To: EGRCorporation
From: Rylan Carper, Sienna Giuseppi, Isabella Panek, and Matthew Prato
Subject: Quantum Sand Machine Design
Date: February 17, 2025

Executive Summary:

A request was placed for teams to build and demonstrate a Quantum Sand Machine vehicle (QSM) that efficiently transferred potential energy contained in a mousetrap to motion traversing a sandy terrain course. While there is a common base design for vehicles utilizing mouse traps for energy there is also much room for optimizing energy use such as limiting friction between the axel and wheel through bearings and employing methods of mechanical advantage such as a small driving axel and large wheels. The team brainstormed and explored multiple designs to effectively utilize energy from the mousetrap in a way that would move as far as possible across a 72” sand pit while holding as much weight as possible. Additionally, the restriction that the vehicle had to be released with the cut of a string meant that the team had to build with durability and reliability in mind, ensuring the vehicle was quick and easy to set up in order to optimize the number of trials that could be run over a 6-minute window. The team practiced the ideal methods of setting up and releasing the QSM with all team members involved leading up to the final test. This led to a carefully crafted and tested vehicle that traveled 44.5 inches in the sandpit while weighing 1.09 pounds.

Approach Description

The vehicle was decomposed into separate parts based on functionality- power generation, vehicle chassis, and wheels. The team brainstormed how to optimize each of these subsections.

Idea Generation

The approach that the team took when it came to brainstorming ideas for the mousetrap car was to generate as many ideas as possible for the car as a whole while also brainstorming different sections of the car. After a twenty-minute session of brainstorming, each member separately wrote down generated ideas. After, each member took time to read and explain ideas to the rest of the group, and build upon each idea. These ideas were combined to create a plan for the whole vehicle’s design and visually represented on a shared sheet of paper (See Appendix- Figure 3).

General QSM design
The team came up with many ideas for the car type itself based on online research regarding mousetrap cars and the team’s general knowledge of physics. One of the members suggested a Monowheel design that would be powered by the mousetrap in the middle. Other ideas that were generated included a two, three, or four-wheel car with a simple chassis that would be able to easily add weight to at a later point.

All versions of the cars would be powered by using the mousetrap with an attached rod as a lever, and a string connecting this system to the axle. By pulling the mousetrap back and wrapping the loose string around the axel, the release of this mousetrap hammer would result in the spinning of the axle, moving the car forward. This brought more ideas to be generated as it was a question of what would be better: front wheel drive or back wheel drive?

Wheels and Axles

Much idea generation came in deciding what would be the optimal design for the car's wheels. Four main sections came into consideration when designing ideas for the wheels: materials of the wheels, treads or no treads, size of the wheels, and how the wheels would be attached to the axles. For the material of the wheels, many ideas were brainstormed for what would be best to traverse the sand track. The three material ideas for the wheels were cardboard using the laser cutter, 3D printed wheels, and foam wheels using a pool noodle.

Then this brought up the question of whether the wheels should include treads or not for digging into the sand to push the car forward. For 3D-printed wheels, this would be easy to modify and create treads, but for the other ideas, the team thought that tape or cutting the cardboard to expose its rigid insides would work best. The sizes of the wheels were the next consideration.

Whether it would be most effective to create same-size wheels for the front and back or larger wheels in the back and smaller wheels in the front. The team considered how wide the wheels should be to disperse the force against the sand and glide onto the sand instead of sinking in. Finally, the team decided the best way to connect the wheels to the axle would be to use bearings in the guiding wheels and then attach them to the axle. The driving wheels were directly attached to the axle and then the axle went through the bearings which are secured to the chassis.

Chassis

Based on the ideas generated for the type of car, the team then took into consideration what the ideal chassis would look like for those types of cars. The team leaned towards a car that had two wheels in the front and two wheels in the back. For the chassis for this type of car, team members generated many ideas. Materials considered for the chassis were wood, foam, and cardboard. The next step was deciding if the mousetrap should be at an angle to maximize the energy and thus alter the endpoint of the lever, or if the mousetrap should be on a flat chassis. The final chassis ideas evaluated were how to add weight. The ultimate goal was to travel the full distance, then add weight to the chassis to maximize the weight of the car and test again to find a good balance between the two goals.

Power Lever

The power lever would be connected to the mousetrap and back axle by a string to generate the power needed to move the car. The team thought of using a metal rod for the lever but then figured that it would be too heavy and hard to attach to the mouse trap, so ultimately decided on a wood dowel. Then the team brainstormed different ideas for the lever length including an eight-inch and four-inch lever. The team decided that each idea needed to be tested on a prototype to see which would maximize distance. The final consideration was how to attach the dowel to the mousetrap bar. The team brainstormed many ideas such as using glue or zip-ties and if the lever should be attached to the side of the mouse trap or in the middle. The team figured this would be decided by testing both options and seeing which would be the sturdiest and avoid breakage.

Idea Selection

The car was divided into subsections to allow for easy idea iteration and for the team members to more easily divide work that could then be completed asynchronously. Additionally, the team scored the ideas from each section on a scale of 1-5 (1 being the worst and 5 being the best) based on a variety of factors, to help determine what configuration would ultimately be selected for the car.

Wheel Idea Selection

A variety of wheel options were explored, including a front / back monowheel, 3D Printed options, cardboard options, and a variety of bearing-axle interactions. As a whole, most of these concepts were selected not necessarily through a Pugh scoring matrix, but through the development of each individual design being prototyped and tested. The final configuration decided was dual cardboard wheels of different sizes, with the driving wheels being bigger to allow for more driving area, and a smaller moment of inertia to initially start the car, proved to be extremely effective. Additionally, these wheels balanced weight and width extremely effectively making sure that the QSM did not sink into the sand, but also minimized friction with the sand to allow the vehicle to move as far as possible.

Table 1. Wheels Pugh Scoring Matrix

	Time	Complexity	Power Efficiency	Weight	Total
Front Monowheel	1	1	3	2	7
Back MonoWheel	1	2	3	2	6
3d printed Wheels	2	3	3	1	9
Cardboard Wheels	3	5	5	5	18
Foam Wheels	3	4	4	5	16

Lever Idea Selection

The team selected to use a lever-string system to connect the mouse trap hammer to the driving axle relatively early in the design process, leaving decisions to be made regarding different lengths of lever as the team tried to decide the optimal amount of torque, and material choices for the lever correlating to how strong the lever needed to be. This aspect was also tested through hands-on prototyping and feedback loop. A few different variations of these ideas included a 8 in level, 4 in lever, and no lever, with each idea also having metal rod and wooden dowel variants.

The end length of the lever was derived from testing the car with these various lever lengths, and seeing which drove the car the farthest distance.

Table 2. Lever Size & Material Pugh Scoring Matrix

	Time	Complexity	Power Efficiency	Weight	Total
8 in lever	2	4	4	2	12
4 in lever	3	4	5	3	15
Minimal / Very Short lever	4	2	2	4	12
Metal Lever	1	1	4	1	7
Wood Dowel.	5	5	3	4	17

Tread Idea Selection

Initially the team was unsure what the best approach to tackling the sand would be, and weather treds would be necessary. The team questioned if the car would need a tread to grip the sand, (this proved to be much too heavy and bulky) or if larger, smooth wheels would be more efficient to roll over the sand without sinking into the surface. After research and hands-on testing of multiple wheel and tread designs (See Appendix-Figure 4.), the team eventually came to the conclusion that with the amount of torque the mousetrap was able to provide, larger, smooth wheels would be the most consistent route to achieving success, and the overall design reflects this decision

Table 3. Wheel Tread & Size Pugh Scoring Matrix

	Time	Complexity	Power Efficiency	Weight	Total
Treaded Wheels	2	3	2	3	10
Smooth Wheels	4	5	4	3	16
Large Wheels	3	4	5	3	15
Small Wheels	4	1	1	4	10

Chassis Idea selection
Two main frame ideas were considered after some initial research, a flat, more standard frame, and a triangular frame. A triangular frame was eventually selected as the group realized that angling the lever would result in more consistent force being applied to the axle, as in the final ~30 degrees of rotation, more overall distance on the string was being pulled, compared to a more standard flat frame. Also, the team removed chunks of cardboard on all three faces of the chassis to reduce mass in an attempt to make the car travel farther. After altering the lever length instead and getting desired results, the team reapplied weight in the form of metal washers placed in the furthest back point on the chassis.

Table 4. Frame Pugh Scoring Matrix

	Time	Complexity	Power Efficiency	Weight	Total
Flat Frame	4	4	1	4	13
Triangular Frame	3	4	5	4	16

Theme Selection
The theme of this QSM was decided after the QSM was completed, as the group wanted to prioritize maximizing the distance and weight of the car first before decorating. The appearance of the prototype aided in deciding the theme; the triangular chassis shape with missing chunks resembled a shipwreck. Thus, the QSM chassis was painted to resemble a pirate ship, and aquatic creatures were painted on the wheels to resemble the moving ocean, following the underwater theme. To add to this idea, the washers that had been used as extra mass were painted to resemble a sunken treasure of golden doubloons. To add another creative touch to the theme of the QSM a flag was created from a paper fan that would open as the lever went forward, “raising” a pirate ship sail as the vehicle moved forward (See Appendix- Figure 5 and Figure 6 for images of decorated QSM).

Conclusion

The team successfully designed, built, and tested a Quantum Sand Machine (QSM) vehicle that efficiently utilized the potential energy from a mousetrap to traverse a sandy terrain. Through extensive brainstorming (including Pugh matrix scoring methods), prototyping, and testing, the team optimized key design elements, including wheel material and size, chassis structure, and power lever configuration, to maximize performance. The final vehicle demonstrated a balance between weight and distance traveled, achieving a movement of 44.5 inches while weighing 1.09 pounds. Additionally, the team creatively incorporated a pirate ship theme, enhancing the aesthetic appeal of the design.

Appendix:

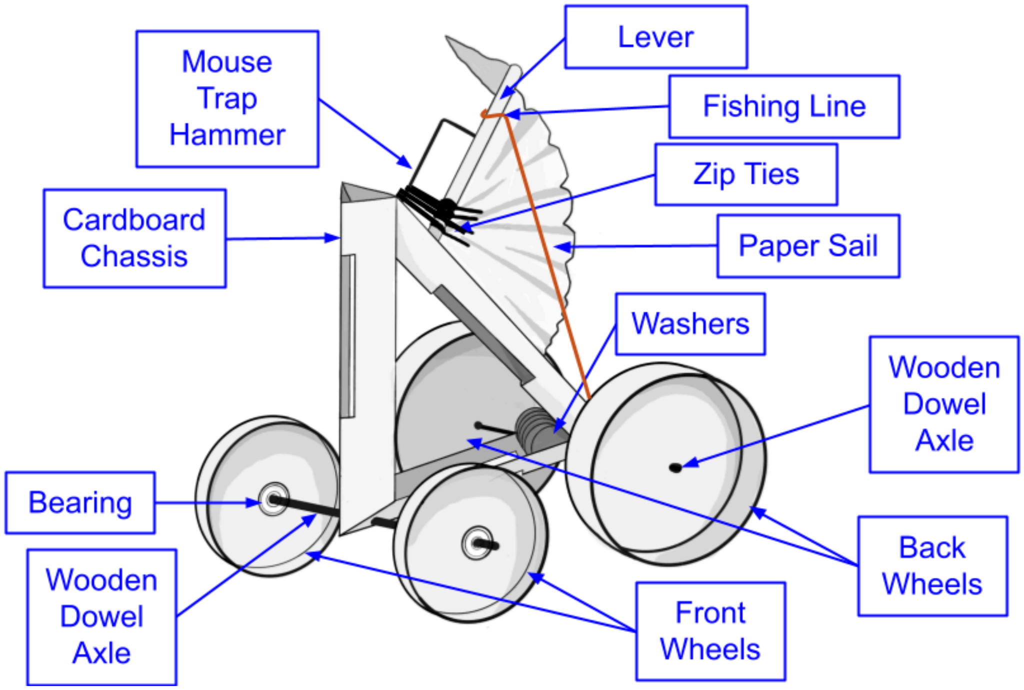

Figure 1. Front Isometric Sketch of QSM (with labels)

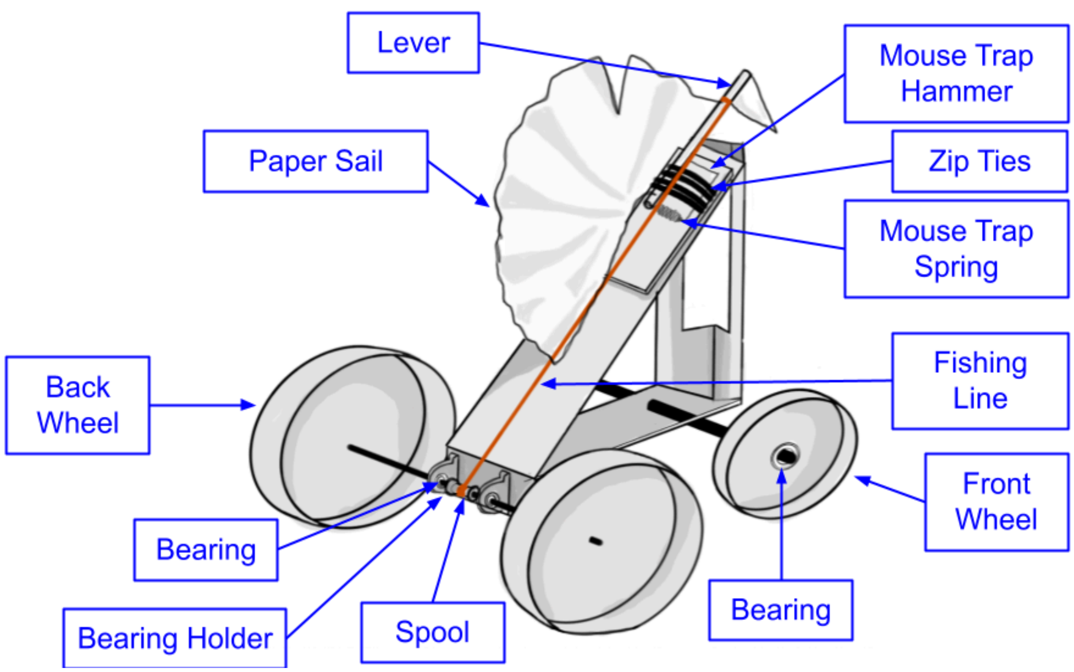

Figure 2. Back Isometric Sketch of QSM (with labels)

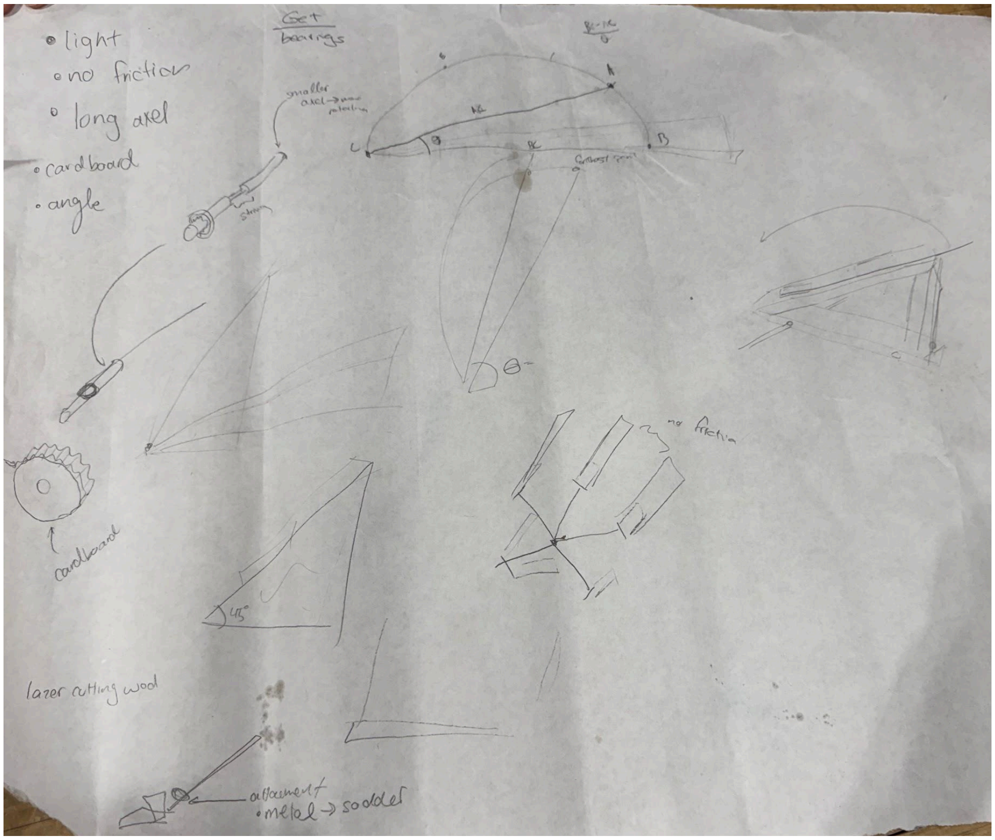

Figure 3. Initial Brainstorming/Planning Sheet

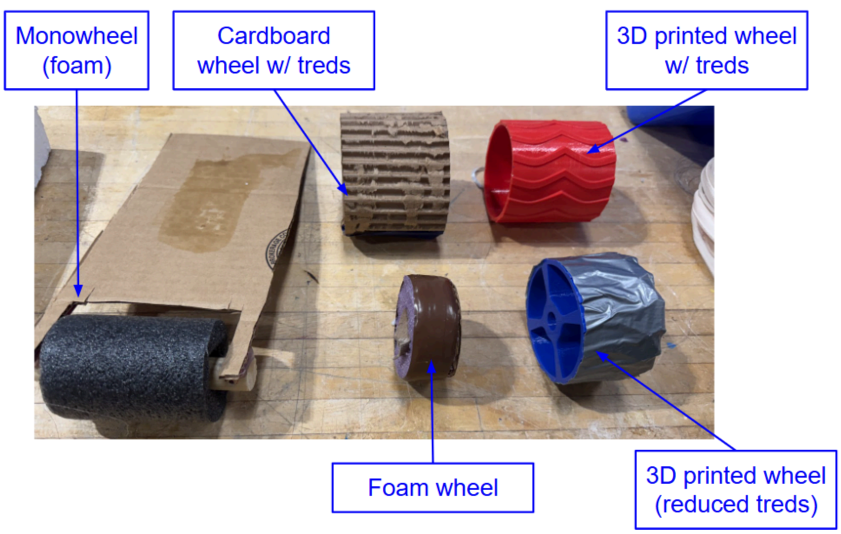

Figure 4. Wheel Design Iterations


Figure 5. Front Isometric Photograph


Figure 6. Back Isometric Photograph

Team Reflection:
Our team was able to successfully complete this design challenge to the best of our abilities, and even impressed ourselves with our QSM's performance on testing day.
Something we believe worked well was our team's collaboration process; when it came down to completing our vehicle on time, our entire team showed up and lifted their weight. We had a team dynamic that allowed each of us to express ideas without fear of judgement, which ultimately made our design the best it could be.

One challenge we faced was finding a time that worked best for us all to work. We wanted to approach this challenge with a divide and conquer mindset, however, the collaborative nature of this project made it very difficult for any one person to complete one item. The entire process involved much iteration and everyone's presence and ideas were necessary for our success.

A lesson we learned was that failure certainly is part of the design process. Our design went through many iterations, most of them resulting in a car that would not even move in the sand, before we were finally able to complete a QSM that traversed the entire length of the test-pit. As frustrating as failure was, each iteration brought us closer to success and an overall better understanding of the engineering behind our project. We believe that failing so many times is what allowed our design to perform so well, because we truly looked at our car from every angle in this problem-solving process.

Finally, as far as growth, our team was able to become more and more accepting of new ideas as our project went on. In the beginning we simply wanted a car that ran, but as we ran into many issues with the vehicle, we began to think more outside the box. In the future we want to begin the engineering process with this outside-the-box thinking, as some ideas that may have sounded odd at first truly led to the best possible product.