Sarge's Siege: An Intuitive Design Interface

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Group 10

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Executive Summary

We were given the task to use a spreadsheet to create a tool for a user to explore the design space of a mechanical device. We choose a mangonel catapult. Live action role players and physics departments can order mangonels easily though an the user interface.

We planned the project at the beginning, setting goals and assigning tasks to team member, compartmentalising the project. The mathematics of a mangonel were broken up into two parts; the launching mechanics and projectile motion. We applied the mathematics to the design parameters of the mangonel. We decided on five design parameters; size, material, angle, wheel size and skin. These were quantised into three to five options per parameter.

We designed and implemented performance metrics based on the catapults design. These were; maximum height, distance, velocity, acceleration, impact force, force required, cost and mass. Dials, bar graphs and images that change relative to the maximum value were used to convey comparative information.

The invoicing, clearing and navigation features of the workbook are described.

Detailed instructions are given on how to navigate the workbook. The contents of each sheet in the workbook are explained with descriptions of the user forms and buttons.

An analysis of a medium sized mahogany mangonel with a 45˚ angle is given. The performance metrics are discussed, adding what impact a change in the input parameters would have on the performance.

Concluding the report, comments regarding my contribution to the group and a reflective discussion are described. The appendices with the layout of our design tool follow soon after.

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Introduction

Spreadsheets have the functionality to be used as a creative tool. Our task was to use a spreadsheet to create a tool to explore the design space of mechanical device, referring to tables of data and specific qualities of our customisable parameters. We were to use Excel macros and forms controls to customise our worksheet. The results generated from the various design choices were to be displayed in a useful form e.g. report summaries, graphs or charts. A table of key information must be retrospectively generated, from our application, for use in Solidworks. There was to be choice for the user to explore the design space. The device was to be mechanical in nature.

We choose a catapult as our mechanical device. After discussing the mangonel, Ballista and Trebuchet variants, we decided to customise a Mangonel catapult in our design space. Our target users are live action role players who wish to add realism to their games and physics departments teaching projectile motion.

Our user interface (UI) is fluid and intuitive. Ordering a catapult in this age is difficult due to the historical nature of our product. Our UI guides the user from start to end. The user has control over customising five parameters of the Mangonel's design. The UI also has the ability to quantifiable measure and compare different designs and order multiple mangonels. Our product enables the user to design a series our Mangonels which caters to their needs.

Our mangonel is a mechanical device. Our interface guides the user start to end linearly. We refer to parameter specific variables to determine design specific metrics. Forms Controls and Macro were written to customise the mangonel, measure the performance and navigate the UI. Mangalore specific performance was demonstrated through an animation, dials and bar graphs. Therefore, our product meets the design brief.

Development

Initially, I facilitated the planning stage of the project. Each team member outlined their goals for the project while identifying their strengths and weaknesses (Appendix 1). Tasks were assigned based on goals, strengths and weaknesses to improve motivation and team synergy. I outlined an estimated project schedule. I took the project objective and specifications, compartmentalising the project. I assigned a task portfolio to each team member. I oversaw the completion of the project from start to end. We compartmentalised the project into five portfolios; Customisation, Physics with Calculations and Animation, Performance and Comparative Metrics, Design and Invoicing. In addition to these portfolios, I worked on UI navigation and integration. I conceptualised each sheet at the beginning of the project with the team agreeing on a design (Appendix 18: Concept Sketches).

After planning, we investigated the mathematics of a mangonel to find a way to measure the mangonels performance objectively. The Mangalore stores energy in a torsion bundle. As the torsion bundle is wound, restrained from recoiling. This bundle is approximated as a spring. During this coiling, the arm is bent downwards. When released, the arm rotates around a pivot point at an angular acceleration with a rotational inertia. A cross beam is struck, converting halting the arm and releasing the loose projectile. Thus, we model projectile motion, assuming the projectile follows a two-dimensional path, and, subject to drag and the force due to gravity. Both drag and the force due to gravity depend on the catapults size.

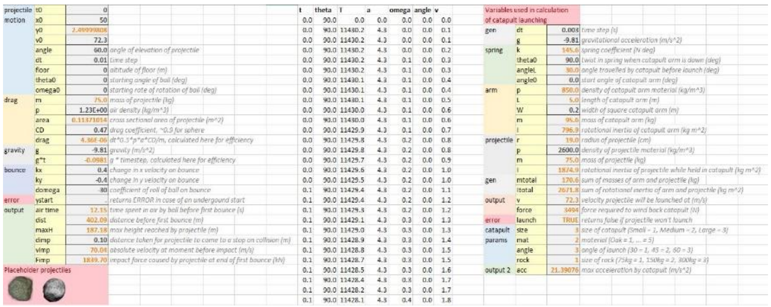
The calculations were done in two stages. First, we calculated the combined rotational inertia of the projectile and catapult arm. The torsion bundle is assumed to be modelled as a rotating spring, then we calculate how much the arm will rotate due to the force in the spring.

This is done by summing the moments around the fixed point the arm is rotating around, and then using $\tau = I\alpha$ to calculate the angular acceleration where I is the rotational inertia. Heavier materials have a greater rotational inertia, therefore, a lower angular acceleration, thus, the projectile will have a lower launch velocity.

We then calculate how both the force of a spring ($\tau = k\omega$) changes and velocity of the arm changes as time progresses. We used a method similar to Euler's to calculate how the angle of the arm changes with time, using a time step. The angular velocity and length of the arm are multiplied together to determine the launch velocity of the projectile when the arm hits the cross beam.

All of these parameters, such as spring constant and length of the catapult arm depend on the input parameters. Once we had the catapult parameters (Figure 1), the angle of release and launch velocity, we have a projectile motion problem. We used another Euler method to calculate the projectile's position in the air. The forces of gravity and air resistance were taken into account with a friction co-efficient of 0.47 and gravity at $9.81m/s^2$. We allowed the projectile to bounce if the height of the projectile was less than the ground, in which case a co-efficient of restitution of 0.4 was applied to new vertical and horizontal velocities, and used the same ratio to put it back above the ground.

We chose to derive a numerical solution using Euler's method for the projectile motion. We deemed an analytical solution and improved Euler's method to be unnecessary as these methods were only slightly more accurate, thus, did not justify the greater computation strain. We decided to use spreadsheet manipulation to perform our calculations instead of function calls due to the spreadsheets greater efficiency and the production of smoother animations (Appendix 2: Calculations).



projectile motion	t0	0	
	x0	50	
	y0	2.49999808	
	v0	72.3	
	angle	60.0	angle of elevation of projectile
	dt	0.01	time step
	floor	0	altitude of floor (m)
	theta0	0	starting angle of ball (deg)
	omega0	0	starting rate of rotation of ball (deg)
drag	m	75.0	mass of projectile (kg)
	p	1.23E+00	air density (kg/m^3)
	area	0.11371014	cross sectional area of projectile (m^2)
	CD	0.47	drag coefficient, ~0.9 for sphere
	drag	4.36E-06	dt*0.5*p*a*CD/m, calculated here for efficiency
gravity	g	-9.81	gravity (m/s^2)
	g*t	-0.0981	g * timestep, calculated here for efficiency
bounce	kx	0.4	change in x velocity on bounce
	ky	-0.4	change in y velocity on bounce
	domega	-30	coefficient of roll of ball on bounce
error	ystart		returns ERROR in case of an undergound start
output	air time	12.15	time spent in air by ball before first bounce (s)
	dist	402.09	distance before first bounce (m)
	maxH	187.18	max height reached by projectile (m)
	dimp	0.10	distance taken for projectile to come to a stop on collision (m)
	vimp	70.04	absolute velocity at moment before impact (m/s)
	Fimp	1839.70	impact force caused by projectile at end of first bounce (kN)
Placeholder projectiles			

t	theta	T	a	omega	angle	v
0.0	90.0	0.0	0.0	0.0	0.0	0.0
0.0	90.0	11430.2	4.3	0.0	0.0	0.1
0.0	90.0	11430.2	4.3	0.0	0.0	0.1
0.0	90.0	11430.2	4.3	0.0	0.0	0.2
0.0	90.0	11430.2	4.3	0.1	0.0	0.3
0.0	90.0	11430.2	4.3	0.1	0.0	0.3
0.0	90.0	11430.1	4.3	0.1	0.0	0.4
0.0	90.0	11430.1	4.3	0.1	0.0	0.4
0.0	90.0	11430.1	4.3	0.1	0.0	0.5
0.0	90.0	11430.0	4.3	0.1	0.0	0.6
0.0	90.0	11430.0	4.3	0.1	0.0	0.6
0.0	90.0	11429.9	4.3	0.1	0.0	0.7
0.0	90.0	11429.8	4.3	0.2	0.0	0.8
0.0	90.0	11429.8	4.3	0.2	0.0	0.8
0.0	90.0	11429.7	4.3	0.2	0.0	0.9
0.0	90.0	11429.6	4.3	0.2	0.0	1.0
0.0	90.0	11429.5	4.3	0.2	0.0	1.0
0.1	90.0	11429.4	4.3	0.2	0.0	1.1
0.1	90.0	11429.4	4.3	0.2	0.0	1.2
0.1	90.0	11429.3	4.3	0.2	0.0	1.2
0.1	90.0	11429.1	4.3	0.3	0.0	1.3
0.1	90.0	11429.0	4.3	0.3	0.0	1.3
0.1	90.0	11428.9	4.3	0.3	0.0	1.4
0.1	90.0	11428.8	4.3	0.3	0.0	1.5
0.1	90.0	11428.7	4.3	0.3	0.0	1.5
0.1	90.0	11428.5	4.3	0.3	0.0	1.6
0.1	90.0	11428.4	4.3	0.3	0.0	1.7
0.1	90.0	11428.2	4.3	0.3	0.0	1.7
0.1	90.0	11428.1	4.3	0.4	0.0	1.8

Variables used in calculation of catapult launching			
gen	dt	0.003	time step (s)
	g	-9.81	gravitational acceleration (m/s^2)
spring	k	145.6	spring coefficient (N deg)
	theta0	90.0	twist in spring when catapult arm is down (deg)
	angleL	30.0	angle travelled by catapult before launch (deg)
	angle0	0.0	start angle of catapult arm (deg)
arm	p	850.0	density of catapult arm material (kg/m^3)
	L	5.0	length of catapult arm (m)
	W	0.2	width of square catapult arm (m)
	m	95.6	mass of catapult arm (kg)
	I	796.9	rotational inertia of catapult arm (kg m^2)
projectile	r	19.0	radius of projectile (cm)
	p	2600.0	density of projectile material (kg/m^3)
	m	75.0	mass of projectile (kg)
	I	1874.9	rotational inertia of projectile while held in catapult (kg m^2)
gen	mtotal	170.6	sum of masses of arm and projectile (kg)
	Itotal	2671.8	sum of rotational inertia of arm and projectile (kg m^2)
output	v	72.3	velocity projectile will be launched at (m/s)
	force	3494	force required to wind back catapult (N)
error	launch	TRUE	returns false if projectile won't launch
catapult params	size	3	size of catapult (Small = 1, Medium = 2, Large = 3)
	mat	2	material (Oak = 1, ... = 5)
	angle	3	angle of launch (30 = 1, 45 = 2, 60 = 3)
	rock	1	size of rock (75kg = 1, 150kg = 2, 300kg = 3)
output 2	acc	21.39076	max acceleration by catapult (m/s^2)

Figure 1: Spreadsheet Calculations

Once we determined an accurate method to influence projectile motion, we began integrating the maths into an UI. We decided to quantise our input parameters in a way to simplify the selection process. We decided to split our mangonel into five customisable parameters; our functional parameters size, material and angle of release, and, our cosmetic parameters wheel size and skin. Size was split three groups; small, medium and large. Material was split into five group; oak, birch, mahogany, willow and ash. The angle was split into three groups; 30˚, 45˚, 60˚. The size of the catapult controls the force stored in the torsion bundle. The material controls the inertia of the rotating arm. The size of the angle changes the position of the cross bar on the, mangonel, therefore, the angular distance, angular velocity and launch velocity of the projectile. The skin was split into five; wood, flames, camo, tiger stripes and jim. Wheel size was split into three groups; small, medium and large. We used the VLookup and HLookup excel functions to access the "Control Variables" and "Database" Sheets parameter properties (Appendix 12 and 13 respectively), to display changes and link the designed catapult to the "Performance", "CalcSheet", "ResultsPage", "Intermediary Invoice" and "Animation" pages (Appendices 7,14,15,8,6). We decided to use lists that always have the customisable parameters selected (Figure 2) instead of dropdowns to improve the user friendliness and aesthetic appeal of the UI (Appendix 5: Design Page).

Figure 2: Parameter Selection with Associated Design

After solidifying our parameter selection, we used the "Database" sheet to allocate unit costs and unit weights relative to the size of the catapult selected. We have not dimensioned our parameters; however, we have proportionality constants incorporated into IF statements (Figure 3) to change the catapult launching parameters in the "CalcSheet" and "ResultsPage" (Appendix 14: Calcsheet and Appendix 15: ResultsPage). We used a series of HLookup, VLookup and INDEX Functions to manipulate costs and weights, placing them in the reference table in the "ReferenceData" worksheet (Appendix 11: Reference Data). We use a series of subroutines to determine the unit costs and total cost of the design. We used GetCatapultFilename and SetCatapultImagesubroutines (Appendix 17: Sub Routines and Functions) to access the image associated the combination for parameters (Figure 4) which are located within the same directory as the workbook. The updated inputs are feed through all relevant pages to keep the workbook consistent with the current design.

spring	k	=112*IF(AG23=1; 0.75; IF(AG23=2; 1; IF(AG23=3; 1.3;"ERROR")))
	theta0	90
	angleL	=IF(AG25=1; 60; IF(AG25=2; 45; IF(AG25=3; 30;"ERROR")))
	angle0	0
arm	p	=1000*IF(AG24=1; 1; IF(AG24=2; 0.85; IF(AG24=3; 1.2;IF(AG24=4; 0.8; IF(AG24=5; 0.55;"ERROR")))))
	L	=IF(AG23=1; 2; IF(AG23=2; 3.5; IF(AG23=3; 5;"ERROR")))
	W	0.15
	m	=$AG$11^2*$AG$10*$AG$9
	I	=$AG$9*$AG$10^3*$AG$11^2/3
projectile	r	=IF($AG$26=1; 19.025; IF($AG$26=2; 23.9705; IF($AG$26=3; 30.201;"ERROR")))

Figure 3: Parameter values based on Selection

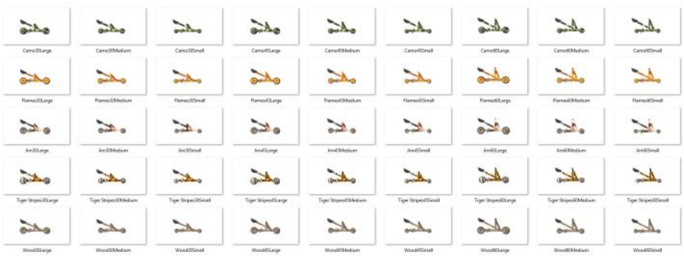


Figure 4: Catapult Image Database

After implementing how to assign and change parabolic performance metric based on design, we began producing methods to display performance. From planning, we agreed on two ways. The first an animation allowing the tracking the projectile's trajectory in real time. Using the calculations set by the parameters, users may select 1 of 3 projectile sizes. The animation uses the mathematics of projectile motion to model the trajectory. The animation scene is drawn each time using the DrawScene() subroutine. The projectile line is drawn and updated with a max height label added along the way. The DrawAnimation() sub routine draws the animation of the projectile moving. The projectile changes position with a DrawFrame() sub routine called iteratively (Appendix 17: Sub Routines and Functions). A keep_ prefix was used on images to prevent their deletion, as the animation resets each time. We decided to use an animation as gives the user an immersive experience, following the vision of an intuitive UI (Appendix 6: Animation Page).

We decided to dedicate a page to displaying key performance metrics based on the user's design (Appendix 7: Performance Page). We decided dials, images and filler bars were the best way to convey the performance data, as all users have a basic understanding of these displays. We choose air time, maximum velocity, impact force, maximum acceleration, maximum height and distance travelled as metrics. The maximum values for all metrics were derived from the parameter variations. The range of the metric (zero to maximum value) is converted into a co-ordinate system for the dials. Based on the metric values derived from the "CalcSheet" and "ResultsPage", a slither of a pie graph is shown overlying a dial display and labelled co-ordinate system (Figure 5). The SERIES function is used in the bar graphs, filled to the actual values derived in the "ResultsPage" between the minimum and maximum values for that metric (Figure 5).

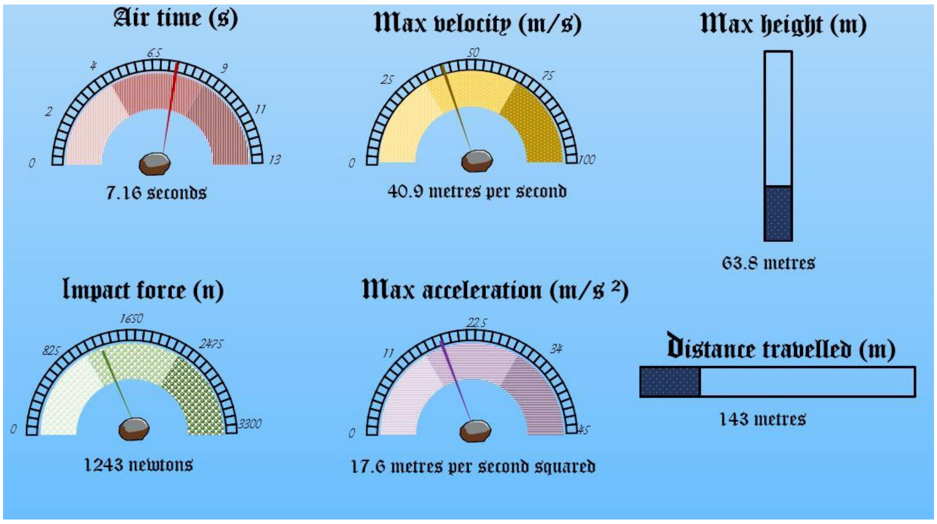


Figure 5: Performance Dial and Bars

We decided to display images relating to the cost, mass of the catapult and force needed to operate the catapult to simplify design comparisons. The subroutine Visible_Images() shows and hides images relative to the design catapults total cost, mass and force required to operate the catapult, using the Excel shape feature .visible = Boolean. We tried to make the display as simple as possible to not confuse the user.

The user reviews the design catapult in an individual invoice (Appendix 8: Intermediary Invoice) where the metric descriptions and user costs are displayed. The user can choose to save the catapult to the final invoice, saving up to a maximum of four catapults per deign, with up to four different designs, for a total of sixteen. We choose sixteen as deemed any more to be unrealistic for our target users. Designs can be reset by a clearing subroutine based on a conditional value in reference table. Discount and Delivery options are incorporated. GST is accounted for with the sub totals and final order totals displayed (Appendix 9: Final Invoice). You can reset your sheet and begin again by using the clear all function, resetting all reference values in the "ReferenceData" sheet (Appendix 11: Reference Data).

The navigator() function allows you to navigate the workbook seamlessly, allowing the user to revist pages previously visited but not pages yet visited. UpdateReference() changes the values in the reference table in "ReferenceData", enabling this functionality. The navigator was used to create a linear a linear and fluid experience for the user.

Submitting your order will bring you to the summary page (Appendix 10: Summary) where all catapults designed will be displayed using the Pedestal() function, showing images relative to the designs.

There are 14 user forms to aid the user. They pop up based on; your stage in the UI, Boolean variables, reset values, select options and error navigation (Appendix 16: User forms).

Instructions

Upon opening the workbook, you are presented with the home page. Click begin to start. You are taken to the design page. Select the parameters you wish to incorporate into the catapult. Your design will be displayed below parameter selection. If you wish to navigate back to the home screen, click the home button where a user form will pop up and take you home. If you don't know what to do, select the help button and the help pop up will show you. A display cost will instruct you on the individual cost of the parameter selected, and, the current design's cost and weight. Click the simulate button to move forward to the animation.

Drag and drop the castle to the desired target distance between 250m to 500m. Select one of the three projectile options in the top left-hand box and click animate. You will see the projectile path generated in front of you. If the projectile strikes the target, you will see an animation. You can select home to navigate home, help for advice on what the page does or results to move forward to see the performance metrics.

You will see four dials, three image sets and two bars indicating the performance of your design. You can adjust the projectile size in the drop box to change your catapults performance relative to the projectile. The metrics are; air time (s), maximum distance (m), height (m), velocity (m/s) and acceleration (m/s^2), impact force (N), force required (N), mass (kg) and Cost (GP). The images on the right approximate the mass, cost and force required to operate the catapult relative to the designs which max out these metrics. When you are ready to see the intermediary invoice, select the Invoice button.

The intermediary invoice gives you a summary of your individual catapult order. You will see a display of the parameters you selected, their associated unit cost and the sub total of the catapult before delivery, labour, GST and discount costs.

If content with your order, click invoice. Otherwise, use the navigator to go back to previously visited pages by selecting the button relating to the page you want to visit under the grey arrow. If the arrow above the button in red, you have not visited that page yet, therefore, you cannot move to that page. You can select the home button to navigate home or help if need a little guidance.

If you selected invoice, you will be presented with a variety of user prompts. First, select the quantity you wish to order and your design will be saved. After, you will be given the option to design another catapult. If click yes, you will be taken back to the design page to design another. If you click no, you will be given the option to choose delivery and payment option. After selecting both, you will be taken to the final invoice page.

The final invoice page displays your entire order. You will see; all parameters, the cost per unit, the delivery option, the payment method, labour costs, discount amount, the delivery cost, the GST charge, a subtotal and the total order cost. You can navigate back to home if you choose to do so or ask for help by clicking the help button. You can clear previous catapult designs by pressing the clear button. You can clear individual catapults by selecting the save slot to clear or clear them all by clicking the clear all button. If you try to clear an empty slot, you will be told you cannot and must select another. If you clear all or one catapult, and have no catapults saved, a prompt will come up asking if you want to start your order. Click Start Order to reset all data and you will be taken to the design page. Click Stop Order to reset all data and be taken back to the home page. If you have catapults saved and are happy with your order, select submit. A form will pop up. Click yes to confirm your order and move forward to the summary page where your designed catapults will be displayed on pedestals. Click no and you will be taken back to the final invoice page to reassess and adjust your order.

Analysis of Results and Outputs

For demonstration purposes, we will choose a medium sized catapult made of a mahogany, with a firing angle of 45˚. The wheel size is medium and skin camo do not affect the performance of the catapult.

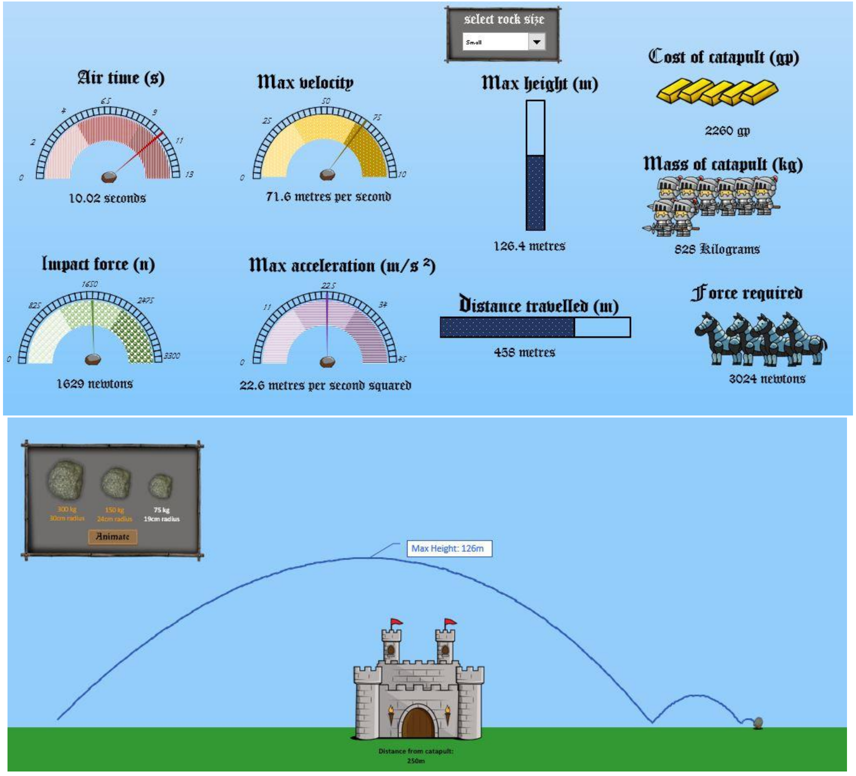


Figure 6: Animation and Performance Output

Here we see multiple performance metrics relating to the flight path of a small projectile fired by the user's catapult. Firstly, we will discuss the dials. As you can see, air time was 10.02 seconds. The smaller angle would decrease the flight time and the max height reached. The maximum velocity is moderately high. The designed catapult is of a size and material light enough to generate a high launch and max velocity. Changes to the size and material of the catapult will change the metric. Impact force and maximum acceleration are proportional due to the relationship F = ma. Changing the size of the projectile, material and catapult size will adjust these metrics. Due to the angle and lightness of the catapult, the trajectory shows the projectile travels a good distance. This will change based on the angle, projectile size, catapult size and material. The maximum height on the animation screen matches the maximum height displayed on the bar in the performance page. On the right above, you will see the cost of this catapult is about half the design of the maximum cost, the mass is a little more than half the heaviest catapult possible and required slightly under half the force require as that of the design which requires the most. The size of the catapult, material, launch angle and the size of the projectile all contribute to the performance of the catapults. Different combinations of parameters will produce different results; therefore, a user will need to tailor an order to their specific needs. These metrics may be used to compare catapults and order a catapult which directly addresses the needs of the consumer. A customer could tailor their order to get catapults that shoot high and close by with a large angle and heavier materials and a catapult that shoots far and flat with a small angle and light materials. Our performance metrics allow the user to diversify their fleet of catapults for sieging.

Group Contribution

I was the group leader. I executed all the project planning at the start of the project, organising the project goals and timeline. I deconstructed tasks and assigned them to the team members. I oversaw the project, checking in on other team members. I tracked progress. I conceptually designed the pages. I planned and ran team meetings. I created the Intermediary Invoice, Final Invoice and ReferenceData sheets for the workbook. I designed and coded 11 of the user forms. I wrote the subroutines and functions in the following modules; Buttons, Calculations, Clearing, Formatting, Navigate, Performance and Saving. I designed the logo and navigator bar. I integrated the sheets into the workbook, creating a functioning user interface. I have personally spent 100+ hours on the project.

Reflective Discussion

Our group worked well together. We had little conflict. All members completed assigned tasks. We settled disagreements constructively. I am happy to work with each member again. Our initial project planning worked well. Outlining the goals, objectives and intentions of each team member. I was able to allocate tasks team members were motivated to complete. All team members completed assigned tasks and enjoyed doing so as suited their skillset and interests. The compartmentalisation of the project also worked well. Everybody had their own portfolio of work to be completed independently. There were no delays waiting for other team members to complete their portion of the project. Work was completed seamlessly. Deconstructing the project into small tasks was really useful. We had a clear direction with little disruption. One leader for everybody to report to worked well. Facebook messenger and face to face meetings were excellent communication tools. I was able to distribute new information very quickly. Transparent communication channels were crucial to product development.

There are a few things I would like to improve upon if given the opportunity. Integrating the final product was difficult as other team member either hard coded large proportions of their code, or, did not write down there thought process or methodology. A shared team workbook would be beneficial for sharing design decisions and cutting down integration time. We need to spend more time during the iterative design process at the start of the project. We jumped into the product very quickly with only a few concepts to go off. Seeing the features other groups incorporated, it would have been good exploring more ideas before deciding what to do. We will implement a more complete and comprehensive iterative design process in the future. I will need to get better at delegating work. As project lead, I took a lot on. I managed but tasks I did would have been best suited to the skillsets of other team members. We didn’t fully explore the features of excel for example active x controls. We may have found features that would enhance our UI. We will spend more time researching tools and features in the future. To conclude, this project has been vastly enjoyable and a huge learning experience in design, coding, teamwork and project management.

Appendices

Appendix 1: Project Planning, Goals

Members	Connor	Matthew	Olivier	Uhalan	Frankie
Goals	• A+ in the Project and Course. • Build teamwork skills • Develop VBA Skills	• Learn how to produce useful and good-looking modelling tools. • Improve in ability to formulate models from real world constraints	• End product proud of • Good Grade	• A in 263 • Develop VBA Skills	• To produce a final result that I am proud of • To work well as a team • Ideally get an A or A+ grade in project/course
Strengths	• Project Management • Grit • Design Skills (Photoshop)	• Programming/simulation of projectiles • Fairly comfortable with photoshop/graphic design	• Programming • Maths • Physics	• Willingness to Learn • Adaptable • Flexible	• Capable User of Excel • Experience with photoshop • Design understanding • Good understanding of physics and equations
Weaknesses	• Working close to deadlines.	• Image Animation	• Design (Photoshop)	• Don't have significant coding strength	• Not quick at coding • Little VBA experience • Public speaking
Most Enjoyed	• Learning new skills • Increase competency with coding	• Satisfaction of making a well working & fully fleshed out tool • Seeing how intricate and accurate we can make our simulation	• Slow assembly of the product • Go deep into things if we want to	• Producing a finished project.	• Improving VBA skills • Producing atheistically pleasing product with good interface. • Linking background calculations with outputs from users
Least Enjoyed	• Rushing Project • Working close to deadlines	• Trying to consolidate programming from multiple different people with different styles		• How Finicky coding can be sometimes, but again, don't mind it too much.	• Research catapult info/entering in parameters and data. • Presentation

Project Timeline						
Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday
16th	17th	18th	19th	20th	21st	22nd
Create Project Deadline	Ideate	Ideate	Finish Research/ Finalise Performance Metrics	Ideate	Complete Template Calculations for all performance metrics	Module Formulation and Design Work
23rd	24th	25th	26th	27th	28th	29th
Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work
30th	31st	1st	2nd	3rd	4th	5th
Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work
6th	7th	8th	9th	10th	11th	12th
Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work	Module Formulation and Design Work
13th	14th	15th	16th	17th	18th	19th
Module Formulation and Design Work	All Design Images Complete		All Coding and Modules Complete	Final Check and Presentation Creation	Presentation Practise	Presentation Practise and Begin Report
20th	21st	22nd	23rd	24th	25th	26th
Presentation Due	Presentation Practise	Report	Report	Report	Report	Final Touches on Reports

Key Dates:

- Presentation 20th September
- Design Project A Report 27th September
- Design Project B Files/Spreadsheet 27th September

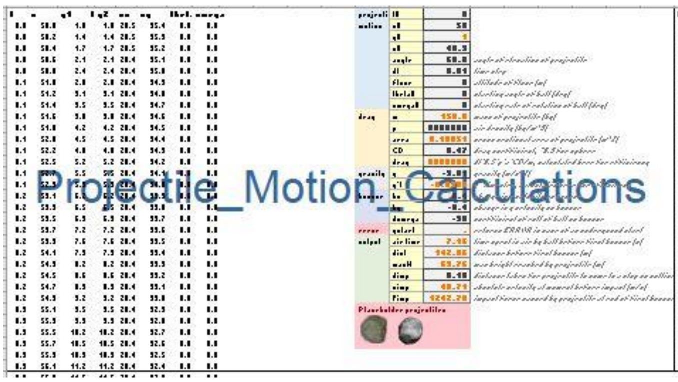
Key Tasks:

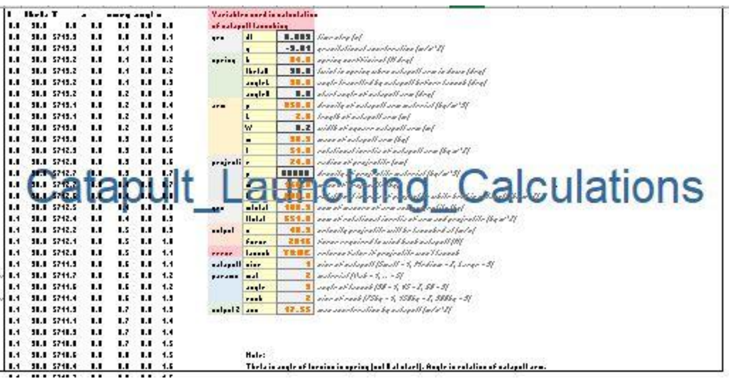
- Modules
    - Number
    - Specific Task of Modules
    - Subroutines versus Modules
- Design (Images, Aesthetics, Processes, Calculations)
    - Allocate one person to the task
    - Cover Page
    - Invoice Form
    - Graphs
    - Catapult Images
- Performance Metrics
    - Graphs, Animations, Relate to Physics
- Animations
    - Flight Path, Trajectory
- Dials, Controls, Performance Measurements
    - Change dependent on performance calculations
    - Previous Iterations comparison, Option to Save?
- Invoice Form
    - Design, Aesthetic

Roles

- Design (1)
    - Create images, graphs, displays for the graphs
- Physics (1)
    - Research and Calculate Performance based on inputs.
    - Investigate mathematics
        - Simple projectile motion, incorporating gravity and air friction co-efficients.
        - Calculations Based On Time Periods
- Model (3 to 5)
    - Organise the creation of modules.
    - Decide what needs to be created.
- Manager (1)
    - Manage Progression
    - Make decisions
    - Oversee entire project
- Performance (3 to 5)
    - Model and create performance metrics
        - Vertical and Horizontal; Distance, Speed and Acceleration?
        - Whether Target Hit

Appendix 2: Calculations





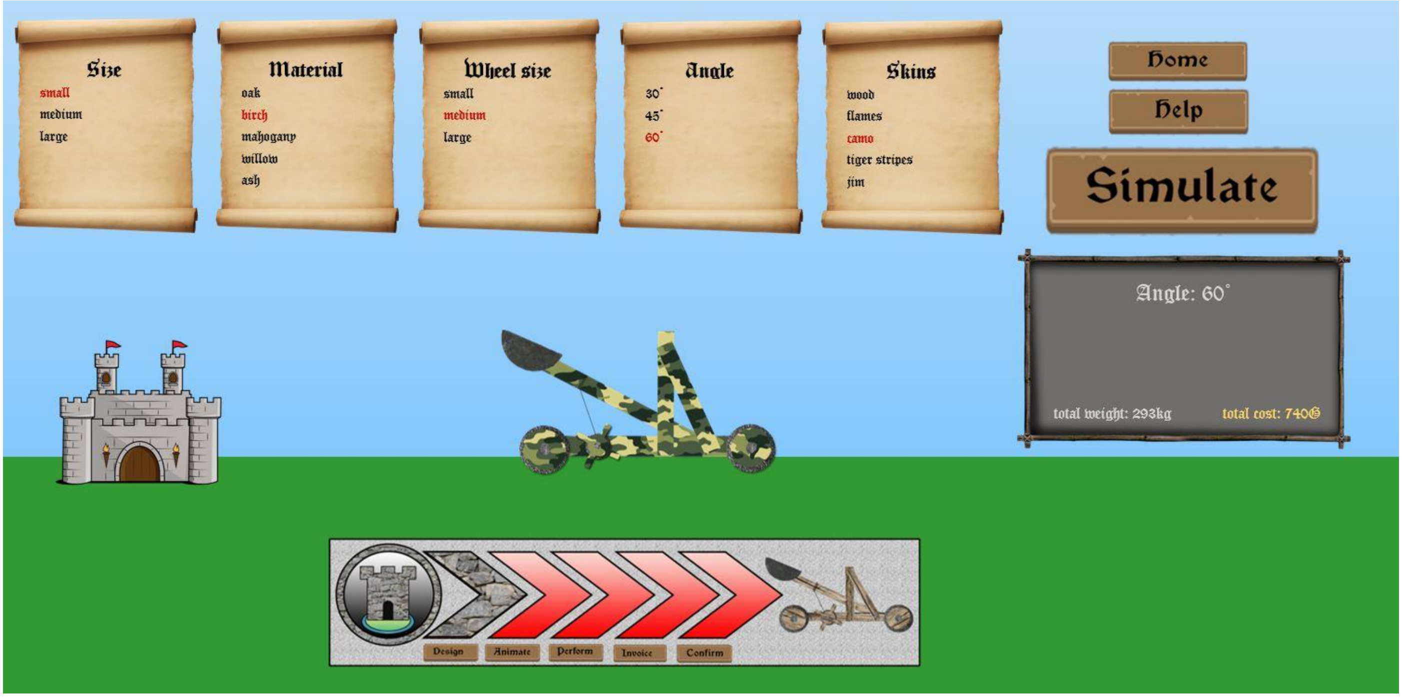
Appendix 3: Calculations with Formulas

Variables used in of catapult launch			
gen	dt	0.003	time step (s)
	g	-9.81	gravitational acceleration (m/s^2)
spring	k	=112*IF(AG23=1; 0.75; IF(AG23=2; 1; IF(AG23=3; 1.3;"ERROR")))	spring coefficient (N deg)
	theta0	90	twist in spring when catapult arm is down (deg)
	angleL	=IF(AG25=1; 60; IF(AG25=2; 45; IF(AG25=3; 30;"ERROR")))	angle travelled by catapult before launch (deg)
	angle0	0	start angle of catapult arm (deg)
arm	p	=1000*IF(AG24=1; 1; IF(AG24=2; 0.85; IF(AG24=3; 1.2;IF(AG24=4; 0.8; IF(AG24=5; 0.55;"ERROR")))))	density of catapult arm material (kg/m^3)
	L	=IF(AG23=1; 2; IF(AG23=2; 3.5; IF(AG23=3; 5;"ERROR")))	length of catapult arm (m)
	W	0.15	width of square catapult arm (m)
	m	=$AG$11^2*$AG$10*$AG$9	mass of catapult arm (kg)
	I	=$AG$9*$AG$10^3*$AG$11^2/3	rotational inertia of catapult arm (kg m^2)
projectile	r	=IF($AG$26=1; 19.025; IF($AG$26=2; 23.9705; IF($AG$26=3; 30.201;"ERROR")))	radius of projectile (cm)
	p	2600	density of projectile material (kg/m^3)
	m	=4/3*3.14159*($AG$14/100)^3*AG15	mass of projectile (kg)
	I	=$AG$16*$AG$10^2	rotational inertia of projectile while held in catapult (kg m^2)
gen	mtotal	=$AG$12+$AG$16	sum of masses of arm and projectile (kg)
	Itotal	=$AG$17+$AG$13	sum of rotational inertia of arm and projectile (kg m^2)
output	v	=INDEX($AC$2:$AC$5002;MATCH(TRUE; INDEX($AB$2:$AB$5002>$AG$7;0);))	velocity projectile will be launched at (m/s)
	force	=AG5*(AG6+AG7)/5	force required to wind back catapult (N)
error	launch	=NOT(ISNA(AG20))	returns false if projectile won't launch
catapult params	size	=SizeSelection	size of catapult (Small = 1, Medium = 2, Large = 3)
	mat	=MaterialSelection	material (Oak = 1, ... = 5)
	angle	=AngleSelection	angle of launch (30 = 1, 45 = 2, 60 = 3)
	rock	=MasterV5.xlsm!RockChanger	size of rock (75kg = 1, 150kg = 2, 300kg = 3)
output 2	acc	=Z3*AG10	max acceleration by catapult (m/s^2)

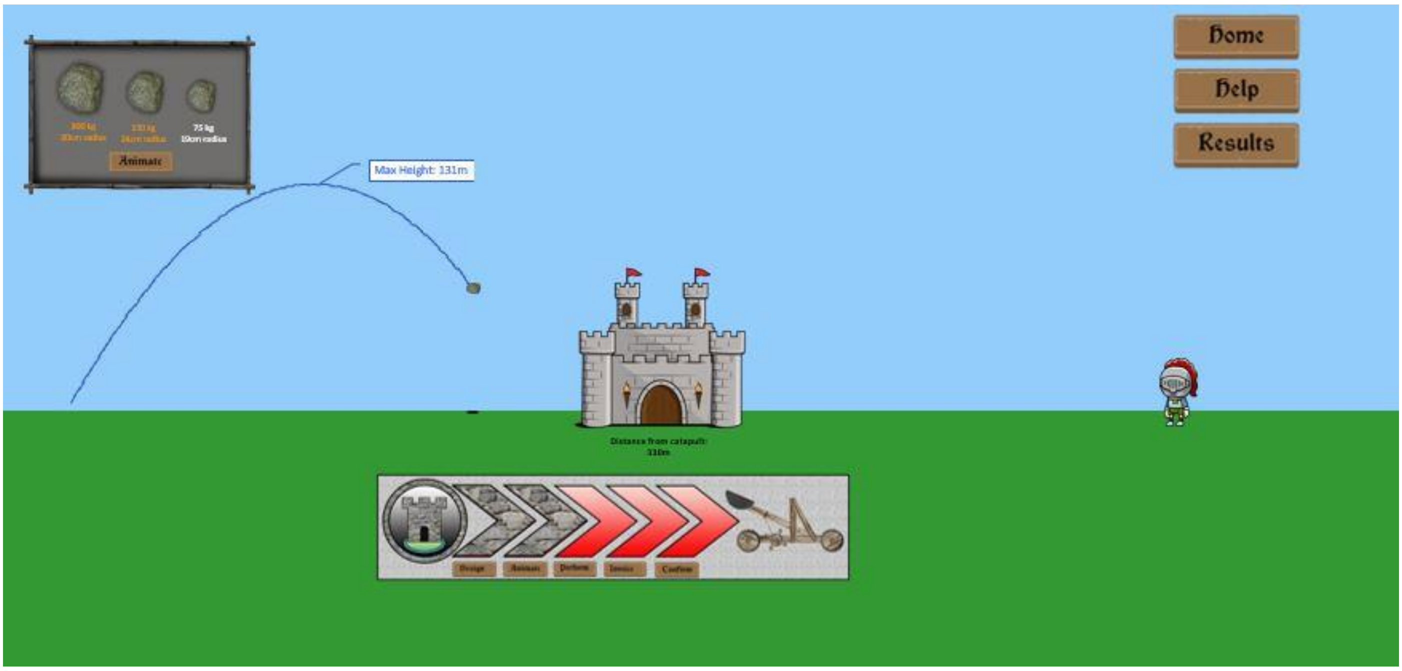
projectile motion	t0	0	
	x0	50	
	y0	=AG10*SIN(AG7*3.14159/180)	
	v0	=AG20	
	angle	=90-$AG$7	angle of elevation of projectile
	dt	0.01	time step
	floor	0	altitude of floor (m)
	theta0	0	starting angle of ball (deg)
	omega0	0	starting rate of rotation of ball (deg)
drag	m	=$AG$16	mass of projectile (kg)
	p	1.225	air density (kg/m^3)
	area	=($AG$14/100)^2*PI()	cross sectional area of projectile (m^2)
	CD	0.47	drag coefficient, ~0.9 for sphere
	drag	=P6*0.5*$P$11*$P$12*$P$13/$P$10	dt*0.5*p*a*CD/m, calculated here for efficiency
gravity	g	-9.81	gravity (m/s^2)
	g*t	=$P$15*$P$6	g * timestep, calculated here for efficiency
bounce	kx	0.4	change in x velocity on bounce
	ky	-0.4	change in y velocity on bounce
	domega	-30	coefficient of roll of ball on bounce
error	ystart	=IF($P$3<$P$7;"ERRORRRR";".")	returns ERROR in case of an undergound start
output	air time	=INDEX(A3:A10002; MATCH(1;D3:D10002;0))	time spent in air by ball before first bounce (s)
	dist	=INDEX(B3:B10002; MATCH(1;D3:D10002;0))-P2	distance before first bounce (m)
	maxH	=MAX(E2:E10002)	max height reached by projectile (m)
	dimp	0.1	distance taken for projectile to come to a stop on collision (m)
	vimp	=SQRT(VLOOKUP(P21-P6; A4:G10002;6)^2 + VLOOKUP(P21-P6; A4:G10002;7)^2)	absolute velocity at moment before impact (m/s)
	Fimp	=0.5*P10*P25^2/P24/1000	impact force caused by projectile at end of first bounce (kN)
Placeholder proje			

Appendix 4: Home Page

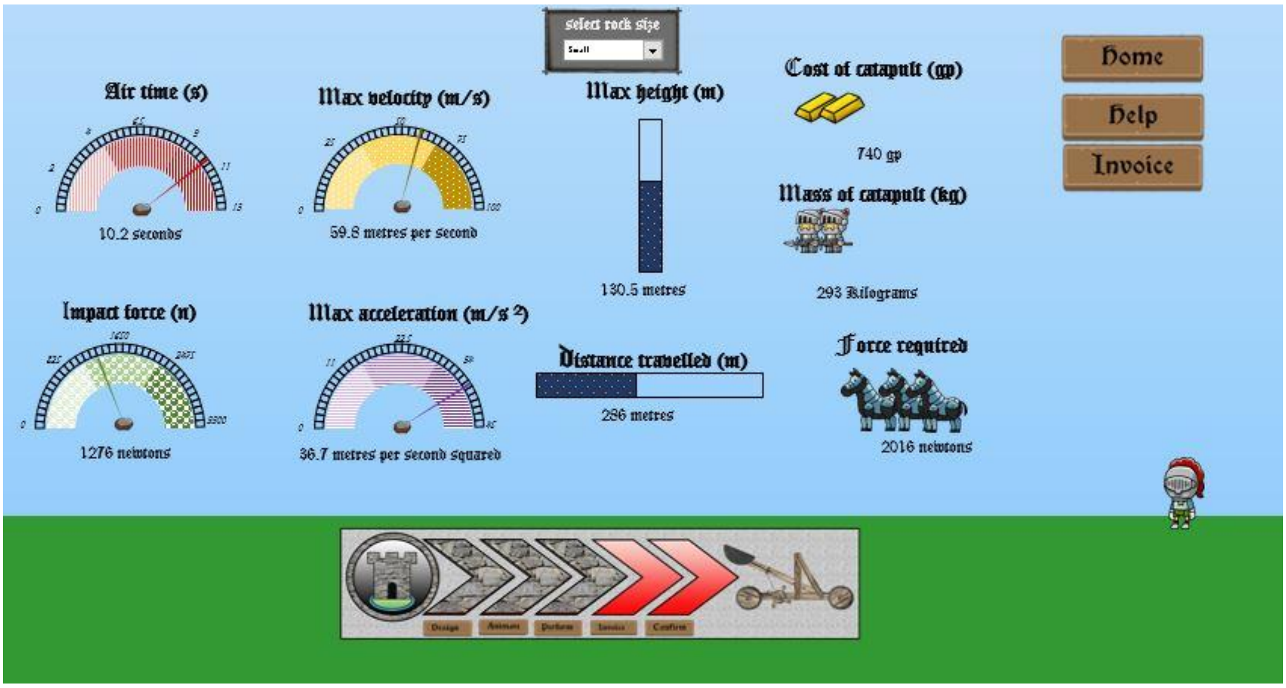
Appendix 5: Design Page



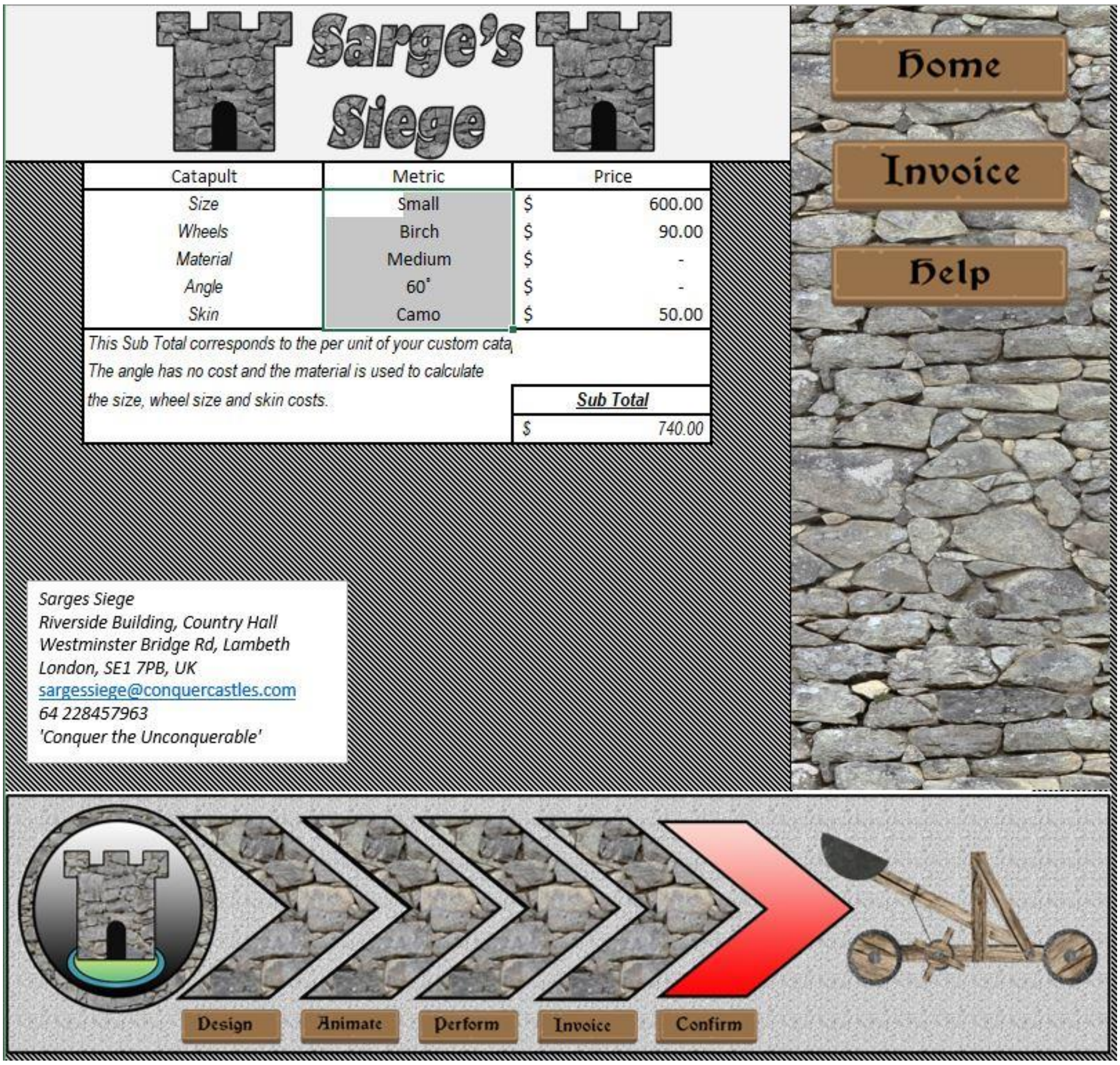
Appendix 6: Animation Page



Appendix 7: Performance Page



Appendix 8: Intermediary Invoice

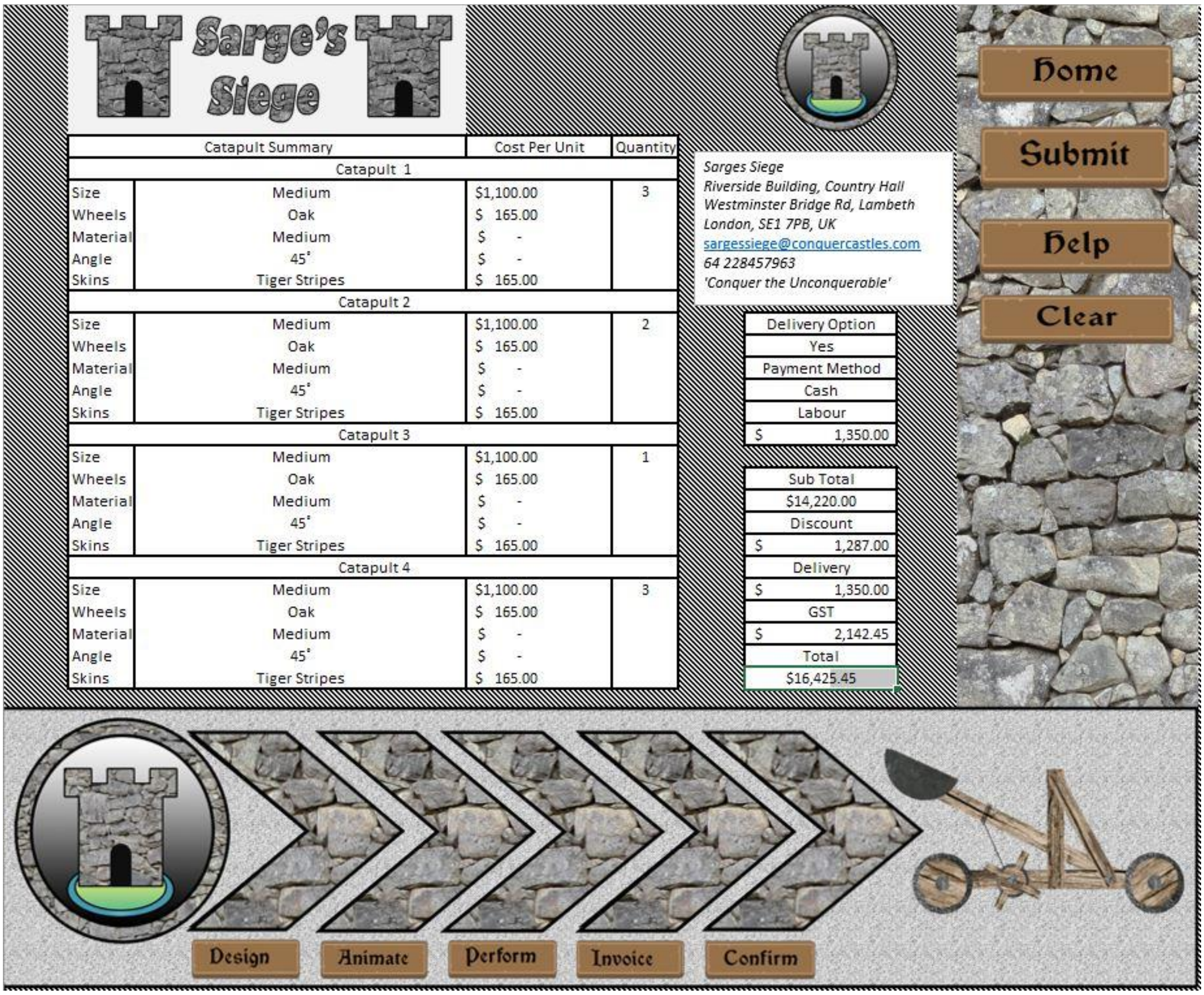


Catapult	Metric	Price
Size	Small	$ 600.00
Wheels	Birch	$ 90.00
Material	Medium	$ -
Angle	60˚	$ -
Skin	Camo	$ 50.00

This Sub Total corresponds to the per unit of your custom cata
The angle has no cost and the material is used to calculate
the size, wheel size and skin costs.

Sub Total
$ 740.00

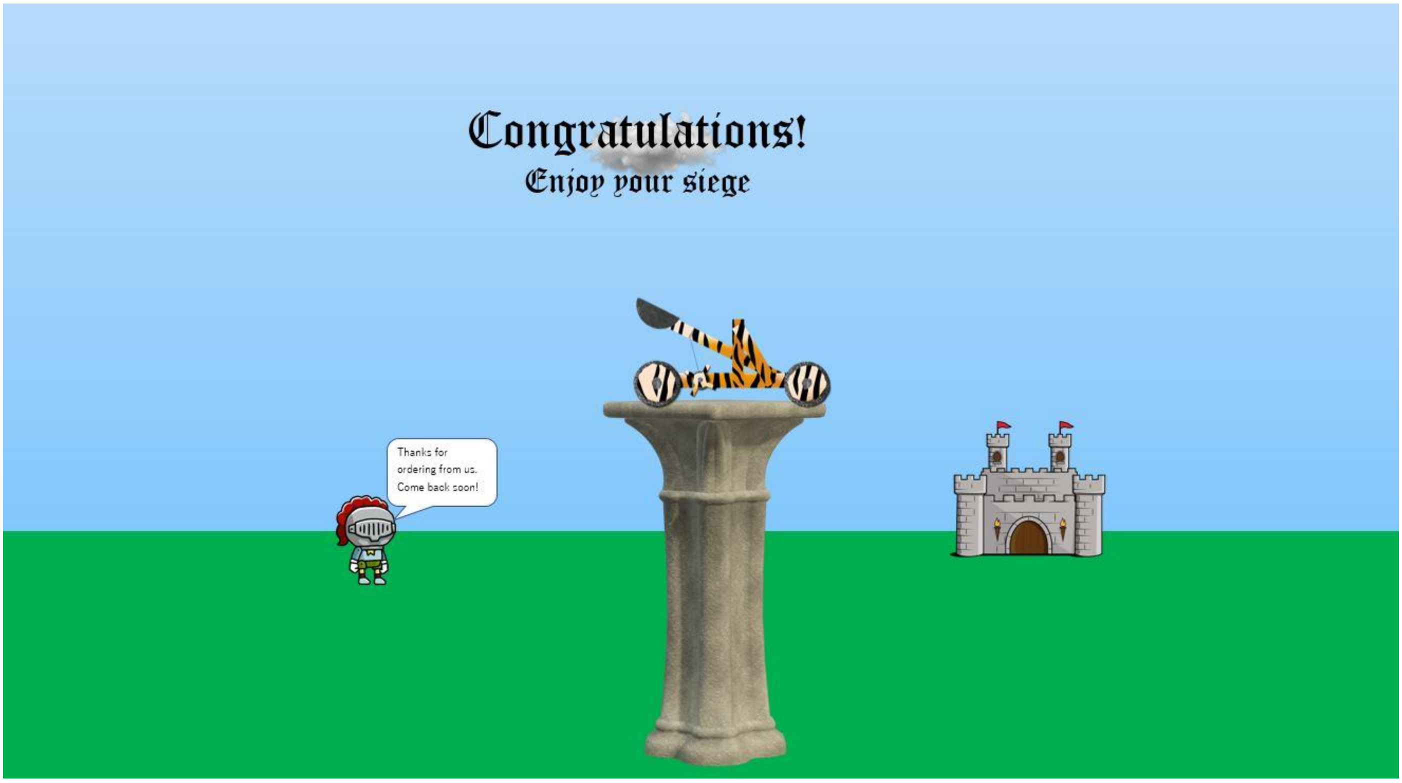
Appendix 9: Final Invoice



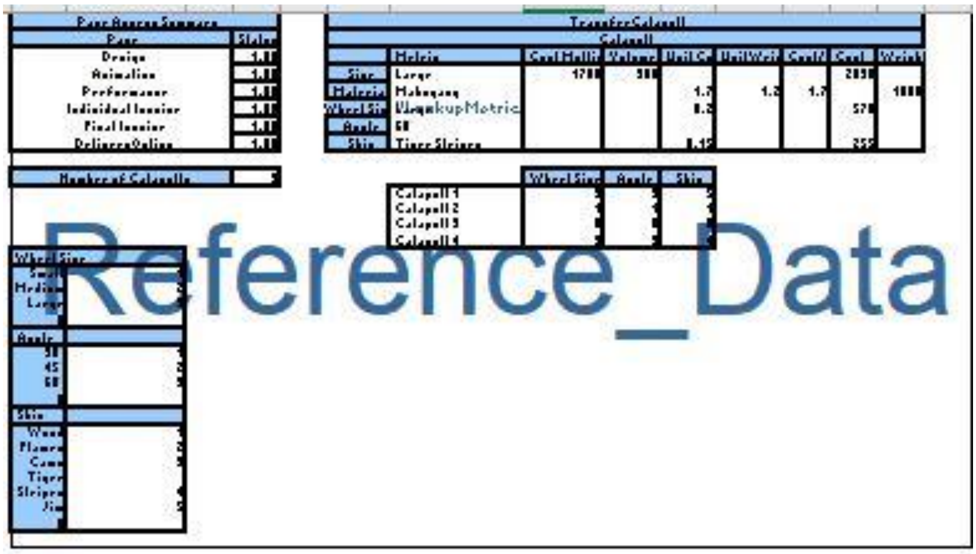
Catapult Summary		Cost Per Unit	Quantity
Catapult 1			
Size	Medium	$1,100.00	3
Wheels	Oak	$ 165.00	
Material	Medium	$ -	
Angle	45˚	$ -	
Skins	Tiger Stripes	$ 165.00	
Catapult 2			
Size	Medium	$1,100.00	2
Wheels	Oak	$ 165.00	
Material	Medium	$ -	
Angle	45˚	$ -	
Skins	Tiger Stripes	$ 165.00	
Catapult 3			
Size	Medium	$1,100.00	1
Wheels	Oak	$ 165.00	
Material	Medium	$ -	
Angle	45˚	$ -	
Skins	Tiger Stripes	$ 165.00	
Catapult 4			
Size	Medium	$1,100.00	3
Wheels	Oak	$ 165.00	
Material	Medium	$ -	
Angle	45˚	$ -	
Skins	Tiger Stripes	$ 165.00	

Delivery Option	Yes
Payment Method	Cash
Labour	$ 1,350.00
Sub Total	$14,220.00
Discount	$ 1,287.00
Delivery	$ 1,350.00
GST	$ 2,142.45
Total	$16,425.45

Appendix 10: Summary



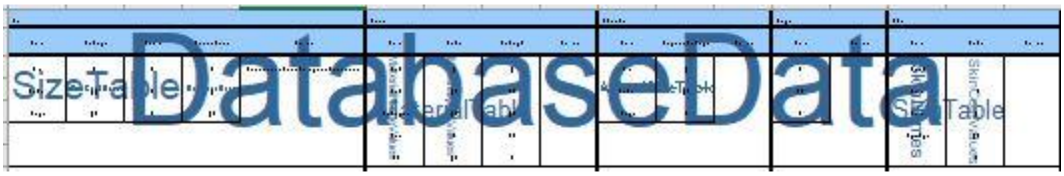
Appendix 11: Reference Data



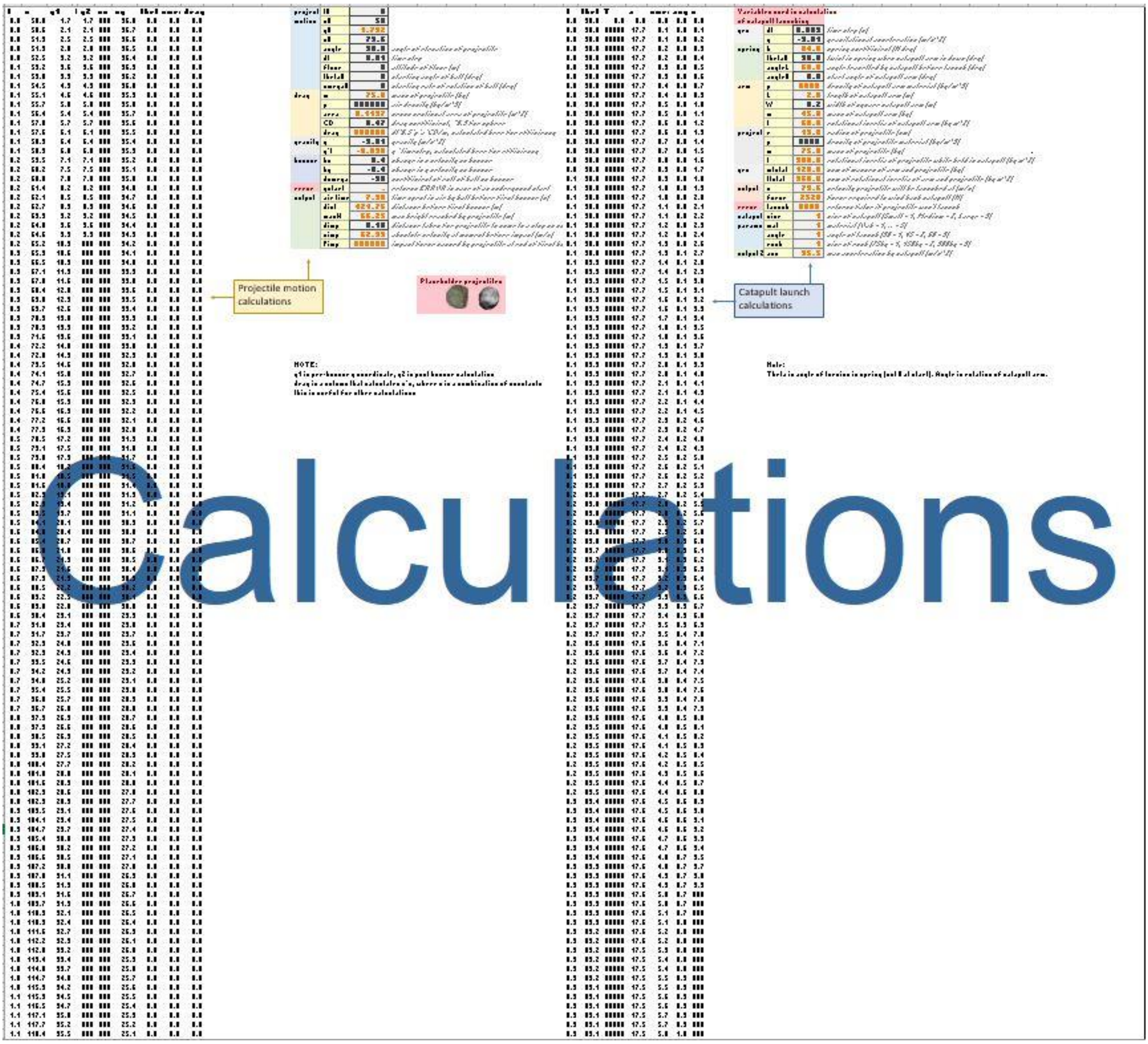
Appendix 12: Control Variables

Catapult Variable Selection		
Title	**Comment**	**Value**
Current Selections		
Size	The current selection for 'size'	1
Material	where 1 = small, 2 = medium etc	1
Wheel Size		1
Angle		1
Skin		1
Displays		
Latest Change Type	What the last selection change was	Skin
Latest Change Numerical Value	What choice the most recent selection was (i.e. change type is size, change value is 3 (large)	1
Latest Change Title	Font & font size is copied over so must be preset in this cell	Skin: Wood
Current Cost Display	These are done here as textboxes don't like concatenation	total cost: 550G
Current Weight Display		total weight: 330kg
Current Unit Cost		cost: 0G
Cost & Weight		
Current Unit Cost	i.e. how much the currently selected skin costs	0
Current Total Cost	Rounded down to the nearest integer	550
Current Weight	Rounded down to the nearest integer	330
Max Possible Cost		3978
Min Possible Cost		495

Appendix 13: Database



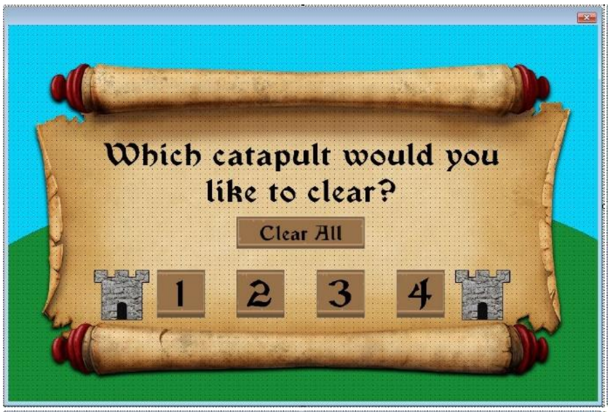
Appendix 14: Calcsheet

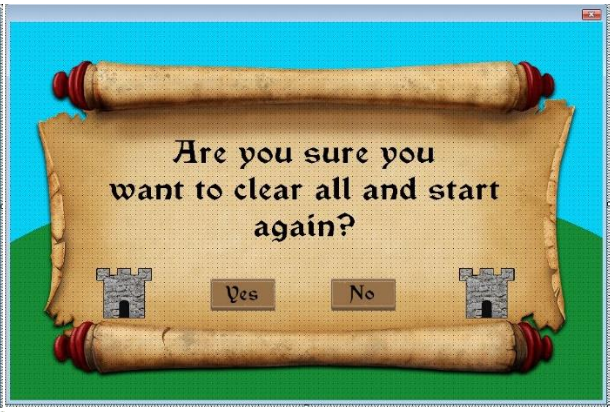


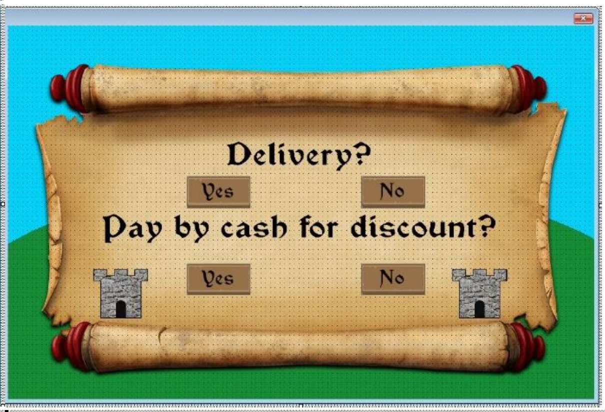
Appendix 15: ResultsPage

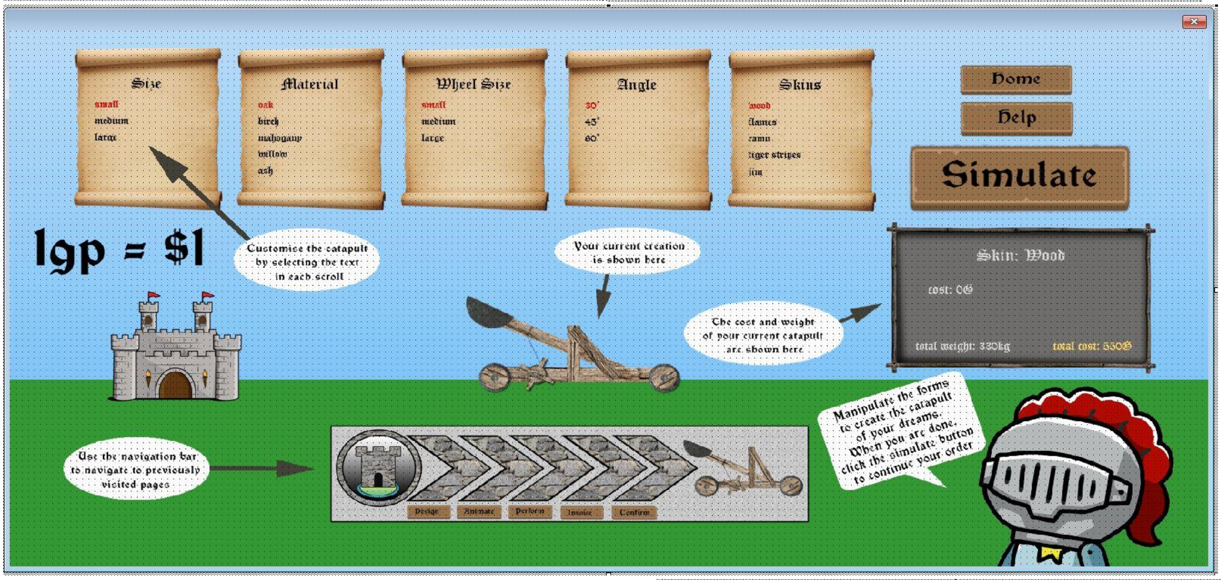
Gauge	Velocity	Chart Axis	Max Valu	185	73.6 metres per second	metres per second
90	133.4902	187	Min Valu	0	35.5 metres per second squared	metres per secoı
30	2	5	Mid Valu	95	1488 newtons	newtons
30	224.5098	5	Small		7.3 seconds	seconds
30	Air Time	5	Medium		422 metres	metres
Height	103.88462	5	Large		66.3 metres	gp
30.13636364	2	5	Other value, needed for dial to work (360-formula-pointer)		550 gp	Kilograms
69.86363636	254.11538	5			330 Kilograms	
Length	Force	5			2520 newtons	
64.92307692	83.418182	5				
35.07692308	2	5	Size of pointer.			
	274.58182	5				
	Acceleratio	5	Formula to convert values for use in dial.			
	145.94444	5				
	2	5				
	212.05556	5				
Max Velocity	102	5	Max Values are the maximum possible value these can be. For calculation purposes.			
Max Accel	45	5				
Max Impact Force	3300	5				
Max Air Time	13	5				
Actual Velocity	73.6	5	Actual Values change based on size of rock.			
Actual Accel	35.5	5				
Actual Force	1488	5				
Actual Air Time	7.30	5				
Max Distance	650	5	Max and Actual values for use in bar graph.			
Max Height	220	5				
Actual Distance	422.00	5				
Actual Height	66.30	5				
Actual Cost	550	5				
Actual Mass	330	5				
Actual Force Requi	2520	5				
Max Force Require	4700	5				
		5				
		5				
		5				
		5				
		5				
		5				
		5				

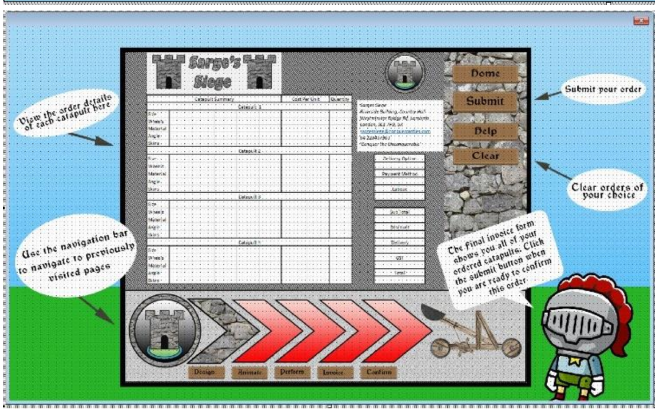
Appendix 16: User forms

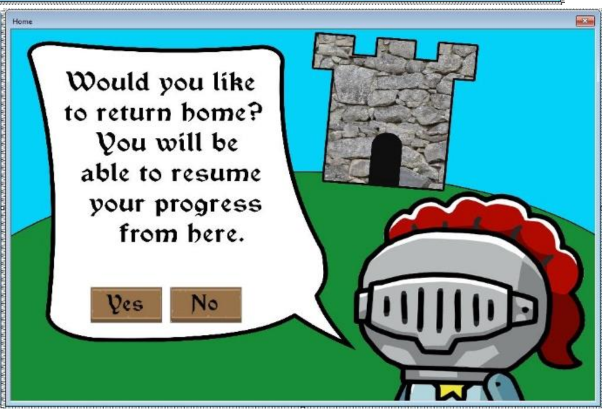


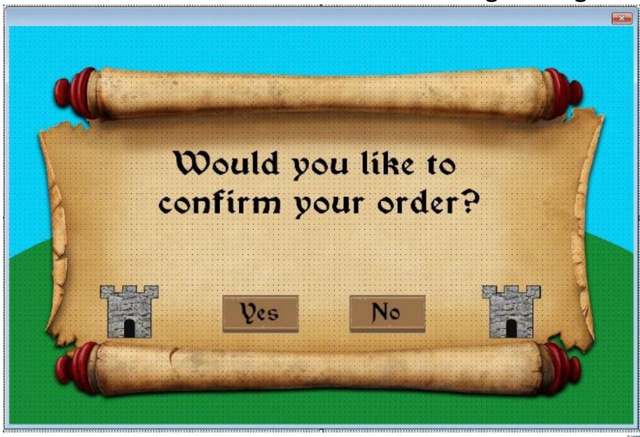




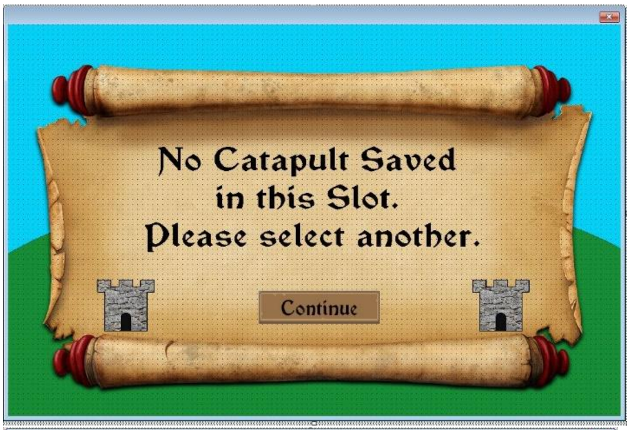


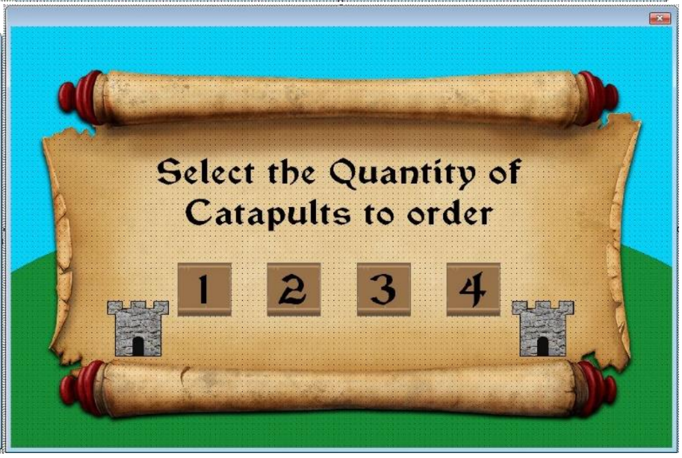


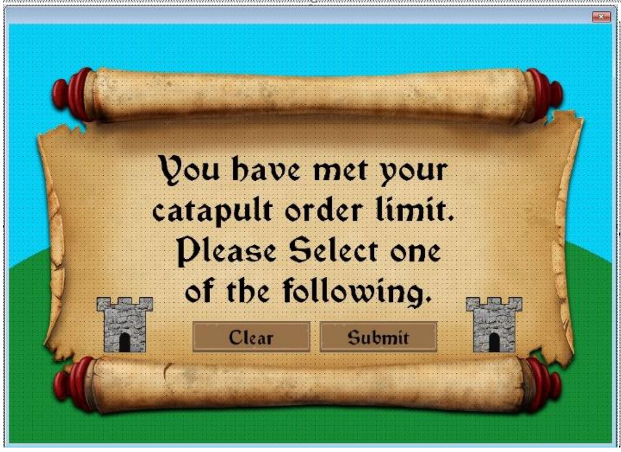


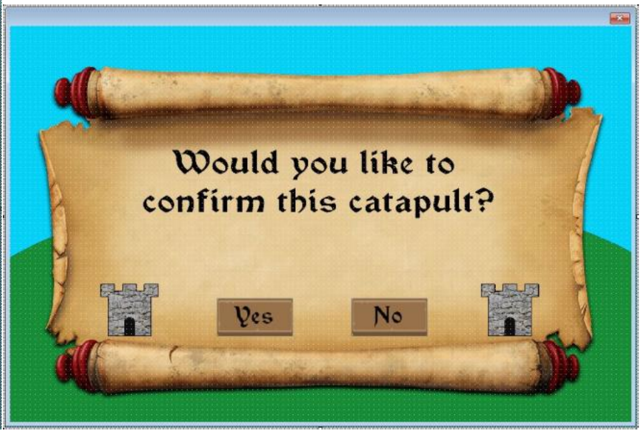

Would you like to confirm your order?
Yes
No

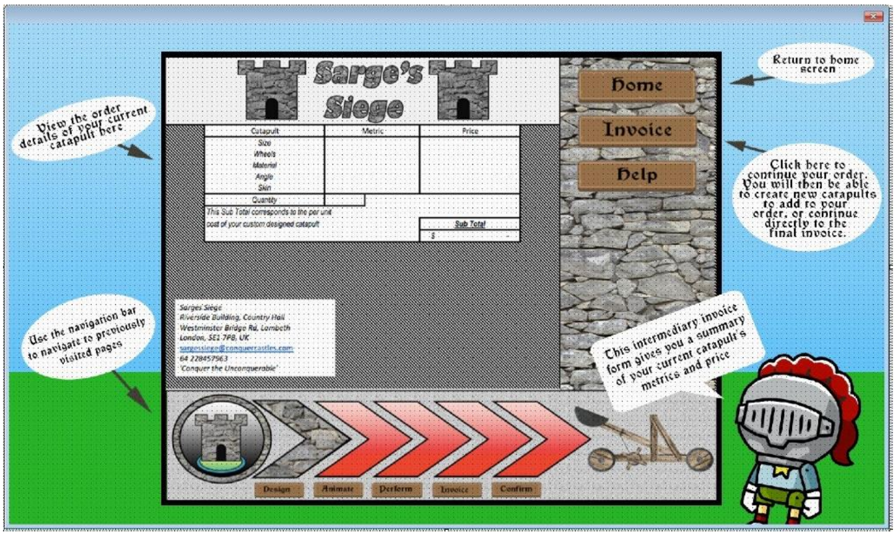

You have no saved catapults
Start Order
Stop Order


No Catapult Saved in this Slot. Please select another.
Continue


Select the Quantity of Catapults to order
1
2
3
4


You have met your catapult order limit. Please Select one of the following.
Clear
Submit


Would you like to confirm this catapult?
Yes
No


Sarge's Siege
View the order details of your current catapult here
Catapult
Metric
Price
Size
Wheels
Material
Angle
Skin
Quantity
This Sub Total corresponds to the per unit cost of your custom designed catapult
Sub Total
$
Home
Invoice
Help
Return to home screen
Click here to continue your order. You will then be able to create new catapults to add to your order, or continue directly to the final invoice.
Sarges Siege
Riverside Building, Country Hall
Westminster Bridge Rd, Lambeth
London, SE1 7PB, UK
sargessiege@conquercastles.com
64 228457963
'Conquer the Unconquerable'
Use the navigation bar to navigate to previously visited pages
This intermediary invoice form gives you a summary of your current catapult's metrics and price
Design
Animate
Perform
Invoice
Confirm

Appendix 17: Sub Routines and Functions

Module	Sub Routine and Function
Animation	Animate() ClearSheet() DrawScene(sC As String, sA As String, size As Double) DrawAnimation(sC As String, sA As String) DrawFrame(sC As String, sA As String, r As Integer, proj As Variant, shad As Variant, curt As Variant, cast As Variant, fire As Variant) Sleep(Duration As Integer) Small_rock_click() Medium_rock_click() Large_rock_click() PositionCastle()
Buttons	Begin() HelpDesign() HomeButton() Begin() SimulateButton() ResultsButton() InvoiceFromPerformance() InvoiceButton() HelpAnimationButton() HelpPerformanceButton() HelpIndividual() HelpFinal() SubmitButton() ClearFinal() NavigateDesignButton() NavigateAnimationButton() NavigatePerformanceButton() NavigateIndividualInvoiceButton() NavigateFinalInvoiceButton() UpdateReference(CellReference)
Calculations	Function GST(Value) Function Cost(Quantity, Rate) Function Discount(Check, Value, DiscountRate) Function TotalCostPerUnit(Sheet, CellReference) As Double Sub UpdateAllCosts() Sub UpdateCount()
Clearing	Sub ClearRange(Sheet, Range) Sub ResetReferenceData() Sub ClearFinalInvoice(Counter) Sub ClearAll()
DesignAndInputs	Sub ProtectSheet() Sub SetButtonColours(selectedVariable, selectedButton) Function GetCatapultFilename() As String Sub SetCatapultImage(selectedVariable) Sub ButtonSize1_Click() Sub ButtonSize2_Click() Sub ButtonSize3_Click() Sub ButtonMaterial1_Click()

	Sub ButtonMaterial2_Click() Sub ButtonMaterial3_Click() Sub ButtonMaterial4_Click() Sub ButtonMaterial5_Click() Sub ButtonWheelSize1_Click() Sub ButtonWheelSize2_Click() Sub ButtonWheelSize3_Click() Sub ButtonAngle1_Click() Sub ButtonAngle2_Click() Sub ButtonAngle3_Click() Sub ButtonSkin1_Click() Sub ButtonSkin2_Click() Sub ButtonSkin3_Click() Sub ButtonSkin4_Click() Sub ButtonSkin5_Click() Function GetUnitCost()

Formatting	Sub FormatFinalInvoice(Sheet, Counter)
	Sub FormatReferenceData(Sheet, Counter)
	Sub FormatFinalInvoiceTotals(Sheet)
	Sub CentreAccrossSelection(Sheet, CellRange)
	Sub CreateBorder(Sheet, CellReference)

HomeAndSummary	Sub Pedestal() Sub castle() Sub CloudMovement(SheetName, CloudName) Sub timeout(duration_ms As Double) Sub Help() Sub Help2() Sub Help3() Sub Help4() Sub WaitFor(NumOfSeconds As Long) Sub CreateZoomWindow(ByVal ZoomThisRange As Range, _ ByVal PreserveRows As Boolean) Sub SetCatapultImage1() Sub SetCatapultImage2() Sub SetCatapultImage3() Sub SetCatapultImage4() Function GetCatapultFilename1() As String Function GetCatapultFilename2() As String Function GetCatapultFilename3() As String Function GetCatapultFilename4() As String
Navigate	Sub NavigateYes(UserForm, SheetObject) Sub NavigateNo(UserForm) Sub ShowTime(UserForm) Function CatapultCounter() As Integer Sub NavigateButton(SheetDestination) Sub ShowImageCondition(SheetDestination, SheetReference, ImageReference, CellReference) Sub Navigator(SheetDestination, SheetReference, ImageReference, CellReference) Function CheckReference(SheetReference, CellReference) Function CheckAllocation() As Integer Sub UpdateReference(CellReference) Function CheckSaveSlot(CellReference) As Integer Function CountCatapults()

Performance	Sub rockSize() Sub visible_Images()
Saving	Sub SaveIndividualCatapult(SheetTo, SheetFrom, Counter, Quantity) Sub TransferCatapultImage(Count) Sub TranferCatapultDesign(SheetTo, SheetFrom, ValueRange, ReferenceRange) Sub Save(Quantity)

```
Function GetCatapultFilename() As String
    ' Gets the filename for the image on disk based on the current selection
    Dim WheelSize As String, Angle As String, Skin As String

    ' Get the values and names of the current selection
    CurrentSkinSelection = Sheets("Control Variables").Range("SkinSelection").Value
    Skin = Application.WorksheetFunction.Index(Sheets("Database").Range("SkinNames"), CurrentSkinSelection)
    CurrentAngleSelection = Sheets("Control Variables").Range("AngleSelection").Value
    Angle = Application.WorksheetFunction.Index(Sheets("Database").Range("AngleNames"), CurrentAngleSelection)
    CurrentWheelSizeSelection = Sheets("Control Variables").Range("WheelSizeSelection").Value
    WheelSize = Application.WorksheetFunction.Index(Sheets("Database").Range("WheelSizeNames"), CurrentWheelSizeSelection)

    ' Concatenate to get the filename
    GetCatapultFilename = Skin & Left(Angle, 2) & WheelSize
End Function
```

```
Sub SetCatapultImage(selectedVariable)
    ' Updates the image of the catapult based on the current selection
    Dim defaultWidth As Integer
    ' The defalt image width
    defaultWidth = 900
    'Set sheet'
    Set Sheet = Worksheets("Design")

    ' Get the current size selected (small/medium/large) and find the relative scale (multiplier for the default width)
    CurrentSizeSelection = Sheets("Control Variables").Range("SizeSelection").Value
    CurrentSizeScale = Application.WorksheetFunction.Index(Sheets("Database").Range("SizeScaleValues"), CurrentSizeSelection)

    ' Calculate the new width
    newWidth = defaultWidth * CurrentSizeScale

    ' Get the image filename and path to it
    Filename = GetCatapultFilename()
    Directory = ThisWorkbook.Path & "\CatapultImages\" & Filename & ".png"

    ' If a catapult image already exists, delete it
    On Error Resume Next
    If Sheet.Shapes("CatapultImage").Name <> "CatapultImage" Then
        ' Catapult image doesn't exist on sheet
    Else
        Sheet.Shapes("CatapultImage").Delete
    End If
    On Error GoTo 0

    ' Check if the directory is valid
    If Dir(Directory) <> "" Then

        ' Insert a new image of the selected size and reposition it
        With Sheet.Pictures.Insert(Directory)
            .ShapeRange.PictureFormat.CropTop = 130
            .ShapeRange.PictureFormat.CropBottom = 130
            .ShapeRange.LockAspectRatio = msoTrue
            .ShapeRange.Width = newWidth
            .ShapeRange.Left = Sheet.Range("R40").Left - .ShapeRange.Width / 2
            .ShapeRange.Top = Sheet.Range("R33").Top - .ShapeRange.Height / 2
            '.ShapeRange.ZOrder msoSendToBack
            .Name = "CatapultImage"
        End With
    End If

End Sub
```

For practical purpose, we listed all sub routines and function names and not the functions themselves. The code for each sub routine and function may be viewed in the Microsoft Visual Basic Window.

Appendix 18: Concept Sketches