DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
THE UNIVERSITY OF TEXAS AT ARLINGTON

PROJECT CHARTER
CSE 4316: SENIOR DESIGN I
SUMMER 2025

THE SUCTIONEERS
THE VACU-ARM

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Revision History

Revision	Date	Author(s)	Description
0.1	07.11.2025	AW, AW, JC, SK	document creation
0.2	07.11.2025	AW, AW, JC, SK	complete draft
2.0	11.25.2025	AW	final draft

Contents

List of Figures

1 Problem Statement

There are many repetitive tasks that involve picking up an object to move it to a different location.

2 Methodology

For our senior design project, we are building the Vacu-Arm, a robotic arm that uses suction to pick up and move objects. It will automate the process of transferring items quickly and accurately. This device is designed to reduce the need for manual handling. By doing so, it will help minimize human error and physical labor.

3 Value Proposition

The Vacu-Arm offers companies a reliable, cost-effective automation solution for repetitive handling tasks. Its adaptable design allows for integration into existing workflows, reducing labor costs and minimizing human error. By adopting the Vacu-Arm, companies can automate manual processes quickly, streamline operations, boost efficiency, and ensure consistent product quality.

4 Development Milestones

This list of core project milestones should include all major documents, demonstration of major project features, and associated deadlines. Any date that has not yet been officially scheduled at the time of preparing this document may be listed by month.

Provide a list of milestones and completion dates in the following format:

- Project Charter first draft - Jul 11, 2025
- Research & Planning Complete - Jul 20, 2025
- System Requirements Specification - Aug 22, 2025
- Architectural Design Specification - Sep 19, 2025
- Demonstration of initial design in application - Sep 20, 2025
- Detailed Design Specification - Oct 10, 2025
- Sensor & Vacuum Integration - Nov 1, 2025
- Testing & Iteration - Nov 11, 2025
- Demonstration of safety sensor system - Nov 15, 2025
- Final Project Demonstration - Dec 3, 2025

5 Background

In many industrial and manufacturing environments, repetitive manual handling of components and materials often causes worker fatigue, injuries, and inconsistencies. These issues can lead to production slowdowns and costly errors. The Vacu-Arm addresses this need by using suction technology to pick up and move a wide range of objects reliably from one location to another. It can handle circuit boards, boxes, delicate parts, and other irregularly shaped items that traditional grippers might damage or struggle to hold securely. By relying on suction instead of fixed mechanical gripping, the Vacu-Arm adapts to different surfaces and materials without causing damage or requiring expensive custom tools for each new task. This makes it practical for many uses across manufacturing lines, assembly stations, packaging areas, and logistics operations where flexibility is important. Potential customers such as factories, warehouses, and assembly lines need automation tools that integrate easily with existing processes. The Vacu-Arm helps reduce manual labor, bottlenecks, and errors while improving overall efficiency.

6 Related Work

Automated material handling systems are a rapidly advancing area of research and development due to the growing demand for efficiency and labor reduction in industrial logistics. Several solutions currently exist for automated loading and unloading, but each have limitations that our proposed system aims to overcome.

Industrial robotic arms from companies such as **KUKA** and **ABB** offer vacuum-based gripping solutions for palletizing and depalletizing applications [1,2]. These systems are highly effective in controlled environments, but they are often expensive, rigid in design, and not easily adaptable to variable object types or mixed load pallets. Moreover, they typically require complex programming and significant infrastructure investment [2].

Research has also explored soft robotics and adaptive gripping technologies. For example, researchers have developed soft suction grippers that use variable vacuum to adapt to irregular surfaces [3]. Although promising, many of these prototypes are limited to lab environments and lack the structural robustness and power needed for larger payloads encountered in freight applications.

Academic work such as the *Vacuum Gripper with Shape Adaptation* [4] has shown that multi-cell vacuum pads can conform to different surfaces. However, such systems still lack the intelligent control and real-time feedback needed for consistent reliability in unstructured truck or pallet environments.

In the enthusiast and maker community, various Arduino-based vacuum lifting arms have emerged, demonstrating low-cost potential [5]. However, these lack safety features, robust control systems, and industrial-grade suction capabilities.

Compared to these solutions, our system emphasizes cost efficiency, adaptability, and ease of deployment. It will incorporate sensors for object detection, automatically adjust suction levels, and maintain a compact form factor suitable for smaller warehouses or retrofitting onto existing logistics platforms. Commercial systems are often too costly or require dedicated setups; our design aims to be deployable in semi-structured and dynamically changing environments with minimal training and configuration.

7 System Overview

The main solution to these repetitive tasks is to program the arm to pick up boxes and place them in a palletized location. Boxes are layed out on a conveyor belt, which are stopped at the end with a photoeye sensor that is connected to the UR20 control box. The arm will start above the box location, slowly go down until enough force is applied on the box, then apply suction to pick it up. The UR20 arm then goes to the palletizing area to place the box down and repeats this process until all boxes are unloaded.

8 Roles & Responsibilities

The main stakeholders are the professors at UT Arlington that are interested in finding a use for the UR20 arm, such as Steven Mcdermott. The undergraduates are one computer engineering major, Andrew Weiler, three computer science majors, Andrew Whitmill, Seezayn Bishwokarma, and Samriddha Kharel, as well as one software engineer, Jonathon Camarce. Future stakeholders are the members that continue the work off the UR20 arm.

9 Cost Proposal

The Vacu-Arm project will require funding to cover major expenses related to mechanical components, control electronics, suction hardware, fabrication materials, and development tools. A significant portion of the budget will be allocated to purchasing high-quality motors, actuators, and a reliable vacuum system to ensure safe and consistent handling of various objects. Additional costs will include sensors, microcontrollers or PLCs, and other control hardware needed to operate and test the arm.

Funds will also support fabrication and prototyping, including materials for building and refining the arm's structure. Software costs will cover any necessary licenses for CAD design, simulation, and control programming tools used throughout development. Development hardware such as a dedicated computer for programming and testing will be required, along with basic testing equipment to validate performance.

9.1 Preliminary Budget

Item	**Estimated Cost (USD)**
Robotic Arm Components (motors, actuators, frame)	$61,200
Vacuum Pump and Suction Cups	$300
Sensors and Control Electronics	$250
Fabrication and Prototyping Materials	$400
Microcontroller/PLC Hardware	$150
Development Computer Hardware	$800
Software Licenses (CAD, simulation, control software)	$500
Testing and Calibration Equipment	$200
Miscellaneous Supplies	$200
Total Estimated Cost	**$64,000**

9.2 Current & Pending Support

The team plans to seek funding through department or university project grants, potential industry sponsorships, and internal support from the engineering program's resources. This budget ensures that the team can build, test, and refine a functional prototype that meets performance goals and demonstrates the feasibility of automating manual handling tasks with a suction-based robotic arm

The main part ordered is suction tubing for increased air flow - $10

10 Facilities & Equipment

The UR20 Palletizing Cobot project is located in ERB 335, a designated laboratory area. A rectangular area approximately 10x5 feet in dimension is necessary for palletizing. For safety reasons, the robot will not operate if any obstacle, especially a person, is within this radius. The lab area includes the appropriate electrical infrastructure accommodating the power requirements of the UR20 robot. It will be necessary for the robot to be bolted into the ground for safe operation. This will be handled by the lab coordinator.

Equipment needed includes 3D printers (already present in the lab), a conveyor belt (already present in the lab), an air compressor (already present in the lab). Materials needed to conduct testing will be a pallet (borrowed from UTA) and boxes of consistent dimensions (printer paper boxes borrowed from UTA).

11 Assumptions

- The robot used for our project will be the Mitsubishi RV-8CRL-D arm
- The safety scanner will be provided, along with the robot arm
- The gripper suitable for palletizing will be purchased/designed by the 3rd sprint cycle
- There will be sufficient space in ERB 335 for the robot's palletizing application
- The Engineering Research Building will provide stable internet connectivity and sufficient power
- The existing safety scanner and PLC setup is fully functional without significant reconfiguration following the integration of a gripper
- All necessary tools and equipment will be provided and readily available in ERB 335

12 Constraints

- final prototype demonstration must be completed by Dec 3rd 2025
- Robot arm shall only be programmed via host PC or Teaching Pendant in ERB 335
- UR20 testing must be done in the space of ERB 335
- Total development cost must not exceed $800

13 Risks

Risk description	Probability	Loss (days)	Exposure (days)
Shipping delay on suction parts	0.50	30	15
Unable to find compatible gripper for product task	0.05	40	2
Issues with hardware or gripper behavior	0.20	7	1.4
Difficulty with setup or connecting to host PC	0.20	5	1
Delay due to member being ill	0.05	5	.25

Table 1: Overview of highest exposure project risks

14 Documentation & Reporting

14.1 Major Documentation Deliverables

14.1.1 Project Charter

This document serves to define and guide the development of the Vacu-Arm project. While there is no fixed schedule for updating the project charter, we plan to hold regular meetings to distribute tasks and make updates as needed. Our goal is to complete an initial version by July 11, with weekly revisions to reflect new findings and progress. A finalized version is expected to be completed around November.

14.1.2 System Requirements Specification

The System Requirements Specification will be maintained in a shared GitHub repository and updated as needed with any changes to the system capabilities. The document will be delivered on August 22nd, 2025.

14.1.3 Architectural Design Specification

Architectural Design Specification will be maintained in a shared GitHub repository and updated following any changes to the system's structure. The document will be delivered on September 9th, 2025.

14.1.4 Detailed Design Specification

The Detailed Design Specification will be maintained in a shared GitHub repository and updated if any significant design changes occur. The DDS document will be delivered at the end of Sprint 5 (October 10th, 2025).

14.2 Recurring Sprint Items

The most common recurring sprint items will be acquisition of materials and placement/recognition algorithm testing. All other sprint items will be completable items related to design and setup.

14.2.1 Product Backlog

Items will be added to the product backlog based system requirements outlined in the SRS. The items will be prioritized during sprint planning meetings based on complexity and impact on ability to move forward with the project.

14.2.2 Sprint Planning

Each sprint will be planned during a sprint planning meeting held at the beginning of the sprint cycle. There will be 8 sprints over the course of both semesters.

14.2.3 Sprint Goal

The sprint goal will be decided collaboratively during the sprint planning meeting by the development team.

14.2.4 Sprint Backlog

The sprint backlog will be selected from the product backlog during sprint planning, focusing on the highest-priority items. The team will use spreadsheets to maintain and track the sprint backlog and update as needed.

14.2.5 Task Breakdown

Individual tasks will be partitioned into hardware, software, or group tasks, and an applicable team member will voluntarily claim uncompleted tasks. Time spent on tasks will be documented in a spreadsheet.

14.2.6 Sprint Burn Down Charts

Sprint Burn Down Charts will not be highly focused on for this project.

14.2.7 Sprint Retrospective

The sprint retrospective will be conducted as a team discussion at the end of each sprint. This meeting will reflect on success and areas for improvement, with all team members offering feedback. The key items will be the ways to improve, what did not work, and what did work well. The teammate responsible for that week's presentation will also be responsible for documenting the team's retrospective discussion.

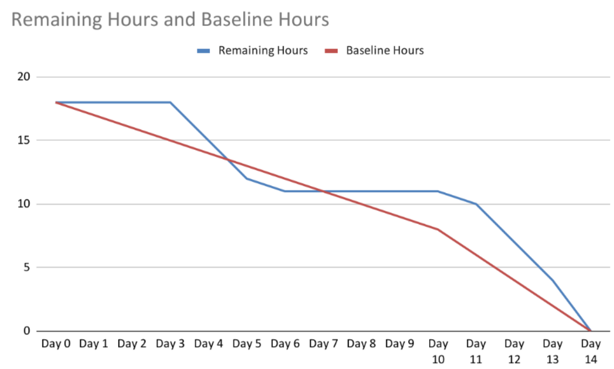

Figure 1: Example sprint burn down chart

14.2.8 Individual Status Reports

Over the sprint and during the group team retrospective, each teammate will document the hours they have worked on each task and discuss the task's completion. The relevant information will be documented individually by each teammate for their individual status report submission, including the teammate additionally responsible for the retrospective presentation.

14.2.9 Engineering Notebooks

An engineering notebook will not be prioritized for documentation.

14.3 Closeout Materials

The required materials will be submitted by the team in December 2025:

- Project poster
- CSE blog webpage
- Documents from 4316 and 4317
- Demo Videos, final demo & extra footage
- Source code and documentation
- Circuit design files

14.3.1 System Prototype

The final system prototype will include the complete integration for the UR20 robot with a gripper and palletizing application. The prototype will be demonstrated by the UR20 robot palletizing boxes in ERB 335 in November 2025.

14.3.2 Project Poster

The project poster will include the project description, system architecture, results, and impact. It will follow standard poster dimensions (36"x48") and will be delivered in November 2025.

14.3.3 Web Page

The project webpage will include the project description, system requirements, demonstration videos, and deliverables. It will be provided at closeout in November 2025.

14.3.4 Demo Video

The video will show the UR20 robot in action performing palletizing tasks. B-reel footage will also be included for future video cuts. The video will be approximately 3-8 minutes long covering system setup, algorithms, and functionality.

14.3.5 Source Code

Source Code is written exclusively on the UR Teaching Pendant. Individual programs are saved and stored on the pendant, which is to be left with the UR20 to be accessible at all times.

14.3.6 Source Code Documentation

Documentation will be written manually due to the nature of the UR20 Teaching Pendant.

14.3.7 Hardware Schematics

The hardware schematics will include wiring diagrams and any PCB layouts required for the integration of the gripper and accessory hardware.

14.3.8 CAD files

The project involves designing and printing a gripper, support components for the conveyor belt, and casing for the photoeye and camera.

14.3.9 Installation Scripts

The programs will be handled by the teaching pendant and can be run from that source with little complication. The installation of the robot will largely involve physical installation in a location.

14.3.10 User Manual

A detailed user manual will be provided, including the setup steps in digital PDF format alongside a setup video demonstrating how the robot works.

References

[1] K. AG, “Robotic palletizing systems: Flexible and efficient automation,” *KUKA Technical Report*, 2022, accessed: 2025-07-11.

[2] A. Robotics, “Automated palletizing solutions,” *ABB White Paper*, 2023, accessed: 2025-07-11.

[3] J. Shintake, S. Rosset, B. Schubert, D. Floreano, and H. Shea, “Versatile soft grippers with intrinsic electroadhesion based on multifunctional polymer actuators,” *Advanced Materials*, vol. 30, no. 29, p. 1707035, 2019.

[4] R. Huang, Y. Ma, and Z. Wang, “Design and evaluation of a multi-cell vacuum gripper for surface-adaptive gripping,” in *2018 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 2018, pp. 5604–5610.

[5] S. Patel, “Diy vacuum gripper using arduino and servo,” https://www.instructables.com/Arduino-Vacuum-Gripper-Robot-Arm/, 2021, accessed: 2025-07-11.