1 Project & Concept Description

1.1 Project Description

The team's project is to design a functional trebuchet to launch a projectile three specified distances within an acceptable range. The trebuchet design must meet specified design constraints, such as being able to be stored within a specified volume, not violate space constraints when launching, and must use given components such as the counterweight or the foosball projectile.

1.2 Project Requirements

The following requirements have been specified for this project:

1. Target Distances: The trebuchet must be able to launch a projectile at a target 1, 2, and 3 meters away.
2. Target Accuracy: The projectile must land within a circular diameter 25 cm around the target.
3. System Weight: The system shall weigh no more than 5kg.
4. System Size: This system shall fit within a 28 x 28 x 43 cm volume when disassembled, and must not have an arm length (sling included) of 100cm when fully extended.
5. Projectile Size: The projectile shall be a "foosball" ball about 35mm in diameter and weighing about 10 grams.
6. The trebuchet must use the provided counterweight and must only be powered by gravity.

1.3 Project Design Concepts

The team has developed 6 design concepts to meet the requirements for the project, described below:

1. Spooled Counterweight Concept
   This design concept deviates from conventional trebuchets by having the counterweight spooled around the pivot dowel. This one also has one end of the sling wrapped around a dowel, and on the end of the sling is a pin, which will be pulled out when the arm is at full extension due to tension.

   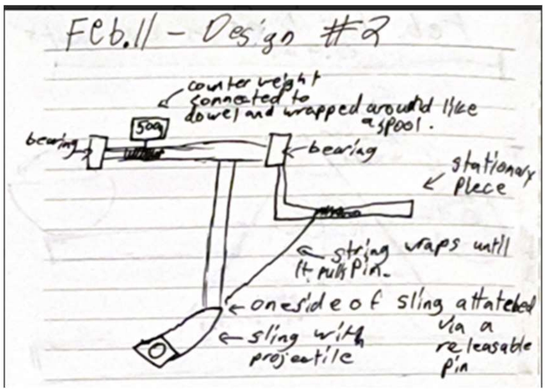

   Figure 1: Design sketch for Concept #1.

2. Stopping Bar Concept
   This concept returns to the traditional dangling counterweight approach and utilizes a "stopping bar" that will stop the arm from rotating and cause the sling to release the projectile. The sling is made of felt, and the hook is made of metal. There is also a ball bearing in the pivot joint.

   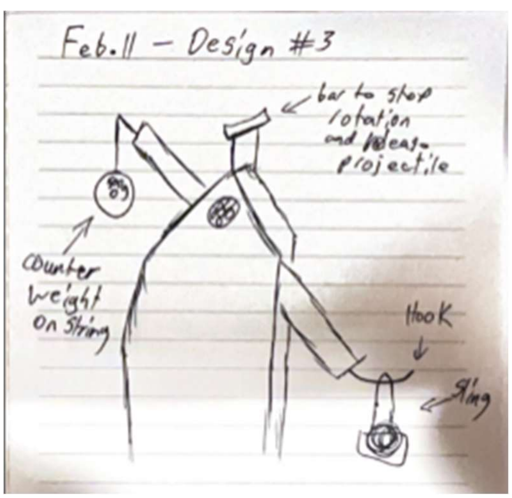

   Figure 2: Design sketch for Concept #2.

3. This concept uses rubber shoes, a ball bearing in the pivot, and some holes in the arm to control the launch distance. The counterweight is also dangled, and the support uses a truss structure.

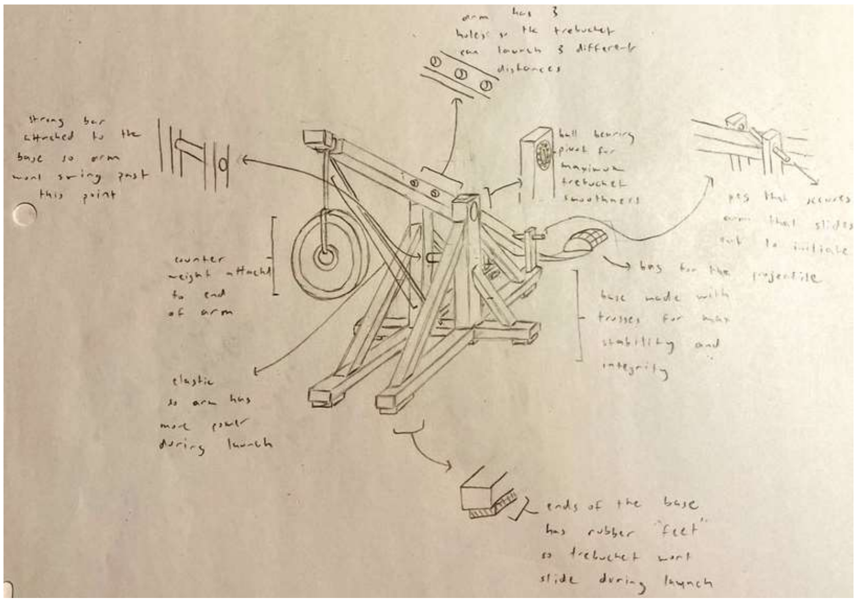

Figure 3: A concept sketch with several labels indicating what the functional purpose of each component is.

4. This fourth concept diverges from the other concepts and utilizes a wheeled base instead of either a smooth surface or rubber shoes.

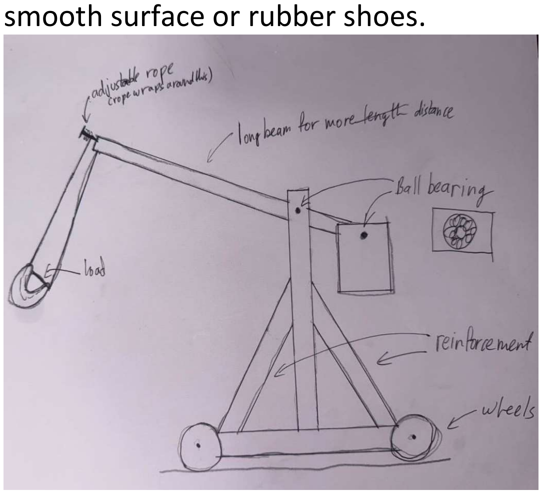

Figure 4: A concept sketch showing a rolling trebuchet, with a hanging mass and a support structure.

5. This concept is similar to the 3rd concept; however, it utilizes a different support structure, using an A-Frame rather than a truss structure, and uses two “forks” to dangle components. Rubber shoes and a bearing are also utilized.

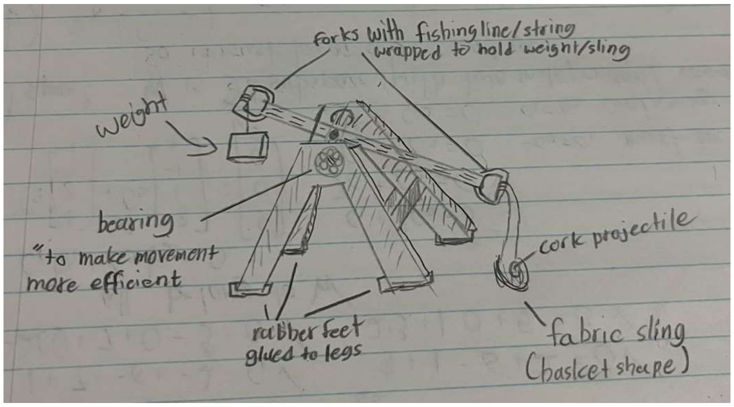

Figure 5: A concept sketch showing “forks” used to dangle the weight and sling, an A-frame, and a bearing in the joint.

6. This final concept is like the previous concepts, using a dangling counterweight, a V-notched track to hold the projectile during launch, and a set of simple supports. This one also utilizes a ball bearing in the joint.

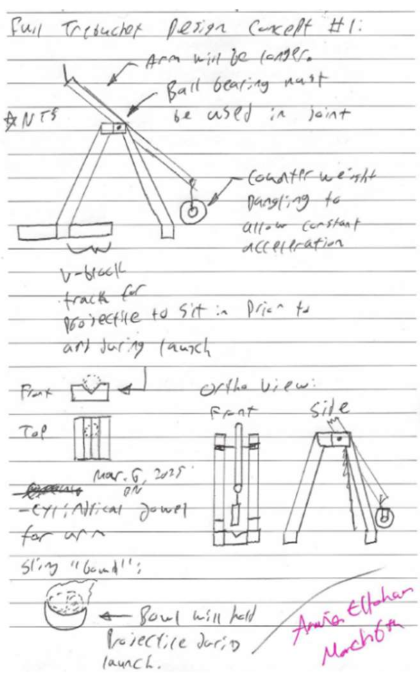

Figure 6: A drawing of a trebuchet concept that also has arrows indicating the function of each component.

2 Concept Evaluation

2.1 Feasibility Judgement

The design concepts developed by the team were subjected to an initial feasibility judgment. The outcome of this activity is as follows.

- Concept(s) not feasible:
  No concepts are totally unfeasible.

- Concept(s) possible under the following condition:

  No concepts are conditionally feasible.

- Concept(s) worth considering:

Concept #1: This concept does not require any unreasonable materials, manufacturing methods, or anything of the sort. Therefore, it is worth considering as wood, fishing line, and felt can be readily obtained.

Concept #2: This concept also does not require any unreasonable materials or manufacturing methods, as felt (or an alternative) is readily available, and a hook can be easily obtained as a stock part.

Concept #3: This concept is feasible as it does not use any materials that are not readily available, as the truss structure is made of wood, and anything like a net or rope can be purchased.

Concept #4: This concept is feasible as it is relatively simple and does not use any materials that we do not have access to. Wheels and bearings can be easily purchased or 3D printed, and the same applies to the support structure.

Concept #5: This concept is feasible as it can be constructed from materials such as wood, and the fabric string, which are easily accessible via the Elko Garage.

Concept #6: This concept is feasible as it is also relatively simple, as the supports can be easily cut from wood or 3D printed, rubber shoes can be easily obtained from rubber stock, the V-Track can be 3D printed or cut from wood, and any string can be purchased.

2.2 Go/No-Go Screening

Go/No-Go screening was performed to ensure the design concepts that passed the feasibility judgement meet the engineering requirements outlined by the stakeholders. The evaluation is summarized in Table 1.

Table 1: Go/No-Go evaluation of design concepts.

Requirements List	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Concept has enough information to be developed further?	No	Yes	Yes	Yes	Yes	Yes
Uses readily accessible and light materials (e.g., wood)?	Yes	Yes	Yes	Yes	Yes	Yes
Design can keep arm length <100cm?	Yes	Yes	Yes	Yes	Yes	Yes
Launches solely via counterweight?	Yes	Yes	Yes	Yes	Yes	Yes
Summary: Go or No-go	No-Go	Go	Go	Go	Go	Go

2.3 Decision Matrix

The design concepts that remained after the previous Feasibility Judgement and the Go/No-Go Screening were compared and ranked against each other using the decision matrix as shown in Table 2. The decision matrix uses a weighted analysis for the various criteria. The weightings are justified as follows:

For the analysis, Concept #2 was chosen as the baseline concept as it is a simple, classic trebuchet that meets the minimum requirements. It has a very basic launch system that would work but could be improved upon.

Weight nor Size were considered as it is currently very difficult to estimate if a concept may be lighter than another due to a lack of physical parts, therefore including such a category could skew results.

Ease of Manufacturing is divided into two categories, the support structure and the arm itself. Ease of Manufacturing is very important to the entire project, as the project may not be completed on time if a component is too complicated. A trebuchet also has two major components that determine how well it works, which are the arm and the support (a flimsy arm and a poor support makes for a very poor trebuchet). These were both given an equal score of 30/100, for a total score of 60/100.

Accuracy and Power are divided into two categories, as one concept may improve the overall power of the trebuchet, but not the accuracy, and vice versa. These were each given the same weight as one dictates how fast the projectile will be launched (from an expected value) and the other how much the projectile deviates from an expected landing area, giving them both a weight of 20/100, and a combined weight of 40/100.

Each concept was given a score of -1, 0, or 1 depending on if it was worse, on par, or better than the baseline concept. For example, Concept #4 was given a score of -1 for Accuracy as the wheeled nature can hinder the accuracy of the trebuchet, most of the concepts were given a score of 0 for the arm as they were each similar to the baseline (save for Concept #5, which uses “forks” to tie the strings to, thus increasing complexity), and Concept #3 was given a score of 1 for Accuracy as the wider base improves the overall accuracy of the trebuchet.

Table 2: Decision matrix for design concept selection.

Evaluation Criteria	Weight	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Ease of Manufacturing - Support -1 - Complicated 0 - About the Same 1 - Simpler	30	S	0	0	0	0
Ease of Manufacturing - Arm -1 - Complicated 0 - About the Same 1 - Simpler	30	S	0	0	-1	0
Launching Power -1 - Hinders Power 0 - No Improvements 1 - Improves Power	20	S	0	0	0	0
Launching Accuracy -1 - Hinders Accuracy 0 - No Improvements 1 - Improves Accuracy	20	S	1	-1	0	0
sum	100					
weighted total +		S	20	0	0	0
weighted total -		S	0	-20	-30	0
weighted score		S	20	-20	-30	0
		Standard	Better	Worse	Worse	About the Same

3 Conclusions

Via the decision matrix, it was decided that Concept #3 was the best concept to develop into the final design. This is because the concept improves accuracy by having a wider base and rubber shoes on the bottom, improves power by having a ball bearing in the pivot joint, is easier to manufacture as the support is comprised of basic geometric volumes (rectangular prisms), and the net used to launch the projectile can be easily purchased.

Going forward, the team will need to assess what further modifications and improvements can be made to Concept #3. This will be done by going back and assessing the other concepts to see what ideas can be integrated into the final design. Once a final design concept has been created, the team will need to look into building a working prototype by looking into manufacturing methods. Then, when a working prototype is constructed, the team will need to conduct tests to ensure that it meets the requirements outlined by the stakeholders (weight, launching distance, etc.). Eventually, once the prototype has been refined, it can be developed into the final design and submitted to the stakeholders for testing day.

Appendix A - Design Concept Evaluation marking rubric

Table A1: Marking rubric for Assignment 'Design Concept Evaluation'.

Assessed Activity	Criteria for Scoring	Substandard (Score 1)	Acceptable (Score 2)	Exceptional (Score 3)	Mark
Section 1.1 & 1.2 **Project Description & Requirements**	Neither project description nor requirements listed	✓			___ /2
	Both project description and requirements are listed		✓		
Section 1.3 **Design Concepts**	Fewer than one design concept presented per team member	✓			___ /3
	One to two design concepts presented per team member		✓		
	More than two design concepts presented per team member			✓	
Section 2.1 **Feasibility**	Feasibility is not assessed, or categorized without any discussion	✓			___ /3
	Concepts are categorized by feasibility with justification			✓	
Section 2.2 **Go/No-Go Screening**	Go/No-Go screening is not done	✓			___ /3
	Go/No-Go screening is done with at least one requirement		✓		
	Go/No-Go screening is done with at least two requirements, AND the results of the screening are summarized for all concepts			✓	
Section 2.3 **Decision Matrix Weights**	Weights are not assigned to criteria, or assigned without justification	✓			___ /3
	Weights are assigned to all criteria with justification			✓	
Section 2.3 **Decision Matrix Analysis**	Analysis is not done	✓			___ /3
	Baseline concept defined, other concepts analyzed as "better", "about the same", or "worse"		✓		
	All of the above, with weighted subtotals of positives and negatives, and weighted sums for all concepts			✓	
Section 3 **Conclusions**	No conclusion or summary provided	✓			___ /3
	A statement of the "best" concept is given		✓		
	The "best" concept is identified, and follow-up plans are discussed			✓	
Total score for Design Concept Evaluation:	_____ /20 (pass grade = 14/20)				