ENGG 160 Project Proposal :

An Open-Source, Accurate Trebuchet

Revisions

Revision	Author	Changes	Date
001	Steven Knudsen	Initial Release	2024-10-30
002	Steven Knudsen	Update for materials, release for general review	2024-11-02
003	Janice Miller-Young, Steven Knudsen	Updated materials. Final version	2025-01-02

ENGG 160 - Intro. To Engineering Design

Project Proposal : An Open-Source, Accurate Trebuchet

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1 Project Definition

An open source trebuchet design that is able to accurately hurl a prescribed object (projectile) to land within a specified area at a specified distance is to be designed and demonstrated.

2 Introduction and Motivation

An early, sophicticated machine is the trebuchet [1]. Designed to be a weapon of war, it embodies several fundamental laws of physics and mechanical engineering principles. At the heart of its operation is the application of Newton's laws to predict the trajectory of a projectile.

In this project, the objective is to verify these principles through the design and construction of a trebuchet that is able to accurately hurl a projectile at a target area. The goal in this project is to show that even for a set of simple requirements and constraints, the engineering solution space is still quite large. This allows for creativity in terms of possible solutions and a chance to reflect on design choices.

The fundamental physics and physical constraints for a trebuchet have been well understood for a very long time. To aid in conceptual design, it is strongly recommended to make use of the "virtual trebuchet" web site [2], which supports interactive design and experimentation as showin in Figure 1.

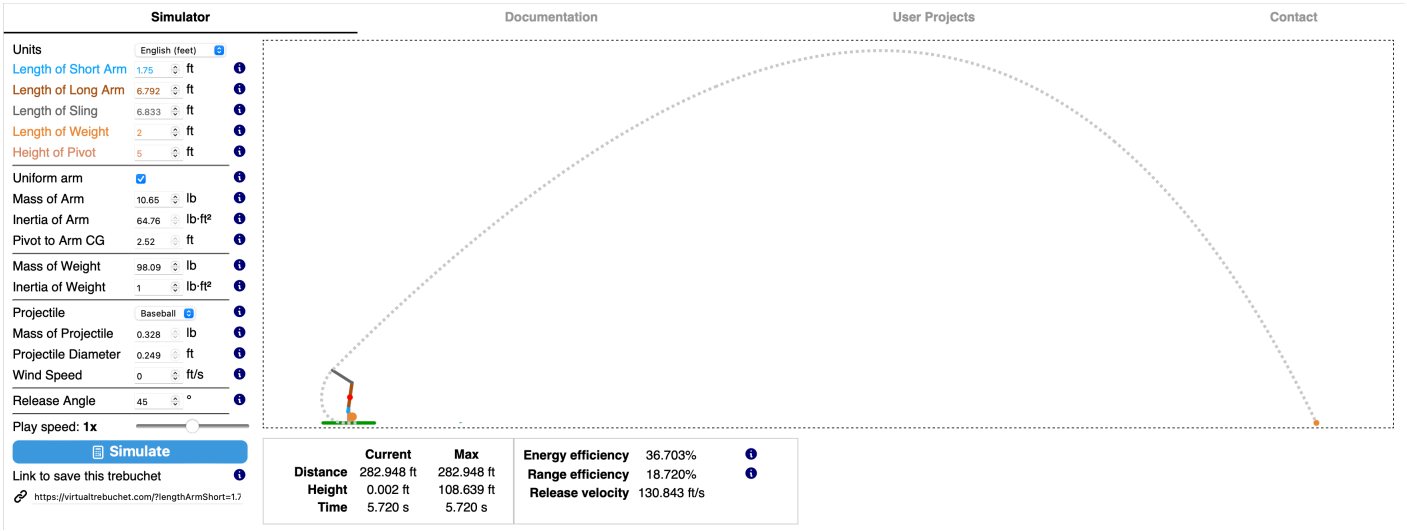

Figure 1 An example design and simulation of a trebuchet from virtualtrebuchet.com [2]

3 Objectives

The main objective is to build an open source trebuchet that is able to accurately hurl a projectile and hit a target within some prescribed accuracy. The challenge is that the trebuchet deisgn and prototype must demonstrate the ability to hit a prescribed target at a minimum of three (3) different ranges.

To accomplish that goal, the design may need to have built-in variability.

As seen in section 5, some parts of the design are constrained, such as the counter-weight to be used.

4 High-level Functional and Performance Requirements

Some high-level functional and performance requirements are provided in Tables 1 and 2 below. There may be other requirements that are found during the conceptual design of the system that can be added to the list. Do not add more than a few.

A requirement is verified either by design and/or by testing. If by design, there should be an analysis, if by test there should be a description of the test and results. If both are indicated in the tables below, then one or both may be included.

Table 1 High-level Functional Requirements (FRs)

#	Name	Description	Met by Design	Measured
FR-1	Target distances	Must be able to hurl a projectile three specified distances	Y	Y
FR-2	Target accuracy	For each distance in FR-1, the projectile must land within a circle 25 centred at the target distance	Y	Y
FR-3	Portable	The complete trebuchet system must be portable by one person	Y	Y
FR-4	Projectile[1]	The projectile must be small and safe to use.	Y	Y

Table 2 Performance Requirements (PRs) referenced to applicable FR

#	Name	Description	FR#	Met by Design	Measured
PR-1	Target distances	The distances are 1, 2, and 3 meters	FR-1	Y	Y

[1] The projectile shall be a standard cork "foosball" provided by the instructional team. With permission from the instructional team, it may be modified as long as it stays within the weight requirement stated in Table 2.

PR-2	Target accuracy	For each distance in FR-1, the target circle is 25 cm in diameter	FR-1 FR-2	Y	Y
PR-4	System Weight	The system shall weigh no more than 5 kg	FR-3	Maybe	Y
PR-4	System Size	The system shall fit within the storage provided for ENGG 160, which is TBD	FR-3	Y	Y
PR-5	System Size	The system shall be between 60 and 100 cm at full extension	FR-3	Y	Y
PR-6	Projectile Size	The projectile shall be a typical “foosball” ball approximately 35 mm in diameter	FR-4	Y	Y
PR-7	Projectile Weight	The projectile shall not weigh more than 40 grams	FR-4	Y	Y

5 Constraints

5.1 End Use

Being open source, the system may be used by anyone with access to the design artefacts (files, drawings, etc.).

5.2 Allowed Costs

Reasonable material and fabrication costs will be covered by ENGG 160 but there are conditions. Any request for additional materials or for a material or fabrication process outside those usually offered by the Elko Garage must be made in writing through your TA. Allow at least two weeks for the review process. Bear in mind that the request may be denied. There is a relatively tight budget for what may be purchased over and above the materials and resources already provided.

5.3 Materials

5.3.1 Elko Garage Materials

Cardboard, acrylic, foamboard, fishing line, a wooden dowel, and other materials as provided by the Garage are allowed. Non-toxic hot glue and other non-toxic glue is allowed.

3D printing of parts for the prototype is allowed. Only PLA filament is provided through the Elko Garage's ENGG 160 3D printing service. 3D printing is restricted to up to three print jobs, a maximum of 8 hours per print job, and less than 18 hours total printing time in the Elko Garage.

5.3.2 Other Materials

Wood and machine screws, small nails, cord, pins, and other simple fasteners are allowed, but must be supplied by students.

Use of recycled and reused materials is encouraged; however, these are non-standard materials that must be reviewed for safety and compatibility with Elko Garage equipment. If there is a recycled or reused material that you wish to use, submit a written request to your TA. Allow two weeks for the review process. Bear in mind that the request may be denied.

5.4 Trebuchet-specific Material Constraints

The preferred arm material is a wooden dowel or similar.

Only the structural supports, trebuchet arm bearings or guides, the pivot arm, the projectile holder, and sling may be 3D printed.

The projectile shall be a standard “foosball” cork ball. These are typically 35 mm in diameter and weight 10 grams. The weight of the ball may be altered to meet the performance requirements. Several balls will be provided to a team, and more available from the teaching team.

The counter-weight will be fixed at 500 g. It is a weight training barbell plate with a 2.5 cm diameter hole and approximately 9 cm in diameter; it is shown in Figure 2. Referring to the Virtual Trebuchet site [2], this means that the “length” of the weight, the distance between the middle of the plate and the end of the short arm, must be at least 5 cm. How it is attached to the short arm is a design decision, but it must be attached so there is no chance of it detaching under normal conditions.

Figure 2 The 500 g counter-weight.

5.5 Storage Size

The trebuchet system must fit into a volume that is 28 cm x 28 cm x 43 cm for storage.

5.6 Operational Constraints

Under normal operating conditions (the 500 g counter weight used and the projectiles meeting size and weight requirements);

- Any design that results in the projectile trajectory exceeding 3 m in height will require redesign, and
- Any design that results in a projectile trajectory that exceeds the distance requirement (PR-1) by more than 50% will require redesign.

In all cases, the team will be given one chance to correct the problem.

In all activities involving the launching of a projectile, suitable down range safety measures must be enforced, including, but not limited to;

- The planned path of the projectile must be vacant (no people) for a lateral distance of ±1 m,
- The projectile shall at all time remain in the room and be recoverable, and
- The trebuchet shall be able function without contacting any other items or people present in the room.

6 Resources

The following resources are explicitly allowed:

1) The Garage maybe used for some construction but ECERF W2-050 is preferred.
2) ENGG 160 materials provided via the Garage.
3) Various computer-aided design tools can be used for 3D printable design development. "Fusion" is free for students and will serve students well if they learn it. "TinkerCAD" is a basic browser-based CAD software recommended by the Elko Garage technicians. "TinkerCAD" is very beginner-friendly. "OpenSCAD" [3] is a Solid 3D CAD Modeller that has good tutorial support; however, it can be difficult to learn if you are relatively new to programming and modelling.

7 References and Links

[1] Wikipedia contributors, "Trebuchet," *Wikipedia, The Free Encyclopedia,* https://en.wikipedia.org/w/index.php?title=Trebuchet&oldid=1253602257, (accessed October 30, 2024).

[2] Virtual Trebuchet, Virtual Trebuchet 2.0, virtualtrebuchet.com, https://virtualtrebuchet.com , accessed October 30, 2024.

[3] OpenSCAD, Solid 3D CAD Modeller, https://openscad.org (accessed November 28, 2023)

8 Intellectual Property Restrictions

This project must be open source. The project should be hosted on Github or Gitlab.

9 Sponsor

The ENGG 160 Instructional Team is the primary sponsor of the project.