Autonomous Delivery Robot (ADR)

Systems Engineering Management Plan (SEMP)

CLIN: HW4
Version Number: 1.0
Version Date: 9/20/2022
Team Name: Team 3
Lead Author: Xinyi Yang
Contributing Author(s): Sidney Leigh Molnar, Manu Madhu Pillai, Mukundhan Rajendiran

Table of Contents

1. Introduction

1.1. Document Purpose

The Systems Engineering Management Plan (SEMP) for the Autonomous Delivery Robot (ADR) elaborates on how system engineering concepts and principles would be applied to design the system. It describes the details of the technical effort put into designing the system. It elaborates on the types of technical processes used, how the project would be organized to accomplish the tasks, information flow within the organization, decision-making structure, and the resources required to complete the task. Additionally, it provides communication between the project management team and the engineering discipline team. This was referenced from [2].

1.2. References

This section provides a list of references used in the development of this document.

1. 621 HW 4 SEMP Template, by Dr. Tony Barber, 2022.
2. NASA System Engineering Handbook, [CrossRef]
3. 621 Wk 2.5 Lecture, Life Cycle Model (LCM) III Development of LCMs, John MacCarthy, 2022
4. 621 HW 4 Dev Sched Template, by Dr. Tony Barber, 2022
5. 621 HW 4 CDRL Responsibilities Matrix Example, by Dr. Tony Barber, 2022

2. System Description

The ADR system is developed essentially for educational institutions seeking to automate the delivery system on campus. One part of the ADR system is a complete autonomous delivery robot capable of navigating its path across the campus using advanced planning algorithms. The robot is equipped with vision sensors, which would make the robot aware of its surroundings for dynamic obstacle avoidance and decision-making. The proposed system is equipped with individual compartments for material storage with sensors onboard for detecting the presence of the item. In addition, it also features an electronic lock system controlled via the app (QR code) to mainly avert theft and unintentional swapping of delivery items.

To make this system a bit more customer and client-friendly, an app is designed for the customer and the client team. The customer app lets them know various details about the robot such as location, estimated time of arrival, pickup time, and also a unique QR code for accessing the specific compartment of their item. The client app helps them control and manage multiple robots around the campus by providing data such as location, battery status, distress signal alerts in case the robot is stuck or has faced unforeseen circumstances, and timings of pickup and dropoff of the package. The management system provides maintenance and logistical support for the ADRs including charging, cleaning, and regular maintenance. This system requires minimal human effort and reduces human error. It increases efficiency and also assures the delivery of the package safely.

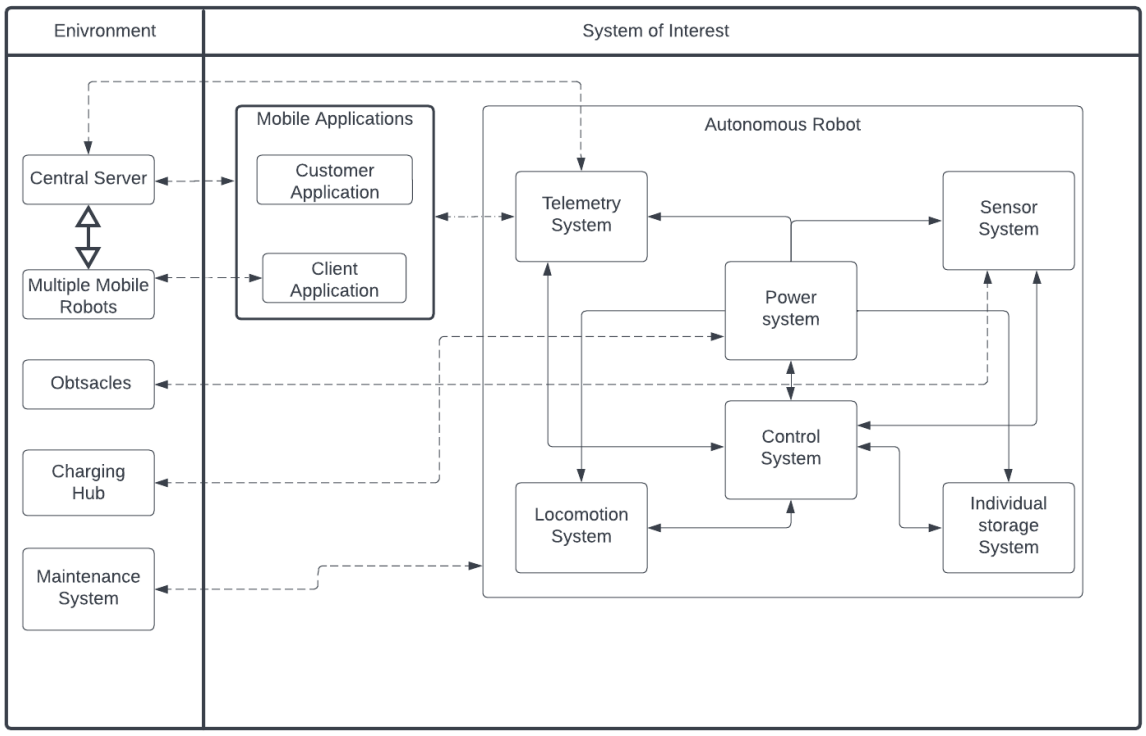

Figure 1. ADR System Block Diagram

The main components of the system are :

1. Control System: The control system runs the algorithms for the decision-making of the system. It takes input from all the other systems and decides the best possible outcome for the system to accomplish its task. One of the commonly used controllers is an NVIDIA JETSON.
2. Power System: The power system is responsible for running all the systems and providing the necessary voltage and current source to the components for the required output. The robot would be powered using batteries.
3. Sensor System: The sensor system primarily is used to make the robot aware of the surroundings and also to achieve additional functionalities within the robot. It uses various sensors like cameras for the perception of the environment, encoders for the distance and speed calculations, positioning sensors to detect the presence of the product, an Inertial Measurement Unit (IMU) for orienting the robot, a Global Positioning System (GPS) for tracking the robot.
4. Telemetry System: The telemetry system helps in acquiring all the information about the robot and helps wirelessly transfer the data to another location such as an app or a central server.
5. Locomotion System: The locomotion system takes care of the movement of the system. It consists of the wheels and the electric motors used to maneuver the system.
6. Individual Storage System: The individual storage system compartmentalizes the storage space of the robot. It helps sort the package to be delivered and it also avoids theft and unintentional

swapping of the packages. Each compartment houses its locking mechanism for advanced safety and sensors to detect the presence of the package.

7. Mobile Application: The mobile application helps the customer and clients by providing necessary information about the robot. The app is updated in real-time.
8. Central Server: The central server is the place where all the information related to the robot is stored and analyzed. Necessary actions are taken according to the task at hand. It helps in fleet management, distress management and to fix any anomalies.
9. Multiple Autonomous Delivery Robots: Multiple robots can be used to increase the efficiency of the system.
10. Obstacles: The obstacles can be static and dynamic. These need to be avoided by the Autonomous Delivery Robot while traversing its path to the destination.
11. Charging Hub: Once the robot is out of charge, the robot will automatically find the nearest charging hub to dock and replenish/swap its battery pack.
12. Maintenance System: The maintenance System takes care of the wear and tear of the robot. All the software and hardware issues are identified and fixed in this system.

3. System Development LCM and Schedule

3.1. Development LCM

The end goal of the project is to develop a preliminary design for the ADR. The project will follow a V Development Life Cycle Model (LCM) provided in Figure 2. The left side of the V model represents the project and the right side of the V model represents project testing and integration. The V model emphasizes the relation between requirements and verification, meaning the requirements need to be clear and verifiable [3]. In addition, testing needs to be done at each level of the given requirements. The scope of this project is to define the stakeholder (DoorDash) requirements, ADR requirements, and the system architecture and models.

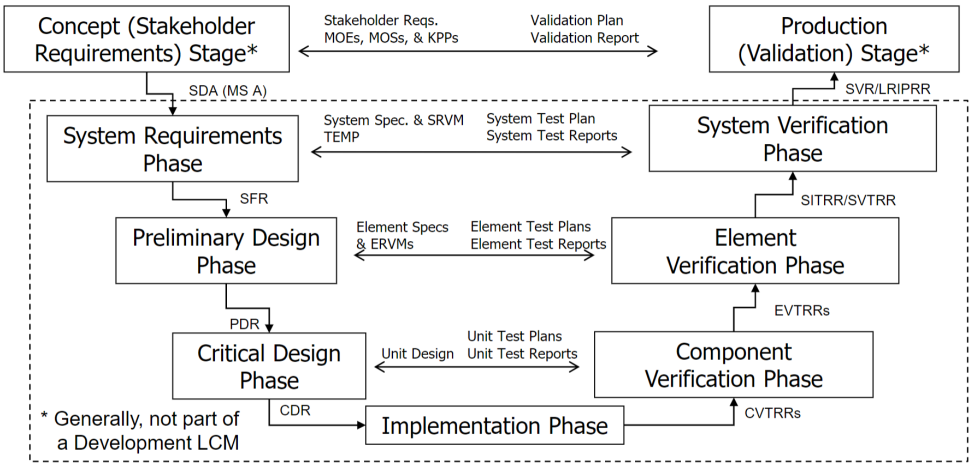

Figure 2: Project V-LCM [3]

The scope of this project is restricted to the concept stage, system requirements phase, and preliminary design phase.

During the concept stage, the project team will determine and note down the stakeholders' needs and requirements. The following products will be developed according to the project CDRL:

1. Project Proposal
2. Project SEMP
3. System context Description, including context-level architecture, Measures of Effectiveness (MOEs), use-cases, and system capabilities.
4. Stakeholders requirements document

The concept stage will conclude with the System Concept Review presentation. The stakeholders will need to approve the CDRL products and allow the team to move to the System Requirements Phase.

In the system requirements stage, the team will develop a system-level architecture and determine the system requirements for the ADR system. The following products will be produced based on the project CDRL:

1. System-Level Architecture.
2. System Requirements Document, with traceability tables.
3. RAM System Performance Analysis.
4. Project Trade-Off Analysis.
5. Project Risk Analysis.

After successfully completing the first two stages of the project, the team will continue on to the preliminary design stage. During this phase, we will produce an element-level architecture and elements of the ADR system. Additionally, we will find the most suitable design for the system that meets the stakeholder requirements. In the end, the project will have a presentation review for the final selected design of the ADR system.

3.2. Development Schedule

The development schedule for the project is shown in Figure 3 below. The schedule consists of key development activities, products, and milestone reviews generated through the Preliminary Design Phase of the V Development LCM.

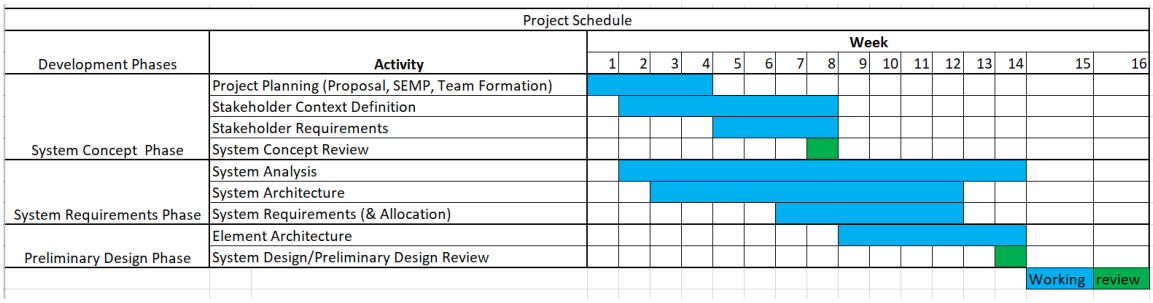

Figure 3: System Development Schedule [4]

1

4. Project Organization and Responsibilities

The project organizational structure is as shown in Figure 4 below:

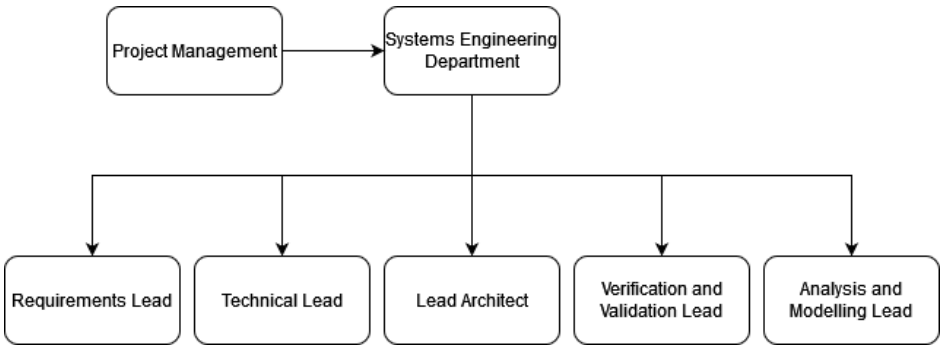

Figure 4: Systems Engineering Organization

The project management team is led by Xinyi Yang and is responsible for overseeing the entire team, resource planning, task allocation, and ensuring that the CDRL products are delivered on time. The project management team is also responsible for maintaining configuration control of CDRL deliverables. The systems engineering department is also led by Xinyi Yang and is responsible for ensuring that proper systems engineering principles and processes are followed on the project. Sidney Leigh Molnar is the Lead Architect of the project. The architecture team is responsible for developing and maintaining the architecture of the entire system. Manu Madhu Pillai is the Technical lead and is responsible for providing technical inputs that will drive the development of the system. Sidney Leigh Molnar is also the Analysis and Modelling Lead. The Analysis and Modelling team is responsible for applying system models to analyze system performance, cost, and key trades. Mukundhan Rajendiran is the requirements lead. The requirements team is in charge of analyzing, formulating, and prioritizing project requirements. Mukundhan Rajendiran is also the verification and validation lead. The verification and validation team is responsible for ensuring that the AMR meets the specifications and requirements so that the AMR is able to achieve all its intended purposes.

The project Contract Data Requirements List (CDRL) Responsibilities Matrix is provided in Table 1 below.

CDRL and Responsibilities Matrix

CLIN	Covered	Draft Due	Final Due	Deliverable Name	Type	Product Lead(s)
HW1	Week 1	N/A	Week 2	Personal Autobiographies	Individual	N/A
HW2	Week 3	N/A	Week 2	Myers Briggs Personality Results	Individual	N/A
HW3	Week 2	Week 4	Week 6	Project Proposal	Team	Xinyi (Cindy) Yang
HW4	Week 3	N/A	Week 4	Project SEMP	Team	Xinyi (Cindy) Yang
HW5	Week 3-4	Week 5	Week 7	System Concept Description-Part I	Team	Manu Pillai
HW6	Week 5-6	Week 7	Week 9	System Concept Description-Part II	Team	Manu Pillai
HW7	Week 5	Week 8	Week 10	Stakeholders' Requirements Document	Team	Mukundhan Rajendiran
HW8	Week 7	Week 9	Week 12	System-Level Architecture	Team	Sidney Molnar
HW9	Week 7	Week 9	Week 12	System Requirements Document	Team	Mukundhan Rajendiran
HW10	Week 10	N/A	Week 12	RAM Performance Analysis	Individual	N/A
HW11	Week 12	Week 13	Week 14	Project Tradeoff Analysis	Team	Sidney Molnar
HW12	Week 12	Week 13	Week 14	Risk Analysis	Individual	N/A
HW13	N/A	N/A	Week 15	Teammate Assessment	Individual	N/A
P1	Week 1-7	Week 7	Week 8	System Concept Review Presentation	Team	Xinyi (Cindy) Yang/Manu Pillai
P2	Week 9-13	N/A	Week 14	Preliminary Design Review Presentation	Team	Mukundhan Rajendiran/Sidney Molnar

Table 1: FA2022 CDRL Responsibilities Matrix [5]