

**Deliverable F:**  
**Prototype I & Customer Feedback**

Daniella Centurione

Maddox Dansereau

David Maksuti

Vanya Micic

Jake Schindel

Faculty of Engineering, University of Ottawa

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Dr. Muslim Majeed

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## Abstract

*This report examines ethical concerns surrounding the implementation of autonomous weapon systems in war. It highlights the risks these systems pose to global stability, safety, and human rights. Mines Action Canada, CRAiEDL, and University of Ottawa students have collaborated to aid in educating people on this topic.*

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## 1. Introduction

Our group's project aims to shift the perception of autonomous robotics away from military applications and towards beneficial civilian uses. After significant brainstorming and conceptual designing, we decided to repurpose the Robomaster S1 to serve as a litter detection robot, inspired by the Pixar character Wall-E. This report details the development and testing of our first prototype. Here, we analyze important systems/components, assess the effectiveness of our approach, and determine possible improvements based on prototype testing.

## 2. Summary of Client Feedback

During the second client meeting, we received feedback on our proposed design concepts. In general, the client was equally happy with all the designs that we shared; however, they emphasized that whatever design we choose to go with should be realistic and achievable within the scope of this course. While this feedback was very general, it was useful to us since it indicated to us that some of our concepts were over-ambitious given the time, resources, and knowledge we currently possess. We took this into account when we decided to further pursue the litter "Wall-E" robot design, as this was the most straightforward and achievable design of those that we had come up with. In addition to recommending we choose an easily achievable design; the client also gave feedback about us altering the appearance of the robot. They liked the idea of making the robot look silly, since it changes one's perspective of the robot in a positive way (rather than looking like a weapon, the robot looks like a children's toy). With this feedback in mind, we will try and leverage the appearance of the robot. Our future design choices regarding the robot's appearance will focus on making the robot appear non-threatening and friendly, as this will improve our final solutions effectiveness at changing peoples' views on automated robots.

## 3. Prototype 1 Overview

Laser Cut Sign: To take away from the hostile look of the robot, a simple "Wall-E" label/sign was laser cut to be mounted at the front of the robot. In later prototypes, further improvements to the appearance will be made (notably, the recognizable Wall-E goggles).

Sound Effects: To promote empathy for the robot and to make it more approachable, the DJI app was used to upload custom, non-threatening, "Wall-E" themed sound effects and play them through the Robomaster S1 speakers. These will later be implemented into the main code section for different uses (played when objects are successfully detected, for example). Currently, the default sounds are being used as placeholders in the main code.

Movement code: For this prototype, our goal was to develop a simple code that enables the robot to detect a coloured line and follow it.

Vision Recognition/Sorting Code: For the first prototype, our goal was to create a code that allowed the vision recognition system to detect either garbage (represented by the letter 'G') or recycling (represented by the letter 'R'). A specific response was also developed based on what symbol is being detected (flashing red chassis lights for garbage, alongside a placeholder audio cue; similarly, flashing blue chassis lights for recycling, and another audio cue).

## 4. Analysis of Critical Components and Systems

### -Robot movement code-

The software that controls the robot's movement to follow a given path or line is a very critical part of our prototype. Making sure the robot's movement can follow a given path is critical for our use, as in practice it would follow for example a park path. It should be able to be given a relatively simple path and be able to comply with said orders.

### -Vision Markers-

The vision markers will be how the robot is able to detect and distinguish "garbage". The detection symbols must work as failure would lead to 'litter' being left behind, which is the whole point of our robot. It should be optimized for accuracy, distance and different lighting conditions to work in lightly varying environments.

### -Robot Appearance-

The robot's appearance, more prominently the headpiece, will be used to take attention away from the weapon attachment, inherently taking away from the message of war the original robot could be perceived as giving. It will be a non-permanent attachment that is made with the inspiration of wall-E and will be easy to attach/ remove. Testing will make sure it doesn't block the vision sensor, as well as making sure it will stay on.

### -Litter/prop creation-

The props will be made from laser cut boxes and will serve as objects that the robot will identify. Having varying sizes of these will help us find our bottom line on how big the garbage would have to be to be seen by our robot.

### -Sound effects-

Sound effects will be used to alert the human operator of garbage, as well as push the Wall-E appearance with sound effects. This brings a function use as well as helps better the image of our little robot friend.

## 5. Documentation

### 5.1. Prototype Test Plan

Tests					Prototypes			
N°	Objective (Why)	Test Method (What)	Usage of Results (How)	Test Duration (When)	Type (What)	Objective (Why)	Fidelity	When to realise
1	Testing robots movement	The purpose of obstacle-lined path movement is to test and evaluate the	Use the results to modify movement control and	1-1.5 hours (Feb 28)	Focused physical	Ensure smooth and smooth path following by	low	Feb 26

		robot's capacity to navigate and adapt to different types of terrains. This is important because this robot is supposed to work independently in unpredictable environments, striking a balance between safe and efficient movement. If it does not offer reliable movement, it meets with its first failure.	traction settings to optimize accuracy in riding, thereby allowing robot movements with a high degree of energy and safety.			the robot without any errors.		
2	Checking symbol detection	The robot must accurately identify symbols for communication with its environment. Without this ability, we cannot make appropriate judgements based on these decisions, such as stopping at designated points or maneuvering around terrains. This is highly critical in the proper application in practical scenarios.	Optimizing camera settings and enhance detection software to improve reliability, ensuring that the robot's visual data interpretation is consistent.	1-1.5 hours (Feb 28)	Focused analytical	Ensure correct identification and interpretation of symbols by the robot as these are crucial for autonomous decision-making.	medium	Feb 27
3	Evaluating headpiece impact	We will concern ourselves that putting a headpiece would not interfere with the robot's vision system. Otherwise, the robot may later have difficulties in adjusting objects or recognizing certain symbols, which may result in mis navigation. The design should ensure that all components are functioned properly.	If the headpiece obstructs the camera, or the detection accuracy is affected, the design should be modified to the necessary need.	1-1.5 hours (Feb 28)	Focused physical	Ensure that the headpiece does not obstruct the vision of the robot on which it can rely for proper navigation.	low	Feb 27
4	Testing the chassis light pattern	The light of the robot is very important in the communication process of actions to its users. Anything that goes wrong with them	Optimal lighting patterns need to be installed and response timing to	1-1.5 hours (Mar 7)	Focused physical	Make sure the function of the lights is visually available so that the	low	Mar 4

		could lead to confusion or safety problems in its operating environment, especially in low visibility.	ensure clear real-time feedback, when the lights are fulfilling their purpose.			robot knows it has detected an object.		
5	Testing the response to the litter	To detect and react to objects in the way, such as the litter, the robot should avoid all accidents or incorrect activities. If not, it will effectively undermine its functional safety and stop the operation of the robot.	Enhance the object detection sensitivity and the response time to allow for effective avoidance or braking for the robot.	1-1.5 hours (Mar 7)	Focused physical	The obstacle detection and avoidance capability of the robot must be valid in a way that no unintended collision occurs.	medium	Mar 5
6	Improving movement stability	Variations in robot mobility could render any kind of reliable functioning under given conditions. Testing on different terrains assures adaptability thus keeping it from failing unexpectedly in real-time applications.	Calibrating motion algorithms and sensor feedback to provide the best smooth and predictable motion.	1-1.5 hours (Mar 7)	Focused analytical	Ensure predictability of the robots' behaviours on different terrains, preventing any erratic actions.	medium	Mar 5
7	Optimizing the detection range	To detect the symbols from the right distance so the robot could react instantly. Otherwise, if the distance is too short, it would not be quick enough and might miss essential signs used for navigation.	Adjust camera focus, software settings, and lighting compensation to achieve maximum detection consistency to improve the detection range.	1-1.5 hours (Mar 7)	Focused analytical	Make sure the robot can identify markers at some working distance, preventing any delays.	medium	Mar 5
8	Finalizing the robots' headpiece design	A perfectly designed headpiece must be visually appealing with a proper concept for usefulness. Contrarily, its sensorial duties may be impaired, making the very presence of a robot less effective and less enjoyable.	A particular sensor ensuring the powerful connection of the headpiece design element naturally seem more favourable.	1-2 hours (Mar 21)	Focused physical	Develop a final headpiece that is aesthetically appealing and functionality without interference.	High	Mar 17

9	Improving the robots' movement	In order for a planned maneuver to be executed properly, the robot must follow paths with a high precision. A higher inaccuracy may mean failed operations by having one miss a stop point or turn in the wrong direction.	Make some refinements, tuning, and speed adjustments to our motor control and path-maintain algorithms in order to optimize movement accuracy.	1-2 hours (Mar 21)	Focused physical	Ensure that the robot has smooth movements without turning errors during navigation.	High	Mar 19
10	Validate the whole systems' integration	Alongside, let every piece of the robot component that we incorporated to work perfectly. The malfunction of just one section brings system malfunction about, which results into unpredictable or unsafe behaviours from the robot.	Test that the movement, detection, and response functions are working in conjunction as it would in the real world.	1-2 hours (Mar 21)	Focused physical	Confirm all subsystems of the robot work the way it needs to work.	High	Mar 21

## 5.2. Prototype Analysis

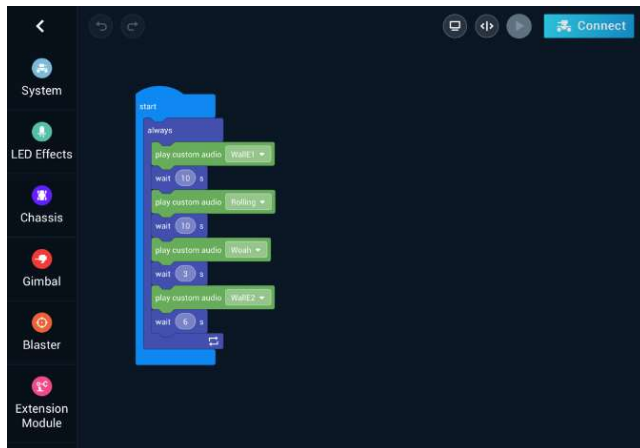
### Robot appearance:



The robot appearance in prototype one was an overall success, our team used Inkscape the design and print a wall-E logo to go on the front of the Robomaster S1 chassis. The picture above shows our first print attempt which was a success as it fit perfectly and was easily added using painter's tape. In our next prototype testing the team is going to build goggles that resemble wall-E's eyes.

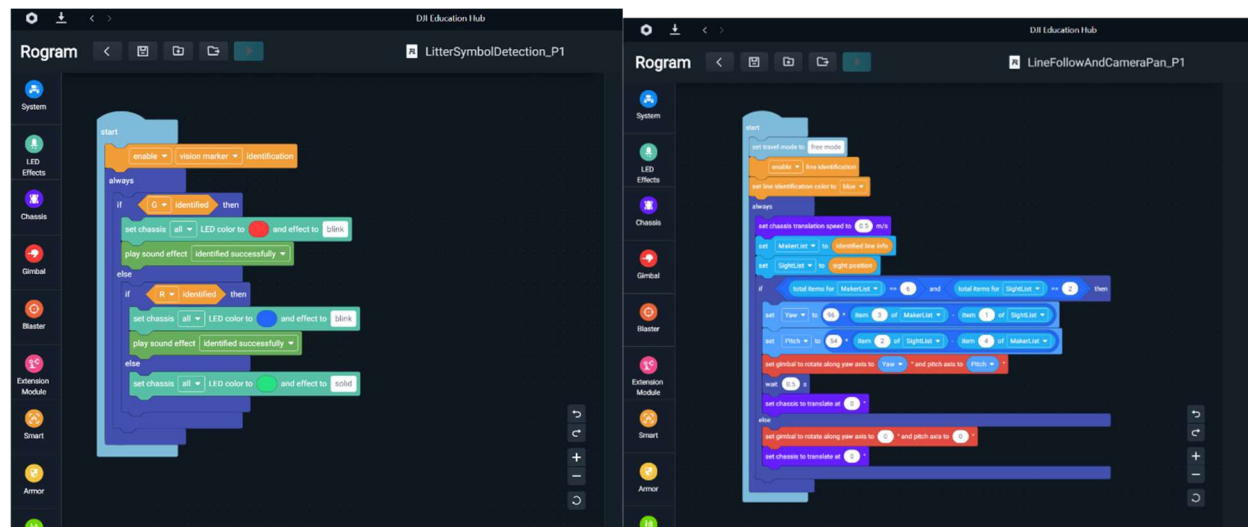


## Sound Effects:



At the end of the prototype testing session, we were able to find and upload all the sounds and voice cues that our robot will be using during our video, these include 2 different versions of the robot saying wall-E, a moving terrain sound and a “woah” sound. We got all of these sounds off of the following site <https://www.voicy.network/official-soundboards/movies/wall-e>. This part of the prototype 1 process took longer than expected as it was difficult and there was not a lot of information online or in the user manual on recording and uploading sounds into the app and then include them in the code. In our next prototype testing the team is going to take these sounds and add them into our movement code blocks to fully incorporate them into our robots functions.

## Robot Movement:



The line tracking code in this section was very successful in the robot’s gimbal would track and move in the direction of the line and it needs no more modification before we add it into the final product. Our team did have trouble with the chassis in the line follow segment part of the code as it did not work as we intended it to. At the end of prototype one the gimbal would follow the line effectively, but the robot would still veer off track because the chassis didn’t fully move as intended. This will need to be edited further and re-tested during prototype 2 to make sure this part of our final product works well.

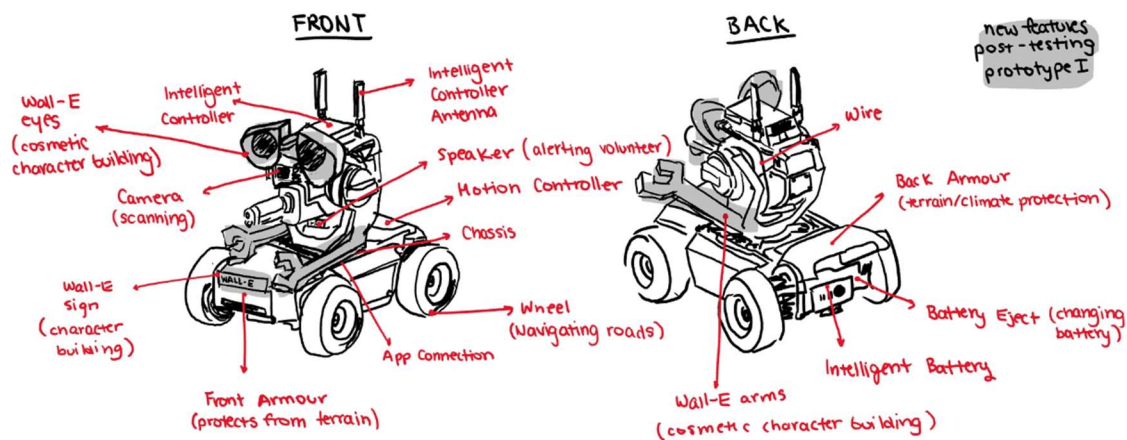
## 6. Prototype Feedback

N°	Prototype Feedback	Test Results	Actual Test duration
1	Motor movement was not smooth; required calibration	Motor jitter reduced after optimizing PWM values	2 hours
2	Structural integrity was weak in certain areas	Reinforced chassis improved durability	1 hour
3	User feedback suggested adding visual interaction	LED indicators were added for better engagement	30 minutes
4	Concerns about how the eyes of the Wall-E robot might affect the functionality of the camera sensor and antennas.	Designed goggles that do not cover camera lens, moved hands to the middle part of the robot that is unaffected by the movement of the head and the tracks.	30 minutes
5	Addition of more complex and useful features to the movement.	Revision of code in scratch to create more complex movement.	1 hour
6	Positive reactions to the Wall-E aspect of the robot.	Brainstorming around Wall-E film and doing additional research to understand how we will tie in themes from the movie.	30 minutes

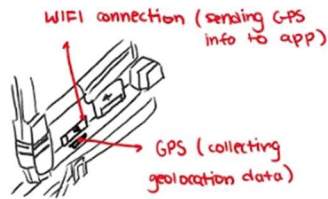
## 7. Post-Testing Updates

Note: Post-Testing Updates included are those that have been changed/updated since the last deliverable. Some features that remained unchanged were excluded.

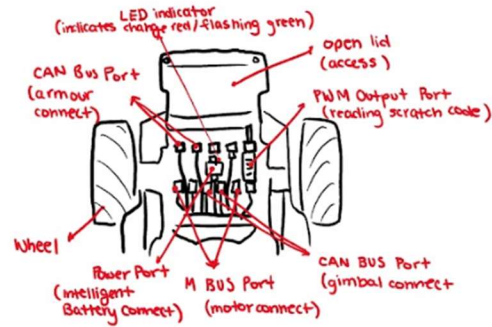
### 7.1. Detailed Design



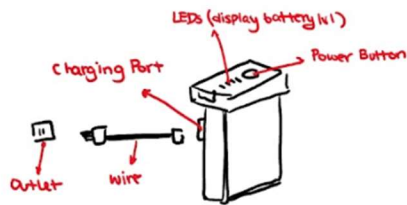
### Connection to App



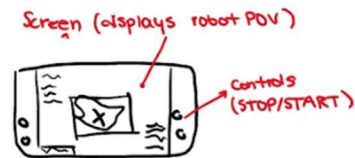
### Motion Controller



### Intelligent Battery System



### Phone Control



## 7.2. Bill of Materials

BOM		
Product	Cost Estimate	Link
Wall-E sound effects	\$0	Free sound links from online. Website link: <a href="https://www.voicy.network/official-soundboards/movies/wall-e">https://www.voicy.network/official-soundboards/movies/wall-e</a>
Wall-E cosmetic features	\$0	Laser-Printed and 3-D printed in Makerspace
Robomaster S1	\$0	<a href="https://www.dji.com/ca/support/product/robomaster-s1">https://www.dji.com/ca/support/product/robomaster-s1</a>
Robot Décor	\$10	Designed and printed in MakerLab or Affordable pre-fab décor
Film Camera	\$0	(previously owned) <a href="https://www.canon.ca/en/products/Video-Cameras---PRO">https://www.canon.ca/en/products/Video-Cameras---PRO</a>
CapCut Editing App	\$0	(previously owned) <a href="https://www.capcut.com/">https://www.capcut.com/</a>
Green Screen		
Litter Prop	\$0	Made from recycled and previously owned materials
OnShape software	\$0	(Free with tuition) <a href="https://www.onshape.com/en/">https://www.onshape.com/en/</a>
DJI Scratch software	\$0	(Free with tuition) <a href="https://scratch3-tello.app/">https://scratch3-tello.app/</a>
Presentation board	\$13	<a href="https://www.staples.ca/collections/presentation-poster-boards-10217">https://www.staples.ca/collections/presentation-poster-boards-10217</a>

## 8. Prototype 2 Test Plan

Tests					Prototypes				Decision Criteria
N°	Objective (Why)	Test Method (What)	Usage of Results (How)	Test Duration (When)	Type (What)	Objective (Why)	Fidelity	When to realise	
1	Improve navigation accuracy	Identify surface properties about motor control.	Adjust the motor speeds.	2 hours	Focused Physical	The chosen core functionalities, together with their feasibility, shall be validated before their final integration.	High	Week 7	The robot is required to follow a defined course with a percentage of 90 Or more accurate results in three trials.
2	Enhance sensor reliability	Find objects from various distances.	Calibrate detection thresholds	3 hours	Focused analytical	Any possible design flaws shall be identified and rectified in the early stages of development.	medium	Week 7	The robot must effectively detect items within various distances, such as 20 cm to 1m, with a minimum of 85% accuracy.
3	Improve environmental adaptability	A test of robotic performance on different surface types (tiles, carpets, grasses) must be performed.	Traction and movement algorithms need to be tuned to the most stable and responsive settings.	2 hours	Focused physical	The robot should be able to optimize under these certain surface types.	medium	Week 8	The robot must navigate 90% of the test course across all surface types without losing stability or getting stuck.
4	Improve user interaction	Check the results of an LED and sound.	Refine interactive elements.	2 hours	Focused analytical	Feedback should be adopted into the prototype evaluation to meet user requirements.	medium	Week 8	The LED and sound cues must function on 100% of detection without any delay.
5	Optimize battery efficiency	Watch for power consumption.	Optimize power settings.	2.5 hours	Focused analytical	Power consumption should be optimized so that performance and battery life	high	Week 9	The robot should work on a full charge for at least 60 minutes while performing tasks.

						may be balanced.			
6	Test load bearing capacity	Weight of structure.	Reinforce material selection.	3 hours	Focused Physical	The structural design must achieve durability and reliability.	high	Week 9	The robot should be able to hold a small amount of load without failure of the structure.
7	Improve response to obstacles	Study sensor reaction to random obstacles.	Improve obstacle avoidance algorithms.	1.5 hours	Focused analytical	The system shall be tested against adaptability to any operating environment.	medium	Week 10	The robot should be able to detect and avoid obstacles within 1 second and reroute itself successfully 95% of the time.
8	Increase speed consistency	Speed up trials of measurement.	Fine-tune speed settings.	2 hours	Focused Physical	Fine-tuning the speed and direction control with enhance consistency of movement.	high	Week 10	The speed of the robot should maintain a constant speed with $\leq 10\%$ variation through 3 test runs.
9	Evaluate software stability	Run software over long periods.	Ensure software is robust.	4 hours	Focused analytical	Validate that the software performance is by design objectives.	high	Week 11	Software should run for 4 hours without crashing or bugging on major functionalities
10	Validate DJI educator blocks code	Carry out preprogrammed motion and reaction scenarios.	Ensure that there are no exceptions while running the code.	3 hours	Focused analytical	Final integration of the mechanical, electrical, and software systems.	high	Week 11	The robot shall be able to perform all the programmed motions without error in 3 repeats.

## 9. Conclusion

In conclusion, the team was able to make good progress in the development of our final product for our clients. We successfully coded, designed and tested for the Robots Wall-E appearance, line movement tracking, vision recognition and personalized sound effects. Things we must work on during the next prototype is symbol detection accuracy, robot chassis movement, and completion of the robots appearance.