Scoping and Requirements Document

Team 4 – Motions 3

2022 SPINE Engineering Project Practice

ENGG2000 and ENGG3000

The Marble Machine

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1. Revision History

Date	Changes Made	Committed By
9/08/23	Added Inclusions and Exclusions	Oliver Gordon
10/08/23	Added constraints and requirements	Tyler Johnson
13/08/23	Added problem definition	Blake Verdi
13/08/23	Formatted document	Tyler Johnson
20/08/2023	Wording changed Inclusions	Tarun Gangolli
20/08/2023	Lists of Tables and Figures Added	Oliver Gordon
20/08/2023	Added minor deliverables and changed introduction.	Reece Deluca

Table 1 Revision History

2. Division of Labour and Workload Acknowledgement

Section	Team Member	Sign off	% Workload
Tyler Johnson	Requirements and Signoffs, Constraints	Completed – Checked by Oliver Gordon	~20%
Oliver Gordon	Inclusions and Exclusions	Completed – Checked by Tyler Johnson, Reece Deluca	~20%
Tarun Gangolli	Deliverables	Completed – Checked by Tyler Johnson, Oliver Gordon	~20%
Reece Deluca	Introduction and Scope	Completed – Checked by Oliver Gordon, Blake Verdi	~20%
Blake Verdi	Problem definition	Completed – Checked by Oliver Gordon, Tarun Gangolli	~20%

Table 2 Division of Labour and Workload Acknowledgment

3. Introduction

ENGG2000/3000 students have been tasked to create a marble machine to be presented at the entrance of the main engineering building. The large marble machine will consist of multiple interchangeable cubes with similar standards. Each cube will receive the marbles and release the marbles with different subsystems to transfer them across. Our group will create a single cube which efficiently and reliably transfers the marble while satisfying the necessary requirements stated below. The reports will provide further details about the design and requirements to accomplish this task.

4. Scope

The main goal of this document is to showcase the initial design of the marble machine motion components. Inside this document, you will find all the important details provided by the customer with evidence to support the functionality of our design. Additionally, the document addresses the initial components design, limitation and requirements for a full overview of the project.

4.1. Terms, Definitions Abbreviations

Abbreviation	Meaning
MQ	Macquarie
TPM	Technical Performance Measures
FR##	Functional Requirement ID
PR##	Performance Requirement ID
IR##	Interface Requirement ID
AR##	Additional Requirement ID
CON##	Constraint ID
IN##	Inclusion ID
EX##	Exclusion ID
COMMS	Team 4 Communications 6
STRUCT	Team 4 Structures 1
MOTIONS	Team 4 Motions 3

Table 3: Terms. Definitions, and Abbreviations

5. Problem Definition

To test the teamwork, problem solving, and technical skills of the ENGG2000/3000 class, each of our teams are to construct part of a kinetic sculpture. The sculpture will comprise of 16 interconnected boxes, collectively measuring 2.4 meters in height and 2.4 meters in length. Each individual box will have dimensions of 250mm x 250mm and will accept, transport, and release marbles in specific ways. The primary objective of this project is to create a kinetic sculpture, wherein a steel marble pass through a number of these different boxes, each controlling the marble in specific ways.

The development of this sculpture will be executed by a collaborative team, organized into sub-teams, consisting of students specializing in structural, motion, and communication engineering. Each sub-team will be responsible for specific tasks that align with their respective disciplines. The ultimate goal is to demonstrate the innovative and cooperative prowess of the engineering faculty through this creative endeavor.

5.1. Subsystems

Below are figures depicting our initial design:

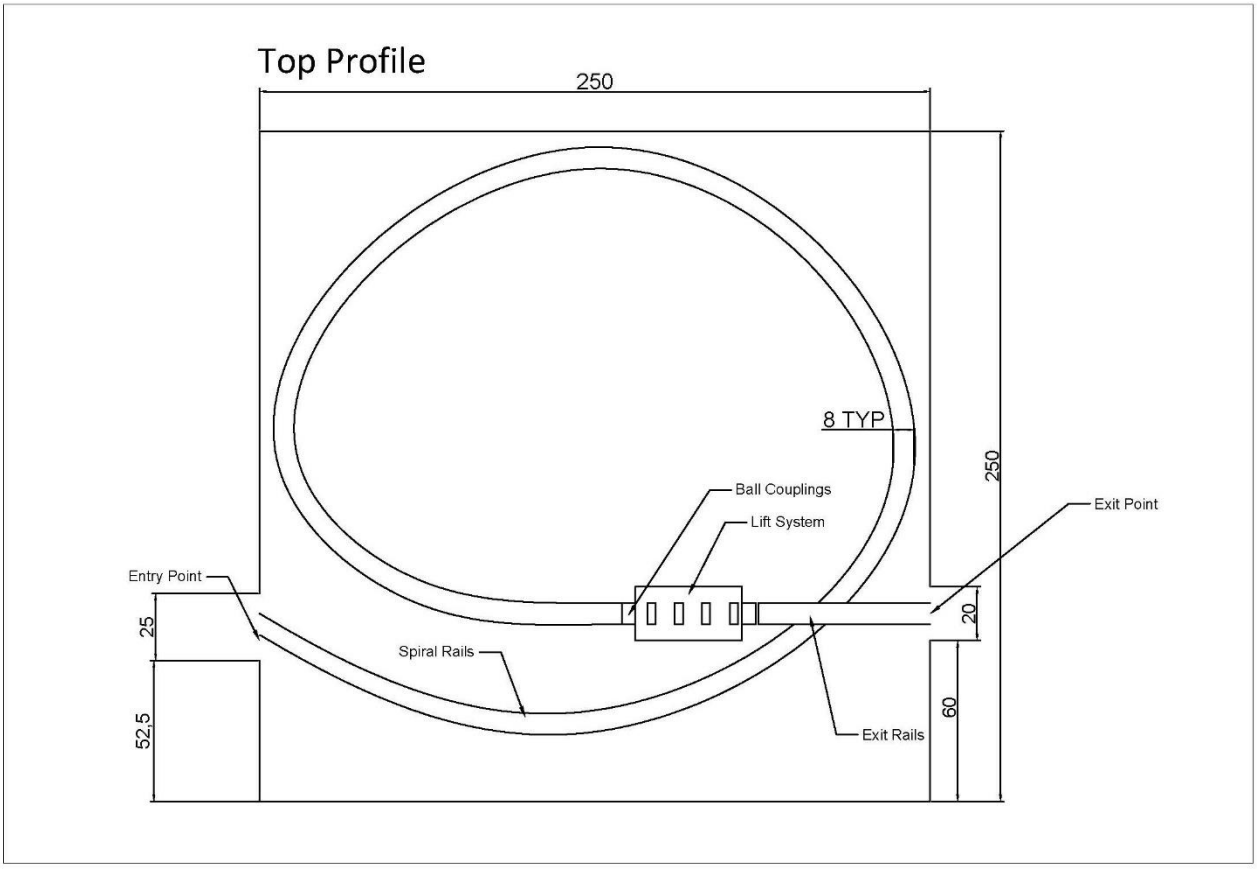

Figure 1: Detailed Design Top View

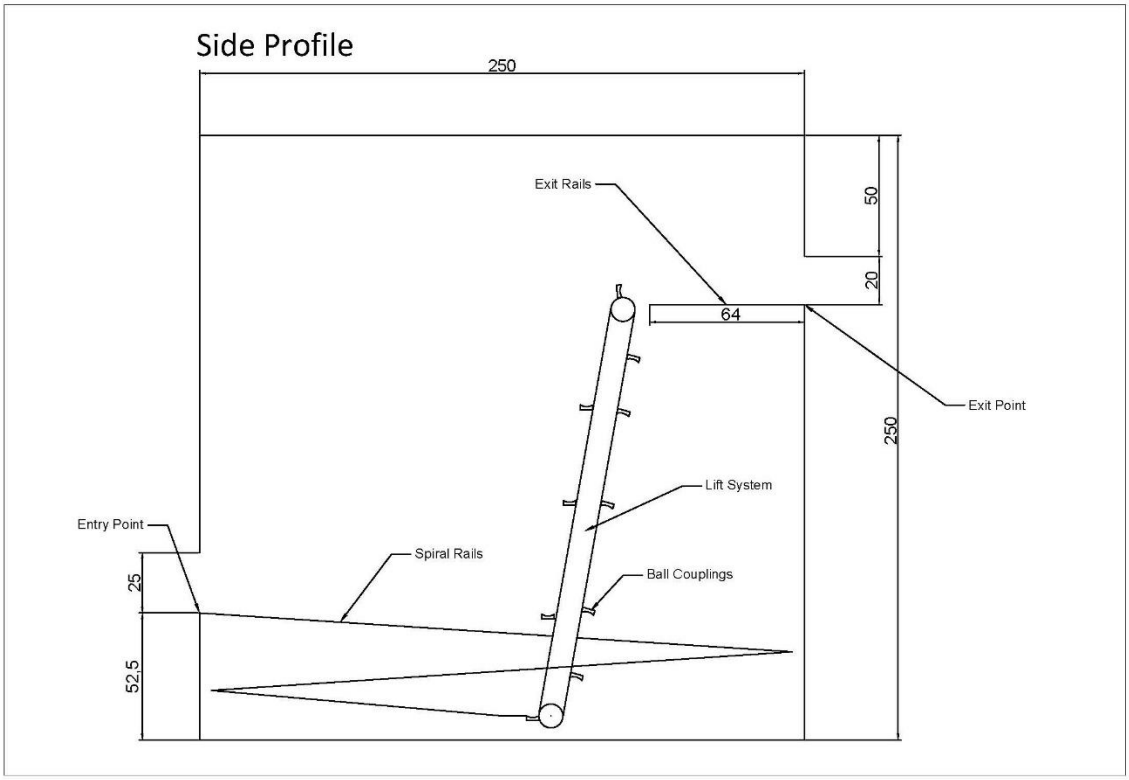

Figure 2: Detailed Design Side View

The project will be divided into subsystems, each subsystem will be in place to complete a certain requirement. These will consist of the following:

Subsystem Name	Description	Addressed Directly
Spiral Rails	A set of 3mm metal rails that run around the perimeter of the box. These rails guide rolling marbles.	FR1, FR5
Lift System	Lifts marbles using a series of receptacles attached to a drive belt, these receptacles collect marbles off the rails and lift them up to the Exit Rails	FR4, PR3, PR2, FR4
Exit Rails	Accept marbles from the Lift System and guide them to the exit.	FR4, FR5

Table 4: Subsystems

To ensure quality and efficiency, the project will be divided into subsystems corresponding to each discipline. Each sub-team will be responsible for their designated section of the sculpture, allowing for specialized focus and effective completion. Regular collaboration among sub-teams will promote a cohesive workflow and showcase the engineering faculty's creativity and skill.

5.1.1. Structures

The structures team will be responsible for the design aspects concerning the housing, as well as the collection and retrieval process of the steel marble. The collection procedure for the steel marble will predominantly rely on gravity in order to minimize the inclusion of complex moving components. On the other hand, the return mechanism for the steel marble will be addressed jointly by the motions team and the structures team. The motions team will be responsible for devising the lift system, encompassing the motorized elements, while the structures team will be tasked with handling the mounting intricacies. The mounting intricacies will fulfil the requirement IR5 where the cube must be placed on one of four mounting positions.

The housing aspect will fulfil the requirements PR1, IR2, IR4, IR6 where the cube must accept a 16mm iron marble. The front surface must not be structural for maintenance purposes, and transparent with the sides and back of the cube being composed of 3mm MDF. The cube must also be placed at the center of a 265*265mm square on a backing board.

5.1.2. Motions

The primary focus of the motions team lies in addressing all moving components present within the marble machine. Additionally, the motions team will be responsible for designing and constructing the lift system required for the return of steel marbles. In this regard, the lift system's development will strictly adhere to structural engineering principles to ensure the elimination of any potential clearance issues. Motions will also handle the Arduino and the coding that follows. Handling the Arduino will fulfil the requirement IR1 where the system must be controlled by an Arduino Uno Microprocessor.

In addition to the above tasks, the motions team will undertake the management of the Arduino integration and the subsequent coding requirements involved in moving components

5.1.3. Communications

Given the nature of this project, the communications subsystem will be relatively less involved compared to other subsystems. Its primary focus will be on enhancing the visual aspect of the marble machine. This will encompass the integration of lighting elements, sensors, and the associated coding required for their proper functioning. This is to fulfill the requirement FR2 where there must be visual indication approved by the customer.

To ensure seamless coordination, the communications team will collaborate with the structures team, particularly in matters pertaining to clearance concerns. The joint effort will guarantee the absence of any interference between different components. This will fulfil the requirement IR3, where the Telecommunications and power must be routed through the rear end port.

Specifically, the communications team will undertake the design of an LED strip, which will be strategically mounted at the top of the box. This LED strip will function as a progress bar, and its activation will be synchronized with the sensor for each steel marble. To achieve optimal performance, fine-tuning of this feature will be required in alignment with the final design of the marble machine.

5.2. Assumptions

Assumptions	Description
Gravity	Acceleration due to gravity is 9.80 m/s^2.
Marble's size and weight	The marble's intended diameter is 16 mm with a mass between 15g - 20g
Cube's structure and measurements	The cube's outer structure is made of MDF with a thickness of 3mm and has a density of approximately 680-720kg/m^s.
Power supply	Assume a 5V and 12V power supply, with ample wattage

Table 5 Assumptions

6. Deliverables

The expected outcomes are a series of documents detailing various components of the project. This range includes documented testing procedures to presentation materials. These anticipated outcomes hold significant importance within the project, as their absence would hinder our overall success.

Deliverables	Date of delivery	Description	Status
Scoping document draft buddy marking	14/08.2023	Each team submits a draft of their scoping document for feedback. The scoping document drafts will be assessed by a separate team. This information will be used to improve the draft for final submission.	Delivered
Scoping document	20/08/2023	This document demonstrates all the elements of the project. This includes: - Problem definition - Requirements - Exclusions and constraints	Delivered
Design draft Review	5/09/2023	Each team will submit a design video draft for peer review.	Delivered
Design Document	10/09/2023	The design document represents the final design of the project. The motions group will include: - Devices - Power budget - Wiring	
Testing Document	29/10/2023	The testing document will evaluate all the testing procedures required to ensure the project works up to standards. This will include: - Material testing. - Reliability testing	
Statement of Work	29/09/2023	The statement of work addresses the changes required to create the final product. These changes need to be addressed to the client and agreed upon.	
Final Product	7/11/2023	The final product will demonstrate and present the functional final product to the client. This includes: - Presentation of the working product. - Description of subsystems. - How the requirements have been achieved.	

Table 6 Deliverables

7. Requirements and Sign Offs

Requirements listed below will form the basis of our TPM's during the testing phase. These have been divided into three groups. Functional requirements must be met for the design to be fit for purpose. Technical Performance requirements describe what conditions the system must be able to accommodate and operate predictably under. Interface requirements outline shared requirements between groups.

7.1. Functional Requirements

Req ID	Requirement	How will this be Achieved?
FR1	The marble makes a full rotation around an imaginary line that MUST NOT intersect the marble, drawn through the cube. The marble's direction must change in at least two dimensions by the size of the marble.	Achieved with the spiral rail subsystem making a 360-degree rotation around the center of the box.
FR2	A cube MUST provide some visual indication using LEDs or other lighting system approved by the customer as to the function being performed.	Achieved using the mounting of an LED strip in a visible location.
FR3	The only forces provided to a cube are gravity and electrical power. A cube MUST NOT use any liquid in its operation and MUST NOT use compressed air or other gases.	The system only requires gravity and electricity.
FR4	Each cube MUST control the marble in such a fashion that the bottom of the exit opening is at least 100mm higher than the top of the input opening.	This is achieved by elevating the marbles through the lift system.
FR5	Each cube MUST accept a marble through an input opening on a surface other than the top surface of the cube. This location must be agreed to by the customer. It MUST expel marbles through a different surface to where they entered.	Location has been agreed upon with the customer and is demonstrated in schematics.
FR6	Each cube MUST accept marbles that are a solid steel sphere with a diameter of 16mm. The cube SHOULD also accept marbles that are made of lighter materials.	Rails, elevator, entry, and exit will be designed with a diameter of 16mm in mind.

Table 7 Functional Requirements

7.2. Technical Performance Requirements

Req ID	Requirement	Measure	Importance
PR2	Each cube MUST accept marbles that are spaced no closer than 1 second apart through the opening port.	Each subsystem must be able to transmit **at least 1 marble/s.**	HIGH
PR3	Cubes SHALL NOT deliberately expel marbles at a speed significantly higher than that attributable to gravity alone.	Marble speed **must not exceed 3m/s.**	LOW
PR3	The Cube is to run 24/7 with minimal downtime.	Lower than **6hrs unplanned downtime per week**.	MEDIUM
PR4	Code written for the Arduino must work predictably and consistently.	System should be able to run indefinitely with no overflow or crashes for at least a **week**.	MEDIUM

Table 8 Performance Requirement

7.3. Interface Requirements and Signoffs

Req ID	Requirement	Team	Signoff	Date
IR1	The system is to be controlled with an Arduino Uno Microprocessor. The system SHOULD implement as few external components as possible.	COMMS	Nicholas Simos - COMMS	20/8/23
IR2	The lighting system should try to minimize occupation of Arduino Uno ports. The way they are controlled must reflect the progress of a marble through the machine.	COMMS	Nicholas Simos – COMS – Lighting system will utilize at most 4 Ports	20/8/23
IR3	Devices selected must be compatible with the Arduino Uno or at least be made compatible.	COMMS	Nicholas Simos – COMMS – Only compatible devices are used.	20/8/23
IR4	Telecommunications and power must be routed through the dedicated rear port.	STRUCT	Adam Amolis – STRUCT – Adequate routing through port.	20/8/23
IR5	Each cube location on the backing board SHALL be in the center of a 265mm square. There is a 15mm distance between cubes.	STRUCT	Sakibul Alam – STRUCT – Mounting will not interfere with internal components	20/8/23
IR6	Rails must be able to interface with the pulley and allow for the marbles to be collected and deposited easily;	STRUCT	Sakibul Alam – STRUCT – Rails will allow adequate clearance (at MOST 16mm between them)	20/8/23
IR7	Cubes MUST be manufactured from 3mm MDF for the back and side pieces, the front surface MUST be transparent.	STRUCT	Tamzid Ahmed – STRUCT – All mounting points are located on the MDF structure. Front face is entirely removable.	20/8/23

Table 9 Interface Requirements

7.4. Additional Requirements

There are also some additional requirements that we as a team have added, these include requirements we have agreed on as a team to ensure a final product of professional quality.

Req ID	Requirement	How will this be achieved?
AR1	Wiring SHOULD be hidden and routed through a dedicated channel to each component. Wiring SHOULD be neat where visible.	The use of cable covers, and preplanned cable routes should mitigate this.
AR2	Components and advanced wiring that are external to the microcontroller MUST be mounted to a prototype board and soldered neatly. Must be mounted where easily accessible.	Soldered board mounted directly above the Arduino, means connections can be neater.
AR3	Cube MUST only be able to run on 5V and 12V as supplied. The cube SHOULD be as energy efficient as possible.	Arduino is a 5V device and can run devices of lower voltages. Motors can use 12V.
AR4	The Cube SHOULD be easily maintainable and run with minimal downtime.	Designing for longevity and minimizing points of failure should address this.

Table 10 Additional Requirements

8. Constraints

Constraints are defined as other limitations placed on the project by both the customer and our own circumstances. These include physical, financial, and time-based limitations.

Req ID	Requirement
CON1	Each cube MUST have a bill of materials, and each bill of materials MUST total to less than AUD$100.00.
CON2	All components MUST be sourced from the allowed suppliers. Bunnings, RS Online, Core Electronics, Hobby King, and Jaycar
CON3	Each cube MUST have the external dimensions of 250mm by 250mm by 250mm.
CON4	We are limited to the 13 Week period defined by the GANTT chart available on iLearn.
CON5	We are limited to the hardware and tools available to us at 44 Waterloo Rd. And tools available to team members within reason.

Table 11 Constraints

9. Inclusions and Exclusions

This section specifies which task is to be included in the project scope for the motions sub team, and which task is to be excluded.

9.1. Inclusions

Inc ID	Inclusions	Description
IN1	Addressing moving components	The MOTIONS team will oversee the implementation of moving components
IN2	Designing and building lifting system	The MOTIONS team will oversee the design of the lifting system
IN3	Arduino coding	The MOTIONS team will be making a combined effort with COMMS
IN4	Arduino integration management	The MOTIONS team will be responsible for integrating the Arduino with the moving components
IN5	Electronic and motorized components selection	The MOTIONS team will be responsible for selecting the moving components involved in the project
IN6	Wiring cover	The MOTIONS team must assist in covering up any wiring for a presentable project

Table 12 Inclusions

9.2. Exclusions

No.	Exclusions	Description
EX1	Mounting of components	The STRUCTURES team will be responsible for mounting the components
EX2	Housing	The STRUCTURES will oversee the housing of the project
EX3	Designing collection system	The STRUSTURES team will oversee the design of the collection system
EX4	LED system	The COMMUNICATIONS team will be responsible for the LED system
EX5	Programming of moving components	The COMMUNICATIONS team will oversee the programming of the electronic and motorized components
EX6	Manufacturing of structural marble tracks	The STRUCTURES team will be responsible for the spiral track.

Table 13 Exclusions

10. References

Reference	Content
Rex Di Bona	Information regarding constraints and details on project requirements/constraints.
Siyuan (Mackenzie) Zhuang	Information and advice on document structure, issues regarding design, and general feedback.
di Bona, R. (2023). *Massive Marvelous Multiple Marble Machine*. [PDF Document] [Accessed 20 2023].	This document served as the project overview and is representative of a brief from a customer. Included information on dimensions, constraints and requirements.
BC Precision. (n.d.). *16mm Carbon Steel Ball Bearings G1000*. [online] Available at: https://www.bcprecision.com/products/16mm-carbon-steel-ball-bearings-g1000 [Accessed 20 Aug. 2023].	Information on the weight/density of G1000 16mm Steel Marbles. Although we may not be using these specific marbles, they are a good estimate.
Skirting 4 u. (n.d.). *MDF vs HDF - The difference between MDF and HDF boards*. [online] Available at: https://www.skirting4u.co.uk/blog/post/hdf-vs-mdf.	Information on the density of MDF, the material used for the box.

Table 14 References

11. List of Tables

12. List of Figures

13. Appendix

13.1. Motions DSM

	task below Depends on -->	1 Mounting	2 Lifting System	3 Arduino	4 Arduino Coding	5 LED Strip	6 Wiring	7 Motor and Performance Analysis	8 Sensor
1	Mounting						X		
2	Lifting System	X		X			X	X	X
3	Arduino	X			X		X		X
4	Arduino Coding			X		X	X		
5	LED Strip	X					X		X
6	Wiring	X		X		X			
7	Motor and Performance Analysis	X		X	X		X		X
8	Sensor	X			X		X		

Figure 3 Design System Matrix