SYSC 4805 A
Computer Systems Design Lab
Lab Section L1
Instructor: Abdullah Kadri

Project Proposal

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1 Project Charter

1.1 Overall Objective

Team Periwinkle's objective for the next several months is to design, build and demonstrate an autonomous snowplow capable of efficiently clearing simulated snow from a controlled indoor arena while navigating static and moving obstacles. The snowplow must also be designed to stay within defined physical boundaries.

Our team's robot will be engineered to operate within strict dimensional and speed constraints, beginning from a designated corner and using a custom-designed plow to push lightweight wooden cubes out of the enclosed area. The robot must complete its task within a five-minute limit, optimizing path planning and obstacle avoidance using sensor inputs and robust control algorithms [1]. Points will be awarded based on the quantity of snow cubes removed and penalties applied for boundary violations, collisions, or manual intervention.

To ensure reliability and modularity, we will develop and unit-test software handlers for all sensors and subsystems, following strict project management and version control practices with regular progress reports and documented criteria for success. Integration will be conducted in stages, allowing for thorough system-level testing and performance verification.

Ultimately, our goal is to deliver a fully autonomous, error-resilient robot that meets or exceeds competition requirements, demonstrates sophisticated engineering design, and provides meaningful, reportable outcomes throughout the development lifecycle.

1.2 Overall Deliverables

Team Periwinkle had defined two types of deliverables to make sure this project successful: milestones and final deliverables.

1.2.1 Milestone Deliverables

The milestone deliverables are interim stages that mark significant progress in the project . They help track development, identify potential issues early and ensure the project stays on schedule. The following milestones are set for this project:

- ***MD-1*: Labs**
  Due Date: October 2, 2025
  The guided labs 1-3 represent the first milestone of the *Autonomous Snowplow* project. During these labs, the team focused on learning about the various sensors such as distance, ultrasonic, line follower, and obstacle detection IR, etc and how to effectively use them in the project [2]. These guided labs are an essential milestone in the

development of the *Autonomous Snowplow,* as they gave the team the basic foundation of the sensors required to ensure the snowplower meets its requirements.

- ***MD-2*: Project Proposal**
  Due Date: October 16, 2025
  The project proposal is a report written by Team Periwinkle that outlines the requirements of the project. This document goes over the deliverables, testing plan and project responsibilities [3]. It provides the team with a plan of action, helping them stay organized and on how to stay on track through this project.

- ***MD-3*: Progress Report**
  Due Date: November 13, 2025
  The progress report is a document written by Team Periwinkle that outlines the progress the team has made during the semester. It details the problems that the team faced and the solutions that were found [4]. It provides an updated version of the milestone deadline which is important to be informed about, in case the team issues any delays in the project.

1.2.2 Final Deliverables

The final deliverables are the completed products of the project. They represent the end goals, and will show the fully developed solution. The following are the final deliverables:

- ***FD-1:* Final Presentation**
  Due Date: November 18, 2025
  The final presentation is where Team Periwinkle presents the *Autonomous Snowplow* project to their professor, TA and fellow classmates. The team outlines their design of the project and their accomplishments.

- ***FD-2:* Final Demo**
  Due Date: November 28, 2025
  The final demo is where Team Periwinkle gives a demo of the *Autonomous Snowplow* in action to their peers. This demonstration would include clearing the wooden cubes which represent the snow in an enclosed area while it attempts to avoid hitting moving obstacles. This milestone highlights the team's achievements and what they were able to accomplish.

- ***FD-3:* Final Report**
  Due Date: December 4, 2025
  The final report is a document written by Team Periwinkle that summarizes the project design and the work that was completed. It also reflects on the lessons learnt throughout the project and outlines future improvements.

2 Scope

2.1 Requirements

The requirements of the project are divided into functional and nonfunctional requirements.

2.1.1 Functional Requirements

This section defines the specific actions and behaviours of the *Autonomous Snowplow* that it must do to achieve its objectives.

- *FR-1:* The robot shall detect and avoid both static and moving obstacles within the area
- *FR-2:* The robot shall follow the black boundary tape and not cross it
- *FR-3:* The robot shall push as many simulated snow cubes as possible out of the defined area
- *FR-4:* The robot shall start from the designated corner
- *FR-5:* The robot shall operate autonomously with no manual interventions during its route
- *FR-6:* The robot shall use ultrasonic, line follower and IMU sensors for environment detection

2.1.2 Non-Functional Requirements

This section outlines the non-functional requirements which describe the performance, reliability, and usability criteria necessary for an optimal design.

- *NFR-1:* The robot must not exceed 226 x 262 x 150 mm in size
- *NFR-2:* The plow must not be not be greater in width than 50mm and not greater in length than 30mm
- *NFR-3:* The robot's speed must not exceed 30cm/s
- *NFR-4:* The robot must clear the snow in 5 minutes or less
- *NFR-5:* The robot's code shall be version controlled and modular for testing individual components
- *NFR-6:* The robot shall undergo unit and integration testing for all major subsystems

2.2 Deliverables

Figure 1 shows the Work Breakdown Structure (WBS) of the *Autonomous Snowplow* project. This hierarchical structure shows how this project is divided into smaller components to make it more manageable for the team.

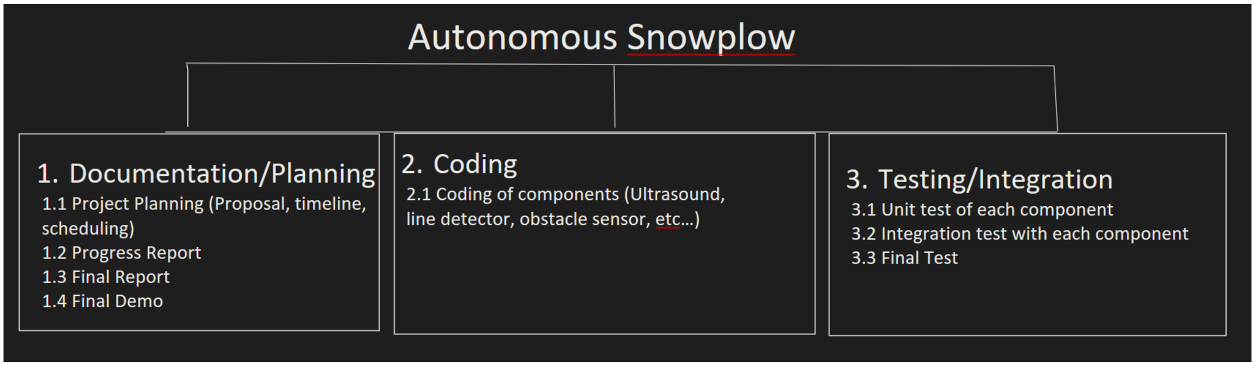

Figure 1: Work Breakdown Structure (WBS) of Autonomous Snowplow Diagram

2.3 Testing Plan

To measure the success of this project, a testing plan has to be developed. The testing plan can be divided into unit and integration testing.

2.3.1 Unit Testing of Components

The unit testing of the components verifies whether each component functions correctly on its own without any interference from other components. This allows the team to establish a baseline and make it easier to identify issues.

1. **Boundary Detection Test**
   Relates to FR-2, FR-6
   This test will evaluate whether the snowplower can remain in the perimeter using a line follower sensor. The line follower sensor should be able to distinguish between black or white surfaces.
   Pass criteria: The line follower sensor should have 90% detection accuracy and a latency response of 50ms or less.

2. **Obstacle Detection Test**
   Relates to FR-1, FR-6
   This test verifies the ultrasonic and IR sensors that can detect obstacles at varying distances and sizes.
   a. Large Object Test
      Pass criteria: All obstacles larger than 10cm should be detected from a distance of at least 30cm with a +/- 10% tolerance.
   b. Small Object Test
      Pass criterial: All smaller obstacles (5cm or less) should be detected from a distance within a minimum of 15cm with a ± 10% tolerance.

3. **Motor Speed Test**
   Relates to NFR-3
   This test measures the motor to maintain a consistent speed below 30cm. The speed would be measured using an accelerometer.
   Pass Criteria: The robot has a speed of 30cm/s or less across all test conditions with minimum fluctuations.

4. **IMU Line Test**
   Relates to FR-6
   This test validates the IMU sensor is able to maintain directional stability when the robot is following a straight line.
   Pass criteria: The snowplower should not deviate more than 5cm from the straight path and should have an orientation accuracy of 95%.

5. **Rotation Accuracy Test**
   Relates to FR-6
   This test checks if the IMU and motor control can perform accurate turns.
   Pass Criteria: The snowplower does 90° and 180° turns with an acceptable margin of error of ± 5°.

6. **Time Test**
   Relates to NFR-4
   The test measures the time it takes for the snowplower to complete a path with efficiency.
   Pass Criteria: The snowplower should clear the snow within 5 minutes while staying below the speed limit.

2.3.1 Integration Testing of Components

Integration testing of components evaluates how the components work together with the system and if the system works as expected.

1. **Obstacle Avoidance and Boundary Test**
   Relates to FR-1, FR-2. FR-6
   This tests the robot's ability to detect and avoid static and moving obstacles while staying inside the perimeter.
   Pass Criteria: The snowplower has no collisions and does not cross the boundary in 3 consecutive runs.

2. **Snow Clearing and Navigation Test**
   Relates to FR-3, FR-5

This test evaluates how the snowplower removes the snow which is represented by the wooden cubes by following its designated path autonomously.
Pass Criteria: The snowplower clears at least 80% of the wooden cubes in the perimeter.

3. **Speed and Performance Test**
   Relates to NFR-3. NFR-4
   This test checks whether the snowplower maintains the speed and performance after the integration of all the hardware components.
   Pass Criteria: The snowplower has a speed below 30cm/s while pushing cubes in the 5 minute time-limit.

4. **Start and Stop Automation Test**
   Relates to FR-4, FR-5
   This test checks whether the snowplower can start its navigation from a corner and complete its route without any manual interference.
   Pass criteria: The snowplower has done runs multiple times and does not require any manual inputs.

5. **Sensors Integrations Test**
   Relates to FR-6
   This test assesses how well the ultrasonic, distance, IMU, and line follower sensors integrate and communicate with each other to have a smooth navigation. The system should take in data from all the sensors and make decisions based on them.
   Pass Criteria: All the sensors provide consistent data for smooth and accurate navigation.

6. **System Reliability Test**
   Relates to NFR-5, NFR-6
   This is one of the final tests that ensures that the snowplower is responsible to complete its tasks without any component or bugs occurring during its operation.
   Pass Criteria: The snowplower has done runs multiple times and has 95% confidence in its reliability.

3 Schedule

3.1 Activities

The list of activities needed that covers the project is as follows:

- A1.0 Preparing/testing the drone with arduino and motor control board for components

- A2.0 Coding and testing of the obstacle sensor
- A2.1 Integration of obstacle sensor with drone

- A3.0 Coding and testing of the line follower
- A3.1 Integration of line follower with drone

- A4.0 Coding and testing of the ultrasonic sensor
- A4.1 Integration of ultrasonic sensor with drone

- A5.0 Coding and testing of the accelerometer, gyroscope and magnetometer
- A5.1 Integration of accelerometer with drone

- A6.0 Integration of the components, arduino, and motor control board
- A6.1 Testing of the fully integrated drone

- A7.0 Creating the shovel for the snowplower
- A7.1 Integration and testing of the shovel with removing blocks

- A8.0 Demonstration of final product

These activities may not be completed in the order presented, but it is a good idea to code, test, and integrate each component sequentially to keep the project modular and iterative, while making final integration testing easier.

3.2 Schedule Network Diagram

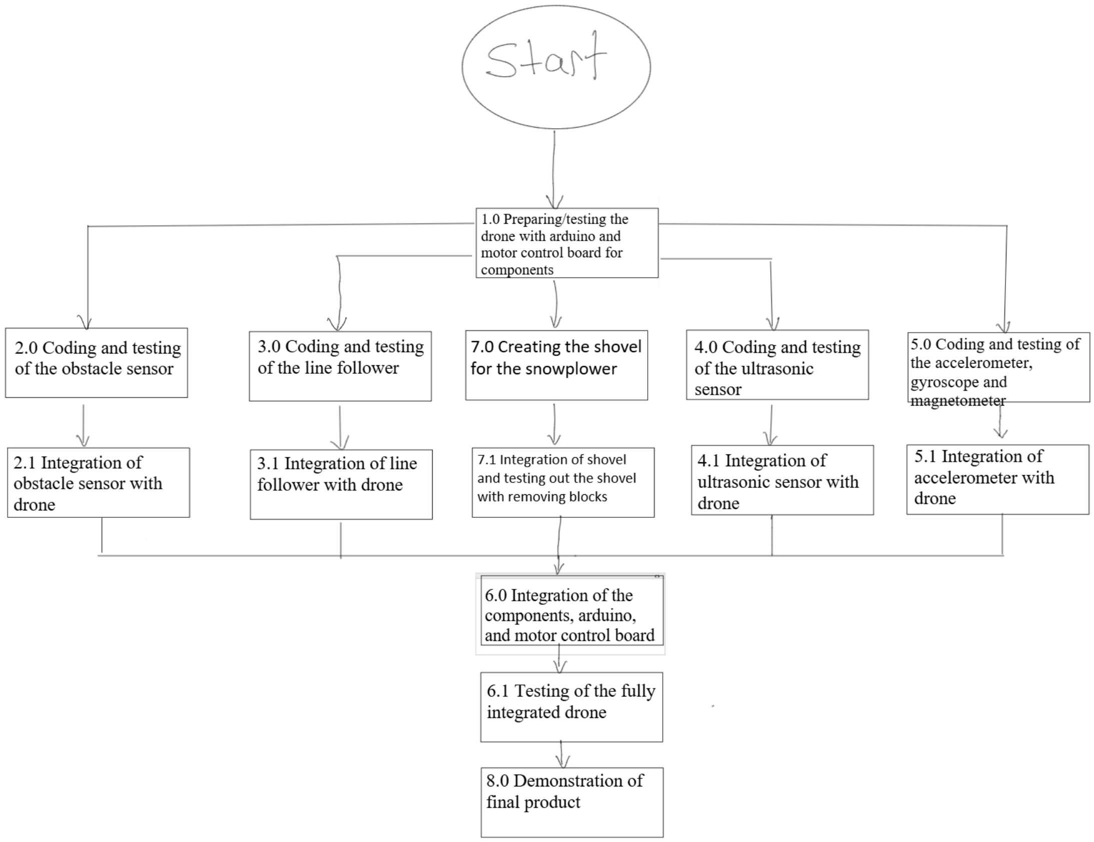

Figure 2: Schedule Network Diagram of Autonomous Snowplow Diagram

3.2 Gantt Chart

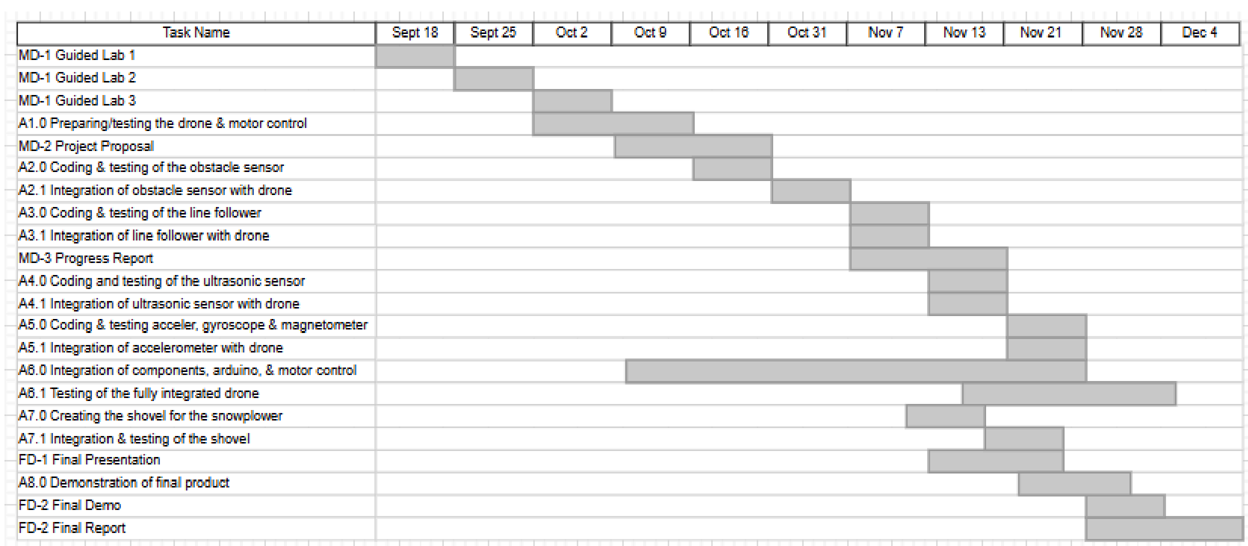

Figure 3: Gantt Chart of Autonomous Snowplow Diagram

4 Cost Baseline

For our team of three members, the estimated cost of the project is around $500 for the drone kit, and an additional $150/hr for working hours.

Table 1: The estimated cost for each activity

Activity	Estimated Time (hours)	Cost ($)
A1.0 Preparing/Testing initial drone	20	3,000
A2.0, A2.1 Coding, Testing, Integration of Line Follower	9	1,350
A3.0, A3.1 Coding, Testing, Integration of Ultrasonic Sensor	12	1,800
A4.0, A4.1 Coding, Testing, Integration of Accelerometer	8	1,200
A5.0, A5.1 Coding, Testing, Integration of Obstacle Sensor	12	1,800
A6.0, A6.1 Coding, Testing, Integration of whole drone	9	1,350
A7.0, A7.1 Creating, Testing of the Plow	1	150
A8.0 Final Demonstration	1	150

Using our estimates from the schedule and future responsibilities, an estimated time of work per week is around 6 or 7 hours per week for the semester. Using the Carleton schedule of 12 weeks, the estimated total cost of the project is between $11,300 and $13,100.

5 Human Resources

5.1 Responsibility Assignment Matrix

Table 2: The responsibility of each activity in the project

Activity	Who is Responsible	Who Approves
Preparing and Testing Drone for Component Addition	All	All
Coding and Testing Obstacle Sensor	Hamnah	Noah
Integrating Obstacle Sensor	Hamnah	Noah
Coding and Testing Line Follower	Hamnah	Alvan
Integrating Line Follower	Noah	Hamnah
Coding and Testing Ultrasonic Sensor	Alvan	Hamnah
Integrating Ultrasonic Sensor	Alvan	Hamnah
Coding and Testing Accelerometer	Noah	Alvan
Integrating Accelerometer	Noah	Alvan
Creating the shovel for the snowplower	Alvan	Noah
Integration of shovel and testing out the shovel with removing blocks	All	All
Integration of the components, arduino, and motor control board	All	All
Testing of the fully integrated drone	All	All
Demonstration of final product	All	Professor/TAs

6 References

[1] Dr. M. Taha, "Computer System Design Lab - Project Description Autonomous Snowplow," brightspace.carleton.ca, Aug. 2024. https://brightspace.carleton.ca/d2l/le/content/372623/viewContent/4450646/View

[2] Dr. A. Kadri, "Computer Systems Design Lab - Inventory," brightspace.carleton.ca, Aug. 2025. https://brightspace.carleton.ca/d2l/le/content/372623/viewContent/4431287/View

[3] Dr. A. Kadri, "Computer System Design Lab - Project Proposal," brightspace.carleton.ca, Aug. 2025. https://brightspace.carleton.ca/d2l/le/content/372623/viewContent/4450656/View

[4] Dr. A. Kadri, "Computer Systems Design Lab - Progress Report," brightspace.carleton.ca, Aug. 2025. https://brightspace.carleton.ca/d2l/le/content/372623/viewContent/4450655/View