CMSC 451 Project 25-347 ECHO

VCU College of Engineering

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Executive Summary

This project focuses on advancing human-robot collaboration, addressing the growing need for safe and efficient interaction between humans and robots in various industries. As robots increasingly integrate into workplaces such as healthcare, manufacturing, and creative sectors, ensuring that robots can operate safely alongside humans is paramount. The primary objective of this multi-year project is to develop advanced systems that enhance the safety, efficiency, and precision of industrial and collaborative robots (cobots), specifically improving their ability to detect and differentiate between humans and non-human objects in real time.

In the initial phase of the project, the team successfully created a prototype for virtual choreography of robotic movements using mixed reality. This system enabled real-world mapping of robot actions for precise replay in industrial settings. In the second phase, the project advanced by integrating sensors that allowed cobots to detect humans, represent them as virtual objects in Unity, and use "go" and "no-go" zones to regulate robotic actions based on proximity. LED lights and a haptic feedback system were also incorporated to help maintain safe distances between humans and robots.

In the current iteration (Phase 3), the team's goal is to focus specifically on collaborative robots, further improving the cobot's sensory precision. The system will be enhanced to detect finer details, such as finger movements, and make more accurate distinctions between humans and non-human objects. This refinement is essential for ensuring situational awareness and responsive actions in increasingly complex environments where close human-robot interactions are necessary.

The project is governed by stringent design requirements and engineering objectives. Key goals include developing a more intuitive system for human-robot collaboration in industrial environments, enabling fine-grained interactions in settings such as labs and hospitals, and creating scalable solutions for diverse industries. The system is designed to detect human proximity, orientation, and gestures with millisecond accuracy, improve robot decision-making, and reduce emergency stops by 50%, all while maintaining safety standards. These objectives are supported by a set of technical specifications, including the use of proximity sensors, computer vision systems, and task-planning algorithms.

Work done to date includes finalizing the project scope, conducting a literature review, and initiating the design of a proximity detection algorithm. The timeline outlines several key milestones, such as the creation of a prototype for proximity and gesture detection systems and the development of an integrated hardware-software framework for human-robot collaboration. The project deliverables include working software, simulations, emergency stop systems, and comprehensive documentation to ensure future scalability.

This project holds significant social as well as commercial value by prioritizing safer, more intuitive human-robot collaboration, which is critical as robots continue to permeate industries that require both precision and creativity. By improving cobot awareness and decision-making capabilities, the team aims to set a new standard for human-robot interaction, ensuring a future where robots and humans can work together safely and effectively across multiple sectors.

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Section A. Problem Statement

History and Background

In recent years, the workplace has undergone significant changes, largely driven by the growing use of robots across various industries. The National Institute for Occupational Safety and Health (NIOSH) has highlighted concerns about the increasing number of injuries related to robotics as automation becomes more widespread.

Historically, industrial robots were designed for high-speed, heavy-duty tasks, often operating in isolation from humans within secure, controlled environments. However, this model no longer meets the needs of modern workplaces. As the demand for industrial robots expands into less controlled environments like laboratories, design studios, and film sets, the need for advanced safety systems tailored to high-traffic, human-robot interactions has become critical.

In response, many robotics companies have developed collaborative robots, or "cobots." These smaller, safer robots are designed to work alongside humans and are equipped with safety features. However, cobots are typically limited to less demanding tasks due to their reduced payload capacity. While they have become invaluable in environments requiring close human-robot collaboration, they are not suited for the high-speed, heavy-lifting applications typically handled by industrial robots.

Phase 1

The primary objective of this project is to ensure the safety and efficiency of cobots in human-robot interactions. This project has been a multi-year project and has made tremendous progress before our team came together. To give a brief overview. During the first year of the project, the team working on this project was able to successfully develop a prototype to allow virtual choreography of robotic movements using mixed reality and successful real-world mapping of virtual robot actions for precise replay in industrial settings.

Phase 2

In the second phase of the project, the team developed a system that equipped the cobot with sensors capable of detecting nearby humans. When a sensor identifies a human, the individual is represented as a virtual object in Unity. In Unity, designated "go" and "no-go" zones are defined based on the human's proximity to the robot. Once the human enters one of these zones, the robot either continues its operations or halts if the person is too close, ensuring safe interaction. The cobot was additionally outfitted with LED lights to indicate to the human which zone they are in, along with a haptic feedback system designed to help maintain a safe distance from the cobot.

Phase 3

For this iteration, our team is focused on advancing the progress made in the second phase. Specifically, we aim to enhance the cobot's ability to detect and differentiate between humans and non-human objects. Our goal is to improve the system's granularity, allowing the cobot to recognize finer details such as finger movements, while also ensuring accurate differentiation between human and non-human elements captured by the sensors.

This refinement is critical to improving the cobot's situational awareness and responsiveness, ensuring it can interact more safely and effectively in complex environments. This highlights the core problem we are addressing: increasing the cobot’s sensory precision and decision-making in real-world human-robot collaboration.

The social value of this project is significant, as it prioritizes improving safety, efficiency, and smooth interaction in environments where humans and robots collaborate. As robots become more integrated into industries like healthcare, manufacturing, and service sectors, the ability to accurately detect human presence and movements—down to granular details like finger motions—ensures a safer workspace and reduces the risk of accidents.

Improving the cobot's ability to distinguish between human and non-human objects also fosters trust and comfort in human-robot collaboration. Workers are more likely to feel secure and confident in environments where robots can reliably recognize and respond to human actions, creating a safer and more intuitive workplace. This improvement opens doors for robots to be used in more dynamic and collaborative roles, expanding their utility in spaces that require delicate precision, such as labs, hospitals, and creative sectors.

In a broader societal context, such advancements contribute to a future where human-robot collaboration supports more inclusive, diverse job roles. This helps improve productivity and quality of life, as humans and robots can work side by side, blending the strengths of human creativity with robotic precision and efficiency.

Section B. Engineering Design Requirements

The design requirements outlined in this section were developed through thorough research and a collaborative decision-making process. Our team began by looking into current human-robot collaboration systems, focusing on their limitations and areas for improvement. We then held multiple meetings with our faculty advisor and project sponsor to identify key challenges and potential solutions.

To refine our goals and objectives, we analyzed case studies from various industries, including manufacturing, healthcare, and creative sectors, to understand real-world needs and constraints. We also consulted with industry experts to gain insights into practical considerations and usability requirements.

Our specifications and constraints were derived from a combination of technical feasibility studies, market analysis of available components, and budget considerations. We used iterative discussions and feedback loops with our advisor and sponsor to ensure that these specifications align with both academic rigor and industry relevance.

The selection of relevant codes and standards was based on a thorough review of international and national regulatory frameworks for robotic systems and human-robot collaboration. We prioritized standards that are widely recognized in the industry and that address the specific safety and performance aspects of our project.

Throughout this process, we continually refined and adjusted our requirements to strike a balance between innovation, practicality, and adherence to established safety and performance standards. This approach ensures that our project goals are ambitious yet achievable within the given constraints of time, budget, and available technology.

B.1 Project Goals (i.e. Client Needs)

The following goals represent the most important needs of our client, and define the overarching purpose of our project. They are designed to address the biggest challenges in human-robot collaboration.

- To explore a more intuitive and safe system for human-robot collaboration in industrial settings
- To enable fine-grained interactions between humans and robots in environments like labs, hospitals, and creative studios (e.g. design, architecture, film production, etc.)
- To create a scalable solution that can be deployed across multiple industries

B.2 Design Objectives

To meet the client's goals, we have defined these specific, measurable objectives. They provide concrete targets that will guide our design process and allow us to evaluate the success of our final product.

The design will…

- allow increased precision of awareness of human proximity, orientation, and gestures within 100 milliseconds
- implement turn-based interaction protocols for collaborative human-robot tasks
- integrate task-planning algorithms to optimize robot actions in a collaborative setting
- improve upon current collision detection systems by allowing robots to operate safely within 30 cm of humans
- reduce robot emergency stops by 50% compared to current systems while maintaining safety standards

B.3 Design Specifications and Constraints

To ensure that we can achieve our objectives, we have defined these specifications and constraints. These parameters set clear boundaries for our design, ensuring that our final product meets both technical requirements and practical limitations.

- The proximity detection system must have a minimum sensing range of 3 meters with 1 cm accuracy
- The computer vision system must be able to track human movements at a minimum of 60 fps
- The system must operate within our $1000 budget constraint
- The system must be compatible with existing industrial robot and cobot arms and controllers
- All sensing and control system components must fit within a 50 cm x 50 cm x 50 cm enclosure to allow for portability
- The system must operate on standard 120V AC power
- The user interface must be operable by individuals with basic computer literacy
- Software must be developed using open-source tools to allow for future modifications

B.4 Codes and Standards

Our design will follow these relevant codes and standards. These guidelines will ensure that our system meets industry requirements for safety, interoperability, and functionality.

- ISO 10218-1:2011 - Robots and robotic devices -- Safety requirements for industrial robots
- ISO/TS 15066:2016 - Robots and robotic devices -- Collaborative robots
- ANSI/RIA R15.06-2012 - Industrial Robots and Robot Systems - Safety Requirements
- IEC 61508 - Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
- IEEE 1872-2015 - Standard for Ontologies for Robotics and Automation

These codes and standards will guide our development process to ensure safety, interoperability, and industry compliance. We will regularly review our design against these standards throughout the project lifecycle.

Section C. Scope of Work

The scope of our project includes the development of advanced human-robot interaction systems, with key objectives focusing on improving robot sensing. The project timeline spans the development of multiple weeks of milestones, all to be completed within the specified timeframe and budget. The team is responsible for the design, testing, and integration of these systems using tools such as computer vision, proximity sensors, and task-planning algorithms, while also ensuring compliance with safety standards, including the implementation of emergency stop mechanisms. Tasks falling outside of the team's scope include large-scale deployment or manufacturing of the systems, which will not be addressed in this phase. The development will follow a chosen methodology, such as agile or waterfall, with close collaboration and clear communication with the faculty advisor and project sponsor to manage expectations, avoid scope creep, and ensure timely delivery of all promised deliverables.

C.1 Deliverables

This project includes multiple deliverables, including project and academic-based deliverables. For the academic deliverables, they are as follows:

- Team Contract
- Project Proposal
- Fall Design Poster
- Preliminary Design Report

The previous list of academic deliverables are all also in order based on due dates. The following list of deliverables is for our project deliverables (in no specific order):

- Create shared Google Drive folder (Available remotely)
- Working mmWave software on an individuals device (Available remotely)
- Working Isaac Sim with given Python code from previous Capstone group (Available remotely)
- Use Isaac Sim/Unity to work with the robot located in East Engineering computer lab (On-campus task)
- Use mmWave and other resources to test proximity detection around the robot (On campus task)
- Emergency stop systems integrated into the robot interface (On-campus tasks)
- Integrated hardware-software framework that supports human-robot collaboration (On-campus task)
- A prototype of proximity and gesture detection systems that allow real-time robot movement adjustment (On-campus task)
- Tutorials and documentation for replicating the system and understanding its design for next Capstone group (Available remotely)

C.2 Milestones

1. Planning & Research Phase
September 25, 2024 – October 18, 2024

- **Milestones:**
  - Finalize project scope and objectives.
  - Conduct literature review on existing proximity management systems and sensor technologies (mmWave, Haptic Feedback System).
  - Identify relevant APIs, hardware, and software tools.
  - Draft initial project plan and timeline.

2. Initial Design & Development
October 19, 2024 – November 15, 2024

- **Milestones:**
  - Fall Design Poster Due Nov 15th
  - Develop a high-level system architecture.
  - Start hardware procurement (sensors, edge devices).
  - Design the proximity detection algorithm.
  - Initial coding setup for communication between sensors and robot systems.

3. Prototyping & Simulation
November 16, 2024 – December 9, 2024

- **Milestones:**
  - Preliminary Design Report Due Dec 9th
  - Set up simulation environment
  - Implement the first version of the proximity detection system.
  - Test the system in simulation for basic functionality.
  - Collect and analyze initial data.

C.3 Resources

mmWave Sensors: For detecting proximity and movements, **Isaac Sim**: Engine designed to interact with 3D objects, allowing us to virtualize the robot, **Unity**: Engine designed to interact with 3D objects, allowing us to virtualize the robot, **Xbox Kinect:** Infrared technology to outline humans and account for granular movements, **Proximity Sensor, LIDAR**

Section D. Concept Generation

A number of methods can be used to help generate design concepts from simple reflection and brainstorming, to working the problem backwards, using reverse thinking techniques, and looking to nature for inspiration (i.e. biomimicry). Existing solutions, or components of existing solutions, can be substituted, combined, adapted, modified, put to other uses, eliminated, or rearranged to meet new design objectives and specifications. A minimum of 3 overall design concepts is required for this section although more are welcome. Provide a brief description of how each design concept addresses the design problem. Discuss the potential pros and cons, including and potential risks of failure, of each of these concepts.

It is likely that each design concept may consist of several components. In this case, one or more of these components may offer a sub-problem that can be further explored, modified, or otherwise improved upon. These sub-problems may lead to the addition of several additional design concepts and may require the inclusion of a design concept chart or matrix to organize all ideas and potential solutions.

Provide any initial design sketches, drawings, 3D renderings, or conceptual models such as data flow diagrams, process flows, etc. developed during the concept ideation phase. All hand drawings should be drawn to scale using basic engineering drafting tools (i.e. ruler, protractor, and compass). Geometric stencils can also be used to help produce quality hand drawings. Drawings should be presented in a professional manner, preferably done on engineering graph paper and using a high-quality scan. All sketches should be labeled to identify major components and different drawing views or projections if applicable. Basic dimensions should be provided to give a general sense of scale. Label each sketch or drawing with the name of the team member responsible for the sketch, the date it was drawn, and the drawing scale.

Section E. Concept Evaluation and Selection

Using a systematic decision-making process, evaluate each of the design concepts and choose the one that is most likely to succeed in meeting the design objectives and constraints. A Decision Matrix, or Pugh Matrix, helps to analyze alternatives, eliminate biases, and make rational decisions through thought and structure. First, work to develop a set of selection criteria for which to evaluate the previously generated design concepts. Selection criteria often include concepts of performance, cost, safety, reliability, risk, etc. Note that the selection criteria developed here will likely be more general than the project design objectives. As with the design objectives, conversations with the client help define appropriate selection criteria.

In many cases, the client may value the selection criteria differently, preferring that more emphasis be placed on some than others. In this case, weighting factors may be used to place more or less importance on the various criteria in the decision making process. Again, conversations with the client can be used to define criteria weighting factors. Often times, these conversations must be analyzed and interpreted by the team to determine which criteria are more important to the client and by how much. Feel free to discuss the assigned weighting factors with the client to see if they seem accurate.

Next, define an associated metric to represent each criteria. Metrics should be specific and quantifiable, providing numerical values that quantify the often vague concepts of the selection criteria. Metrics can be obtained, generated, or estimated through a number of methods including simple background research, preliminary design calculations, or basic analyses. Note that these metrics do not need to specifically align with the design specifications although there may be some commonality between the two. Provide a brief discussion of the rationale for selecting each of the assigned metrics.

Using the defined metrics, evaluated each design concept against all selection criteria by filling out a Decision Matrix. Design concepts can be compared by using simple rank scoring, raw scoring, or weighted scoring techniques and design concept with which to move forward can be selected. This type of process provides a meaningful, unbiased means for choosing a preliminary design concept prior to moving forward with more comprehensive, detailed analyses as provided in the design methodology section below. The results of this process should be discussed with the project client prior to moving forward with the selected design. Table 1 provides an example of a simple decision matrix.

Table 1. Example of a Decision Matrix.

	Design Concept A	Design Concept B	Design Concept C	Design Concept D
Criteria 1				
Criteria 2				
Criteria 3				
Criteria 4				
Criteria 5				
Total Score				

Note: Weights can be assigned to each criterion if desired.

Section F. Design Methodology

Provide a detailed explanation of the methods that will be used to help evaluate, improve, and evolve the design through the iterative engineering design process. Consider that ultimately, the final design must be verified and validated to ensure that it meets all of the previously developed and listed design objectives and specifications. Verification ensures that the design meets all specification, while validation confirms that the design functions as intended such to meet the client's needs. While it is common for initial design concepts to first be evaluated using simplified design criteria and metrics, the chosen design should be advanced, and later verified, using engineering calculations, computational models, experimental data, and/or testing procedures.

Use this section to describe any underlying physical principles and mathematical equations that govern the design. Provide details of any computer-aided modeling techniques used to evaluate the design including the software used, prescribed boundary conditions, and assumptions. Include a detailed description of any experimental testing methods including required testing equipment, test set-up layout, data acquisition and instrumentation, and testing procedures. If one or more prototypes is to be produced and tested, provide a detailed description of how each will be evaluated.

Note: The contents of this section are expected to vary from project to project. Subsections may be appropriate for providing details of analytical, computational, experimental, and/or testing methods. Some potential subsections that may be included in this section are provided. While critical design equations may be provided here, lengthy mathematical derivations may be included in an appendix. Validation procedures are critical and all projects should address such topic.

F.1 Computational Methods (e.g. FEA or CFD Modeling, example sub-section)

F.2 Experimental Methods (example subsection)

F.3 Architecture/High-level Design (example subsection)

F.5 Validation Procedure

Describe how the design team will validate that the final design meets the client's needs. This section should include a plan to meet with the client towards the end of the project to discuss final design details and demonstrate a prototype, experimental test, and/or simulation results. Provide a relative time frame for this validation to occur (e.g. "mid-March" or "early-April"). Include a brief discussion on how client feedback will be captured, such as a formal survey, interview, or observation notes of the client using the prototype. It may also include plans to solicit feedback from other stakeholders and/or potential users.

Section G. Results and Design Details

Use this section to highlight the major results of the design methodology described above including important analytical, computational, experimental, modeling, assembly, and testing results. This section should be one of the most substantial sections of the report showcasing all of the hard work and effort that went into the completion of the final design and delivery of the project deliverables. Show how the identified problem was solved.

Highlight the prominent features of the final design through analysis results, modeling, drawings, renderings, circuit schematics, instrumentation diagrams, flow and piping diagrams, etc. to show that the design functions as intended and meets all design objectives and constraints. Overview designs such as dataflow diagrams, process flow, swim lane diagrams, as well as presentation-layer designs (e.g. storyboards for front-ends) should be included here. Detailed designs such as database designs, software designs, procedure flowcharts, or pseudocode should be included here. Support computational and experimental results with key plots and figures. All supporting figures should be clearly labeled and annotated to highlight the most important points of the figure (i.e. explicitly point out what the reader should focus on or understand about the image).

Note that while all results should be used to help inform design decisions, not all results may be necessary to include in the main body of the report. Extraneous supporting results (e.g. graphs, data, design renderings, drawings, etc.) that are not necessary for presenting the fundamental findings can be placed in one or more appendices. Detailed documentation of each program module can be provided as appendix.

G.1 Modeling Results (example subsection)

G.2 Experimental Results (example subsection)

G.3 Prototyping and Testing Results (example subsection)

G.4. Final Design Details/Specifications (example subsection)

Note that while the design constraints and specifications may have provided minimum or maximum values, or ranges or values, that the design needed to meet, the final design specifications should be listed here showing that the required design values were met. A list of final design details can also be included demonstrate fulfillment of the design objectives.

Note: Preliminary results should be included in the Preliminary Design Report to show the progress made of the selected design concept to-date. This section should be updated for the Final Design Report to include documentation of all of the work that was completed on the project throughout the entirety of the academic year.

Section H. Societal Impacts of Design

In addition to technical design considerations, contemporary engineers must consider the broader impacts that their design choices have on the world around them. These impacts include the consideration of public health, safety, and welfare as well as the potential societal, political/regulatory, economic, environmental, global, and ethical impacts of the design. As appropriate for the project design, discuss how each of these considerations influenced design choices in separate subsections. How will the design change the way people interact with each other? What are the political implications of the design? Does the technology have the potential to impact or shift markets? Does the design have any positive or negative effects on the environment? Don't forget to consider unintended consequences such as process or manufacturing byproducts. What impacts might the design have on global markets and trade? Are there any ethical questions related to the design?

While it is hard to forecast the various impacts of a technology, it is important to consider these potential impacts throughout the engineering design process. When considered during the early stages of the design phase, consideration of these impacts can help determine design objectives, constraints, and specifications and help drive design choices that may mitigate any potential negative impacts or unintended consequences.

Note: A minimum of 4 of these design considerations, including the consideration of public health, safety, and welfare, are required for the Preliminary Design Report while a section for all considerations must be included in the final design report.

H.1 Public Health, Safety, and Welfare

Provide a list of all design safety features and provide a brief description of each. Discuss the potential effects the design may have on public health, safety, and welfare. References to the codes and standards previous provided and the organizations that produced them may be summarized or referenced here.

H.2 Societal Impacts

H.3 Political/Regulatory Impacts

H.4. Economic Impacts

H.5 Environmental Impacts

H.6 Global Impacts

H.7. Ethical Considerations

Section I. Cost Analysis

Provide a simple cost analysis of the project that includes a list of all expenditures related to the project. If an experimental test set-up or prototype was developed, provide a Bill of Materials that includes part numbers, vendor names, unit costs, quantity, total costs, delivery times, dates received, etc. Do not forget to include all manufacturing costs incurred throughout the completion of the project. If the design is expected to become a commercial product, provide a production cost estimate including fixed capital, raw materials, manufacturing (including tooling and/or casting), and labor costs to produce and package the device. Note that this type of detailed cost analysis may be listed as a project deliverable.

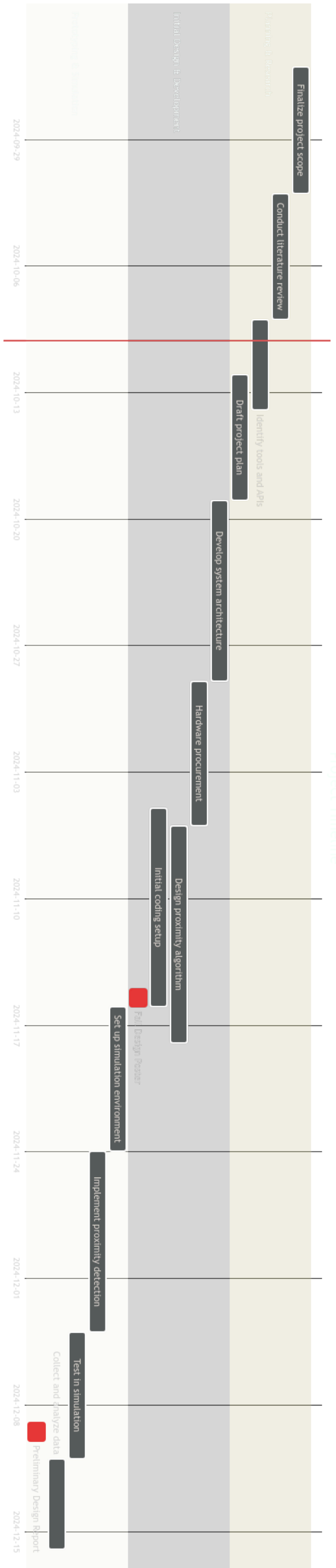
Note: The Preliminary Design Report should include all costs incurred to date. It is expected that this section will be expanded and updated between the preliminary and final design reports.

Section J. Conclusions and Recommendations

Use this section to summarize the story of how the design team arrived at the final design. Focus on the evolution of the design through the use of the engineering design process including lessons learned, obstacles overcome, and triumphs of the final design. Revisit the primary project goals and objectives. Provide a brief summary of the final design details and features paramount to the function of the design in meeting these goals and objectives.

A discussion may be included to discuss how the design could be further advanced or improved in the future. If applicable, summarize any questions or curiosities that the final results/design of this effort bring to mind or leave unanswered. If this project might continue on as a future (continuation) senior design project, detail the major milestones that have been completed to date and include any suggested testing plans, relevant machine drawings, electrical schematics, developed computer code, etc. All relevant information should be included in this section such that future researchers could pick up the project and advance the work in as seamless a manner as possible. Documents such as drawings, schematics, and codes could be referenced here and included in one or more appendix. If digital files are critical for future work, they should be saved on a thumb drive, external hard drive, cloud, etc. and left in the hands of the project advisor and/or client.

Appendix 1: Project Timeline



Appendix 2: Team Contract (i.e. Team Organization)

Step 1: Get to Know One Another. Gather Basic Information.

Task: This initial time together is important to form a strong team dynamic and get to know each other more as people outside of class time. Consider ways to develop positive working relationships with others, while remaining open and personal. Learn each other's strengths and discuss good/bad team experiences. This is also a good opportunity to start to better understand each other's communication and working styles.

Team Member Name	***Strengths each member bring to the group***	***Other Info***	***Contact Info***
Ian Richards	Organizing notes, planning ahead, coding experience	*Access to advanced networking resources*	richardsig@vcu.edu
Gianni Bautista	Industry experience, Cloud experience, React, Spring Boot, Full Stack Dev	*Access to someone with AR technology experience*	bautistag@vcu.edu
Ekta Shethna	Industry experience in Full Stack Development, Angular and Springboot	*Also majoring in Bioinformatics*	shethnaec@vcu.edu
Samuel Sarzaba	Industry experience in Full Stack Development, Angular and Springboot	N/A	sarzabase@vcu.edu

Other Stakeholders	***Contact Info***
Tamer Nadeem	tnadeem@vcu.edu
Shawn Brixey	brixey@vcu.edu

Step 2: Team Culture. Clarify the Group's Purpose and Culture Goals.

Task: Discuss how each team member wants to be treated to encourage them to make valuable contributions to the group and how each team member would like to feel recognized for their efforts. Discuss how the team will foster an environment where each team member feels they are accountable for their actions and the way they contribute to the project. These are your Culture Goals (left column). How do the students demonstrate these culture goals? These are your Actions (middle column). Finally, how do students deviate from the team's culture goals? What are ways that other team members can notice when that culture goal is no longer being honored in team dynamics? These are your Warning Signs (right column).

Resources: More information and an example Team Culture can be found in the Biodesign Student Guide "Intentional Teamwork" page (webpage | PDF)

Culture Goals	***Actions***	***Warning Signs***
Meeting once a week without fail	- Set up meetings in shared calendar - Send reminder email in day before meeting	- Student misses first meeting unexcused, warning is granted - Student misses meetings afterwards – issue is brought up with faculty advisor
Informing the group of any delays in completing assignments	- Stay up to date with each other's project responsibilities - Set reasonable deadlines and note when an extension is needed	- Student shows up for weekly meeting with no considerable work done
Weekly sprints	- Set up Google Meet every week - Send reminder in discord before each meeting	- Student fails to show decent progress without reasoning

Step 3: Time Commitments, Meeting Structure, and Communication

Task: Discuss the anticipated time commitments for the group project. Consider the following questions (don't answer these questions in the box below):

- What are reasonable time commitments for everyone to invest in this project?
- What other activities and commitments do group members have in their lives?
- How will we communicate with each other?
- When will we meet as a team? Where will we meet? How Often?
- Who will run the meetings? Will there be an assigned team leader or scribe? Does that position rotate or will the same person take on that role for the duration of the project?

Required: How often you will meet with your faculty advisor advisor, where you will meet, and how the meetings will be conducted. Who arranges these meetings?
See examples below.

Meeting Participants	***Frequency Dates and Times / Locations***	***Meeting Goals Responsible Party***
Students Only	As Needed, On Discord Voice Channel, Required-Every Thursday 6-6:50,	Update group on day-to-day challenges and accomplishments (Gianni will record these for the weekly progress reports and meetings with advisor)
Students + Faculty Advisor/ Sponsor	Will meet every Friday in zoom/ In person. In person will be every other week	Update faculty advisor/sponsor and get answers to our questions
Students (Working Sessions)	As Needed,	Most work will be done independently and will be assigned using Trello. If individual needs help then they can ask for help on the discord and will have a work session with someone who can help

Step 4: Determine Individual Roles and Responsibilities

Task: As part of the Capstone Team experience, each member will take on a leadership role, ***in addition to*** contributing to the overall weekly action items for the project. Some common leadership roles for Capstone projects are listed below. Other roles may be assigned with approval of your faculty advisor as deemed fit for the project. For the entirety of the project, you should communicate progress to your advisor specifically with regard to your role.

- **Before meeting with your team**, take some time to ask yourself: what is my "natural" role in this group (strengths)? How can I use this experience to help me grow and develop more?
- **As a group,** discuss the various tasks needed for the project and role preferences. Then assign roles in the table on the next page. Try to create a team dynamic that is fair and equitable, while promoting the strengths of each member.

Communication Leaders

Suggested: Assign a team member to be the primary contact for the client/sponsor. This person will schedule meetings, send updates, and ensure deliverables are met.

Suggested: Assign a team member to be the primary contact for faculty advisor. This person will schedule meetings, send updates, and ensure deliverables are met.

Common Leadership Roles for Capstone

1. **Project Manager:** Manages all tasks; develops overall schedule for project; writes agendas and runs meetings; reviews and monitors individual action items; creates an environment where team members are respected, take risks and feel safe expressing their ideas.
   Required: On Edusourced, under the Team tab, make sure that this student is assigned the Project Manager role. This is required so that Capstone program staff can easily identify a single contact person, especially for items like Purchasing and Receiving project supplies.
2. **Logistics Manager:** coordinates all internal and external interactions; lead in establishing contact within and outside of organization, following up on communication of commitments, obtaining information for the team; documents meeting minutes; manages facility and resource usage.
3. **Financial Manager:** researches/benchmarks technical purchases and acquisitions; conducts pricing analysis and budget justifications on proposed purchases; carries out team purchase requests; monitors team budget.
4. **Systems Engineer:** analyzes Client initial design specification and leads establishment of product specifications; monitors, coordinates and manages integration of sub-systems in the prototype; develops and recommends system architecture and manages product interfaces.
5. **Test Engineer:** oversees experimental design, test plan, procedures and data analysis; acquires data acquisition equipment and any necessary software; establishes test protocols and schedules; oversees statistical analysis of results; leads presentation of experimental finding and resulting recommendations.
6. **Manufacturing Engineer:** coordinates all fabrication required to meet final prototype requirements; oversees that all engineering drawings meet the requirements of machine shop or vendor; reviews designs to ensure design for manufacturing; determines realistic timing for fabrication and quality; develops schedule for all manufacturing.

Team Member	***Role(s)***	***Responsibilities***
Ian R	Finance	• Get a detailed list of resources needed • Note prices and find less expensive items that do not impede on quality • In charge of ordering items on time • In charge of delivering items to project meeting location
Gianni	Project Manager	• Makes sure that everyone is one track with the to- do list for the meeting • Ensures that everyone is aligned with project goals • Helps plan out the scope and objectives of the project
Ekta	Manufacturing Engineer	• Coordinates all fabrication activities to ensure they meet the final prototype requirements. • Ensures that all engineering drawings comply with the specifications of the machine shop or vendor, and reviews designs to guarantee manufacturability. • Establishes realistic timelines for fabrication and quality, and develops a comprehensive manufacturing schedule.
Samuel	Systems Engineer	• Lead product specification based on client design. • Monitor integration of subsystems in the prototype. • Develops and recommends system architecture and manages product interfaces.

Step 5: Agree to the above team contract

Team Member: *Signature: Ian Richards*

Team Member: *Signature: Ekta Shethna*

Team Member: *Signature: Gianni Bautista*

Team Member: *Signature: Samuel Sarzaba*

Appendix 3: [Insert Appendix Title]

Note that additional appendices may be added as needed. Appendices are used for supplementary material considered or used in the design process but not necessary for understanding the fundamental design or results. Lengthy mathematical derivations, ancillary results (e.g. data sets, plots), and detailed mechanical drawings are examples of items that might be placed in an appendix. Multiple appendices may be used to delineate topics and can be labeled using letters or numbers. Each appendix should start on a new page. Reference each appendix and the information it contains in the main text of the report where appropriate.

Note: Delete this page if no additional appendices are included.

References

Provide a numbered list of all references in order of appearance using APA citation format. The reference page should begin on a new page as shown here.

[1] VCU Writing Center. (2021, September 8). *APA Citation: A guide to formatting in APA style.* Retrieved September 2, 2024. https://writing.vcu.edu/student-resources/apa-citations/

[2] Teach Engineering. *Engineering Design Process*. TeachEngineering.org. Retreived September 2, 2024. https://www.teachengineering.org/populartopics/designprocess