GNG1103: Intro to Engineering Design

Design Project User and Product Manual

The Grand Extraction

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December 3, 2024

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Table of Contents

Table of Contents 2
List of Figures 4
List of Tables 4
List of Acronyms and Glossary 6
1 Introduction 7
2 Overview 8
2.1 Conventions 9
2.2 Cautions & Warnings 9
3 Getting Started 10
3.1 Configuration Considerations 10
3.1.1 Overview 10
3.1.2 System Walkthrough 10
3.2 User Access Considerations 15
3.3 Accessing/Setting Up the System 15
3.3.1 Physical Set-Up 15
3.3.2 Digital Set-Up 16
3.4 System Organization & Navigation 18
3.4.1 Physical Features 18
3.4.2 Digital Features 19
3.5 Exiting the System 21
3.5.1 Physical Exit 21
3.5.2 Digital Exit 21
4 Using the Game 23
4.1 Storyline 23
4.1.1 Prologue 23
4.1.2 Tasks 23
4.1.3 Epilogue 23
4.2 Gameplay 24
4.2.1 Task Locations 24
4.2.2 Method of Elimination 25
5 Troubleshooting & Support 26
5.1 Error Messages or Behaviors 26
5.2 Special Considerations 26

5.3 Maintenance 26
5.4 Support 27
6 Product Documentation 28
6.1 Robomaster 28
6.1.1 BOM (Bill of Materials) 28
6.1.2 Equipment List 28
6.1.3 Instructions 28
6.2 Cards and Props 29
6.2.1 BOM (Bill of Materials) 29
6.2.2 Equipment List 30
6.2.3 Instructions 30
6.3 Testing & Validation 31
6.3.1 Robomaster Testing 31
6.3.2 Card and Prop Testing 32
7 Conclusions & Recommendations for Future Work 33
Bibliography 34
Appendix I: Design Files 35
Appendix II: Trello Link 35
Appendix III: Task Schedule 36
Appendix IV – PFME Analysis 36

List of Figures

Figure 1: Screenshot from the demonstration video of The Grand Extraction 8
Figure 2: All components in the game bag 10
Figure 3: Default set-up for props 11
Figure 4: Player Cards 11
Figure 5: DJI Edu Hub. 11
Figure 6: Players debating the options at the police station 12
Figure 7: Visual instructions of prop assembly 15
Figure 8: Event Card (with prompt) 15
Figure 9: Power button location 16
Figure 10: Login page 17
Figure 11: Character Card 18
Figure 12: Smart tab with features 19
Figure 13: Prototypes of props. Event Cards are placed within. 24
Figure 14: Event Cards 24
Figure 15: Elimination symbol present on the back of the Character Cards. 25
Figure 16: Screenshot from Robomaster S1 simulation 29
Figure 17: Prototype for the early design of a Character Card 30
Figure A: Fishbone Diagram derived from PFME analysis 37

List of Tables

Table 1: Acronyms 6
Table 2: Glossary 6
Table 3: Input and Output Table for Police Station Interaction 12
Table 4: Input and Output Table for Hospital Interaction 13
Table 5: Input and Output Table for Government Building Interaction 13
Table 6: Scenario description chart. 23
Table 7: Contact information and area of focus of BOOM members 27
Table 8: Bill of Materials for Robomaster S1 implementation 28
Table 9: Equipment List for Robomaster S1 implementation 28
Table 10: Bill of Materials for Props 29
Table 11: Equipment List for Props 30
Table 12: Robomaster S1 testing criteria, metrics, and results 31

Table 13: Cards and Props testing criteria, metrics, and results 32
Table A: List of Design Files available on MakerRepo 35
Table B: Plan for Tasks from October 20 to December 7, 2024 36

List of Acronyms and Glossary

The following section consists of useful keywords and acronyms that are used throughout the User and Product Manual.

Table 1: Acronyms

Term	Acronyms	Definition
Bill of Materials	BOM	A comprehensive list of all the materials and tools needed to manufacture a product.
Computer-Aided Design	CAD	Digital representations of physical prototypes.
Lethal Autonomous Weapons System	LAWS	A weapon system that can independently identify and engage targets without human intervention.
Medium-Density Fibreboard Boards	MDF	Smooth, light material made from wood fibres. This material is used on most, if not all, physical aspects of The Grand Extraction.
Predictive Failure Modes and Effects Analysis	PFME	A risk analysis tool used to identify potential obstacles and related contingencies.
User and Product Manual	UPM	This document, which provides a general overview of The Grand Extraction.

Table 2: Glossary

Term	Definition	Remarks
DJI Edu Hub	Software used to program Robomaster S1 a crucial part of The Grand Extraction.	Link
Inkscape	Software used to create and design laser cutting documents.	Link
Mines Action Canada	Humanitarian disarmament organization. This project is commissioned by said organization.	Link
Robomaster S1	Physical robot used to simulate the existence of a LAWS.	Link
Vision Markers	Specific symbols in red and white that are used by the Robomaster S1 for identifying purposes.	Link

1 Introduction

Mines Action Canada has commission BOOM to create an immersive experience that highlights ethical concerns of LAWS. The physical components of the experience must be easy to pack, quick to set up and quick to play. The game avoids glorification of autonomous warfare and remains neutral to all identities. It is designed for ages 10-23. The expii8erience should leave participants with a sense of loss, regardless of their performance.

This User and Product Manual (UPM) provides the information necessary for developers and end-users to effectively use The Grand Extraction and for prototype documentation.

The UPM will be targeted towards two main groups of potential users—developers and end-users. Sections 3 through 5 are more end-user-oriented, containing set-up instructions, a brief outline of the experience and FAQs. Other developer-oriented sections contain technical information, prototyping process, and recommendations from BOOM if further development were to occur.

It should be noted that the UPM is written as of *2024-12-02.* Information may not be up to date. The UPM includes multiple warnings and suggestions for a safe experience with The Grand Extraction. Such warnings are noted with ⚠. In addition, BOOM is not responsible for the maintenance and troubleshooting of Robomaster S1. For more information regarding the functionality of Robomaster S1, please contact DJI Edu Hub.

Please be aware that the UPM is only for the use and development of The Grand Extraction. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, including photocopying, recording, or other electronic or mechanical methods, without the prior written permission of the publisher (BOOM), except in the case of brief quotations embodied in critical reviews and certain other noncommercial uses permitted by copyright.

2 Overview

In the modern world, weapons manufacturers begin to opt for developing lethal autonomous weapons systems (LAWS). While it may seem that such LAWS can effectively uphold the rule of law, implementation of LAWS may lead to severe ethical concerns. Most notably, the inability for a LAWS to explain why, a decaying relationship with technology, digital dehumanization, and the lack of accountability. It is important for The Grand Extraction to emphasize the potential risks of engaging in LAWS development, specifically with the public. With the joint effort of the public, it is expected that pressure be exerted on such manufacturers, reminding them that the risks outweigh the apparent benefits.

In The Grand Extraction, players will be randomly assigned a player card with a number. The player with the lowest number will automatically be considered the major target in tasks. This emphasizes the inability for a LAWS to explain why. Following the role assignment, players will then move on to solve Tasks 1 to 3. In each task, players will read a prompt from a physical prop. From the prompt, players will then be required to decide as a group. The decision may lead to termination of the major target or survival of certain members. When a player is terminated, they must flip over their player card. The Robomaster S1, standing in as a LAWS, will target the player as a target, and indicate their termination. Regardless of the players' performances, the experience will end with a sense of loss, demonstrating the realistic effects of LAWS.

Figure 1: Screenshot from the demonstration video of The Grand Extraction

Prior to the project, BOOM narrowed the design to three major criteria: length, storage size and game area. The Grand Extraction was made with a heavy emphasis on such criteria that may have gone unnoticed for other groups. To facilitate this, The Grand Extraction became a decision-based game. This helps each task to proceed with a sense of freshness and remain entertaining when it goes on for too long yet remains simple enough for it to be short and concise. In addition, The Grand Extraction made use of flexible physical props. The props are light and easy to assemble. Not only do they help facilitate a simpler game and reduce packing size but also allow the game to be set up at a wide variety of locations.

2.1 Conventions

1. Various acronyms and specific keywords are used throughout the document. They can be understood through List of Acronyms and Glossary.
2. Underlined words in blue are hyperlinks to exterior documents or another section in the UPM. Cross-referencing is common throughout the UPM.
3. List of Figures and List of Tables include all important work within the UPM. Appendixes include critical and important work contributing to the production.
4. Multiple warnings and suggestions for a safe experience with The Grand Extraction are noted with ⚠.

2.2 Cautions & Warnings

⚠ The Grand Extraction includes strobing effects that may affect photosensitive players.

⚠ The Grand Extraction contains references and simulations to gunshots, which could be distressing to some players. Please proceed with caution and take care of your mental well-being. If you find this topic triggering, it might be best to opt out of the experience or seek support from a trusted individual or professional.

⚠ Certain parts of the storyline is emotionally invoking and can be unsettling or uncomfortable to some players.

3 Getting Started

3.1 Configuration Considerations

3.1.1 Overview

The Grand Extraction is an exciting survival game set in a city under siege by lethal autonomous weapon systems (LAWS). Following an official evacuation order, players must navigate the city, making critical decisions to reach the extraction point. The stakes are high, with each choice determining the survival of individual players or the entire group.

This manual provides step-by-step instructions for setup, gameplay, and exit, including visual aids for clarity.

3.1.2 System Walkthrough

The following section includes materials, inputs and potential outputs in different sections of The Grand Extraction.

3.1.2.1 Pre-Experience Section

1. Unboxing and Components

- Open the game bag and verify the contents:
  - **Player Cards**: Includes player numbers and elimination symbols on the rear.
  - **Structures**: The different POIs around the game area (Hospital, Police Station, Government Building)
  - **Robomaster S1**: The robot itself
  - **Decision Prompt Cards**: Includes scenarios and choices for gameplay.
  - **Instruction Manual**: Detailed guide for gameplay.

Figure 2: All components in the game bag

2. Configuration

- Lay out the game board and structures.

- Distribute player cards inside their respective buildings.
- Place Robomaster in the middle of the playing field facing the structures.

Figure 3: Default set-up for props

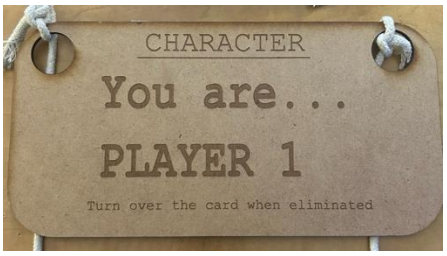
3. Special Setup Steps (For Further Development)

If the game is to be presented tomorrow:

1. Assemble and test all components for completeness.
2. Pre-arrange the board for a full play through.
3. Provide a visual quick-start guide in IKEA-style illustrations:

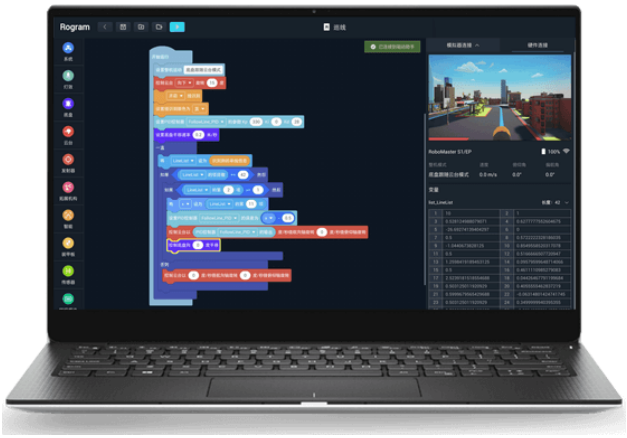
Step 1: Lay out the board and cards.
Step 2: Assign player numbers.

Figure 4: Player Cards



Step 3: Start the game with Scenario 1. *Refer to Figure 3.*
Step 4: Upload Robomaster S1 Code for beginning of game.
To upload the code, the DJI Education Hub software must be installed, and you must ensure the code is downloaded properly. Once these steps are completed, press the Run button in the DJI software.

Figure 5: DJI Edu Hub.



3.1.2.2 During-Experience Section

Police Station Interaction

Description

At the police station, players must contact local authorities to determine the extraction point. This feature tests the group's decision-making skills and sets the tone for the rest of the game.

Input and Output Table

Table 3: Input and Output Table for Police Station Interaction

Input Type	User Action	System Output	Notes
Decision Card (Landline)	Select "Use the Landline" option	The Robomaster traces the call, resulting in the elimination of one player.	Eliminated player reveals their card.
Decision Card (Computer)	Select "Use the Computer" option	Communication with authorities is successful, and players receive extraction point details.	Group avoids elimination in this scenario.

Process Flow

1. Players are given two decision cards: "Landline" and "Computer."
2. The group votes on the preferred option.
3. If **Landline** is selected:
    a. The Robomaster enters the scene, eliminating one player.
    b. The eliminated player reveals their target card.
4. If **Computer** is selected:
    a. The group successfully communicates with authorities via a secure VPN.

Visual Aid

Figure 6: Players debating the options at the police station

Hospital Interaction

Description

On their way to the hospital, one player becomes injured. The group must decide whether to assist the injured player or prioritize their own survival, knowing the consequences.

Input and Output Table

Table 4: Input and Output Table for Hospital Interaction

Input Type	User Action	System Output	Notes
Decision Card (Stay)	Choose to stay with the injured player	Robomaster arrives and eliminates the injured player and one additional group member.	Two players are eliminated.
Decision Card (Leave)	Choose to leave the injured player behind	The injured player is captured and eliminated by the Robomaster.	Only the injured player is eliminated.

Process Flow

1. One player is designated as injured (Player with lowest number).
2. The group votes on whether to stay or leave.
3. If **Stay** is selected:
    a. The Robomaster intercepts and eliminates the injured player and one uninjured player.
4. If **Leave** is selected:
    a. The injured player is captured and eliminated.

Government Building Interaction

Description

At the government building, players individually decide how to reach the extraction point. This final decision determines their survival based on timing and strategy.

Input and Output Table

Table 5: Input and Output Table for Government Building Interaction

Input Type	User Action	System Output	Notes
Decision Card (Daytime)	Choose to escape during the day	Player successfully evades the Robomaster and survives.	The Robomaster remains focused on the hospital.

Decision Card (Nightfall)	Choose to wait until nightfall	Player is detected by the Robomaster's thermal sensors and eliminated.	Thermal sensors detect all players at night.

Process Flow

1. Each player individually selects their choice of escape: "Daytime" or "Nightfall."
2. If **Daytime** is selected:
    a. The Robomaster continues hospital patrols, and the player escapes successfully.
3. If **Nightfall** is selected:

The Robomaster detects the player using thermal sensors, resulting in elimination.

3.2 User Access Considerations

The Grand Extraction is designed for 10 to 23-year-olds. However, certain aspects of the game, notably the storyline, contain references and simulations to gunshots. Certain parts of the storyline may also be emotionally invoking.

⚠ *For players under the age of 18, adult supervision is advised.*

In addition, Robomaster S1 includes a pellet-shooting feature. For safety reasons, a flash of light is implemented in place. The light may simulate a strobing effect, which may affect photosensitive players.

⚠ *Proper eye protection is advised for photosensitive players.*

3.3 Accessing/Setting Up the System

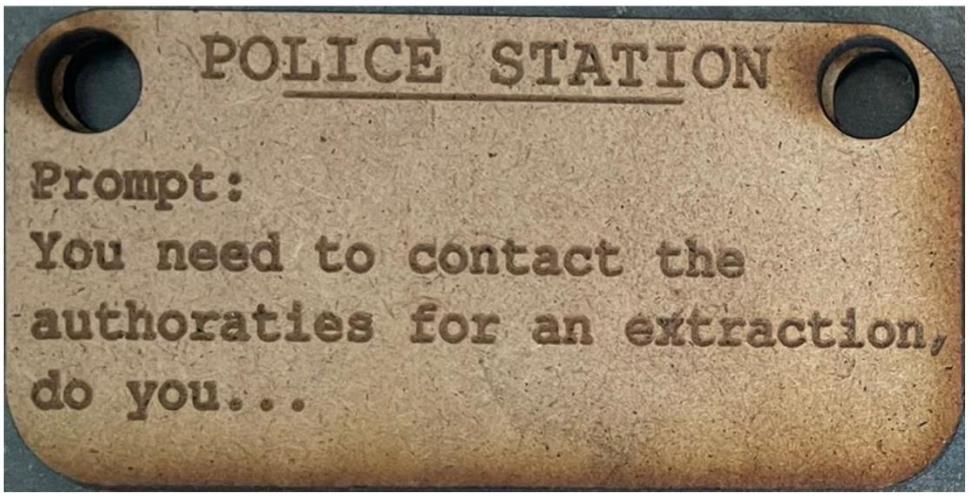
3.3.1 Physical Set-Up

The assembly of props can be done so according to instructions printed on the pieces. The pieces are labelled top, bottom, left, right, front, and back. See Figure 7 for a visual representation.

Figure 7: Visual instructions of prop assembly

The assembly of Character Cards and Event Cards consist of little to no steps. For Character Cards, the ropes must be tied properly to the holes on the corners. As for Event Cards, the card with the prompt must be placed on the top to facilitate a smooth game experience.

Figure 8: Event Card (with prompt)



⚠ *Props and Cards are made of MDF boards. Dropping them from a certain height may cause injuries. Caution is advised.*

3.3.2 Digital Set-Up

Properly turning on the Robomaster S1 system ensures that the robot initializes correctly and that all software components are ready for use. The following steps outline the actions required to power on the system, establish a connection, and log in (if applicable).

1. Power On the Robomaster S1

To begin, ensure the Robomaster S1 is in a safe, flat area where it can freely move without obstruction. Then, follow these steps to power it on:

1) Locate the power button on the Robomaster S1 (typically on the side or top of the robot).
2) Press and hold the power button for 3–5 seconds until the status indicator light turns on. The light will flash to indicate that the robot is starting up.
3) Wait for the robot to complete its startup sequence, which may take up to 30 seconds. Once the light remains steady, the robot is ready to connect.

Figure 9: Power button location

2. Launch the Control Application

On the control device (laptop, tablet, or smartphone), open the DJI Robomaster app or Scratch-based control interface to establish a connection.

1) Ensure that the device's Wi-Fi or Bluetooth is enabled and that it is connected to the same network as the Robomaster S1.
2) In the Robomaster app, select the Robomaster S1 from the list of available devices to establish a connection.
3) Wait for the app to display a confirmation message that the connection has been successfully established.

3. Log In to the System (if applicable)

If the system requires a user to log in for personalized settings or data tracking, follow these steps:

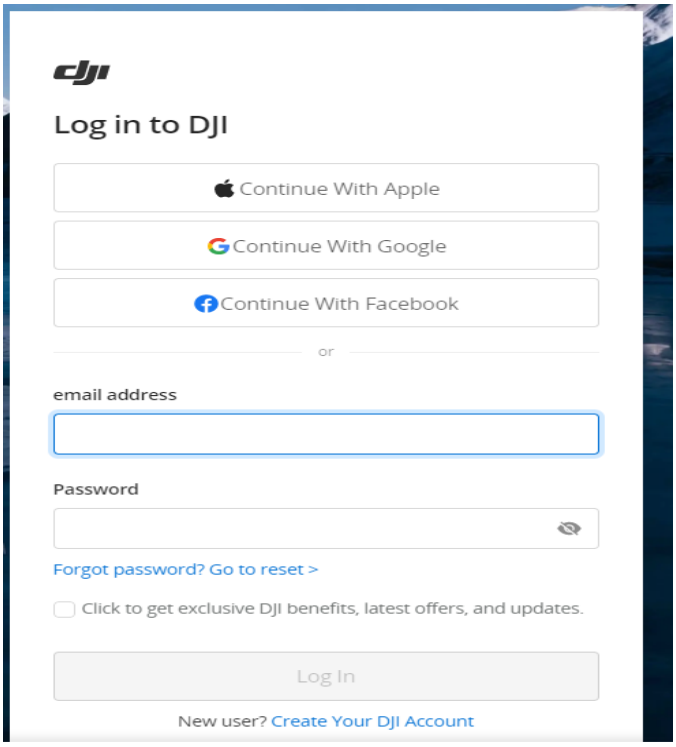
1) On the login screen, enter the User ID or username and password provided during registration.
2) Click the "Log In" button to access the system dashboard.
3) If the user does not have an account, select "Create Account" and follow the prompts to register a new user ID. This process typically requires an email address, username, and password.

4. Changing or Resetting a Password (if applicable)

If the user needs to change or reset their password, they can do so through the following steps:

1) Navigate to the Settings or Account section within the Robomaster app.
2) Select "Change Password" and enter the current password, followed by the new password. Confirm the new password to complete the change.
3) If the user has forgotten the password, click on the "Forgot Password" link on the login page.
4) Enter the registered email address and follow the instructions in the password reset email to set a new password.

Figure 10: Login page



5. Initialize System Functions

Once logged in, the user may need to initialize specific system functions:

1) Set the travel mode (e.g., “Free Mode” or “Target Identification Mode”) through the control dashboard.
2) Adjust settings such as gimbal rotation speed, exposure level, and sound effects based on the operating environment.
3) Ensure that the robot is ready to perform tasks by checking the battery level and system diagnostics.

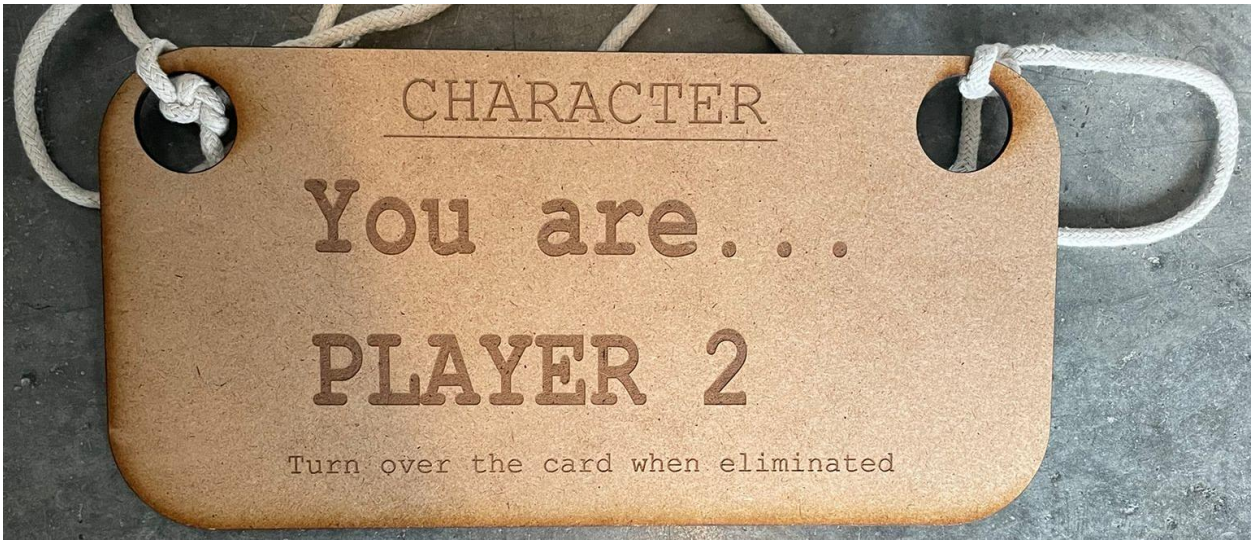
By following these steps, the Robomaster S1 will be properly powered on, connected, and ready for operation, with user credentials securely managed.

3.4 System Organization & Navigation

3.4.1 Physical Features

The physical side of the system is split into three items: Character Cards, Event Cards and Props.

Figure 11: Character Card



Character Cards are MDF boards tied to a piece of string. These are used for players to be aware of their player number. On the back of these cards is a red and white symbol. When players are eliminated, they must flip the card over for the Robomaster to identify as targets. For more information, see 4.2.2 Method of Elimination.

Event Cards are similarly made MDF boards, but much smaller. For each task, there is a pair of cards: one stating the prompt and choices, the other stating the consequences to said choices. These are then placed in props, which are MDF board-made boxes. The boxes state the task location with engraving. In each task, players must open the boxes and read the cards. For more detailed instructions with set-up, see 3.3.1 Physical Set-Up; for their application within the game, see 4.2.1 Task Locations.

3.4.2 Digital Features

This software prototype for the Robomaster S1 is designed to ensure intuitive navigation and efficient interaction with the robot's core functionalities. The system is divided into distinct components accessible through a central system menu, allowing users to seamlessly operate, control, and troubleshoot the Robomaster. Each feature is carefully organized to facilitate ease of use, especially for users with varying levels of technical expertise.

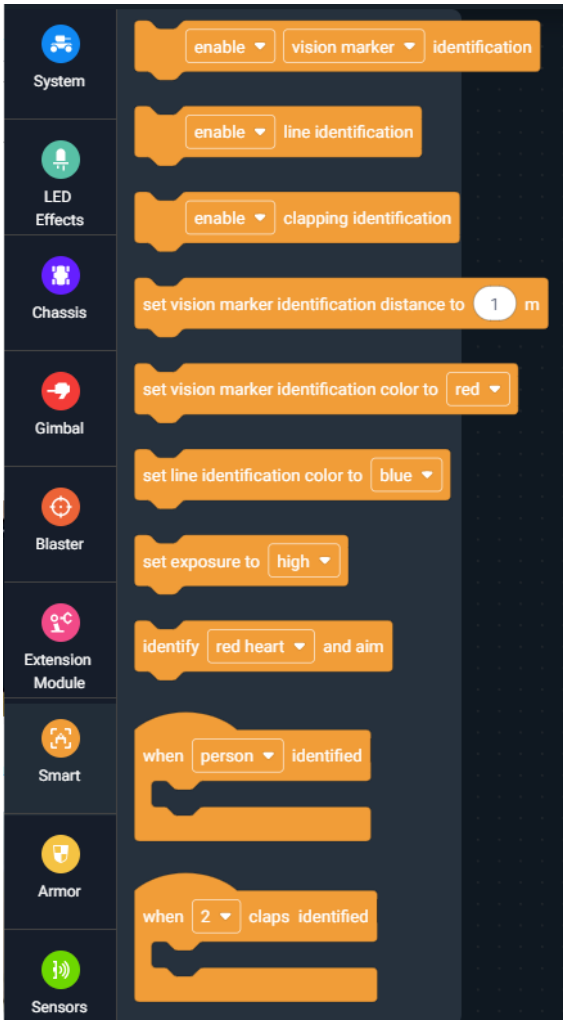
3.4.2.1 Navigation tabs to Main Functions

Navigation between the system's primary functions is structured through a series of well-defined tabs. These tabs are designed to ensure that users can efficiently access all necessary features without confusion. Below are some of the tabs of the system and what they control.

3.4.2.2 Smart

The "Smart" section is accessible from the home page and allows users to activate the vision marker identification system. Once activated, the system continuously scans for targets. If a target is identified, the system prompts users to engage with a single-shot infrared beam.

Figure 12: Smart tab with features



3.4.2.3 Movement and Gimbal Control

Users can navigate to the movement and gimbal control interface via a dedicated button labeled "Control." From this interface, users can manually adjust the robot's movement direction, gimbal rotation speed, and pitch angle using on-screen sliders or directional buttons.

3.4.2.4 Gimbal

A "Gimbal" tab provides access to various gimbal configurations, such as adjusting pitch and yaw angles, modifying gimbal rotation speed, direction of rotation. These settings are clearly visible for ease of use, allowing users to quickly find and modify specific parameters.

3.4.2.5 Command

The "Command" section is where the control flow statements are located. It contains loops, if statements, and stop command.

3.4.2.6 Operators

The "Operators" section is where users change the value of any variables and compare variables to each other.

3.5 Exiting the System

3.5.1 Physical Exit

When the game experience has completed, place Event Cards into their respective props. (i.e. Hospital cards should return to the Hospital prop) It is advised that the pieces be placed in a manner to reduce set-up time for future use. Refer to Accessing/Setting Up the System for set-up requirements.

3.5.2 Digital Exit

Properly exiting and shutting down the Robomaster S1 system ensures that the robot's hardware and software remain in optimal condition, prevents data loss, and avoids potential damage to components. The following steps outline the actions required to safely turn off the system:

1. Stop All Active Processes

Before shutting down, ensure that all active processes, such as target identification, movement, and gimbal rotation, are stopped. This can be done by navigating to the Control Dashboard and pausing or terminating any ongoing commands.

1) If the system is in "Free Mode" or "Target Identification Mode," switch it to an idle state by pressing the "Stop" button on the control panel.
2) Wait for the robot to cease all movement and for any gimbal rotation to return to its neutral position.

2. Save Progress and Settings (if applicable)

If any configurations, settings, or adjustments were made during the session, navigate to the Settings menu and select "Save Settings." This ensures that any modifications are preserved for future use.

1) Check that all logs or recorded data are stored properly.
2) If using the Robomaster app, sync data with the user account to prevent data loss.

3. Disconnect from the Control Device

To prevent abrupt disconnections, properly terminate the connection between the Robomaster S1 and the control device (laptop, tablet, or smartphone). This can be done through the Settings menu:

1) Select "Disconnect" to safely sever the link between the robot and the device.
2) Wait for confirmation that the connection has been terminated.

4. Turn Off the Robomaster S1

Once all processes have stopped and the connection is severed, power down the Robomaster S1 using the physical power button on the robot:

1) Press and hold the power button for 3–5 seconds until the status indicator light turns off.

2) Ensure that the system is fully powered down before handling or storing the robot.

5. Shut Down the Control Device (optional)

If desired, the control device (laptop, tablet, or smartphone) can also be shut down or put into sleep mode after the robot has been powered off.

6. Store the Robot Safely

After powering down, store the Robomaster S1 in a clean, dry location. Ensure that all components, such as sensors and wheels, are free of debris, and charge the battery if necessary to prepare for the next use.

By following these steps, users can ensure a safe and proper shutdown of the Robomaster S1, preserving the integrity of both the hardware and software components.

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4 Using the Game

The following sub-sections provide step-by-step instructions on how to use the various functions or features of The Grand Extraction.

4.1 Storyline

The following consists of a simplified description of the storyline. For more detailed descriptions, see 3.1.2.2 During-Experience Section.

4.1.1 Prologue

The game is set in a city under siege by enemy forces deploying Lethal Autonomous Weapon Systems (LAWS). Following an official evacuation order from your government, your objective is to navigate through the city and reach the designated extraction point. To survive, you must complete a series of critical tasks, each integral to your progress and safety.

4.1.2 Tasks

General Rules:

- Players will engage in **three scenarios**, each involving their own critical decisions.
- The group collaborates during the first two scenarios and then makes an individual decision during the final one.
- Decisions impact the survival of you and your team.

Table 6: Scenario description chart.

Scenario 1: The Police Station	
Task:	Contact authorities to locate the extraction point.
Decision:	Use the **landline** or **computer**.
	○ **Landline**: Traced by the Robomaster, leading to the elimination of one player. ○ **Computer**: Safe option due to the VPN masking location.
Scenario 2: The Hospital	
Task:	Decide whether to stay and assist an injured player or leave them behind.
Decision:	○ **Stay**: Results in the death of two players. ○ **Leave**: The injured player is eliminated.
Scenario 3: The Government Building	
Task:	Each player must decide to escape during the day or wait until nightfall.
Decision:	○ **Daytime Escape**: Ensures survival. ○ **Nightfall Escape**: Results in death due to the robot's thermal sensors.

4.1.3 Epilogue

The surviving player(s) is/are extracted. For the rest of their live(s), they attempt to find the person responsible for the activation of LAWS. Unfortunately, years and years have passed, yet no one is convicted and made responsible in the court of law due to the lack of evidence. You have survived today, but are you always safe from the LAWS?

4.2 Gameplay

The following consists of gameplay instructions for each task. For a clear visual representation of gameplay, click here to see a simulated video.

4.2.1 Task Locations

Figure 13: Prototypes of props. Event Cards are placed within.

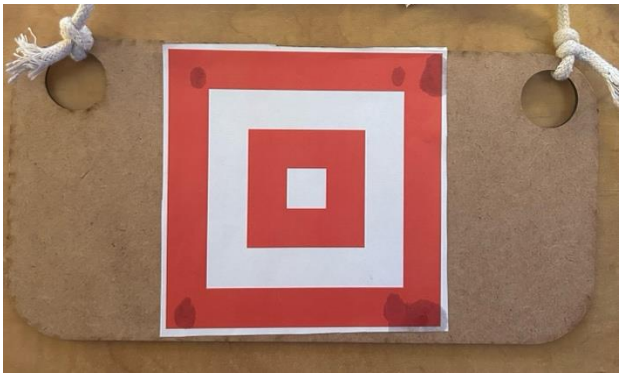
In The Grand Extraction, players will engage in three distinct scenarios. During the first two scenarios, the group must collectively decide between the two presented prompts. These prompts are written on Event Cards, which are placed in respective props.

Figure 14: Event Cards

Players must then make decisions based on the prompts. These prompts carry significant consequences, as one option may result in the death of individual members or the entire group, while the other may ensures everyone's survival. In the final scenario, each player faces an individual decision, with one choice leading to survival and the other resulting in death.

4.2.2 Method of Elimination

Figure 15: Elimination symbol present on the back of the Character Cards.



1. The Robomaster targets the player with the lowest assigned number.
2. The eliminated player must reveal their Target card.
3. The Robomaster activates its laser pointer and plays a gunshot audio to symbolize elimination.

⚠ *The Robomaster S1 emits a strong, green laser towards the eliminated player in this process. Strobing effects may affect photosensitive players.*

5 Troubleshooting & Support

This section outlines the recovery and error correction procedures necessary for maintaining the Robomaster S1. It is designed for users who may not have an engineering background but need clear, actionable steps for troubleshooting common issues, performing maintenance, and accessing support.

5.1 Error Messages or Behaviors

Several common errors may arise during the operation of the Robomaster S1, each with specific causes and corrective actions. One frequent issue is that the gimbal does not rotate as expected. This is often caused by setting the gimbal rotation speed too high or using angles that exceed the hardware's limits. To correct this, the user should ensure the gimbal rotation speed is kept within safe limits, such as reducing it from 30°/s to a more conservative value.

Another issue that users may encounter is the failure of the system to identify a target. This problem is frequently due to poor lighting conditions or incorrect exposure settings. Ensuring that the exposure is set to "high" or adjusting it to suit the environment's lighting can resolve this problem.

Lastly, there may be instances where the Robomaster does not respond to an identified target, which is typically due to a "logic error" within the loop structure of the code. Users should carefully review the logic in the "repeat" blocks to ensure that the condition for identifying a target is functioning as intended.

5.2 Special Considerations

Several special considerations should be considered during the operation of the Robomaster S1 to prevent errors and ensure smooth performance. It is important to operate the Robomaster in a well-lit, open area with minimal obstacles to prevent interference with the target identification process. Additionally, users should ensure that the battery is fully charged before extended use, as an insufficient charge may lead to unexpected shutdowns.

Another critical consideration is respecting the gimbal's rotation limits. The gimbal should be kept within its specified range, such as -45° to 45°, to prevent mechanical damage. Ignoring these limits could result in hardware failure.

5.3 Maintenance

Regular maintenance is crucial for the continued performance and longevity of the Robomaster S1. Users should routinely inspect the wheels, gimbal motors, and infrared sensors for dust and debris, cleaning them as necessary to ensure optimal operation. Additionally, it is important to update the firmware regularly via the DJI Education Hub to maintain compatibility with the latest software updates and features.

Periodic code reviews are also recommended to identify and correct any logical errors or redundant loops that may have been introduced during programming. These reviews help maintain efficient and error-free operation.

5.4 Support

While The Grand Extraction does not involve many technical operations, emergency assistance and system support can be acquired through the following contact information. Please include "Support: The Grand Extraction" in the subject line. If available, provide a carbon copy email to other team members.

Please be aware that the following contact information is for system support purposes. BOOM reserves the right to take legal action if any form of misuse were to be found.

Table 7: Contact information and area of focus of BOOM members

Name	Email	Area of Focus
Isaac Chan	nchan098@uottawa.ca	Laser Cutting (Character Cards and Event Cards)
Spencer Irwin	sirwi010@uottawa.ca	General Inquiries, Storyline and Gameplay
Trevor Lo	tlo067@uottawa.ca	Laser Cutting (Props)
Adam Nasimi	anasi028@uottawa.ca	Robomaster S1 Implementation

Please note that BOOM is not responsible for the troubleshooting of Robomaster S1. For more information regarding the functionality of Robomaster S1, please contact DJI Edu Hub.

In the event of an emergency or technical issue, users can seek assistance through various support channels. For urgent issues, the Robomaster support team can be contacted via DJI's official website. Users should also maintain contact with the designated support personnel through the information provided above.

For reporting problems, users should document the issue in detail, including screenshots of the code, error logs, and information about the operational environment when the issue occurs. This information can be submitted through the Robomaster S1 app's feedback option or via official support channels.

6 Product Documentation

The following section consists of required materials, equipment and instructions regarding producing The Grand Extraction based on BOOM's prototypes.

More information with instructions and testing can be available in Deliverable F, G and H. See Appendix I: Design Files.

6.1 Robomaster

6.1.1 BOM (Bill of Materials)

The following lists potential materials related to the Robomaster S1 implementation required for producing or reproducing The Grand Extraction. Supplementary or alternative materials not listed in the BOM may be required. Price, source, and quantity may also vary in different production approaches.

Table 8: Bill of Materials for Robomaster S1 implementation

Material	Description	Quantity	Source	Price (CAD)	Remarks
Paper	Used for printing Vision Markers for target identifying	Varies	Varies	$5 (may vary)	Paper can be replaced with other printing materials. Non-reflective materials are suggested.

6.1.2 Equipment List

The following lists equipment related to the Robomaster S1 implementation required for producing or reproducing The Grand Extraction.

Table 9: Equipment List for Robomaster S1 implementation

Equipment	Description	Quantity	Source
DJI Edu Hub	Simulation and programming software for Robomaster S1	1	DJI
Robomaster S1	Physical robot used for simulation of LAWS	1	Makerspace

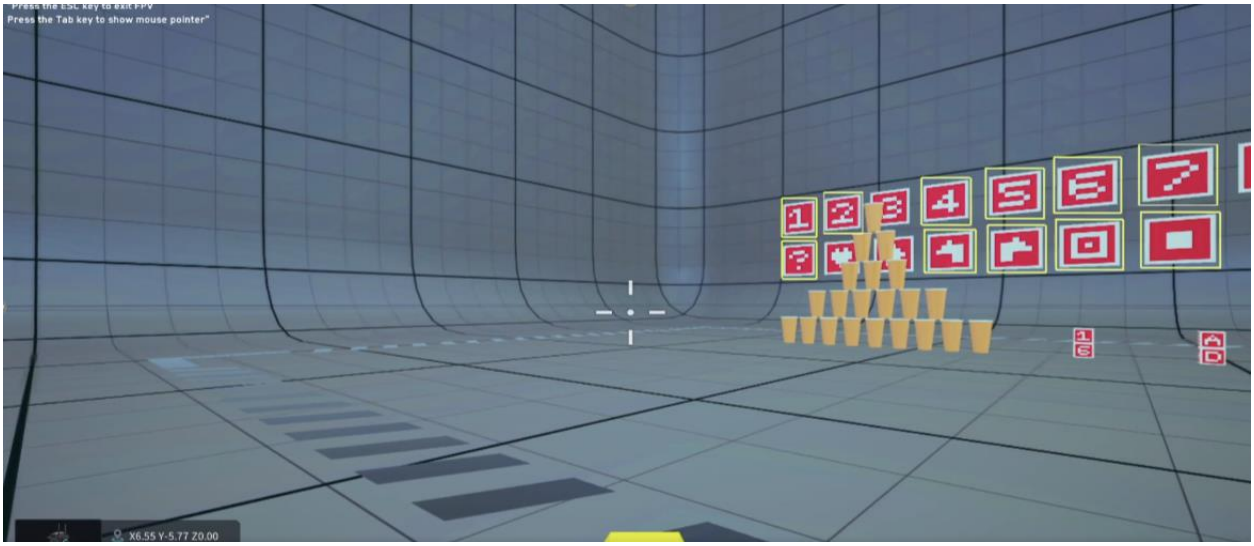
6.1.3 Instructions

During the production of the Robomaster S1 code for The Grand Extraction, multiple steps and repeating sequences are required.

Initially, one should separate the code into different modules. In The Grand Extraction, they were separated as "targeting", "rotating" and "shooting". The codes were then developed and tested separately.

For early phases of prototyping, simulations were done through DJI Edu Hub's application. This confirms whether the code would work properly in optimal cases.

Figure 16: Screenshot from Robomaster S1 simulation



In later phases, the Robomaster S1 is put to physical testing. This is to show whether the non-targeting code remains operational. For BOOM, testing was done initially with rotating. Alterations with speed and angle was done subsequently to ensure the turret rotates in the desired positions.

When physical props were available, testing with distance and scanning were carried out. A major criterion in testing is the range of identifying symbols and the effects of glare. It is important for the test to give near-expected results. For example, the symbols should be recognised by the Robomaster S1 within the 3-metre radius. However, metrics close to 3 metres are still acceptable. Such testing was done when a new environment is used for The Grand Extraction. If the environment does not give positive results, alterations to the environment is required.

6.2 Cards and Props

6.2.1 BOM (Bill of Materials)

The following lists potential materials related to the props required for producing or reproducing The Grand Extraction. Supplementary or alternative materials not listed in the BOM may be required. Price, source, and quantity may also vary in different production approaches.

Table 10: Bill of Materials for Props

Material	Description	Quantity	Source	Price (CAD)	Remarks

MDF Boards	Character and Event Card production	3	Makerspace	Free	In the production of prototypes, MDF Boards are purchased for free at Makerspace.
Rope	Hanging Character Cards on players	1	Dollarama	$2	-
Super Glue	Event Card production	1	Dollarama	$3	-

6.2.2 Equipment List

The following lists equipment related to the props required for producing or reproducing The Grand Extraction.

Table 11: Equipment List for Props

Equipment	Description	Quantity	Source
Inkscape	Software for creating documents for laser cutting	1	Inkscape
Epilog Laser Helix 24”×18” 60W	Laser cutter for creating props and engraving text on MDF boards.	1	Makerspace

6.2.3 Instructions

In the production of MDF props, there are three major steps.

First and foremost, a document must be created. This can be done through the Inkscape software. The document created would be in SVG format and should be exported to a thumb drive in a PDF format. Note the document properties before moving on to the following step.

Next, import the PDF file to the laser cutter of your choice. Follow the guided settings on the laser cutter. This may vary between brands and models. Be aware that the document may be too complex at times. If so, separate documents into different ones and do them separately. Multiple cuts along with design updates are advised. This helps enhance the quality of the physical product.

Figure 17: Prototype for the early design of a Character Card

Finally, while this is an optional step, it is recommended that some pieces be glued together. Event Cards must be glued together. Character Cards, on the other hand, should not. It is optional for props to be glued together. As this depends on whether the user opt for an easy set-up or a smaller storage size.

6.3 Testing & Validation

6.3.1 Robomaster Testing

In the Robomaster S1 part of The Grand Extraction, two major tests were done. These include a test on whether the Robomaster S1 could rotate as expected and whether the targets can be identified. The following table includes the method of testing and the results.

Table 12: Robomaster S1 testing criteria, metrics, and results

Criteria	Metrics	Test and Result	Pass/Fail
When the Robomaster runs the code, does it demonstrate non-targeting features?	Boolean	The Robomaster is capable of rotating. However, due to the design of the Robomaster, its rotation is not smooth. Nonetheless, the group expects this to be a minor problem and will not pose as an obstacle in the final product.	**PASS**
Can the Robomaster detect the character cards, if so, does it continue to run its following code?	Boolean	The Robomaster works exactly as the DJI Edu Hub simulation. However, distance and glare are major factors in whether the cards are recognised.	**PASS**

6.3.2 Card and Prop Testing

For the testing regarding the cards and props, physical tests were done. For simplicity, as both cards and props were made with the same material and underwent the same testing, the following table will be an amalgam of both unless stated otherwise.

Table 13: Cards and Props testing criteria, metrics, and results

Criteria	Metrics	Test and Result	Pass/Fail
PROPS ONLY Size	**PROPS ONLY** Area (cm^2)	**PROPS ONLY** The laser cutting document is put into production. The final product is then measured to ensure it can easily fit in a backpack.	**PASS**
Can the MDF cards withstand the average weight of a player?	Weight (kg)	When average human male (50-60 kg) steps on the MDF props for 3 times, there is no observable damage.	**PASS**
Do the MDF cards easily get scratched from sharp objects?	Boolean	When the cards and props are scratches with sharp nails and keys, there are no observable changes.	**PASS**

7 Conclusions & Recommendations for Future Work

During the production of The Grand Extraction, BOOM overcame several obstacles. In initial stages of production, BOOM had decided to 3D-print props for a more immersive experience. However, feedback with the instructor and peers yielded concerns, most notably towards the estimated print time. BOOM then pivoted from 3D-printing to laser cutting, which gave a less immersive environment, but exceed other user needs with flying colours. With laser cutting, not only can the props be easily broken apart and assembled but also reduce the storage size. This enhances the flexibility and portability of the game, a major area of focus of the project.

For future work, BOOM recommend a clear production schedule and cost estimation prior to prototyping. Time for laser cutting a simple piece varies and heavily depends on the availability of equipment. With a clear schedule and phase, different pieces can be done at various times to facilitate testing with Robomaster S1.

Another important aspect of The Grand Extraction is the use of Robomaster S1. Due to the lack of availability during prototyping and uncertainty regarding the Robomaster S1's functionality, many testing had to be done based on assumptions from simulations. If BOOM had given more production time, more thorough testing and production of physical prototypes would be done, optimizing the target identification feature of the game.

A final important suggestion from BOOM would be to keep the storyline simple. A recurring concern from clients, the instructor and peers are the concern over a complicated storyline confusing potential user. As a result, BOOM removed multiple features. If future work and/or adjustments were to be applied on The Grand Extraction, simplicity is an essential part behind each feature of the game.

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Appendix I: Design Files

Throughout the production of The Grand Extraction, BOOM followed a step-by-step process. In each step, a deliverable is produced. Such deliverables are critical documents that help BOOM evaluate their weekly work and create a strong baseline for later production phases. These deliverables are available on MakerRepo.

Table A: List of Design Files available on MakerRepo

Document Name	Document Location and/or URL	Issuance Date
Deliverable A – Team Contract	Link	2024-09-20
Deliverable B – Needs Identification and Problem Statement	Link	2024-09-29
Deliverable C – Design Criteria and Target Specifications	Link	2024-10-06
Deliverable D – Conceptual Design	Link	2024-10-13
Deliverable E – Project Schedule and Cost	Link	2024-10-27
Deliverable F – Prototype I and Customer Feedback	Link	2024-11-03
Deliverable G – Prototype II and Customer Feedback	Link	2024-11-10
Deliverable H – Prototype III and Customer Feedback	Link	2024-11-24
Deliverable I – Design Day Presentation Material	Link	2024-11-27
Deliverable J – Project Presentations	Link	2024-11-11
Final Code	Link	2024-11-28

Appendix II: Trello Link

During the production of "The Grand Extraction," BOOM made use of the Trello platform to keep track of weekly tasks and upcoming schedule. Click here for the hyperlink to the board.

Appendix III: Task Schedule

The following lists the task schedule beginning in the week of October 20 – 26 and includes deliverables following the creation of a Global Concept, client feedback, and prototyping steps. Aside from the order of tasks, their dependencies, due date, duration, and the group member(s)-in-charge are also included. For simplicity, the order of tasks listed below are in order of the due date.

Table B: Plan for Tasks from October 20 to December 7, 2024

#	Task	Dependencies	Due Date	Duration	Group Members
0	*Deliverable D*	*Deliverable D is done prior to the range of this table*			
1	Client Meeting #2	Task 0	2024-10-24	1 session	Everyone
2	Adjust Global Concept	Task 0, 1	2024-10-26	2 days	Lo
3	Deliverable E: Project Plan & Cost	Tasks 0, 1, 2	2024-10-27	7 days	Everyone
4	Build Prototype I	Task 3	2024-10-31	4 days	Everyone
5	Customer Feedback (Prototype I)	Task 4, 5	2024-11-02	1 day	Chan
6	Deliverable F: Prototype I and Customer Feedback	Tasks 4, 5	2024-11-03	7 days	Everyone
7	Client Meeting #3	Task 0	2024-11-05	1 session	Everyone
8	Build Prototype II	Task 7	2024-11-08	5 days	Everyone
9	Customer Feedback (Prototype II)	Task 8	2024-11-09	1 day	Nasimi
10	Deliverable G: Prototype II & Customer Feedback	Tasks 7, 8, 9	2024-11-10	7 days	Everyone
11	Deliverable J: Project Presentations	Task 10	2024-11-15	4 days	Everyone
12	Build Prototype III	Task 10	2024-11-22	12 days	Everyone
13	Customer Feedback (Prototype III)	Task 12	2024-11-23	1 day	Irwin
14	Deliverable H: Prototype III & Customer Feedback	Tasks 12, 13	2024-11-24	14 days	Everyone
15	Deliverable I: Design Day Presentation Material	Task 14	2024-11-27	3 days	Everyone
16	Design Day	Task 15	2024-11-28	1 session	Everyone
17	Deliverable K: User & Product Manuals	Task 14	2024-12-03	5 days	Everyone

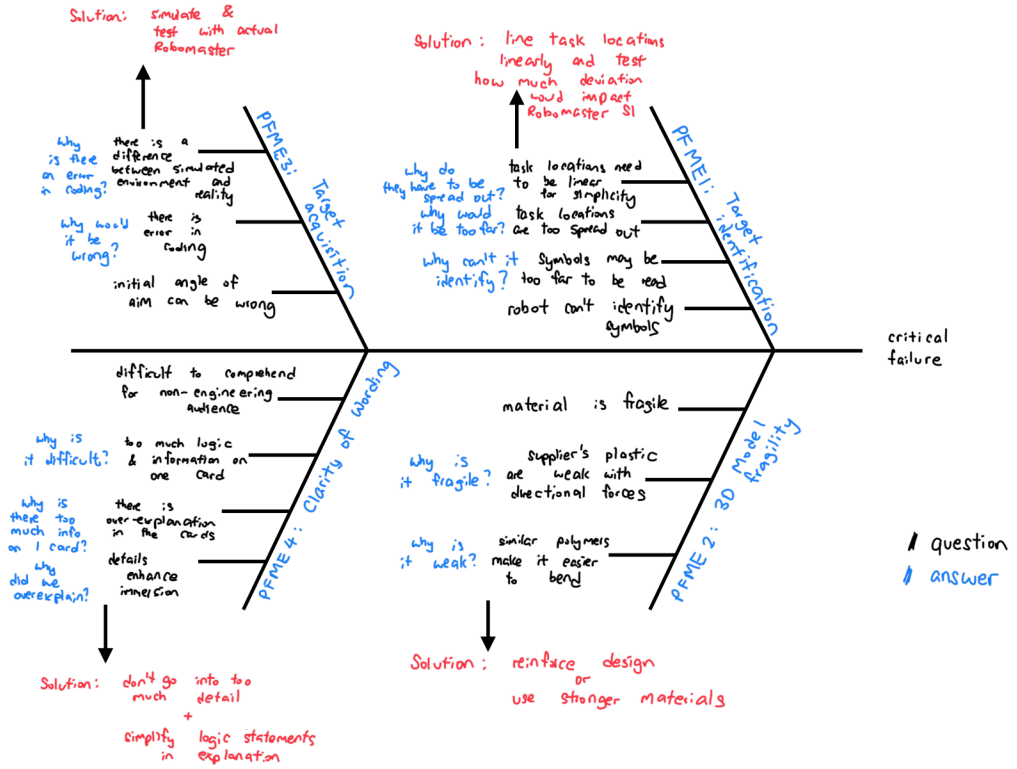
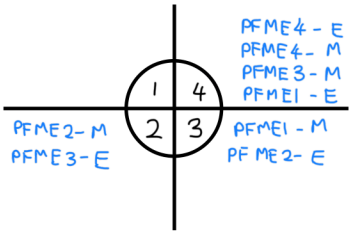
Appendix IV – PFME Analysis

The following consists of a Fishbone diagram derived from the group's Predictive Failure Modes and Effects (PFME) analysis. The Fishbone diagram narrows the potential risks down to four major PFMEs:

target identification, 3D model fragility, target acquisition and clarity of wording. Each aspect is then further discussed to pinpoint the root problem.

With a clear idea of potential risks, each of the PFME is then given a score from 1 to 4 in terms of effect and mode. A table is then drawn to demonstrate which PFME, and its aspects are of utmost importance and should be a priority in prototyping.

Figure A: Fishbone Diagram derived from PFME analysis



PFME	Effect	Mode
①	4	3
②	3	2
③	2	4
④	4	4