Autonomous Delivery Robot

Initial Divide and Conquer Document
EEL4914 - Senior Design I
Group B

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Chapter 2: Project Description

2.1 Project Background and Motivation

The first Industrial Revolution in the 18th century marked the emergence of factories as a transformative force in manufacturing and production. Factories revolutionized how goods were created, enabling mass production, reducing costs, and fostering innovation across industries. Through the centuries, the world has witnessed multiple Industrial Revolutions as technology continuously developed. Today, with the rise of automation, the world of manufacturing is experiencing a so-called “Fourth Industrial Revolution” [1]. Advanced robotics, artificial intelligence, and other complex technologies are quickly becoming essential in making factories more efficient and flexible, allowing them to meet the global demands of the 21st century. Automation not only builds on the legacies of efficiency introduced during the previous revolution, but also paves the way for unparalleled advancements in productivity and precision.

From their inception as early prototypes, autonomous robots have undergone significant advancements. Over the past century, autonomous machinery has been continuously developed and improved. Autonomy can be implemented in both industrial and everyday life to improve efficiency and quality of life. In industries such as logistics, healthcare, manufacturing, and e-commerce, autonomous robots have become indispensable in increasing efficiency, reliability, and cost-effectiveness. The growing adoption of autonomous systems is driven by their potential to reduce human labor and streamline operations.

Despite the progress in this field, there are limitations that need to be addressed. Existing systems often lack affordability for small-scale use and fail to provide a simple and easy-to-use experience. This project aims to bridge these gaps, providing a flexible, cost-effective, and efficient system tailored for small and large-scale factory use.

The motivation for this project arises from the increasing demand for automation in both household and industrial applications. Businesses often face logistical challenges that could be lessened with the implementation of an adaptable autonomous delivery system. The project integrates different advanced hardware to achieve efficient autonomy and operation: a short range high frequency (HF) passive Radio Frequency Identification (RFID) system for payload identification, a LiDAR (Light Detection and Ranging) sensor for object detection, a two wheel differential drive system, among other hardware working in tandem with complex software that allows for autonomous navigation.

This project allows for the collaboration of different engineering disciplines to achieve a common goal to create a fully functioning autonomous delivery robot. Capable of object avoidance, payload identification and delivery, and floor map navigation, this project will address real-world challenges and develop an optimal solution. The autonomous delivery robot project addresses the growing need for versatile and accessible delivery systems. By leveraging modern technology and focusing on practicality, this project provides a prime solution to inefficiencies and represents a step forward in the world of industrial autonomy.

2.2 Current Technologies and Prior Work

2.2.1 Starship Technologies - Autonomous Robot Deliveries (ARD)

Starship Technologies released the first and leading autonomous robot delivery that offers capabilities for deliveries of hot food, industrial supplies and groceries. Their goal was to address the limitations of effectively delivering goods without the added factor of human interference. It relies on artificial intelligent algorithms to properly navigate across a path that constantly operates throughout a 12 hour duration.

The *ARD* system itself utilizes a complex sensor suite containing ultrasonic sensors, time-of-flight cameras, stereo cameras, distance sensors, radar and an alarm system. In addition, various LEDs, the flag and luminous reflectors make them visible even in low-light conditions. This forms a type of awareness bubble for object detection and enhances navigation ability in a three-dimensional space.[2] This system is able to identify objects 200 ft away while reducing its speed when near an adjacent object not in front of it, and makes a full stop when an object is in front. Operating from sunrise to sunset, the robot uses both front and rear LEDs that illuminate across a distance of at least 500 ft.

In terms of navigation, They utilized an AI path planning algorithm that follows pre mapped routes with real time implementation in the case of road closures and construction. The ARD system is monitored by employees which can be taken over to control their autonomous driving features if an area is unable to be traversed. The robots are available to employees anytime and anywhere on site through a browser based platform. The user is able to use their mobile device to be able to track the ARD and receive notifications when the delivery has arrived.

With our project we want to align and fulfill our engineering requirements based on the Starship's AR design weighing in 35 kg. In our case we aim to make the mechanism more affordable as this will be on a lower budget making the body of the robot to be estimated to be less than 20 kg. With the load requirements to be about a 5 kg load however, this will be tentative based on the robots design. The biggest difference that our project will have compared to Starships ARD is the mode of navigation. Due to our time constraints and budget ability the robot will be using an open source route planning algorithm that will likely only utilize 2-3 sensors (LiDAR, ultrasonic and HF RFID sensor). This decision was made based on where the robot would primarily function within an indoor environment.

Another difference would be the energy efficiency and the speed at which it operates. The starship's ARD use of a 1260 Wh battery approximates a 12hr drive time at a maximum speed of 6 kph. With the environmental difference, we have to adjust the speed to about 20 cm/s ideally consistent for all payloads operating on at least 12V battery.

Although the capabilities between both robots vary, we aim to bridge the gap and improve on affordability and versatility in indoor environments

2.2.2 Doll-E Automatic Tracking Platform

Doll-E is a previous senior design project that we have taken inspiration in regards to our project. Doll-E was built to have the same functionality as a traditional autonomous robot however their goal was to have the robot follow the user while also having to be able to carry various load capacities. Their aim was to target everyday consumers and were set on improving the traditionally dolly cart and eliminating having the user push the cart itself to have the platform to follow from a distance. Their first main specification was to have 20 lb load capacity that maintained a consistent speed of 2-3 mph. Doll-E employs a user-tracking system to follow a person around, while also utilizing ultrasonic sensors to stop within 1 cubic foot before colliding with an object. This is accompanied by the fact the platform must be able to detect the direction of the user within a 45° resolution at an 80% accuracy. We are keeping in mind that the Doll-E did come with its challenges when optimizing the motor and battery combination that increased the budget due to accompanying the 20lb capacity. We will primarily utilize 2 wheels to optimize cost but still keep the capabilities of traversing indoors.

Although our project shares similar functionalities for object detection and carrying capacity, there are various differences and improvements that can be made. Doll-E was designed for single-purpose tracking of the user within a 20lb load capacity, our robot will use the RFID tag to identify the payloads placement which will then trigger the pre mapped route. We will then have to ensure consistent moving speed in an indoor environment and reduce speed when nearing an object within 1m. System integration in Doll-E was limited pretty much to following and angular object avoidance, while our delivery robot will use RFID payload identification integrated with the payload alongside the mobile application that will access premade floormaps are the highlighted features of the project. Where Doll-E focused on tracking precision, our robot focuses on multi-destination support and a return to sender functionality.

Based on this, our work addresses other challenges of autonomous delivery in route planning for multi-destination routes and independence from any user operation. For our project, we hope to execute these improvements based on our autonomous robot predecessors.

2.3 Goals and Objectives

2.3.1 Overview of Project Goals and Objectives

This project's focus is to build a robot to aid in transporting payloads within a warehouse or other industrial environment. The three levels of goals are described below.

Basic Goals: The robot is able to safely transport payloads from one location to another and return to its home location while avoiding obstacles. Design a mobile application for the user to view the robot's status and indicate target location.

Advanced Goals: The robot is able to detect if a payload is on top of it and identify the payload correctly. The robot is able to create a new path to the target location if the original path is blocked.

Stretch Goals: The robot is able to deliver multiple payloads and is capable of creating a new floor map instead of the one given to it. The robot is able to pick and place payloads from a shelf and onto the robot.

To achieve the above goals, our team has certain objectives for the robot in order to perform as expected. Our robot will include a photoresistor to detect the presence of a payload on top of the robot, ensuring that the robot can confirm when an item is loaded or removed. A short range HF RFID sensor will be used to identify specific payloads, allowing the system to differentiate and track payloads effectively. To navigate safely, the robot will use an array of distance sensors to detect objects in its path and reroute its path accordingly. The robot's navigation system will be powered by an API/mapping toolbox running on an onboard Raspberry Pi. Additionally, a mobile application will allow the user to select target delivery locations and offer an intuitive interface for interaction and monitoring. The robot with the features and functionalities described in the following section will achieve our main goals of transporting payloads.

2.3.2 Project Features and Functionalities

The project will have several key features and functionalities. The robot will be able to avoid objects, detect whether payloads are present, create a path to the target location, create a path to its indicated home location, and a user interface in order to control.

Object Avoidance: The robot will be able to detect obstacles in its path and will then stop until the obstacle is removed. This functionality helps support our goal of being able to safely transport payload as it will not run into any person or damage itself or other property.

Payload Detection: The robot will be able to detect if a payload has been placed on its surface. This feature is important in achieving this project's goal of having a system that automatically returns to its home location. It will know that it is ready to return to its home location after the payload has been removed from its surface.

Payload Identification: The robot will have an RFID tag sensor on the surface to be able to correctly identify a payload placed. This feature will satisfy our Advanced Goal of payload identification.

Path to Target Location: The robot will already have a map of the permanent obstacles and structures of the room. Using this map the robot will be able to create a path to location that the user indicates. This path will be an efficient route that will have the robot then drive too. In our Advanced Goal, the robot will be able to create a new path if the original path is blocked by an unforeseen obstacle. In our first Stretch Goal, the robot will be able to deliver multiple payloads. In this case the robot will create a path to deliver the first payload, wait for its removal and then deliver the second payload. Our second stretch goal is for the robot to be able to have a new mode in which it creates its own map of obstacles instead of being provided one by a user ahead of time. The robot would go around the room and indicate the presence of these obstacles. Then when it is time to create a path to a target location it would use this map.

Path to Home Location: The robot will be able to autonomously determine an efficient path to its home location with no help from the user. It will know when the payload is removed and it is time to return to its home location.

User Interface: The robot will be accompanied with an app that will act as the user interface. The user will be able to upload a new map of the room the robot will be housed in. The user will also be able to enter a location on the app that they want the robot to deliver to. One of our Advanced Goals is to have the robot be able to automatically identify the payload. In this case then the user would not have to indicate where they want the robot to deliver to because the robot will have identified the payload and know where that payload is supposed to be delivered too.

2.4 Technical Specifications

The specifications and requirements that we will focus on meeting throughout this project are outlined in the following table. The yellow highlighted rows are the specifications that are demonstrable.

Table 1: Specifications and Requirements

Parameter	Specification	Engineering Requirement	Marketing Requirement
System Specifications			
Delivery System	Within 1m of destination	Accurately able to reach target location within 1 m	6
Object Avoidance	Detects object up to 1m away	Object Avoidance Sensor must detect objects within 1m	1, 6, 7
App Response Time	At most 5 seconds	Once a target location has been selected on the app, app must	2, 3

		show path to location within five seconds	
Identification Accuracy	90% accuracy	Identification must correctly identify a payload with RFID tag 90% of the time	8
Payload Detection	90% accuracy	Robot must correctly detect if a payload is present or absent 90% of the time	8
Payload Capacity	At least 25 kg	Robot's must be able to carry at least 25 kg payloads	4
Movement Speed	At least 20 cm/s	Robot's speed must be at least 20 cm/s	1, 3
Cost	Less than $500	The Robot's complete construction will cost less than $500	4
Dimensions	60cm x 60cm x 16cm	Robot's platform must be large enough to carry payloads at least 3600 cm^2	1, 3
Component Specifications			
Battery Voltage	12 V	Battery must be able to supply the motors, MCU, peripherals	9
Battery Capacity	3Ah	Battery must be able to meet current requirements of the motors, mcu, peripherals	9

Battery Lifespan	At least 5 years	Battery must function successfully for at least five years	9
Wheel Radius	16 cm	Small wheel radius is ideal for smooth indoor and flat surfaces	5, 9

Marketing Requirements

1. The system is safe.
2. The system responds quickly to the user.
3. The system has a consistent movement speed.
4. The system should minimize cost.
5. The system is able to hold a high load capacity.
6. The system autonomously navigates from one place to another.
7. The system has object avoidance.
8. The system includes an easy to use user interface.
9. The system should be able to meet load requirements.

2.5 House of Quality

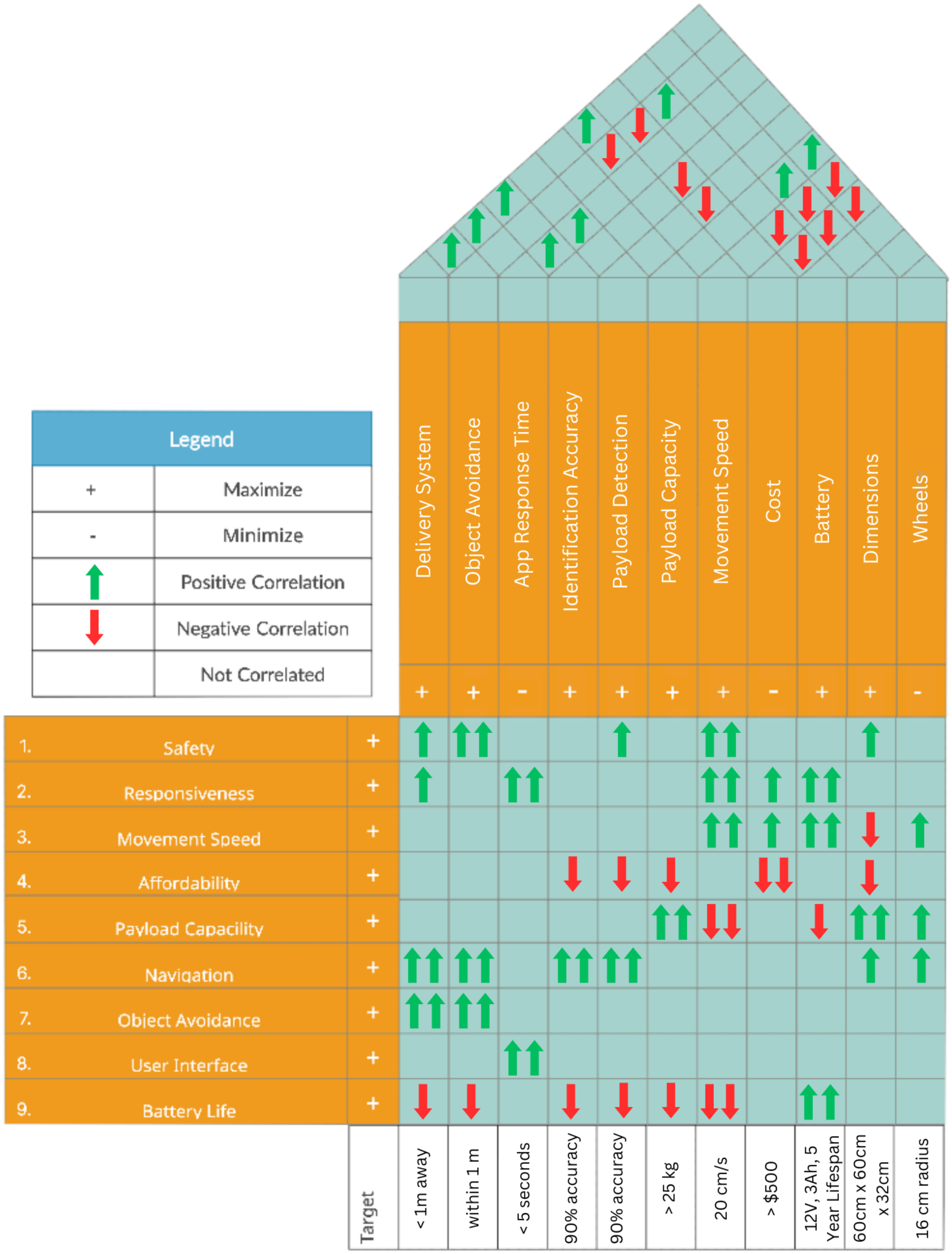

Figure 1: House of Quality by Authors

2.6 Project Block Diagrams

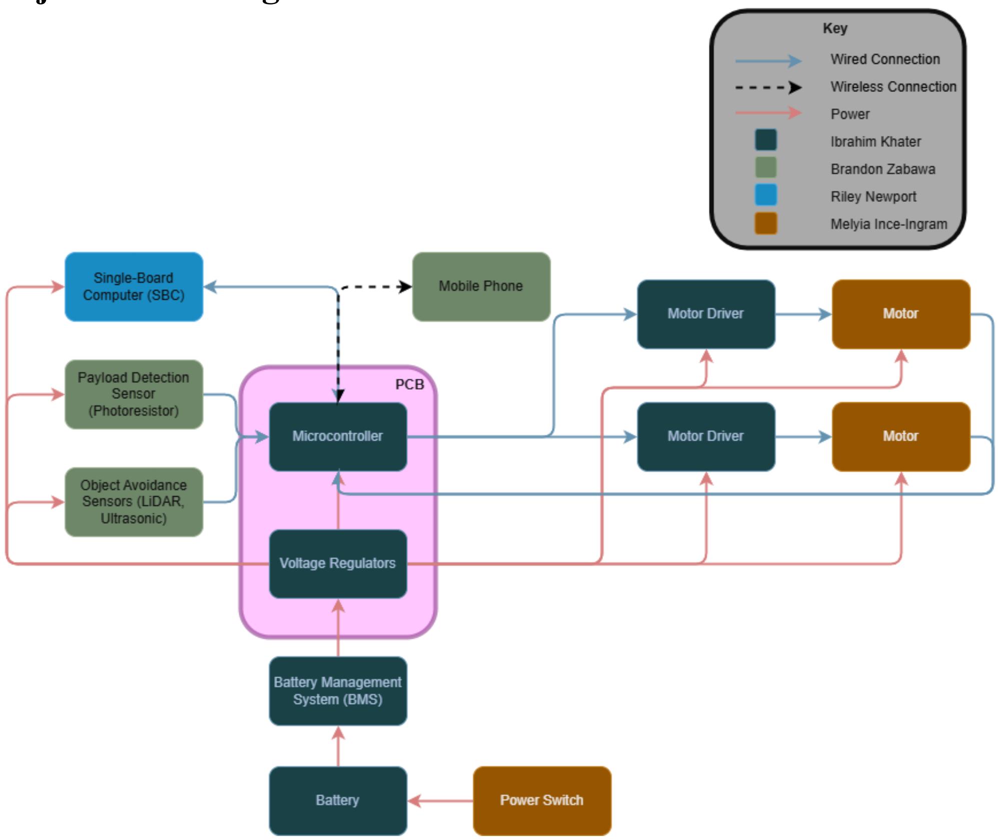

Figure 2: Hardware Block Diagram by Authors

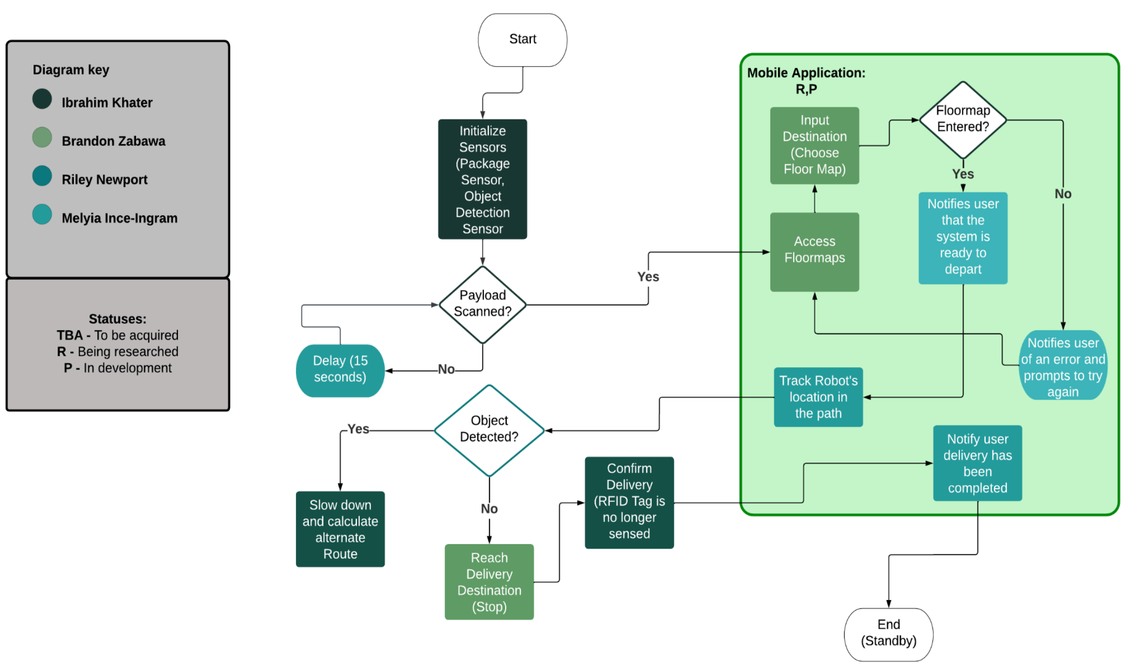

Figure 3: Software Flowchart by Authors

Chapter 10: Administrative Content

10.1 Budget

Below is our budget estimation, The cost of the materials will primarily be covered by the group and we aim to put in at most 500$ with possibility that this value may change.

Table 2: Budget Estimation

Part Description	Quantity	Estimated Cost	Total Cost
3S LiPo	1	$30	$30
Sensor	6	$5	$30
MCU	20	$0.50	$10
Wheel and Motor	2	$80	$160
PCB + Shipping	5	$4	$35
Wood	1	N/A	$50
Estimated Cost	$315		
Max Budget	$500		

10.2 Project Milestones

Table 3: Senior Design 1 Milestones

Senior Design 1 - Spring 2025		
Week	**Tasks**	**Assignment Due Dates**
1-2	Form Group and Discuss Project Ideas	N/A
3	Refine Project Idea Attend Bootcamp Form Review Committee Write Divide and Conquer Document (10 pages)	Divide and Conquer Document 1/24
4	D&C Meeting Revise D&C Document	

5	Revise D&C Document Start Individually Researching Components (Chapter 3)	Revised D&C 2/7
6	Individually Researching Components (Chapter 3)	
7	Individually Researching Components (Chapter 3) Standards and Design Constraints (Chapter 4) Comparison of ChatGPT (Chapter 5)	
8	Standards and Design Constraints (Chapter 4) Comparison of ChatGPT (Chapter 5)	
9	Hardware Design Chapter 6 Software Design Chapter 7	Quizzes 3/7
10	Hardware Design Chapter 6 Software Design Chapter 7	
11	Review each others sections and final adjustments on Midterm Report (60 pages)	Midterm Report 3/24
12	Midterm Report Revisions Chapter 8 PCB Layout Chapter 9 System Testing and Evaluation	
13	Submit Midterm Report Revision Chapter 8 PCB Layout Chapter 9 System Testing and Evaluation	Midterm Report Revision 4/4
14	Chapter 8 PCB Layout Chapter 9 System Testing and Evaluation	
15	Review each others sections and final adjustments on Final Report Make Mini Demo Video	
16	Submit Final Report Submit Mini Demo Video	Final Report 4/22 Mini Demo 4/22

Table 4: Senior Design 2 Milestones

Senior Design 2 - Fall 2025		
Week	**Tasks**	**Assignment Due Dates**
	PCB Design and Ordering	
1-2	PCB Testing and Construct Body of Robot	
3-7	Develop Software	
8	Full Assembly Test	
9-12	Research Solutions, Make Changes	
13	Full Assembly Test 2	
14	Practice Demo and Final Presentation	
15	Live Demo	

Appendices

Appendix A – References

[1] America, "Starship Technologies Autonomous Delivery Robots- Robot Guide," *Bots & Drones America*, 2022. https://botsanddrones.co/commercial-robots/f/starship-technologies-autonomous-delivery-robots---robot-guide?blogcategory=%40Starship+Technologies (accessed Jan. 19, 2025).

[2] C. Bai, P. Dallasega, G. Orzes, and J. Sarkis, "Industry 4.0 technologies assessment: A sustainability perspective," *International Journal of Production Economics*, vol. 229, no. 229, p. 107776, Nov. 2020, doi: https://doi.org/10.1016/j.ijpe.2020.107776.

[3] "Starship Technologies - Starship Robot," *Wevolver*. https://www.wevolver.com/specs/starship-technologies-starship-robot

[4] "Our Robots - Starship Technologies: Autonomous robot delivery - The future of delivery - today!," *Starship Technologies: Autonomous robot delivery - The future of delivery - today!*, Nov. 15, 2024. https://www.starship.xyz/our-robots/

[5] "Index of /seniordesign/fa2022sp2023," *Ucf.edu*, 2022. https://www.ece.ucf.edu/seniordesign/fa2022sp2023/ (accessed Jan. 24, 2025).