; detailed and graphic builder's guide; TETRIX® PRIME EV3 Module; and five TETRIX® PRIME EV3 Mounting Brackets (2-pack) [3]. Figure 5 and Table 1 respectively shows a TETRIX® beam that seats the mounting bracket, and the type of screw that is used to secure the mounting bracket onto the beam.

Figure 4 Zoom-in of the TETRIX® beams from the TETRIX® PRIME Robotics Set for EV3

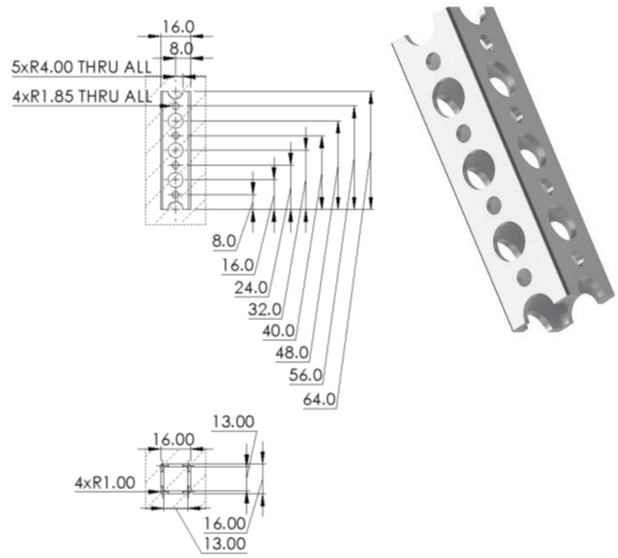
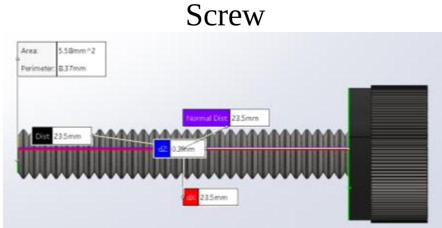


Figure 5 2D technical drawing of TETRIX® beams on SOLIDWORKS

Table 1 Measurements of screw

Component	Measurements	
	Thread Radius	Thread Length
Screw 	1.753 mm	23.50 mm

1.1 Technical Background

There is a snap-on mechanism for the motor so one would not have to worry about the TT motor falling out when it is operating, implementing the concept of tolerance force fit [4] – [7], but it will also be less time consuming to remove the TT motor from the mounting bracket. This snap-on feature also includes a mounting mechanism that slide in and out of the TETRIX® beam. It can mate in any three (or six) orientations: vertically, horizontally, and outwards. This mounting bracket is designed in a vertical orientation using a tolerance fit so that the bracket will not slide down due to gravity (i.e., there is sufficient friction required to prevent the component from sliding off easily), and support to hold the mounting bracket in place (e.g., the screws provided in the TETRIX® kit).

1.2 Objective

The objective of this report is to investigate a feasible solution to create a mounting bracket for the TT DC motor so that it attaches to the TETRIX® beams in different orientations. This is explored through the process of engineering judgement and science, and experimentation to develop the best engineering solution.

2.0 Functions

The functions that were implemented into this design involve creating a mounting bracket that can orientate the TT motor in 6 positions (i.e., the vertical, horizontal, and outer axis positions). The bracket must be secured to the TETRIX® beam along with holding a minimum weight of the 30.6-gram motor. The methods that were explored were mating to the beam, mating to the motor, and attaching and detaching the motor from the bracket. This underlined the functions required to brainstorm concepts for the final product. Therefore, this project provides a feasible solution so that the TT DC motor will have a place to seat on, connecting them to the TETRIX® beams.

2.1 Constraints and Criteria

The main constraint is that the mounting bracket for the TT motor must have a measurement tolerance of +0.05 (Table 2) [8] so that when proceeding to 3D print the prototype, it would slide in with minimal force—a friction fit. With that, the object must be able to slide with ease on the TETRIX® beam; if one forcefully pulls it in and out, the filament will start to scratch or may even break. When the TT motor is operating, it should be strong enough to hold the loads (i.e., when using the motor to build a Rope Brake dynamometer). The design must be simple enough that placing the mounting bracket into the TETRIX® beam is self-explanatory; but accurate enough that the wires from the TT motor do not interfere with the running motor.

The criteria are to minimize the cost when manufacturing this product, but also consider that this product should be resistant to long-term wear. The total cost to pay for this prototype should be minimum 3 CAD dollars and maximum 5 CAD dollars. The greater the volume of the material used to prototype the bracket, the pricier it will be. Less than 3 CAD dollars and the mounting bracket is more susceptible to breaking. This assumption is proved in the section *3.2b.iii Third Prototype* where the prototype snapped while mating the TT motor.

3.0 Technical Progress

This section outlines the technical progress and material, and design choices in all prototypes. There are justifications for the chosen material using research, and explanations of the design choices using measurements obtained from the TT motor to convert into drawings on AutoCAD, along with the 3D models built on SOLIDWORKS.

3.1 Choosing the Material

The material chosen in preparation for the final prototype is 3D printing filament. Filaments used in 3D printing are thermoplastics, which are plastics polymers that melt (rather than burn when heated), can be shaped and molded, and solidify when cooled [9].

This material was chosen because it is the most convenient and inexpensive, though it takes more time to complete a task than laser cutting, and machining. 3D printing this bracket takes roughly twelve hours, while laser cutting or machining the part may take below three. Sometimes 3D printing a part may face complications such as a "print failure" in some cases the printer's nozzle may get jammed, or the 3D printed part may collapse while printing.

The question is which type of filament would be ideal for this design but is also available at WATiMake in the University of Waterloo: PLA, ABS, Flex-45, PETG and Carbon Fibre. To first narrow down those options, research was conducted on which of the filaments are best for prototyping. This narrows down the options to PLA, ABS and PETG.

These following subsections make a comparison on those three types of filaments which comply with the constraints and criteria: price, heat-resistance, and long-term use. Ultimately, the choice of filament depends on the specific requirements of the mounting bracket and the application it will be used in.

3.1a *PLA Filament*

PLA (Polylactic Acid) filament is a popular choice for 3D printing material due to its ease of use, low cost, and good print quality [9] – [11]. PLA is the least expensive of the three materials, making it ideal for prototyping in low-cost projects [9], [10]. PLA filament is the cheapest option out of the three filaments with the approximate low and high cost: $\text{PLA}_{\text{low price}} = \$15.00\ \text{CAD}$ (Geeetech: 1.75 mm, 1KG/2.2LBS) and $\text{PLA}_{\text{high price}} = \$52.00\ \text{CAD}$ (PRO Series: 1.75 mm, 1KG/2.2LBS) [10]. To factor in heat resistance, PLA filament is impractical because it tends to deform or melt in high heat situations [10] – [12]. This material is also brittle when it is greatly impact [10], [11]. PLA is also a very easy material to print with and does not require the use of a heated print bed [10] – [12]. This means that 3D printing is simple to learn and that you can quickly iterate on your designs [10], [12]. When it narrows down to functional prototyping, PLA would not be a great option.

3.1b *ABS Filament*

ABS (Acrylonitrile Butadiene Styrene) filament is a 3D printing material combining strength, flexibility, and durability [9], [11], [12] – [14]. ABS filament is typically less expensive than other 3D printing materials and a versatile material that can be used in a wide range of applications, making it a popular choice for both beginners and experts [14]. ABS filament is the second cheapest of these three options: $\mathrm{ABS_{low\ price}} = \$17.59\ \mathrm{CAD}$ (SUNLU: 1.75 mm, 1KG/2.2LBS) and $\mathrm{ABS_{high\ price}} = \$73.90\ \mathrm{CAD}$ (HatchBox: 1.75 mm, 1KG/2.2LBS) [10]. Though more expensive, it is longer lasting and less susceptible to stress than PLA. This is critical for the mounting bracket as it can deteriorate from repeated use or holding heavy objects in place. ABS filament is durable and scratch resistant, making it a great option when the product will be used frequently or in harsh environments [11], [13], [15]. ABS filament is strong and long-lasting, making it an excellent choice for parts that will be stressed or weighed. ABS can provide the strength required for mounting brackets to support the weight of the object that is being mounted [11], [13], [15]. ABS filament can also withstand higher temperatures than PLA and PETG filaments [10], [11], [12], [14], [15], therefore being the preferred material for heat-sensitive parts. This is especially important for mounting brackets that will be used in potentially high temperature environments, such as the TT DC motor.

3.1c *PETG Filament*

PETG (Polyethylene Terephthalate Glycol) filament is a 3D printing material that has some advantages over PLA and ABS filaments when prototyping mounting brackets. PETG filament is the most expensive option: $\mathrm{PETG_{low\ price}} = \$21.99\ \mathrm{CAD}$ (PolyMaker: 1.75 mm, 1KG/2.2LBS) and $\mathrm{PETG_{high\ price}} = \$75.00\ \mathrm{CAD}$ (PRO Series: 1.75 mm, 1KG/2.2LBS) [10]. This type of filament has all the same qualities as ABS filament but better in some senses [12], [14]. A disadvantage is the price, so preferably this type of filament would be better to use for the final product. PETG filament contains glycol, which reduces brittleness and improves impact resistance and durability [12]. Though, this unfortunately makes it prone to scratching which may ruin the edges of the bracket [11], [15]. PETG is strong enough to withstand the stress or weight of the 30.6-gram motor being mounted [10], [11] while remaining flexible enough to absorb shocks and vibrations. Comparing the resilience of the two strongest filaments of these three options: the PETG filament has a tensile strength of 7079 psi compared to ABS which has a lower amount of 5872 psi [14]. In other words, the PETG filament is more flexible than ABS interpreting it as less likely to crack or break under stress. PETG filament is also simple to print and has good layer adhesion, resulting in a smooth surface and strong printed part [15].

3.1d *Chosen Material*

The ABS filament is the best option of the three filaments. This is because this prototype requires material that can withstand heat-resistance, long-term from repeated use, and cost-effectiveness. ABS has a higher temperature resistance than the PLA and PETG filaments. ABS can withstand higher temperatures before softening or deforming. This makes it more suitable for applications where the mounting bracket for the TT motor, as well as the motor itself, may be exposed to heat. ABS has greater impact resistance and toughness than PLA. This means it is less likely to crack or break under stress, making it an excellent choice for applications where the bracket must support a heavy load or is subjected to frequent impacts. However, PETG filament has an advantage when loading strength is considered, ABS is more affordable for prototyping.

Table 2 shows the dimensional tolerance for ABS filament which is considered while 3D printing the bracket and adjusting the printing settings (shown in Figure 6). To achieve the desired tolerance, one must adjust the flow rate, extrusion multiplier, and retraction settings in the slicing software. This is because different 3D printers may have different accuracy. These options will assist in fine-tuning the amount of filament extruded to match the required dimensions considering the dimension tolerance of +0.05 mm.

Table 2 The dimensional tolerance of each brand of ABS filament [8]

Type of Filament	**Brand**				**Dimensioning Tolerance**			
ABS	Amazon Basics	Hatchbox	SUNLU	MH Build Series	±0.03 mm	±0.03 mm	±0.02 mm	±0.05 mm

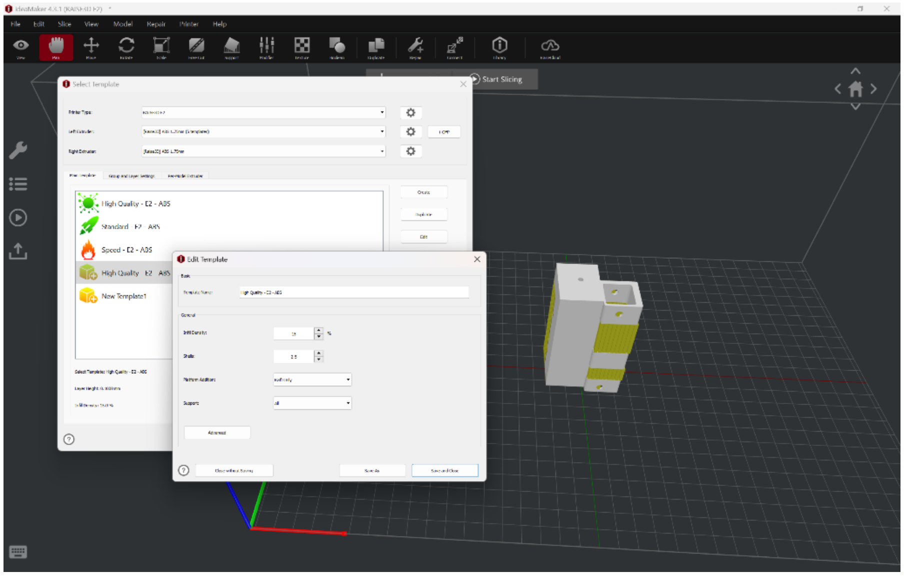


Figure 6 Settings on ideaMaker for the mounting bracket to be 3D printed

3.2 The Frame

The final version of the base was manufactured by 3D printing the prototype using ABS filament. The ABS filament is the best of the three options for prototyping this project as mentioned in *3.1 Choosing the Material*.

3.2a *Solutions Considered*

In terms of the frame's thickness, the first prototype was made of 1.0 mm thick cardboard. The cardboard was strong enough to support the TT motor, indicating that the ABS filament would be as well. Based on research and experimentation, several ideas were identified as potential solutions. The following designs were prototyped to determine which one was the most feasible. The design that works the best was used in the development of the final prototype.

One possible technique is to create a prototype with an attachment frame on one of the orientations to slide onto the TETRIX® beam. Dimension tolerances, specifically force fit, where one part is forcefully pressed into another part as a friction fit to secure it to the beam, must be considered here.

Another solution is to align the TETRIX® beam with the prototype, align it with the center of the prototype frame, and add holes into the bracket of the frame. A screw can go into the holes and TETRIX® beam and be secured. For this solution, dimension tolerance must be accounted for.

The prototype can also be hung due to gravity, clamped, or pinned like a trailer. The sketches of these designs are respectively depicted in Figure 7.

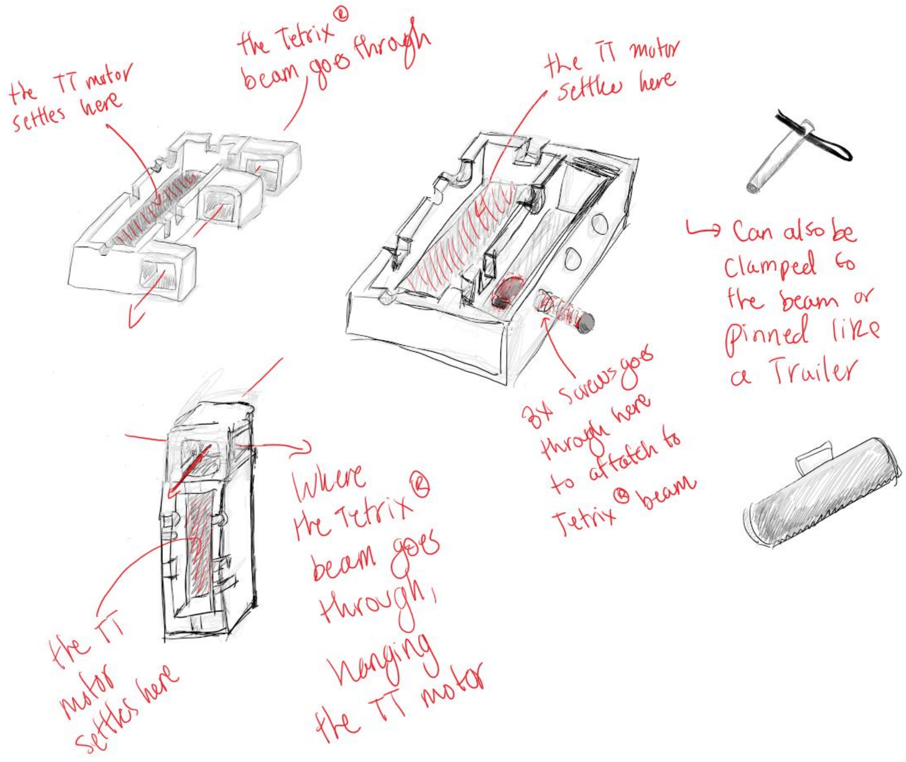


Figure 7 The solutions considered for prototyping the mount

3.2b *Progress to Date*

3.2b.i First Prototype

The first prototype is made from recycled cardboard. This is because before 3D printing the prototype, a cheap prototype was constructed so the probability of a successful 3D printed prototype is higher. The aim for this first prototype is to create a frame before continuing with the mounting bracket function. The TT motor was measured using a vernier calliper to dimension the frame, and those measurements were translated into an orthographic drawing on AutoCAD (Figure 5) to be constructed using cardboard. After taping the sides together, the TT motor fits perfectly into the frame. The cardboard prototype was clamped to a higher elevation to test its durability. It did not collapse, making the first prototype successful. Moving forward with the following prototypes, a concept that was incorporated is called layering functionality. This means that each prototype added on a function, constraint, or criterion. The first prototype can be seen in Figures 8 and 10.

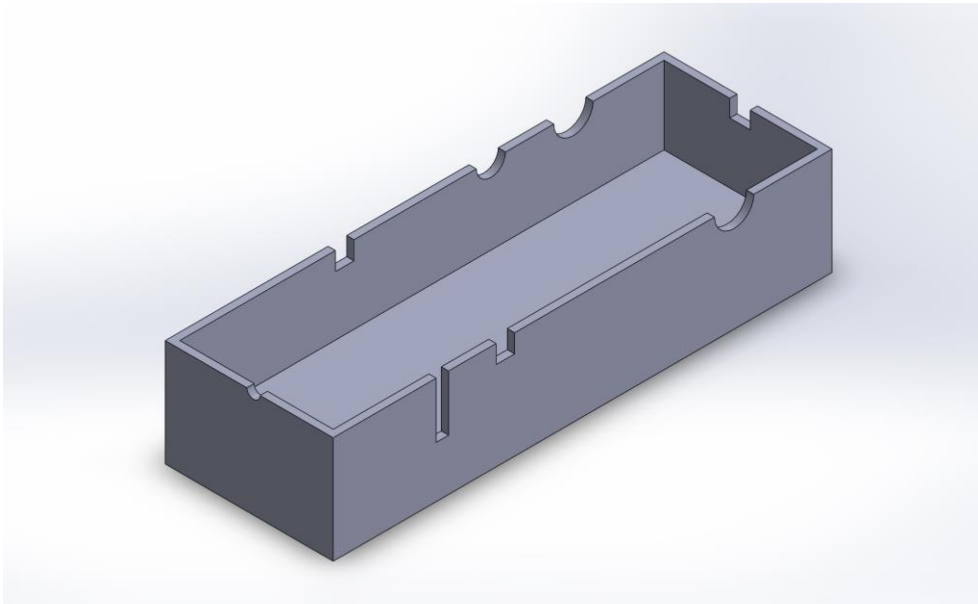


Figure 8 SOLIDWORKS 3D model of the first prototype

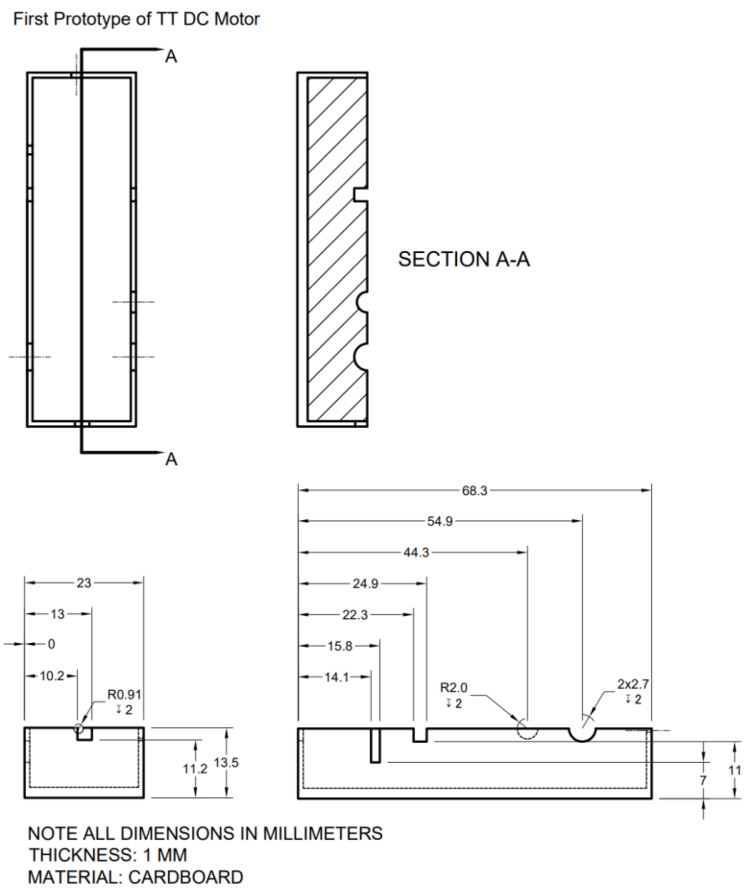


Figure 9 AutoCAD 2D technical drawings of the first prototype

TOP VIEW	FRONT VIEW	RIGHT SIDE VIEW	ISOMETRIC VIEW

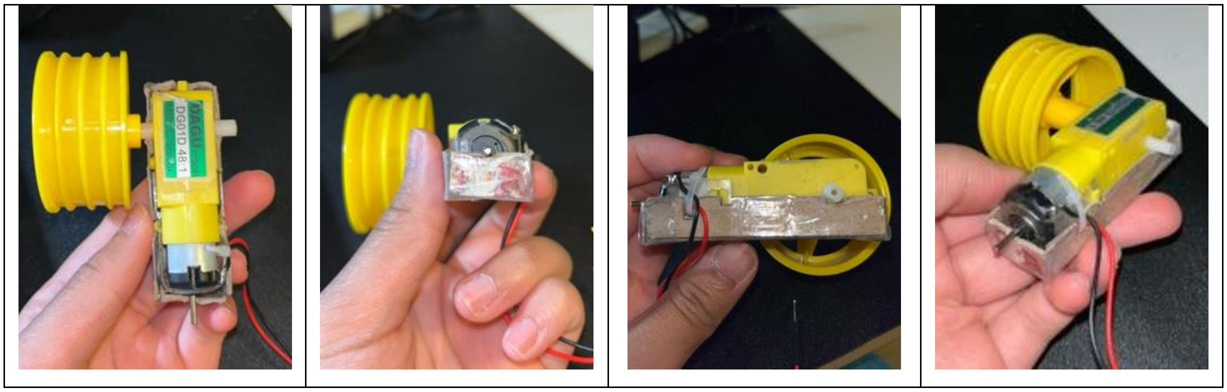


Figure 10 Orthographic and Isometric views of the first prototype mounting the TT motor

3.2b.ii Second Prototype

The second prototype incorporates the mounting mechanism. As previously mentioned under *3.2a Solutions Considered*, one solution is to have a mounting feature of the prototype slide onto the TETRIX® beam. This is where dimension tolerances must be considered, precisely force fit—the prototype is forcefully pressed into the TETRIX® beam. The mounting feature is located at three areas of the prototype (refer to top-left drawing in Figure 11). This is to avoid the interference of the plastic shafts when the TT motor mated to the prototype is being forced through the beam. From the right-side view, the first and last locations of the mounting feature have the same measurements: the width and height are both 16.1 mm considering the length of the beam (16 mm) and dimension tolerance of ABS filament used to be 3D printed (0.05 mm for every edge), and the length is 10 mm so that the mounting feature does not overlap with any of the holes. There were several issues after 3D printing the second prototype. This prototype is only able to mate horizontally and outward. The next prototype implemented the function that the prototype can orientate in six positions, including the vertical positions. The front view can be covered to ensure that the motor will stay in place when it is positioned vertically. The second prototype can be seen in Figures 11 and 12.

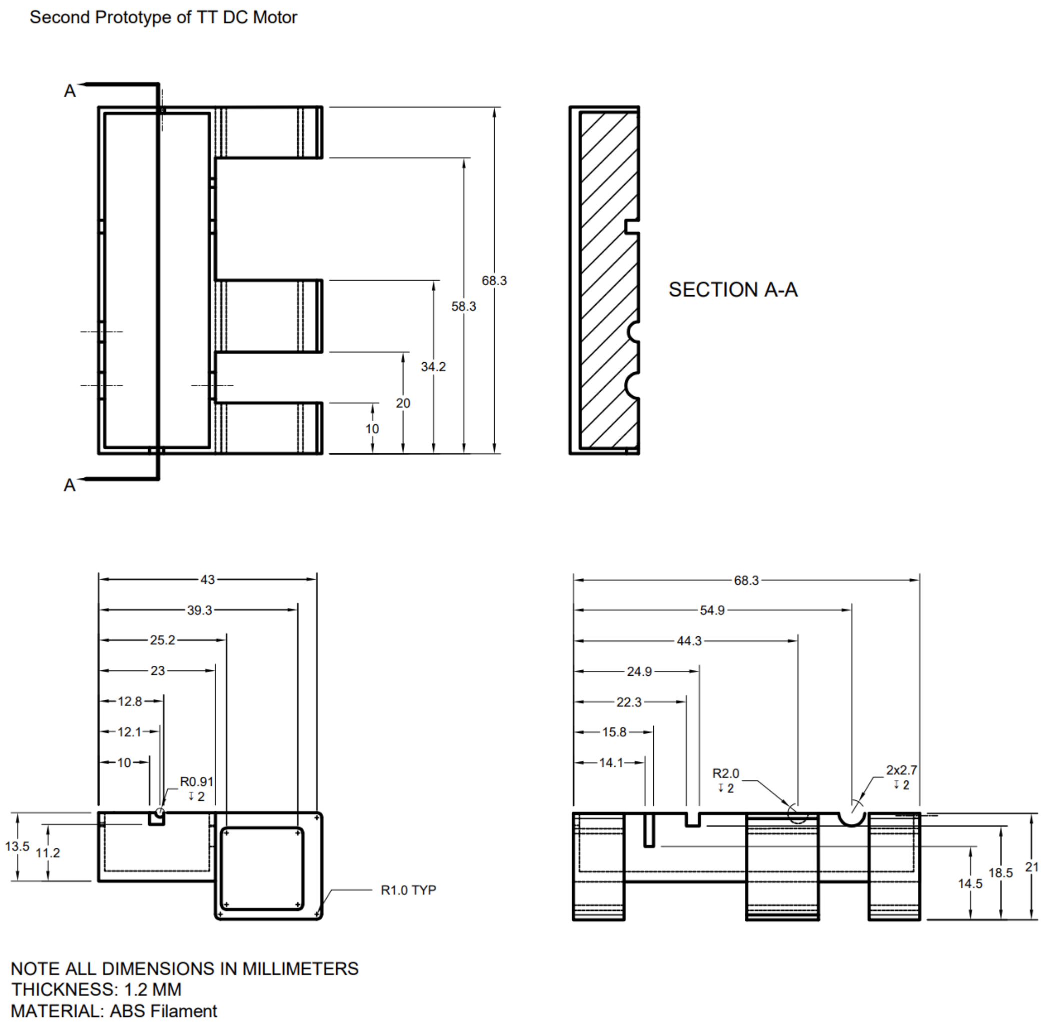


Figure 11 AutoCAD 2D technical drawing of the second prototype

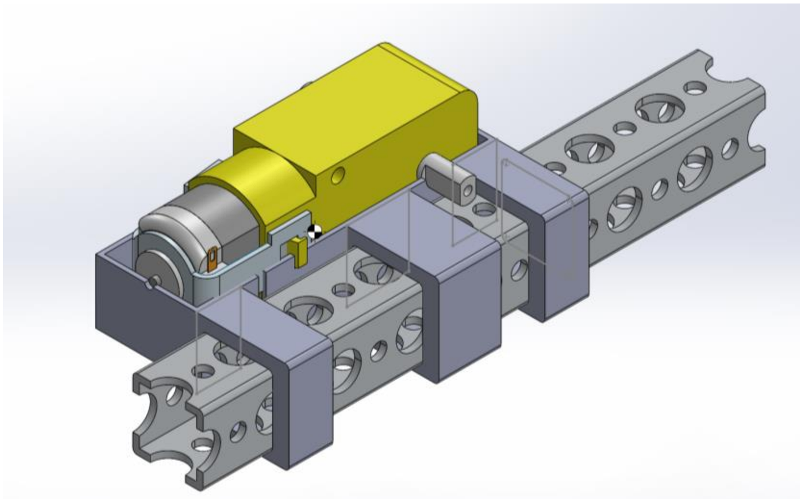


Figure 12 SOLIDWORKS 3D model of the second prototype

3.2b.iii Third Prototype

The third prototype improves compared to the second prototype where the front view of the mounting bracket is fully covered opposed to half covered. When mounting the TT motor on the second prototype (Figure 12) at a vertical orientation, the motor fell off the bracket and the bracket was slightly moving down the TETRIX® beam. To solve this, holes were created on the prototype to put the screws in (demonstrated in Figure 13). That way using the screws, it will tightly fascine the prototype and beam together. The screw could not slide in properly because the radius of the hole in the prototype is too small, so there was a need to refine the radius to the right fit for the next prototype. The prototype was fidgety when the TT motor was running while seated on the prototype. Also, when forcefully seating the TT motor onto the prototype, the frame snapped (shown in Figure 14). This can be refined by designing the back view of the prototype to be about 1/3 less its original height (the change shown in Figure 15). This addresses the orientations of the prototype, specifically vertical. This model also must sustain much force when putting the TT motor into the frame of the third prototype (Figure 15). So, for the next prototype, the bottom thickness should increase to solidify its balance which is still under the maximum criterion for the cost as this prototype cost 2.51 CAD dollars. The third prototype can be seen in Figure 13.

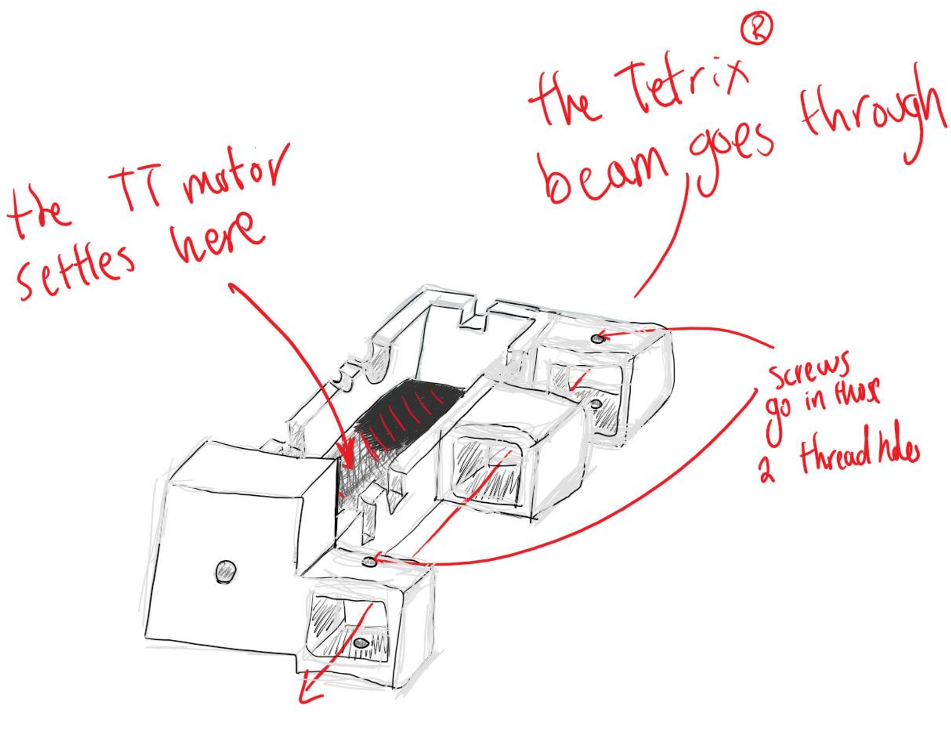


Figure 13 A sketch of the third prototype

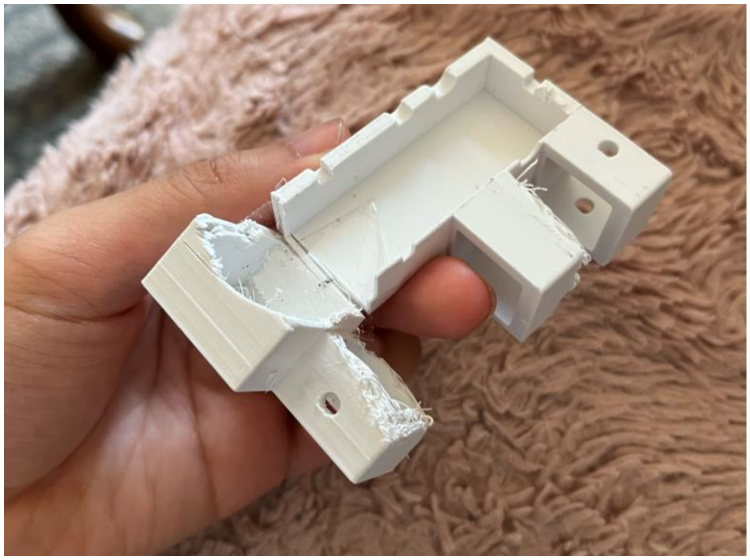


Figure 14 The third prototype snapped while the TT motor was seated

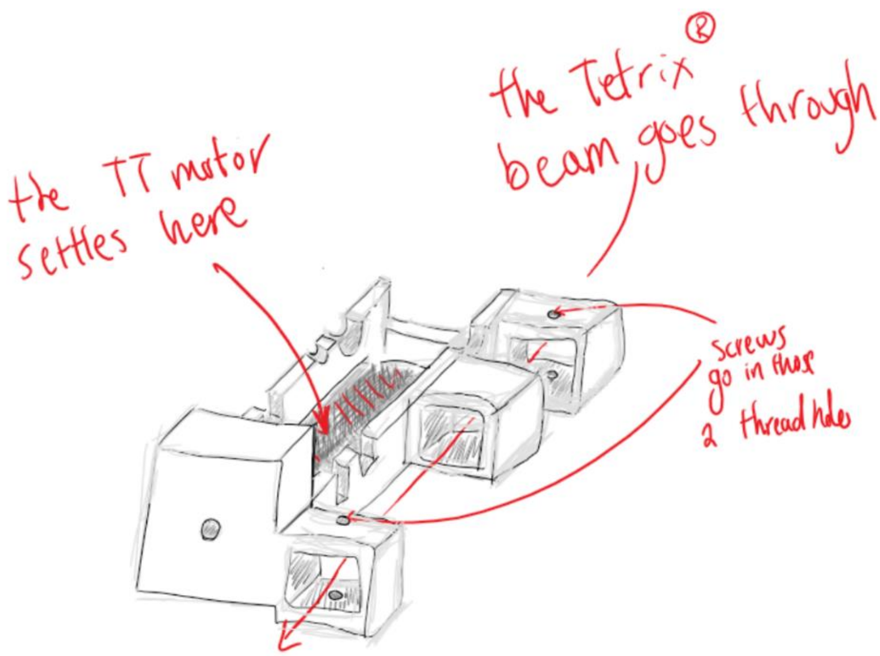


Figure 15 A sketch of the final design

3.2b.iv Final Design

The final prototype was finalized after continuous endeavours in experimentation and observation, using the reasoning from *3.2b.iii Third Prototype* and creating a sketch (Figure 15). The design was finalized where the back view of the prototype was fixed to be about 1/3 less its original height (the change shown in Figure 15), which addresses the vertical orientation of the prototype. The bottom of the prototype was 3D printed thicker where it rendered the prototype more durable. This prototype costs 4.09 CAD dollars which still meets the criterion of the manufacturing cost being below 5 CAD dollars. The final product can be seen in Figure 16.

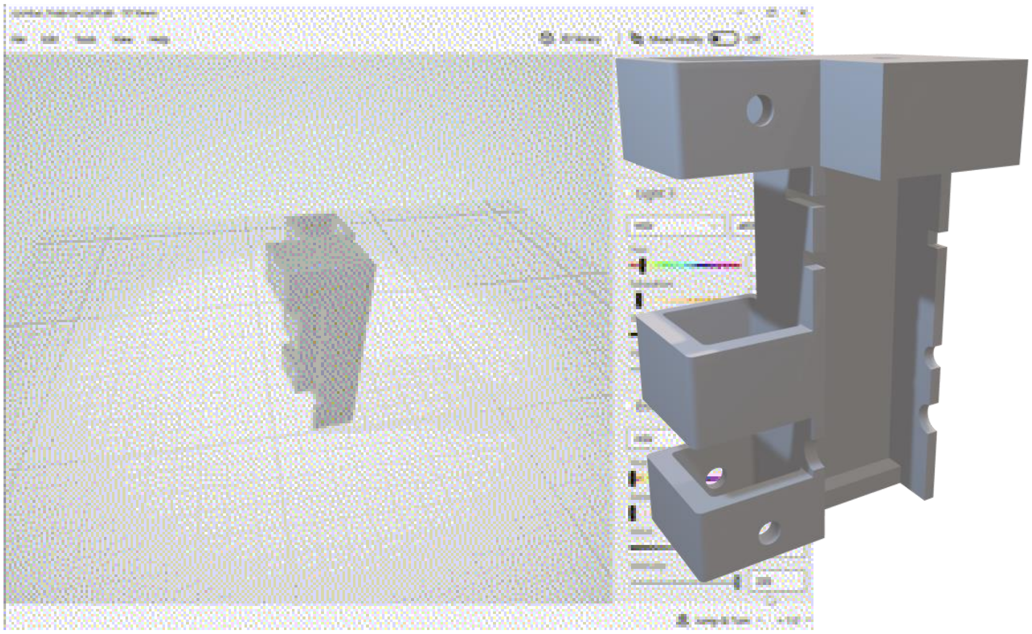


Figure 16 3D model of the last prototype (with an interactive 3D model)

However, problems arose because there was an assumption made about the numerical value of the tolerance fit. Thereby, a further investigation of what would be the best tolerance fit so that the mounting bracket is neither too tightly attached to the beam nor too loose—that the operating TT motor will move freely. When given the beams, the 5-hole square beam appeared to fit through the prototype at first (shown in the left image of Figure 17), assuming that the width and the height of the beam were equivalent for all the different-hole beams—a measurement of 16 mm by 16 mm. This was however not the case. The 7-hole square beam was too tight. It took a lot of force to fit into the beam but still had not fully fit through, as shown in the right image of Figure 17. Contrarily, the other 5-hole square beam fit perfectly involving a slight push of force required, as shown in the left image of Figure 17. To allow the TETRIX® beams to slide in easily, the tolerance was slightly modified to accommodate for all the types of TETRIX® beams.

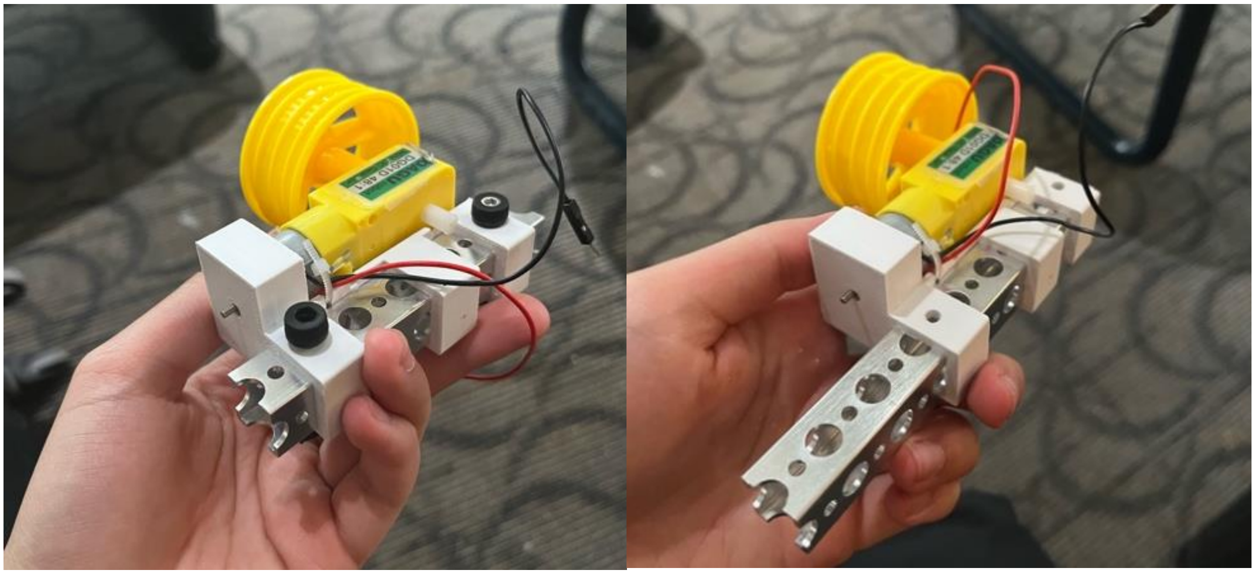


Figure 17 Final prototype attached to 5-hole square beam and to 7-hole square beam, respectively

After resolving this unforeseeable error due to incorrect tolerance, the prototype was finalized (shown in Figure 18). To fix this mistake costed 4.45 CAD dollars. Below in Figures 19 and 20 is the 6-orientations of the final version including views of the product with and without the TT motor and the beam attached.

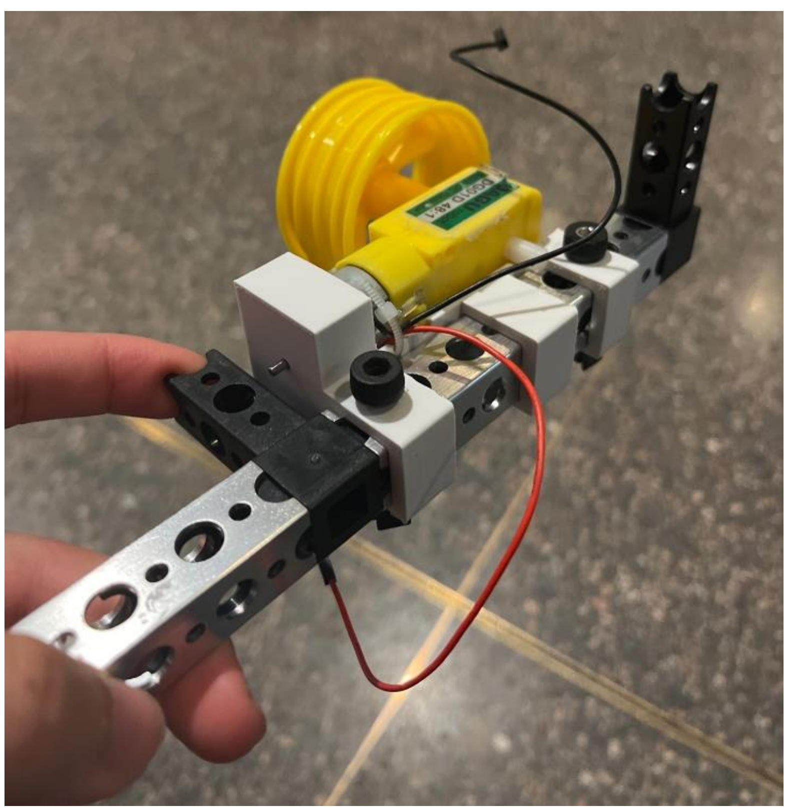


Figure 18 The final-revised product for the Design of TT DC motor mounting bracket for TETRIX® beams

TOP VIEW	BOTTOM VIEW	FRONT VIEW	BACK VIEW	RIGHT SIDE VIEW	LEFT SIDE VIEW

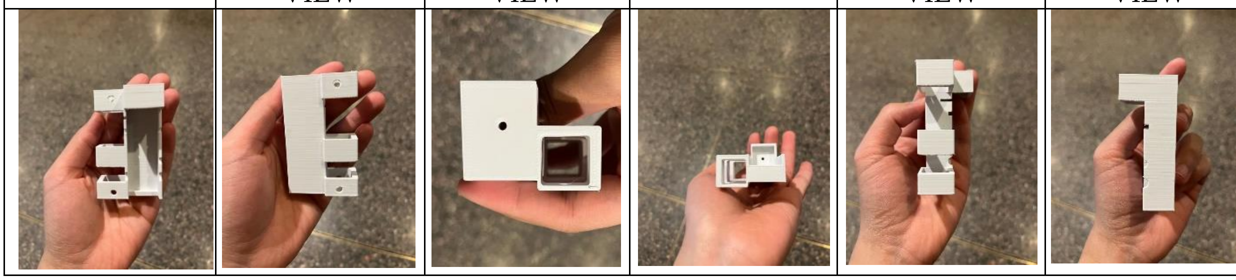


Figure 19 The 6-orientations of the final-revised version of the prototype

TOP VIEW	BOTTOM VIEW	FRONT VIEW	BACK VIEW	RIGHT SIDE VIEW	LEFT SIDE VIEW

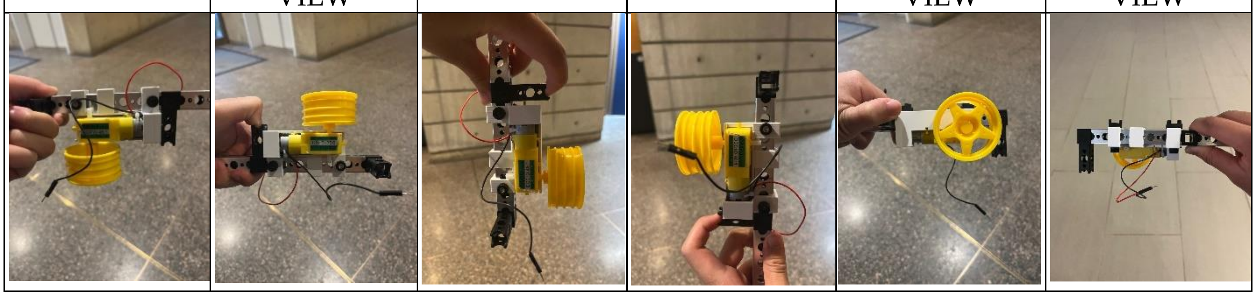


Figure 20 The 6-orientations of the final-revised version of the prototype with the motor and beam attached

4.0 Conclusions

The final product fulfills its design requirements for a TT DC motor mounting bracket for the TETRIX® beams (Figure 18) via experimentation and engineering judgement. The research and development were successful in producing a feasible solution for a mounting bracket for the TT DC motor to assure it mates to each of the TETRIX® beams in six distinct orientations while weighing the 30.6-gram motor. This satisfies the functions of the mounting bracket design that was developed through a process called layering functionality. The main constraints had been achieved with the mounting bracket having a tolerance of +0.05, being simple to use, and being able to mount the motor while avoiding interference with its wires. The criteria were also satisfied including being below the maximum cost of 5 CAD dollars with the cost of 3D printing this mounting bracket being 4.45 CAD dollars while ensuring long-term wear with the selected material. This was performed by deciding on what material to use for the prototype and minimizing the volume of material used, this would simultaneously minimize the cost. The material that was selected for the prototype was a 3D printing filament, and the following varieties have been compared: PLA, ABS, and PETG. ABS ultimately was selected as the filament because of its durability, inexpensive, and resistance to high temperature. Therefore, since the functions, constraints, and criteria satisfy the feasible solution, to create a mounting bracket for the TT DC motor so that it attaches to the TETRIX® beams in different orientations, the final design was a success.

4.1 Recommendations

To conclude this report, the objective was met, and the functions, constraints and criteria were a success. However, the secure feature of the mounting bracket can be further enhanced. For example, one can add a velcro strap to secure the TT motor onto the bracket. This can evade the risk that the motor would not fall off the bracket when it is operating (i.e., the orientations at risk when held upside-down shown in Figure 20 including the front, left-side, and right-side view). What also must be considered is that there is different branding of TT motors which have different dimension measurements, so the dimensions of this mounting bracket may need to change to accommodate for another type of TT motor. To elaborate, the final design of the mounting bracket may fit a specific TT motor too loosely, too tightly, perfectly, or not at all. Furthermore, from looking at the prototype, there was an assumption made about the wheel attached to the TT motor. This assumption was that the wheel would be on the TT motor's left axis, however, did not consider that one may require the wheel to be on both plastic shafts. If that is the case, the mounting mechanism of the prototype can be integrated onto the bottom of the prototype with the additional velcro strap to secure the TT motor into the prototype.

References

[1] A. Barela. "Make it Move with Crickit." Adafruit Learning System. https://learn.adafruit.com/make-it-move-with-crickit/continuous-dc-motors#geared-motors-2990891. (accessed Mar. 16, 2023).

[2] “DC Gearbox Motor - ‘TT Motor’ - 200RPM - 3 to 6VDC.” Adafruit Industries. https://www.adafruit.com/product/3777. (accessed Mar. 16, 2023).

[3] "TETRIX® PRIME Robotics Set for EV3." Pitsco Education. https://www.pitsco.com/Shop/TETRIX-Robotics/TETRIX-PRIME/Robotics-Sets/TETRIX-PRIME-Robotics-Set-for-EV3. (accessed Mar. 16, 2023).

[4] "Guide to 3D Printing Tolerances, Accuracy, and Precision." Formlabs. https://formlabs.com/blog/understanding-accuracy-precision-tolerance-in-3d-printing/. (accessed Mar. 21, 2023).

[5] J. Garcia. "3D Printing Tolerances: Basics Explained." Maker Industry. https://makerindustry.com/3d-printing-tolerances/. (accessed Mar. 21, 2023).

[6] J. Flynt. "Tolerance in 3D Printing – What It Is and How It Can Be Controlled." 3D Insider. https://3dinsider.com/tolerance-in-3d-printing/#:~:text=How%203D%20printing%20tolerance%20can%20be%20improved%201,5%20Reduce%20travel%20speed%20...%206%20Post-processing%20. (accessed Mar. 21, 2023).

[7] J. Baleshta and R. Consell, ME/MTE 100 MECHANICAL AND MECHATRONICS ENGINEERING GRAPHICS & DESIGN COURSE NOTES – 2021 EDITION For First Year Mechanical and Mechatronics Engineering Students, Waterloo: University of Waterloo Faculty of Engineering, 2021.

[8] Toglefritz. "Why a Consistent Diameter is Important for 3D Printer Filament." Toglefritz's Lair. https://toglefritz.com/why-a-consistent-diameter-is-important-for-3d-printer-filament/#:~:text=For%20example%2C%20Amazon%20Basics%201.75mm%20PLA%2

0filament%20has,large%20as%201.80mm%20or%20as%20small%20as%201.70mm. (accessed Jan. 11, 2023).

[9] T. Hoffman. "3D Printer Filaments Explained." PCMag. https://www.pcmag.com/how-to/3d-printer-filaments-explained#:~:text=Filaments%20used%20in%203D%20printing%20are%20thermoplastics%2C%20which,be%20shaped%20and%20molded%2C%20and%20solidify%20when%20cooled. (accessed Mar. 21, 2023).

[10] J. Bricknell. "Best 3D Printing Filament in 2023: PLA, ABS, PETG and more." CNET. https://www.cnet.com/tech/computing/best-3d-printing-filament/#jumplink1. (accessed Mar. 21, 2023).

[11] G. Slump. "PLA vs ABS vs PETG: The Main Differences." All3DP. https://all3dp.com/2/pla-vs-abs-vs-petg-differences-compared/. (accessed Mar. 21, 2023).

[12] J. Flynt. " All 3D Printing Filaments Types Explained: Detailed Guide." 3D Insider. https://3dinsider.com/3d-printing-filaments-types/. (accessed Mar. 21, 2023).

[13] "PLA, ABS, and PETG Shrinkage: Everything You Need To Know." 3DSOURCED. https://www.3dsourced.com/guides/3d-print-shrinkage-pla-abs-petg/. (accessed Mar. 21, 2023).

[14] J. Flynt. "PETG vs. ABS – Which One is Better?." 3D Insider. https://3dinsider.com/petg-vs-abs/. (accessed Mar. 21, 2023).

[15] "ABS vs PETG: Which is Best For 3D Printing?." 3DSOURCED. https://www.3dsourced.com/3d-printer-materials/abs-vs-petg/. (accessed Mar. 21, 2023).