VM250 Final Report
Of Catapult Design and Manufacturing
Summer 2013

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Contents

1. Abstract

This report contains detailed information about my team's project 2 in VM 250, which is to design a metal catapult. It starts with introducing the background information of our project, including our expected goals and design criteria. After that, it delineates my team's concept generation process, during which it shows readers our PDS, QDF, and final design drawn by UG. Next, the report highlights our handmade prototype, containing pictures and descriptions for its different parts. Then, the report demonstrates the quantitative tests that my teammates have made to the prototype in order to justify our design, which includes our data and data processing. Later, it contains our manufacturing process, assembly procedure, and cost estimation. Finally, the report contains my team's recommendation for later groups to further improve our design, followed by a final conclusion.

2. Introduction

Our team is assigned a task of designing a metal trebuchet for TOYABC, a company of making table toys. We need to set up a scheme and build a prototype using raw materials. The conventional trebuchet, or catapult, is an ancient war tool that is used to throw or hurl large stones to destroy the city walls. Our goal of design is to build a specified small metal catapult model, and use it to throw provided balls into desired areas.

The catapult design will be judged by the following criteria: First, the size of the metal catapult should not exceed a box with length 40 cm, width 20 cm, and height 40 cm. Second, the catapult prototype should have a maximum shooting range greater than 15 meters, and can hit the scoring spot (4m, 5m, and 6m) with a tolerance of 20 cm. Third, the prototype should contain wheels to make it movable. Last, the prototype should sustain a free falling from 1.5 meters high.

In the following part of report, we will present our catapult design in detail. We start with introducing our PDS and QDF, our concept generation process, and our prototype. Then, we will talk about our manufacturing process, and cost estimation. We conclude the project at the end of the report.

3. Product Design

3.1 Problem Definitions

3.1.1. Customer Requirements (CR)

In order to attract more customers and get a greater share of market, several basic customer requirements need to be satisfied. Apart from the having the basic function of a cell phone, 10 requirements from the customers are included to increase the competitiveness of the design.

1. Be able to through a stone with diameter 3cm over 15 meters
2. Control the landing distance within 20 cm
3. Be able to fit into a 40cm*40cm*20cm box
4. Be inexpensive
5. Does not break after dropping from 1 meter high
6. Use metal as raw material
7. Be environmentally friendly
8. Looks good
9. Be safe to play with
10. Lasts a long time

3.1.2. Engineering Specifications (ES)

In order to better satisfy the customer requirements, 10 engineering specifications are employed.

1. Young's modulus (MPa)
2. Yield strength (N)
3. Cost ($)
4. Maximal deformation of main beam (mm)
5. Main beam length (cm)
6. Spring maximum loading (N)
7. Effective spring constant (N/mm)
8. Cross section moment of inertia (mm^4)
9. Spring material fatigue related constant (Characterized by σ_f with MPa and non-dimension constant A and B)
10. Support maximal dimension (cm)

3.1.3. Quality Function Deployment Diagram and Results (QFD)

In order to satisfy all the requirements and figure out the weight of the CR and the relationships between CR and ES, we developed the following QFD table.

Correlation between eng. Specs

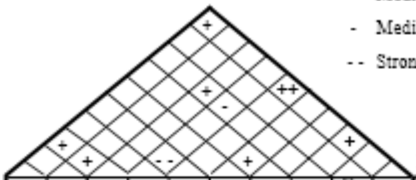
++ Strong Positive

\+ Medium Positive

\- Medium Negative

\- - Strong Negative

Quality Function Development (QFD)



Benchmarks

	Weight (1-10)	Young's modulus	Yield strength	Cost	Maximal deformation of main beam	Main beam length	Spring maximum loading	Effective spring constant	Cross section moment of inertia	Spring material fatigue related constant	Support maximal dimension	Competitor A
Be able to through a stone with diameter 3cm over 15 meters	9	1		3		9	9	9		3	1	3
Control the landing distance within 20 cm	8		3		9	3	9	9	3			4
Be able to fit into a 40*40*20 box	7			3					9		9	5
Be inexpensive	6			9		3					1	3
Does not break after dropping from 1 meter high	3		9	3					3			3
Use metal as raw material	2	9	9	3			9		3			1
Be environmentally friendly	1			9				1	3			2
Looks good	4			9		9		1			3	2
Be safe to play with	10		9				3	3				4
Last a long time	5		3	3	1		3			9		3
Measurement Unit		Mpa	Mpa	$	mm	cm	N	N/mm	cm^4	Mpa	cm	
Target Value				100	2	30	40	1	0.7		35	
Total		27	174	177	77	159	216	188	105	72	90	
Normalized		0.02	0.14	0.14	0.06	0.12	0.17	0.15	0.08	0.06	0.07	
Competitor A		3	3	5	1	5	4	3	5	1	4	

Competitive benchmarks

5 = satisfies perfectly

4 = satisfies "mostly"

3 = satisfies "somewhat"

2 = satisfies "slightly"

1 = doesn't satisfy at all

Correlation between customer reqs and eng. Specs

9 = Strong Relationship
3 = Medium Relationship
1 = Small Relationship
(blank) = Not Related

Fig.3.1.3-1 QFD

3.1.4. Product Design Specifications (PDS)

Items	Specifications
Performance, and life in service	• Shoot the ball over a distance. • Shoot the ball accurately at a target. • Robust enough to bear a dropped from 1.5m height.
Environment	• Temperature: -20℃ ~ 60℃ • Relative humidity: 0% ~ 99%
Product life span	• 3 years
Maintenance	• Regularly replace springs • Regularly replace steel wires
Target product cost	• ￥132.28
Competition	• Trebuchet models made by other VM250 teams.
Manufacturing facilities	• Extrusion machine for aluminum alloy • Plastic injection machine for the plastic parts • Spring production line • Assembly line • Packing line
Packing	• Prevent damage • Look attractive
Shipping	• Prevent violent knock • Prevent contact with corrosive substance
Size	• Length: 40cm • Width: 20cm • Height: 40cm
Weight	• **1.55 kg**
Materials	• Aluminum alloy (rods) • Stainless steel (screws, bearings, wires) • Plastic (cup, wheels)
Safety	• No sharp edges or corners

	● Firmly attached and hidden springs ● No toxic or recycling materials ● Safe shooting speed
Installation	● Attach the springs
Documentation	● Using instruction ● Warranty bill ● Qualifications

3.2 Concept Generation

3.2.1. Brainstorm

In our first brainstorm, we analyzed the objectives for our catapult.

1) Achieve the maximum shooting distance, 15 meter.
2) Adjustable shooting range.
3) Accuracy within 20cm.

To achieve the maximum shooting distance, we are supposed to make best use of the given spring. To make the shooting distance adjustable, we should not only consider a method to mark the length of the spring corresponding to different length, but also the limitation of size. To meet the accuracy target, we think of stable structures and thin marking lines.

3.2.2. Preliminary Sketches

According to the objectives mentioned above, we separately designed five concept designs for basic shape.

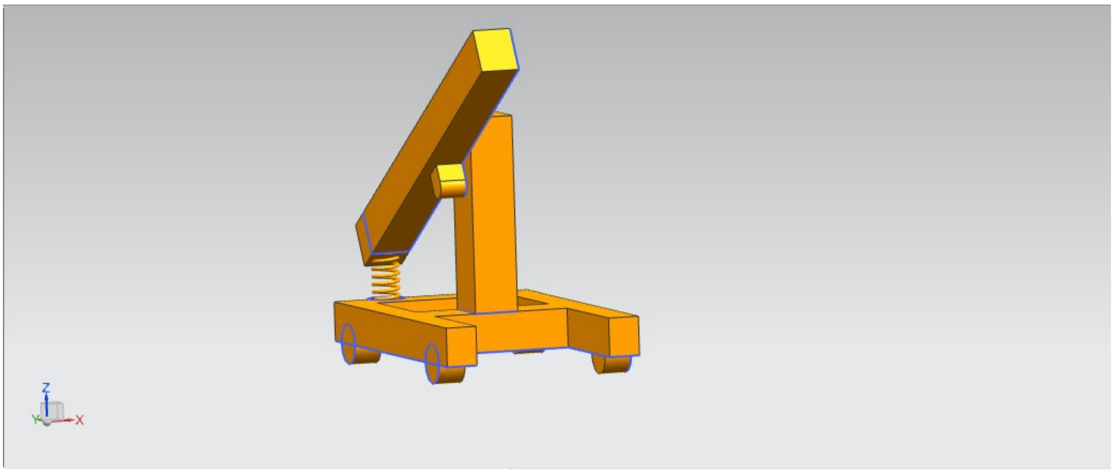


Figure 3-2-1 concept design 1

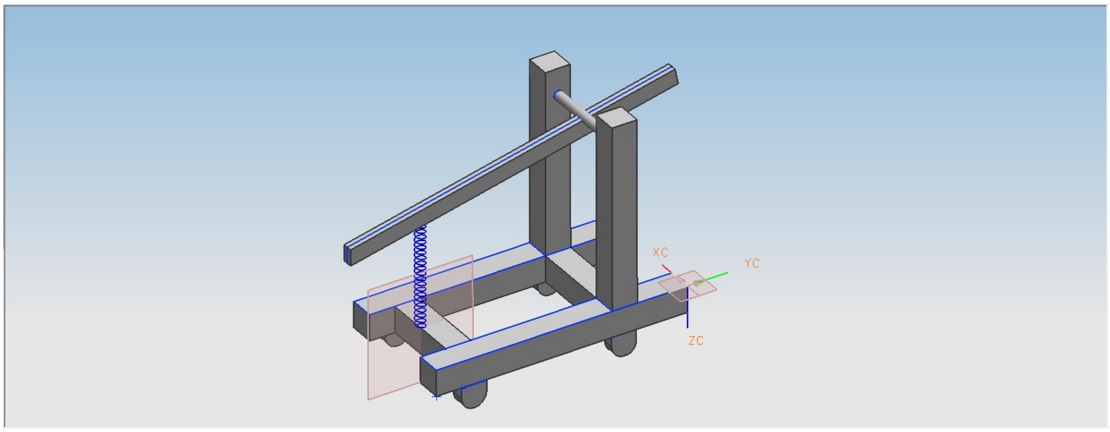


Figure 3-2-2 Concept Design 2

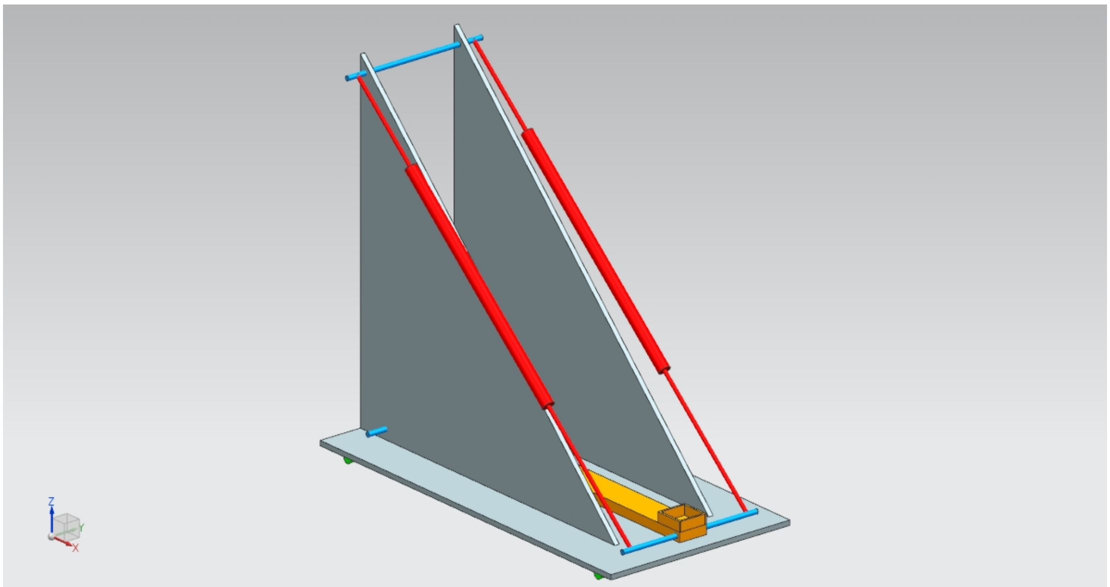


Figure 3-2-3 Concept Design 3

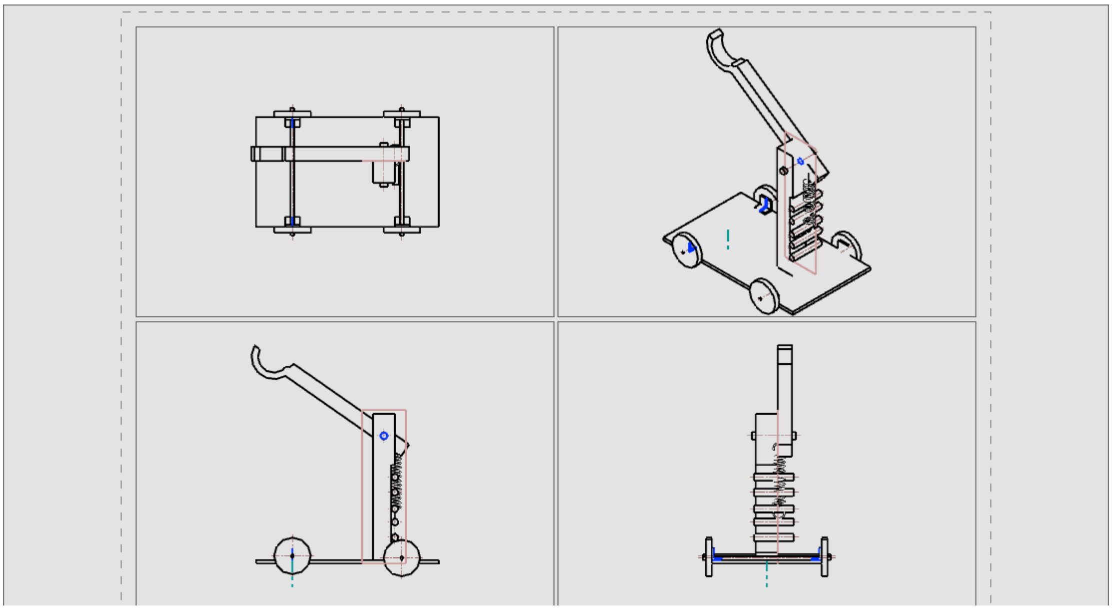


Figure 3-2-4 Concept Design 4

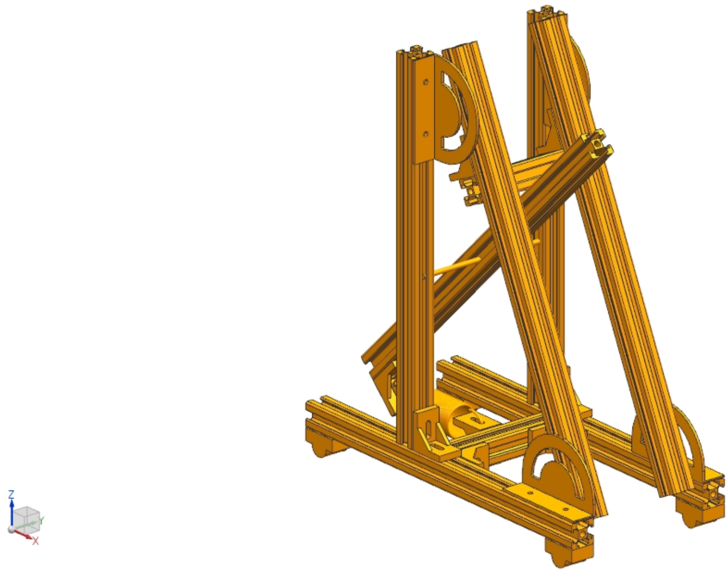


Figure 3-2-5 Concept Design 5

3.2.3. Concept Selection

A) Structure

We finally chose the aluminum frame design based on the following two reasons.

First, the aluminum frame design is easy to re-assemble. When fabricating the prototype, we need to adjust the dimensions frequently. As is shown in the assembling part, the aluminum bars can be adjusted easily to fit different lengths of spring and launching angles.

Second, comparing with the given steel board, the aluminum bars can be drilled easily because of its hardness and density.

Due to the two aspects, we gave up the bottom board design and replaced it with a rectangular frame.

B) Distance Control

We have three options for the distance control.

a) Set several gears on the support rod and attach one end of the spring onto the gears. (Concept Design 4)

b) Mark on the orbit. (Concept Design 3)

c) Protractor around the steel axis. (Concept Design 5)

Apparently, the protractor design provides more precise marks and more options of distance, which is the best choice for an aimer.

C) Spring

We have two options for using the given spring as the driving force. First, we can use the 100mm spring directly. Second, we can clip off the 100mm spring to two identical pieces of 50mm spring. Since we are not acknowledged any parameters about the spring, we decide to make the selection according to the experiment result.

We first tested the 100mm condition. We tried to achieve the maximum extension under our design, and launched the ball at 45°. The ball reached a distance of 16m, which met the requirement. However, we took the fatigue of the spring into consideration. For a spring under long-term tension, the accuracy may be greatly influenced and the maximum distance may be shorter. Therefore, we clip off the spring and tested the catapult again, and the maximum distance requirement was also achieved.

D) Movability

We used 30mm-diameter plastic wheel in our design to meet the movability criteria. Also, we used plastic bars to attach the wheels to the catapult. The whole structure could be folded above the base. This foldable design benefits two aspects in the competition. Firstly, when we are shooting the target, we hide the wheels above the base, and the catapult will not move because of the counterforce greater than rolling friction. Secondly, for the firmness test, the plastic bars and wheels are much weaker than the aluminum alloy, which is not competent to the task of impact site.

3.3 Final Design UG Drawing

Figure 3-3-1 Final Design Pictorial

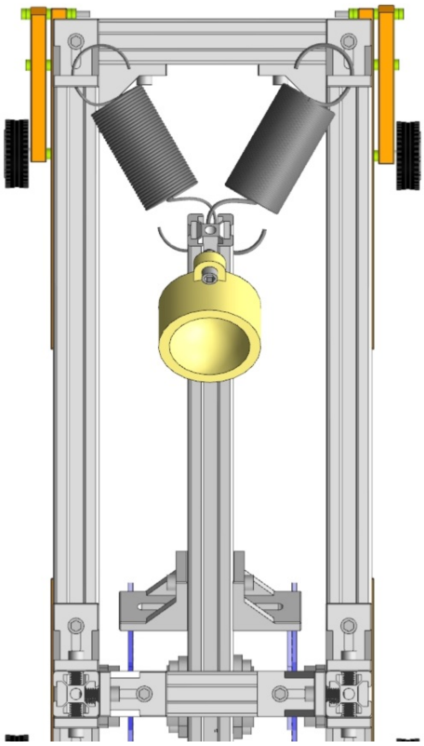


Figure 3-3-2 Final Design Top View

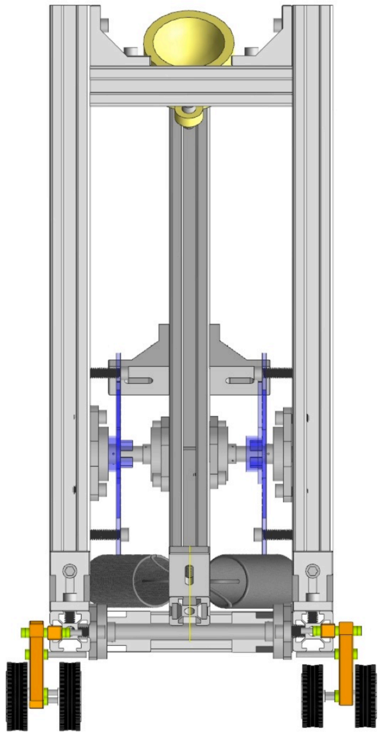


Figure 3-3-3 Final Design Front View

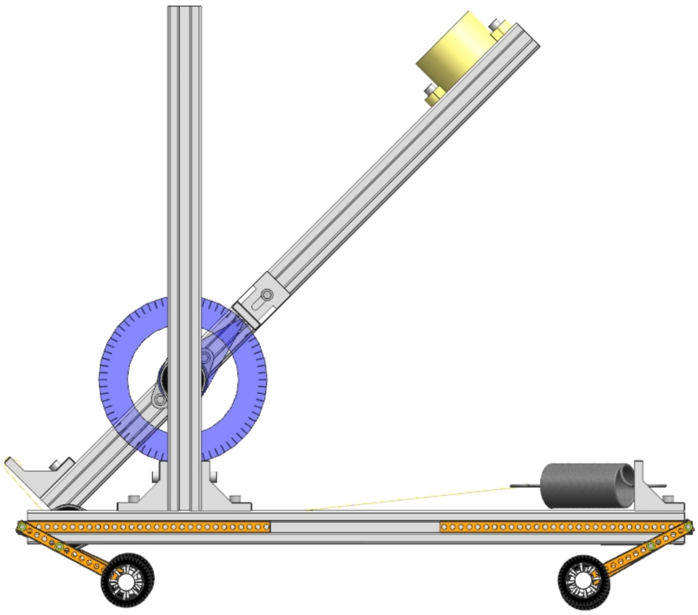


Figure 3-3-4 Final Design Right View

4. Prototype

Whole Machine

The following pictures are the overview of our catapult. In the pictures, you can see that, our catapult is made by Aluminum section bar and it has no baseboard. We use corner fitting to fix the frame of the catapult.

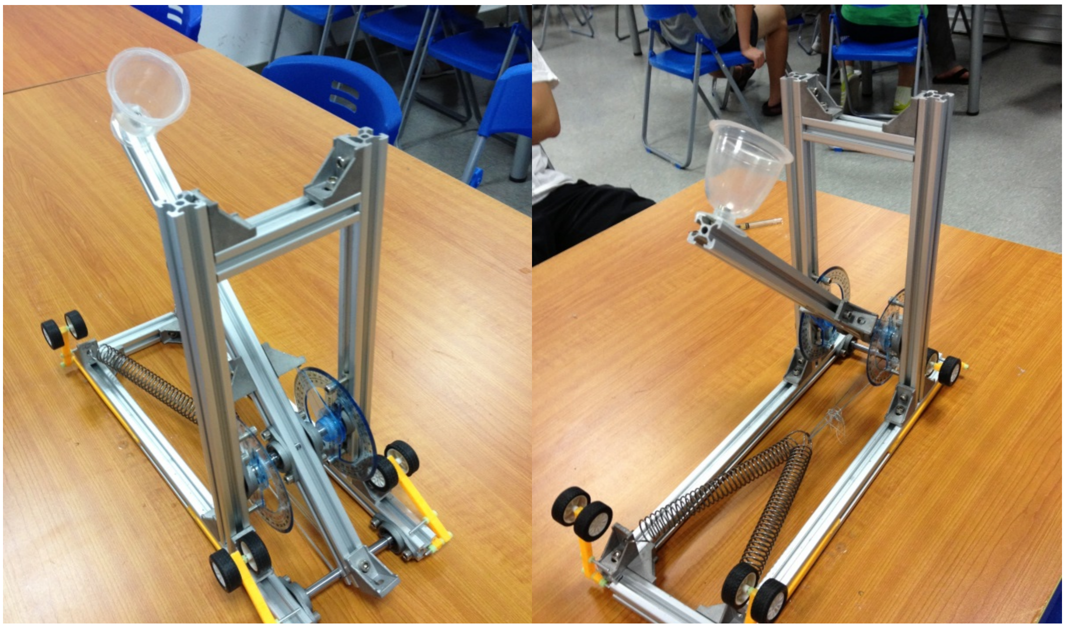


Figure 4-1 The Whole Machine

Ejector

We use a 3D print container as the ejector. At the bottom of the container, we designed two holes to fix it on the aluminum bar with a screw.

Figure 4-2 The Ejector

Tire

The tires of our catapult are made of plastic. Usually, tires will hide themselves, because we want to protect them from impact. When it needs to move, we can put out its tires and it can move smoothly on the flatform.

Figure 4-3 The Tires

Aimer

We want to hit the target more precisely, thus we install an aimer on our catapult and fix with bearings. This aimer is made by protractor. Before we take part in the game day, we will make a lot of tests. In these test, we will record the distance and its angle. The next time we want to hit a certain distance, we just need to find out the right angle we record before.

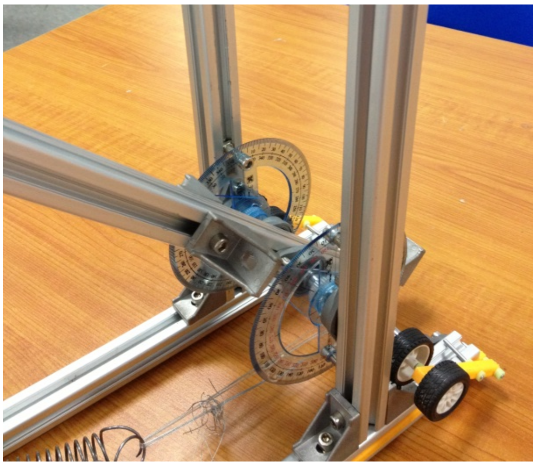


Figure 4-4 Aimer

Spring

The original spring length is 100mm. We clip off the spring into two 50mm by nipper pliers. One end is hooked at the tail of catapult, the other end is hooked by steel strings.

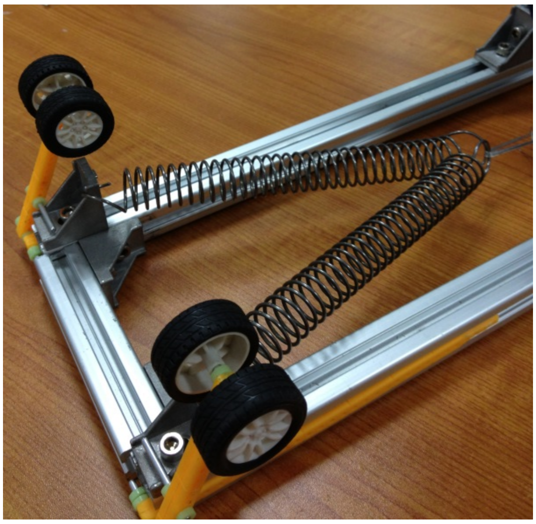


Figure 4-5 Springs

5. Test

5.1 Functional Test

Mobility test

This test is to see whether the tires can roll. During the test, we put out the tires and push it on different types of the road. In the end, we found that the catapult can move smoothly on the cement road. But it may slide on the marble road. Also, we test the speed on different roads. And the result is that it will move much faster if it slides.

Robustness test

This test is to see whether the catapult can bear the crash at a height of 1.5m. Before the test, we will hide its tires to protect them from impact. After that we raise it to 1.5m and release it. The result shows that it can remain its origin shape and function after such an impact.

5.2 Distance Tests

In this test, we collect four groups of data when we use catapult to hit a target at 4m, 5m, 6m and 7m. We want to prove that the accuracy of these hits is high and they satisfy normal distribution.

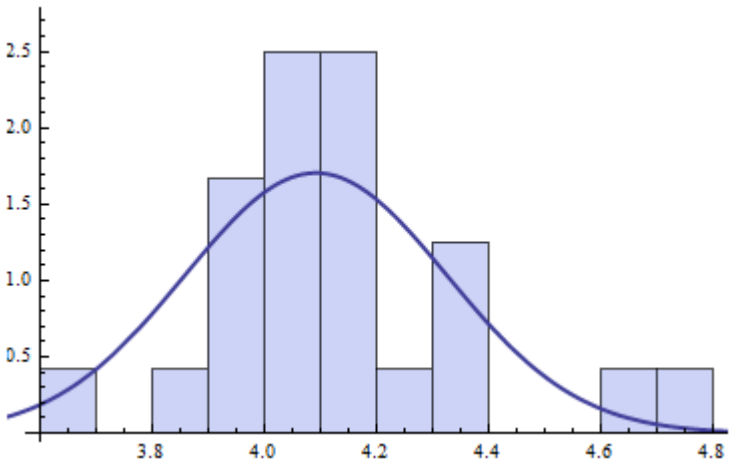
4 meters:

```
data1 := {4.1, 4.15, 4.3, 3.9, 4.2, 4.6, 3.95, 4.7, 4.1, 4.0, 3.95, 4.1, 4.1,
  4.0, 3.9, 4.3, 4.1, 4.0, 4.0, 4.0, 3.8, 3.6, 4.05, 4.3}
Mean[data1]

4.09167

StandardDeviation[data1]

0.233902
```



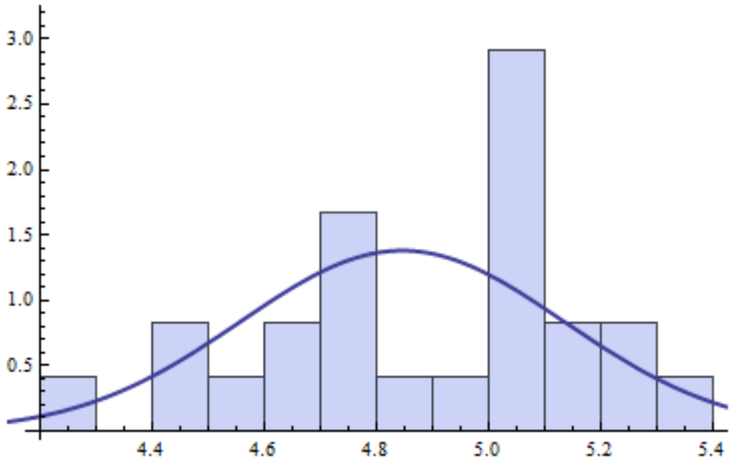
5 meters:

```
data2 := {5, 5.1, 5, 5.3, 4.7, 5.1, 5.2, 5.0, 4.6, 4.7, 4.4, 5.2, 4.9, 5, 5.05,
  4.75, 4.7, 5, 4.85, 4.6, 5.05, 4.2, 4.4, 4.5}
Mean[data2]

4.84583

StandardDeviation[data2]

0.288895
```



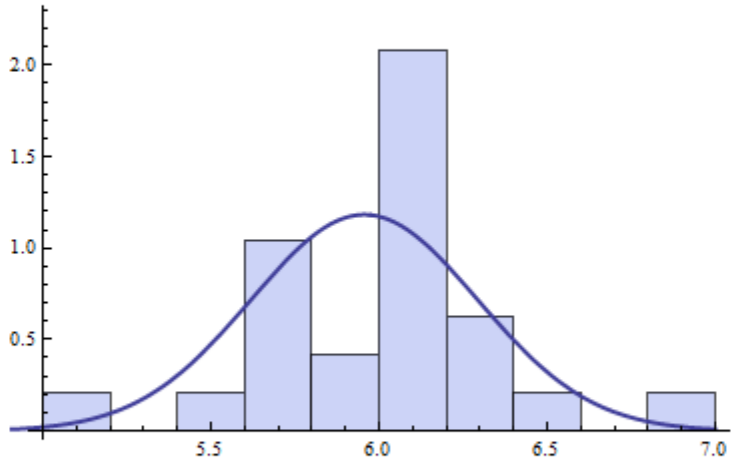
6 meters

```
data3 := {6.1, 6.0, 6.8, 6.1, 5.1, 6.0, 6.2, 5.7, 6.0, 6.4, 5.7, 6.0, 6.0, 6.2,
  5.7, 6.1, 6.1, 5.95, 5.9, 6.2, 5.7, 5.6, 5.4, 6}
Mean[data3]
```

```
5.95625
```

```
StandardDeviation[data3]
```

```
0.337289
```



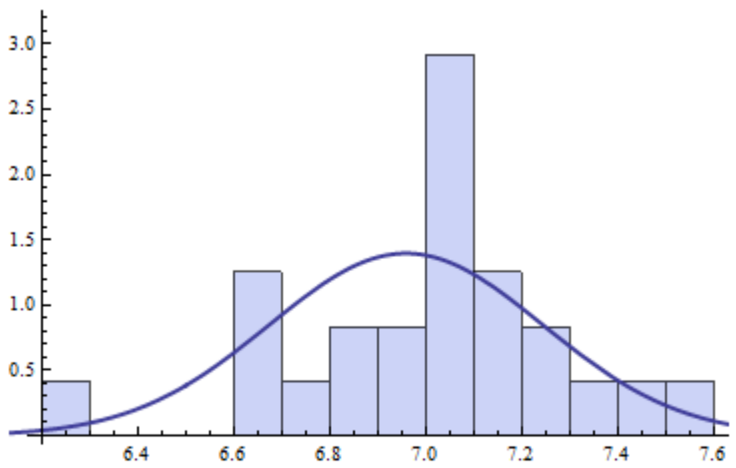
7 meters

```
data4 := {6.9, 6.6, 7.2, 7.1, 6.2, 7.0, 7.0, 7.4, 7.5, 7, 7.1, 6.6, 6.8, 7.1,
  7.2, 7, 6.8, 7.3, 6.7, 6.6, 7, 6.9, 7, 7}
Mean[data4]
```

```
6.95833
```

```
StandardDeviation[data4]
```

```
0.285774
```



Result Analysis

In the diagrams, we can clearly see the distribution of the data. For each distance, over 70% hits are distributed in the reasonable range which is ±0.2m. However, we notice that we should improve our performance at the distance of 5m and 6m, since the catapult is less accurate at these two distances.

For the longest distance test, we also have a good performance. We test it for 10 times and the final average result is 18.2 meters, which is longer than 15 meter.

6. Manufacturing

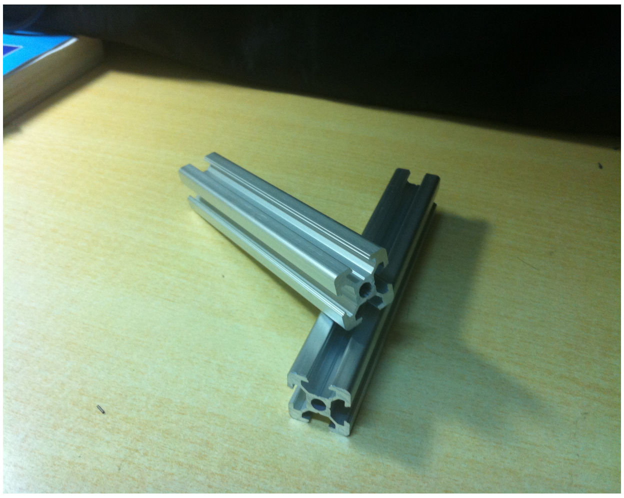
6.1 Material

The material used in this design is listed as the following:

Item	Number
3D Printed Ball Container	1
300mm*20mm*20mm Aluminum Section Bar	2
100mm*20mm*20mm Aluminum Section Bar	2
50mm Spring (100mm Given)	2
100mm*8mm-Diameter Steel Axis	2
Plastic Protractor	2
390mm*20mm*20mm Aluminum Section Bar	3
20mm*5mm-Diameter Flange Nuts and Bolts	4
150mm*7mm*7mm Plastic Bar	6
8mm-Diameter Bearing	6
10mm*30mm-Diameter Plastic Wheel	8
300mm Steel Wire	8
30mm*3mm-Diameter Steel Axis	12
Corner Fitting for 20mm*20mm Aluminum Section Bar	13
1mm*3mm-Diameter Circlip	32
12mm*5mm-Diameter Flange Nuts and Inner Hexagon Screw	35

The dimension for most of the necessary material with simple geometry can be read off from the material table given above. The following diagrams give the crucial dimension for two important components with relatively complicated geometry. The first orthographical diagram shows the dimension for the corner fitting for 20mm*20mm aluminum section bar. The second drawing gives the cross sectional area geometry of all different length of 20mm*20mm aluminum section bars used in this design. The area moments of inertia with respect to the vertical and horizontal axis are both equal to 0.72 cm^4.

Here are some graphs of our material:



20mm*20mm Aluminum Section Bar

Corner Fittings

Plastic Protractor

8mm-Diameter Bearings and axis

7mm*7mm Plastic Bar

3D Printed Ball Container

6.2 Manufacture Techniques

The manufacturing process for our design is not complex. The material we chose can be obtained easily. To get the aluminum section bar, we recommend using extrusion, and then cut it into proper length. The plastic toy car sticks should also be cut into equal lengths by machines. Punching holes on the design is another critical process. The holes should be punched accurately, especially on the shooting arm, so that the projectile will be straight. Some reaming is needed to make the size of the holes in our favor. Finally is the assembling part, the manufacturer should assemble all the parts in correct sequence and fix the screws and nuts tight. A small challenge in assembly is to insert the pointer of our plastic protractor into a pair of corner fittings on the shooting arms.

6.2 Assembling

In order to assemble the prototype after manufacturing is completed, one hexagon bar wrench with 5 mm as diameter and one hexagon bar wrench with 1 mm as diameter are needed. The Step by Step assembling process is shown graphically below.

Step 0: Check all necessary parts and tools for assembling.

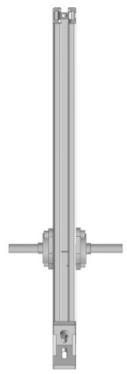
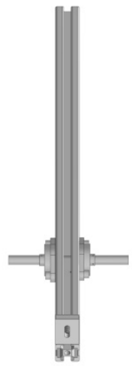
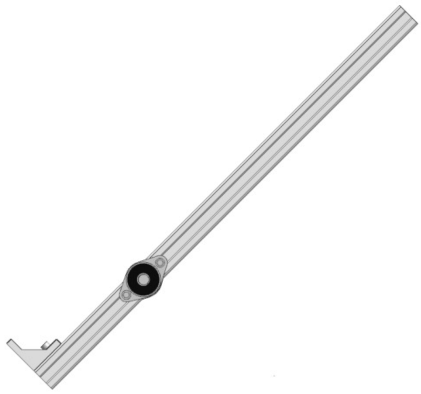
Step 1: Assemble the throwing bar, axis and bearing.

Necessary material (Only added materials are included.):

Item	Number
390mm*20mm*20mm Aluminum Bar	1
8mm-Diameter Bearing	2
100mm*8mm-Diameter Steel Axis	1

12mm*5mm-Diameter Flange Nuts and Bolts	5
Corner Fitting for 20mm*20mm Aluminum Bar	1

Orthographical view for the finished assembling:

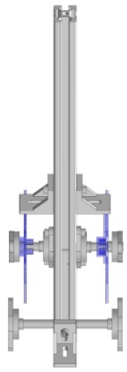
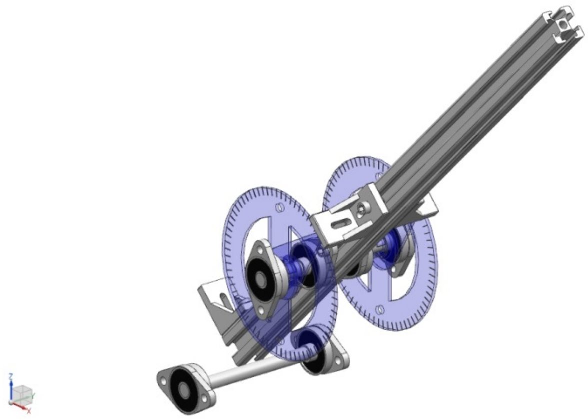
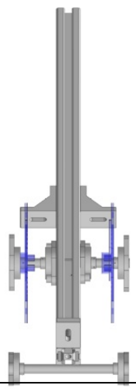
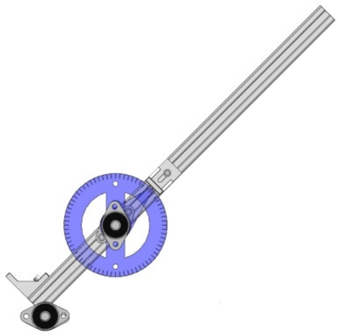
	
Top View	Pictorial
	
Front View	Right View

Step 2: Assemble the contractor and bearing.

Necessary material (Only added materials are included.):

Item	**Number**
390mm*20mm*20mm Aluminum Section Bar	1
100mm*8mm-Diameter Steel Axis	1
12mm*5mm-Diameter Flange Nuts and Inner Hexagon Screw	2
Plastic Protractor	2
Corner Fitting for 20mm*20mm Aluminum Section Bar	2
8mm-Diameter Bearing	4

Orthographical view for the finished assembling:

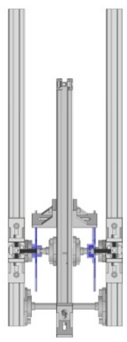
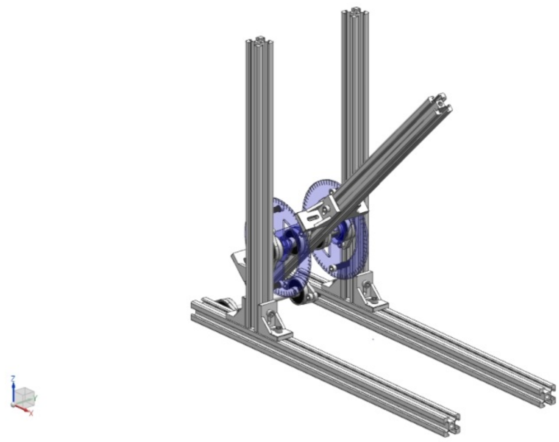
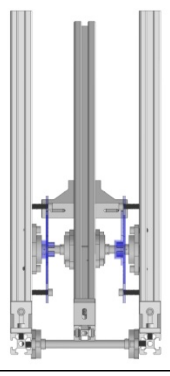
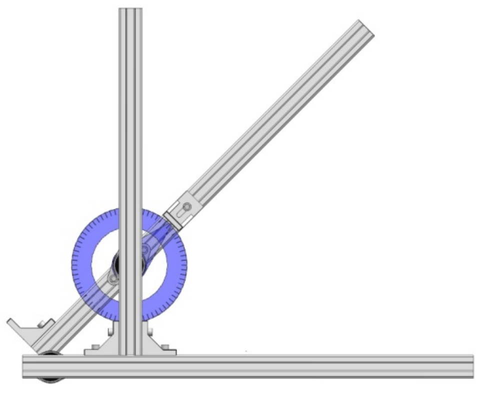
	
Top View	Pictorial
	
Front View	Right View

Step 3: Assemble the main frame.

Necessary material (Only added materials are included.):

Item	Number
100mm*8mm-Diameter Steel Axis	1
390mm*20mm*20mm Aluminum Section Bar	2
390mm*20mm*20mm Aluminum Section Bar	2
20mm*5mm-Diameter Flange Nuts and Bolts	4
Corner Fitting for 20mm*20mm Aluminum Section Bar	4
12mm*5mm-Diameter Flange Nuts and Inner Hexagon Screw	16

Orthographical view for the finished assembling:

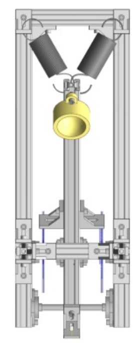
	
Top View	Pictorial
	
Front View	Right View

Step 4: Assemble the spring, ball container and frame.

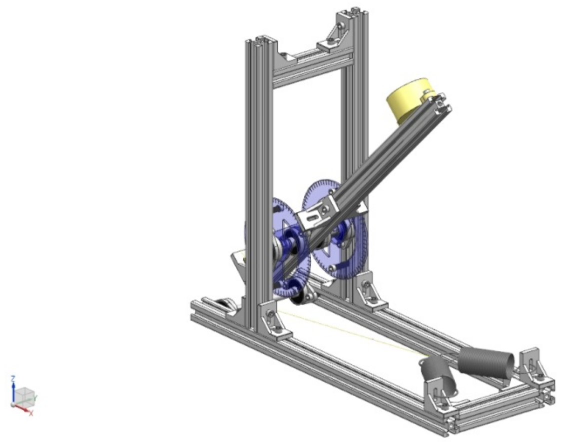
Necessary material (Only added materials are included.):

Item	Number
3D Printed Ball Container	1
100mm*20mm*20mm Aluminum Section Bar	2
390mm*20mm*20mm Aluminum Section Bar	2
50mm Spring	2
300mm Steel Wire	8
Corner Fitting for 20mm*20mm Aluminum Section Bar	6
12mm*5mm-Diameter Flange Nuts and Inner Hexagon Screw	12

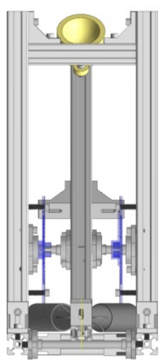
Orthographical view for the finished assembling:



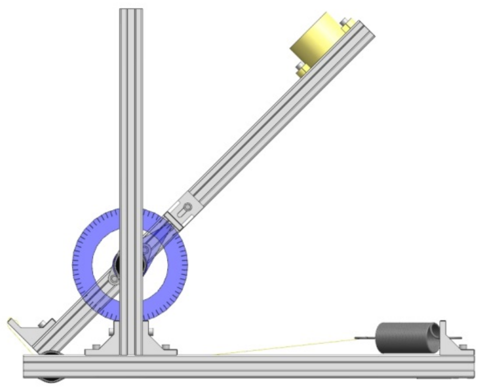
Top View



Pictorial



Front View



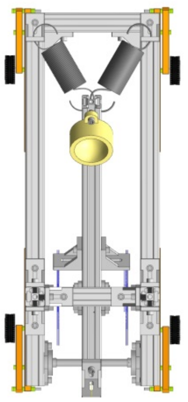
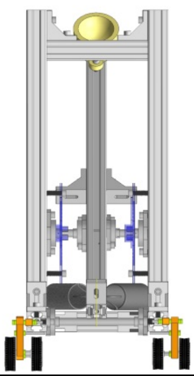
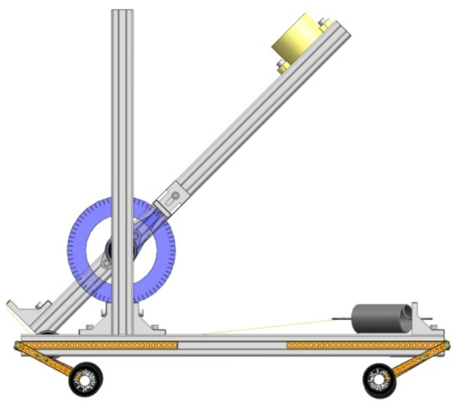
Right View

Step 5: Assemble the foldable wheels.

Necessary material (Only added materials are included.):

Item	Number
Plastic Protractor	2
150mm*7mm*7mm Plastic Bar	6
300mm Steel Wire	8
10mm*30mm-Diameter Plastic Wheel	8
30mm*3mm-Diameter Steel Axis	12
1mm*3mm-Diameter Circlip	32

Orthographical view for the finished assembling:

	
Top View	Pictorial
	
Front View	Right View

7. Cost Estimation

<table>
<tr><th>Item</th><th colspan="2">Amount</th><th>Unit Price (yuan)</th><th>Price</th></tr>
<tr><td>390mm*20mm*20mm Aluminum Bar</td><td>3</td><td rowspan="3">1.97m</td><td rowspan="3">13.5/m</td><td>27</td></tr>
<tr><td>300mm*20mm*20mm Aluminum Bar</td><td>2</td><td></td></tr>
<tr><td>100mm*20mm*20mm Aluminum Bar</td><td>2</td><td></td></tr>
<tr><td>Corner Fitting for 20mm*20mm Aluminum Bar</td><td colspan="2">13</td><td>1.5</td><td>19.5</td></tr>
<tr><td>150mm*7mm*7mm Plastic Bar</td><td colspan="2">6</td><td>1</td><td>6</td></tr>
<tr><td>50mm Spring (100mm Given)</td><td colspan="2">2</td><td>6/100 mm</td><td>6</td></tr>
<tr><td>8mm-Diameter Bearing</td><td colspan="2">6</td><td>3.9</td><td>23.4</td></tr>
<tr><td>100mm*8mm-Diameter Steel Axis</td><td colspan="2">2</td><td>30/m</td><td>6</td></tr>
<tr><td>30mm*3mm-Diameter Steel Axis</td><td colspan="2">12</td><td>0.4</td><td>4.8</td></tr>
<tr><td>Plastic Protractor</td><td colspan="2">2</td><td>2.3</td><td>4.6</td></tr>
<tr><td>10mm*30mm-Diameter Plastic Wheel</td><td colspan="2">8</td><td>1.2</td><td>9.6</td></tr>
<tr><td>1mm*3mm-Diameter Circlip</td><td colspan="2">32</td><td>0.04875</td><td>1.56</td></tr>
<tr><td>3D Printed Ball Container</td><td colspan="2">1(4.5g)</td><td>0.3</td><td>1.35</td></tr>
<tr><td>300mm Steel Wire</td><td colspan="2">8(1.2m)</td><td>0.6/m</td><td>0.72</td></tr>
<tr><td>12mm*5mm-Diameter Flange Nuts and Bolts</td><td colspan="2">35</td><td>0.55</td><td>19.25</td></tr>
<tr><td>20mm*5mm-Diameter Flange Nuts and Bolts</td><td colspan="2">4</td><td>0.65</td><td>2.6</td></tr>
<tr><td colspan="4">Total Cost</td><td>132.38</td></tr>
</table>

(Grimm,2012)

8. Recommendation

There are some recommendations below, which can be useful for further improvement in similar catapult toy products.

- Lateral Accuracy

Improvement in lateral accuracy is necessary for our catapult design. During our projection practice, we found that the ball was not projected in the original direction as we expected. It will fly to right or left. We checked our prototype and solved part of the problem by replacing the jelly container with a customized ball container which has a more stable shape. However, the slight offset of the main arm still exists after continuously practice.

- Trigger

We gave up the design of a trigger because of the limit of space. However, it’s still a worthy improvement for future groups. A lack of trigger will result in slight impedance when releasing the projection arm. Also, the large impulse caused by the spring may also hurt the operator.

9. Conclusions

In conclusion, our team works as a united group and makes a successful trebuchet prototype. Every team member dedicate his or her best effort into the project from the beginning to the end. In concept generation part, we compare our different ideas and argue for the best design scheme. In prototype building section, everyone wants to stand in the frontline. In testing part, we work in different roles, some help shoot the ball, some help make recordings, some help pick the ball. Those pictures are impressed in our heart and make us understand that a good team spirit can overcome big challenges.

Our design is very good in quality and shooting accuracy. We are the first group to finish the prototype and start testing. Based on the testing results, we make several adjustment in our prototype. We are confident that our metal trebuchet will perform well on the game day.

10. Reference

Todd Grimm (2012). *The Real Cost of Materials.*. [ONLINE] Available at: http://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/4280/The-Real-Cost-of-Materials.aspx [Last Accessed 1 August 2013].

11. Acknowledgement

We would like to extend my sincere gratitude to many people who give us many helpful instructions in this project. We wish to acknowledge the help form Professor Qi Huan in designing process and manufacturing process, and the help from our Teaching Assistant Li Hao, Xu Tianxiang, Xu Chenyu in engineering drawing skills.

Appendix A: UG NX Drawings For Components

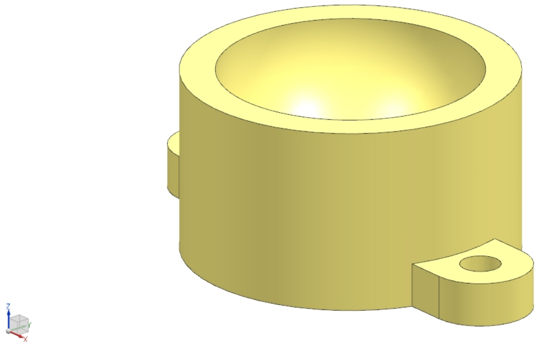


Figure A-1 Ball Container

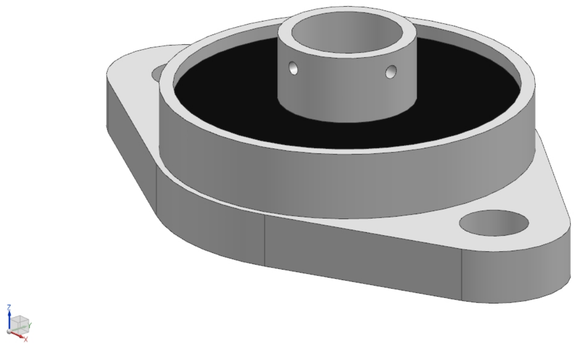


Figure A-2 Bearing

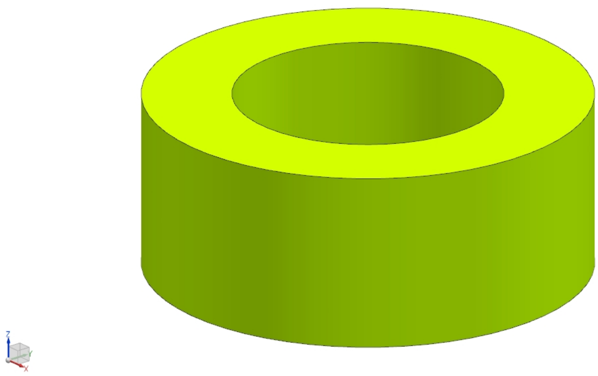


Figure A-3 Circlip

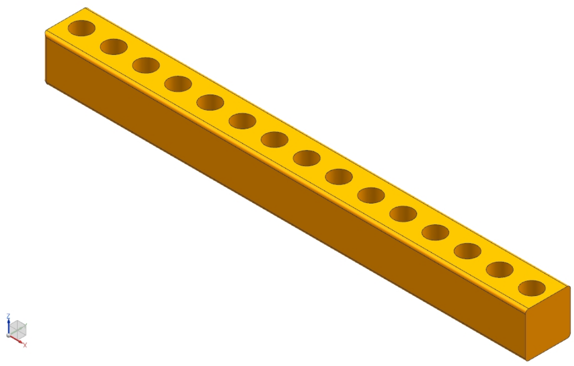


Figure A-4 Plastic Beam

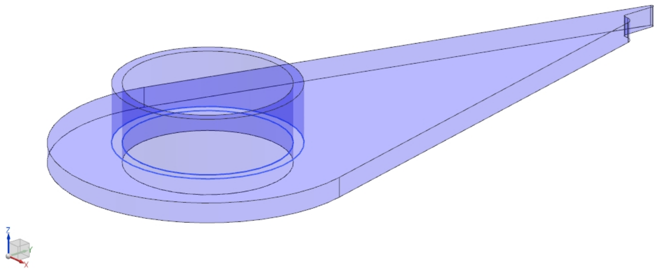


Figure A-5 Pointer

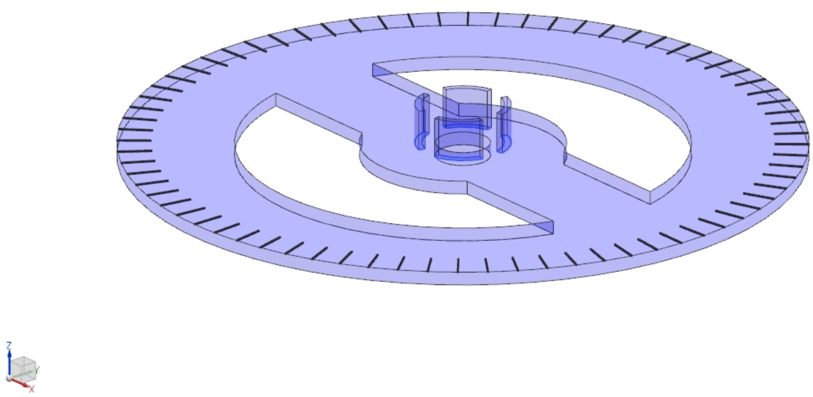


Figure A-6 Protractor

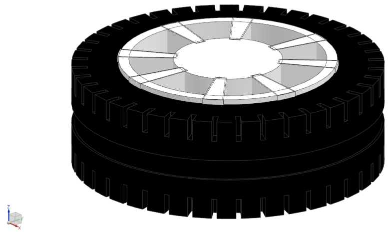


Figure A-7 Wheel

Figure A-8 Short Spring

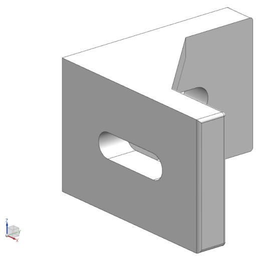


Figure A-9 Ball Container

Figure A-10 Ball Container

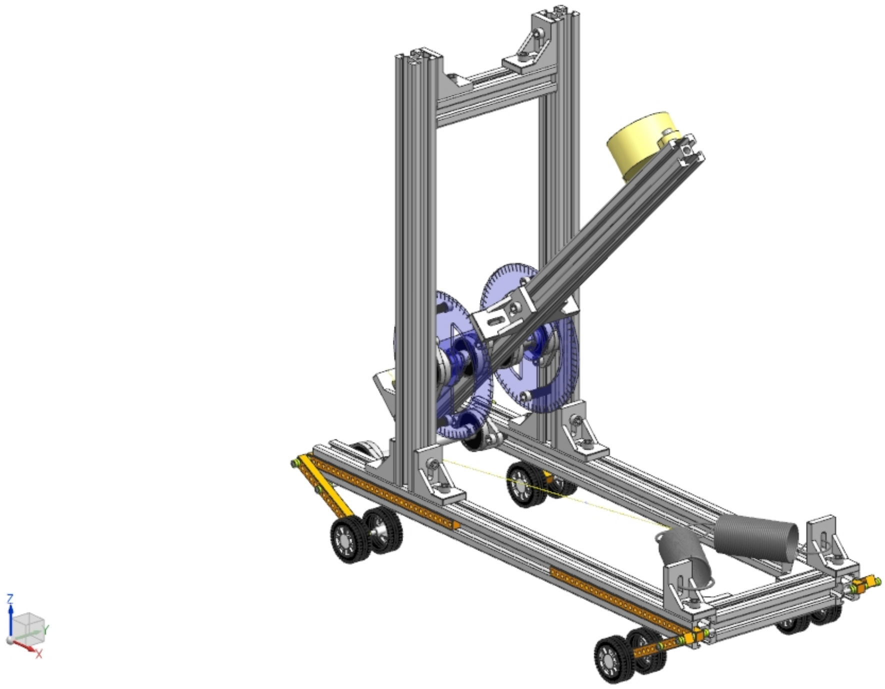


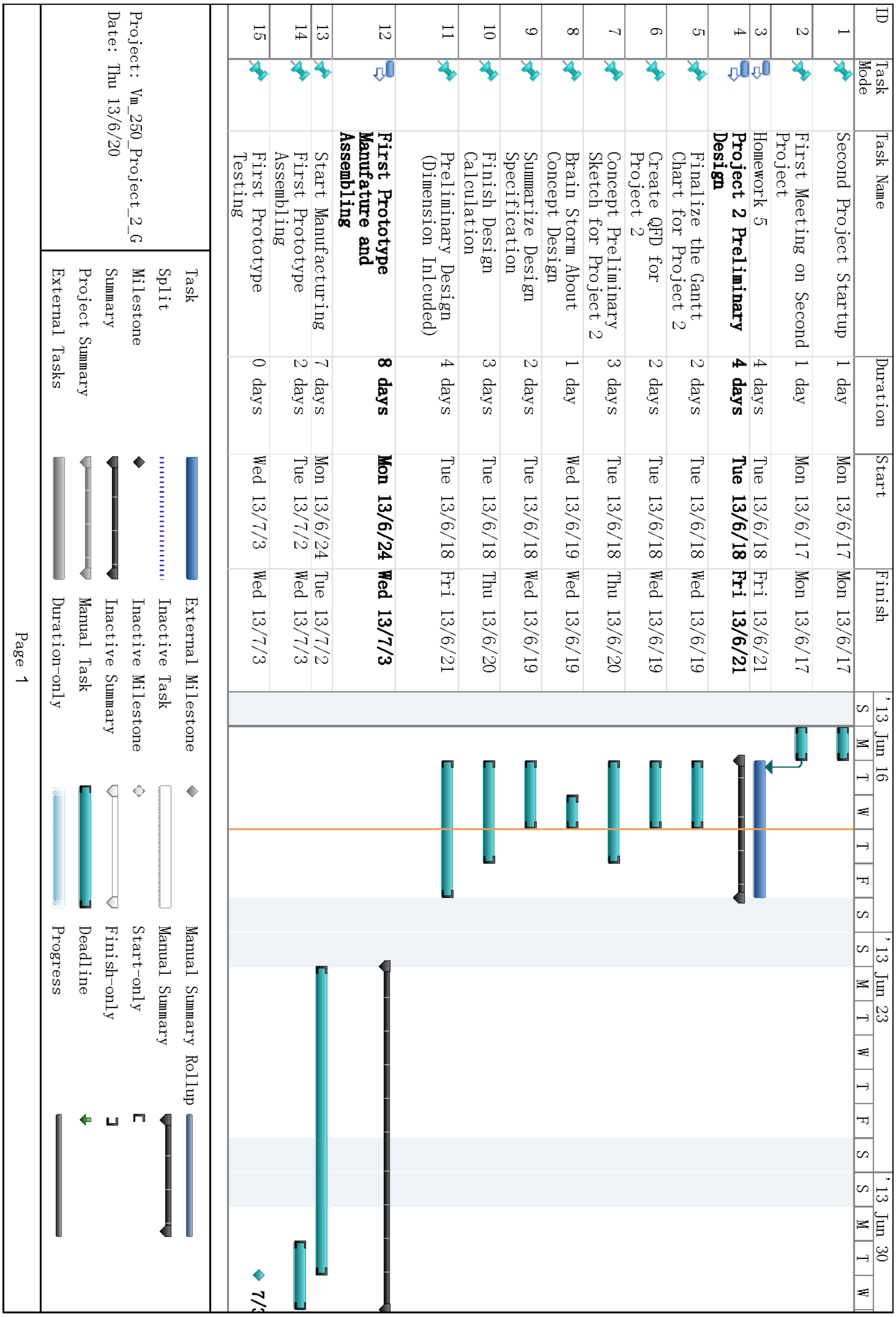
Figure A-11 Fully Assembled Catapult

Appendix B: Product Design Specifications

- **Performance**
  The performance of the product is a toy trebuchet.
- **Environment**
  The product can work normally in the environment ranging from -20℃ to 60℃ in temperature and 0% to 99% in relative humidity. The environment noise does not affect the function of the product.
- **Life in service**
  The product is a toy trebuchet that entertains people by shooting balls to a certain distance. The shooting range is at least 15 meters. It should be accurate enough to shoot the ball to an area within a tolerance of ±0.2m around the target. It should be robust enough not to break if dropped from a height of 1.5m. Movability is also required.
- **Maintenance**
  The springs and steel wires are likely to have defects due to long service time or improper usage. Therefore, matching springs should be available for maintenance.
- **Target product cost**
  ￥132.28
- **Manufacturing facility**
  We need the following Manufacturing facilities:
  a) Extrusion machine for aluminum alloy
  b) Plastic injection machine for the plastic parts
  c) Spring production line
  d) Assembly line
  e) Packing line
- **Size**
  Length: 40cm
  Width: 20cm
  Height: 40cm
- **Weight**
  1.55kg
- **Product life span**
  The simple style design and the usage of metal as material make the product hard to break. With proper use and maintenance, the expected life span of the product is 10 years.
- **Safety**
  The product should not have any sharp edges or corners. The springs should be firmly attached and should not be exposed to the user to prevent possible harm. No toxic or recycling materials should be used in any parts of the product. The shooting speed should be low enough so as not to hurt people if they get hit.

- **Competition**
  Other teams from VM250 also made other trebuchets, they are our main competitors.
- **Installation**
  Before using, the user needs to install the springs to the product by attaching them between the hooks on the back and the steel wires.
- **Packing**
  The packing of the product should contain enough protection material to prevent the damage from the shipping process. It should also look attractive for larger sales.
- **Shipping**
  The shipping process the product should prevent violent knock or contact with corrosive substance to prevent destruction of the product.
- **Disposal**
  Many disposed parts of the products need recycling for environmental protection and material saving purposes. The metal materials such as aluminum alloy and the spring steel in the disposed main body should be recycled for other proper use.
- **Legal**
  The design and manufacturing processes of the product must not violate any rules of any laws or regulations, international laws or local laws alike.
- **Documentation**
  The documentation of the product includes the using instruction, the warranty bill, and the qualifications from various testing organizations.
- **Testing**
  The plastic used in the product mush be safe for direct contact with human body, so the related qualification, such as the PAH testing, must be obtained. To guarantee the functionality, the FFU test should be done, including the Stability Test, the Strain Relief Test for the springs, the Stress Test for the aluminum alloy rods, and the Load Test for the wheels.
- **Customer**
  The customer of this product can be children or adults who are interested in weapon modeling.
- **Quality reliability**
  The product should pass various tests on functionality, safety, and legality. The manufacturing process should pass professional qualifications on legality, labor usage, and environmental protection. The quality of the final product and the whole process is thus guaranteed.

Appendix C: Gantt Charts



ID	Task Mode	Task Name	Duration	Start	Finish
16		First Porotypte Testing	1 day	Wed 13/7/3	Wed 13/7/3
17		**Second Prototype Manufature and Assembling**	**5 days**	**Wed 13/7/3**	**Wed 13/7/10**
18		Team Meeting: Identify Defects and Things to Improve	1 day	Wed 13/7/3	Wed 13/7/3
19		Redesign Prototype	2 days	Thu 13/7/4	Fri 13/7/5
20		Manufacture and Assemble	2 days	Mon 13/7/8	Tue 13/7/9
21		Second Prototype Testing	0 days	Wed 13/7/10	Wed 13/7/10
22		**Final Prototype Manufature and Assembling**	**5 days**	**Wed 13/7/10**	**Wed 13/7/17**
23		Team Meeting: Identify Defects and Things to Improve	1 day	Wed 13/7/10	Wed 13/7/10
24		Redesign Prototype	2 days	Thu 13/7/11	Fri 13/7/12
25		Manufacture and Assemble	2 days	Mon 13/7/15	Tue 13/7/16
26		Final Prototype Testing	0 days	Wed 13/7/17	Wed 13/7/17
27		**Project 2 Report**	**15 days**	**Wed 13/7/17**	**Tue 13/8/6**

'13 Jun 16: S M T W T F S
'13 Jun 23: S M T W T F S
'13 Jun 30: S M T W

Project: Vm_250_Project_2_G
Date: Thu 13/6/20

Task	External Milestone	Manual Summary Rollup
Split	Inactive Task	Manual Summary
Milestone	Inactive Milestone	Start-only
Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

ID	Task Mode	Task Name	Duration	Start	Finish
28		Team Meeting: Distribute Work for Project 2 Report	1 day	Wed 13/7/17	Wed 13/7/17
29		Complete Sections for Project 2 Report	5 days	Thu 13/7/18	Wed 13/7/24
30		Typeset and Rearranging	2 days	Thu 13/7/25	Fri 13/7/26
31		Project 2 Report Internal Review	2 days	Sat 13/7/27	Sun 13/7/28
32		Final Report Revising	7 days	Mon 13/7/29	Tue 13/8/6
33		Team Meeting: Project 2 Wrap Up	1 day	Wed 13/8/7	Wed 13/8/7
34		Project 2 Game Day	0 days	Fri 13/8/9	Fri 13/8/9
35		Final Report Submission	0 days	Fri 13/8/9	Fri 13/8/9

'13 Jun 16: S M T W T F S
'13 Jun 23: S M T W T F S
'13 Jun 30: S M T W

Project: Vm_250_Project_2_G
Date: Thu 13/6/20

Task	External Milestone	Manual Summary Rollup
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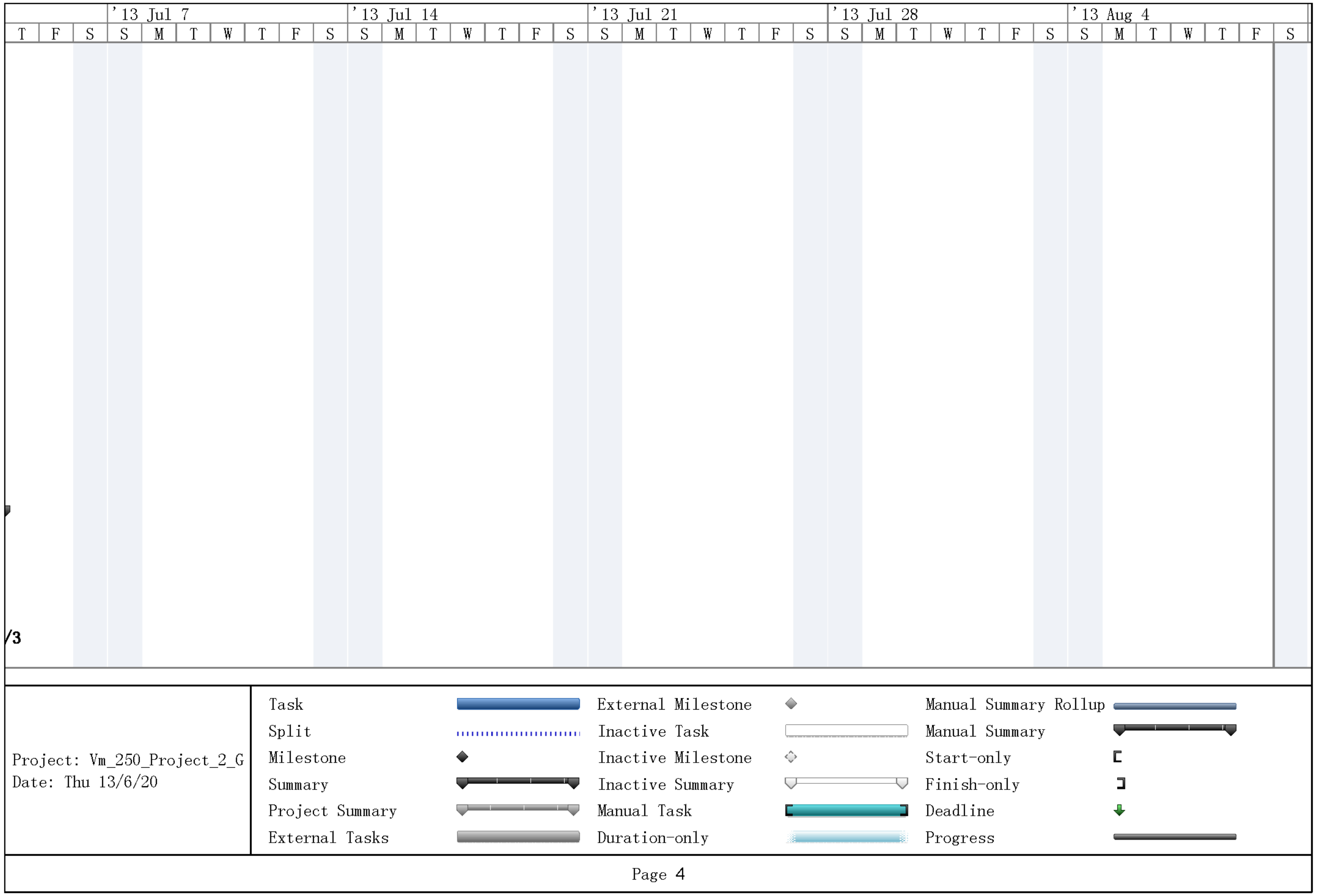
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress

Page 3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Project: Vm_250_Project_2_G
Date: Thu 13/6/20
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Summary
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External Tasks
External Milestone
Inactive Task
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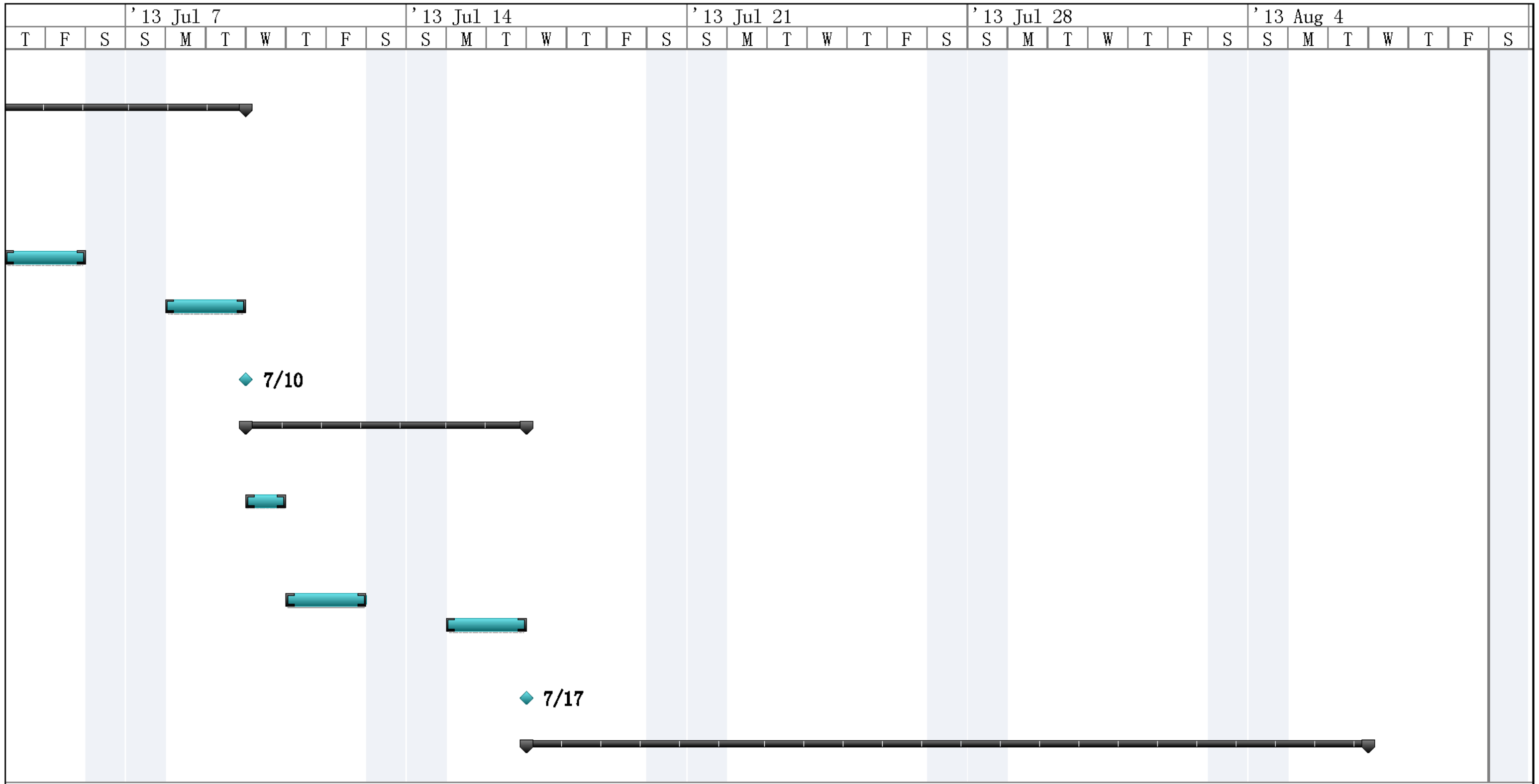
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress
Page 4



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Date: Thu 13/6/20

Task	External Milestone	Manual Summary Rollup
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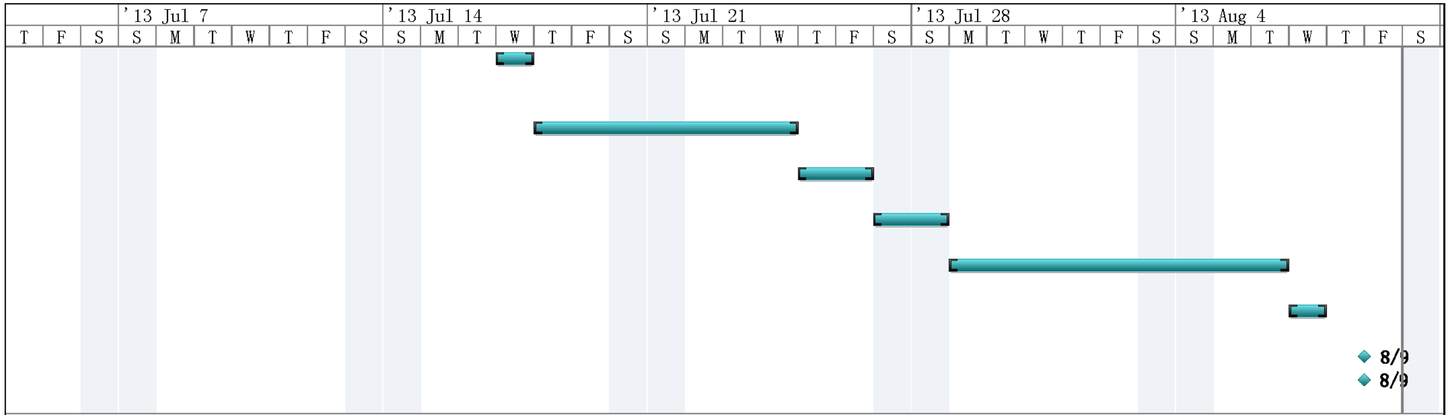
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress



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Summary	Inactive Summary	Finish-only
Project Summary	Manual Task	Deadline
External Tasks	Duration-only	Progress