Warehouse Automation

DESIGN DOCUMENT

sddec20-10
Client: N/A
Advisers: Dr. Diane Rover

Jacob Ramsey-Smith/Backend Developer
Amir Hamza/Embedded Developer
Stamatios Morellas/Frontend Developer
Jack Creighton/Autonomy Engineer

Team Email: sddec20-10@iastate.edu
Team Website: sddec20-10.sd.ece.iastate.edu

Revised: 2/23/2020 v1

Executive Summary

Development Standards & Practices Used

MVC style coding in backend.

Agile and Test Driven Development practices will be used

Must follow FAA flight regulations.

Summary of Requirements

- Have some method to take inventory in a warehouse
- Create a module design which can be integrated into different warehouses
- Design and develop an aerial vehicle
- The drone should navigate autonomously
- The drone must scan barcodes off of pallets in each aisle
- The gathered data from the scanner must be transmitted to the server via wireless communication
- Data in the server must be viewable in a web application

Applicable Courses from Iowa State University Curriculum

- CprE 288
- CprE 488
- Com Sci 309
- Com Sci 319

New Skills/Knowledge acquired that was not taught in courses

A lot of the skills and knowledge required for this project are a part of CprE 488, which no one on the team has taken. So many of the skills needed for making and controlling a flying drone.

Table of Contents

1 Introduction 4

1.1 Acknowledgement 4

1.2 Problem and Project Statement 4

1.3 Operational Environment 4

1.4 Requirements 4

1.5 Intended Users and Uses 4

1.6 Assumptions and Limitations 5

1.7 Expected End Product and Deliverables 5

2. Specifications and Analysis 6

2.1 Proposed Approach 6

2.2 Design Analysis 6

2.3 Development Process 6

2.4 Conceptual Sketch 6

3. Statement of Work 7

3.1 Previous Work And Literature 7

3.2 Technology Considerations 7

3.3 Task Decomposition 7

3.4 Possible Risks And Risk Management 7

3.5 Project Proposed Milestones and Evaluation Criteria 7

3.6 Project Tracking Procedures 7

3.7 Expected Results and Validation 7

4. Project Timeline, Estimated Resources, and Challenges 8

4.1 Project Timeline 8

4.2 Feasibility Assessment 8

4.3 Personnel Effort Requirements 8

4.4 Other Resource Requirements 9

4.5 Financial Requirements 9

5. Testing and Implementation 9

5.1 Interface Specifications 9

5.2 Hardware and software 9

5.3 Functional Testing 9
5.4 Non-Functional Testing 10
5.5 Process 10
5.6 Results 10
6. Closing Material 10
6.1 Conclusion 10
6.2 References 10
6.3 Appendices 11

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

1 Introduction

1.1 Acknowledgment

The team appreciates Dr. Rover for choosing our team for the warehouse automation project. Our team is excited to contribute efforts in this regard and would like to deliver a project that is sustainable, integrative, and cost-effective. Our team has a wide range of skills from embedded systems and circuit design to application development. These skills can be combined to deliver an effective product that meets all the requirements set by the client.

1.2 Problem and Project Statement

Warehousing contributes up to 30% of the cost of logistics in most developed economies. Billions of dollars of capital are locked up at a time, in high-volume-high-value inventory. Since the rise of the internet, eCommerce has exponentially increased in consumer demand and efforts need to be made to keep up with this demand. Traditional warehouse workers are falling short and need technological integration to help keep track of the high volume of inventory moving in and out of the warehouse.

Our team will research, design, build, and demonstrate a warehouse inventory application using ground and/or air AV technology. The team will need to realistically scope the project for the time, resources and expertise available. The team is responsible for creating a small warehouse environment appropriate for the AV technology being used. The team needs to identify and select a cost-effective off-the-shelf robot and/or drone. This application will serve as a demonstration to potentially initiate a larger automated warehouse testbed for the department with industry collaboration.

A modern warehouse is expected to use technologies such as RFID, QR code, sensors, autonomous ground, and aerial vehicles, and computer vision to improve its efficiency. The team has opted for the aerial autonomous vehicles as a means to automate the inventory tracking of a warehouse.

Autonomous aerial drones will be utilized to scan the barcodes for each pallet at different heights in an aisle. Our team will be designing and building drones with a vision tracking system to identify barcodes and a barcode scanner will be installed on the drone to scan that barcode. Data will be transmitted from the drone to the server via wireless communication. A frontend will also be developed to run analytics on the data generated from the drones as they scan each aisle in the warehouse.

1.3 Operational Environment

The operational environment of our project will be a warehouse atmosphere. Since this is indoors, the team isn't worried about any potential environmental hazards that might affect the drones in flight. However, there're indoor hazards that the team is taking into consideration. As the drones will be operating autonomously, the team wants to include sensors like lidar and cameras for obstacle detection while performing tasks. This will ensure that drones don't collide with each other or any item present in the warehouse.

1.4 Requirements

- **Market requirements:**
    - Create a module design which can be integrated into different warehouses
    - Develop a cost-effective system

    - Ensure low running cost
    - Ensure customer requirements are being met through seeking feedback on the project
- **System Requirements:**
    - Design and develop an aerial vehicle
    - Ensure autonomous navigation through the use of sensors
    - Integrate scanners into the system to scan barcodes
    - Use wireless communication to transmit data from the aerial vehicle to the server
    - Develop a web application which shows the warehouse data gathered by the drones
- **Administrative Requirements:**
    - Create a Gantt chart to keep track of the project
    - Assign tasks on Trello to each member of the team
    - Weekly team meeting to discuss progress and concerns
    - Weekly team meeting with the faculty advisor to discuss progress
- **Functional Requirements:**
    - The drone should be able to fly to the height of the warehouse
    - The drone should navigate autonomously
    - The done must scan barcodes off of pallets in each aisle
    - The gathered data from the scanner must be transmitted to the server via wireless communication
    - Data in the server must be viewable in a web application
    -

1.5 Intended Users and Uses

The intended users for our project are the companies operating warehouses for their inventory. Our product will be used to automate inventory tracking in those warehouses. This will enable warehouse owners to keep track of their inventory effectively and will result in long term savings through better analytics and elimination of existing personnel.

1.6 Assumptions and Limitations

- **Assumptions:**
    - There is sufficient space between the aisles for operating multiple aerial vehicles simultaneously
    - The drones aren't intended to be used outdoors
    - Since the location is indoors, no extra water or dust protections will be installed
    - The environment is well lit for the drone to scan barcodes
- **Limitations:**
    - A single drone shall operate for a minimum of 2 hours on a single charge (Project Requirement)
    - The drone shall be no larger than 300 mm in length (Project Requirement)
    - The drone shall not have a swappable battery (Size Constraint)
    - The drone shall use a lithium-ion battery (Feasible and Affordable)
    - The drone shall always operate in the range of a wireless access point (Project Requirement)

1.7 Expected End Product and Deliverables

The expected end product will be a drone with a charging base station. The drone will be operating autonomously in the warehouse while keeping track of the inventory. This autonomous navigation will be achieved through lidar and cameras. The lidar will ensure obstacle detection and the camera will be used to detect barcodes on the pallets in every aisle of the warehouse. The drone shall also have a scanner built-in which will be responsible for scanning the barcodes. The data will then be transmitted to the server via wireless communication. The drone shall be powered with a battery with a minimum operating life of 2 hours. Once on a low charge, the drone will move to the base station for charging and will continue once fully charged.

A web application will also be shipped with the drone which will show the data in the server. This data will be updated in real-time as shipments move in. The user will also have the option to run analytics on the existing data to see which aisle has been the busiest or which product has been shipped the most etc.

	Project Deliverables	Status
1	Product Design	Done
2	Preliminary Design Review	In Progress
3	Critical Design Review	To do
4	Product Prototype	To do
5	Product Testing	To do
6	Test Readiness Review	To do
7	Product Delivery	To do

2. Specifications and Analysis

2.1 Proposed Approach

The team's approach for undertaking this task will consist of both functional and nonfunctional requirements.
When considering the project functional requirements, the aerial drone should be able to navigate autonomously in the warehouse, this means avoiding obstacles while performing its tasks. The drone has to scan barcodes off of pallets in each aisle of the warehouse. The data from the scanner will then be transmitted to the backend server and this data is viewable through a web application that will be developed by our team.

When considering the nonfunctional requirements, the drone must operate autonomously with the help of lidar for obstacle detection and a camera to detect barcodes on each pallet in the warehouse. A scanner will be integrated into the drone to scan the barcodes after being detected by the camera. The drone will be using an onboard computer to perform all the calculations and gathering input from the scanner. The onboard computer will be powered by a battery that will provide a minimum of 2 hours of operating capability. The data gathered from the scanner will be transmitted by the onboard computer to the backend server via HTTP requests. A web application will be developed by the team to view and analyze data collected by the drone.

For NIST standards, general security practices should be implemented and continuously assessed to make sure the drones are operating as expected. For IEEE standards would just be to meet FAA standards, which are not set for drone flight indoors.

2.2 Design Analysis

Most of the team's discussion thus far has been focused on long-term planning, primarily about whether the team wants to pursue ground or air-based robots for our project. The team has decided to opt for aerial vehicles after consulting our faculty advisor. The team believes that aerial drones are an exciting technology with an immense amount of possibilities and can be effective in a warehouse environment.

Thus far, the drone project has been working well. The team is currently deciding on the hardware components needed for the project to function as needed. There's still a lot of planning needed to satisfy hardware and software limitations and requirements.

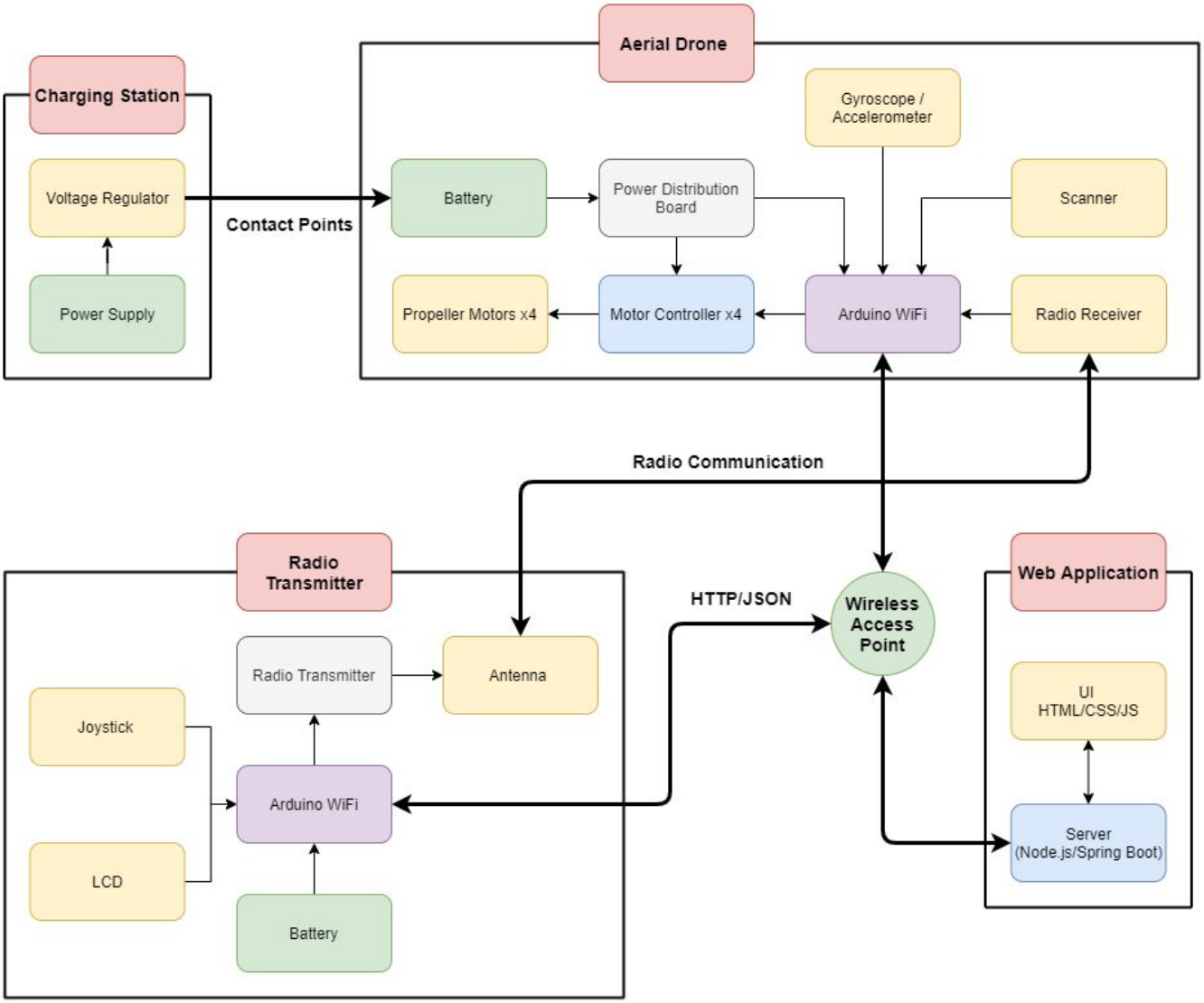
The autonomy aspect of the robot still needs to be decided upon. Autonomous navigation can be implemented in multiple ways and the team is currently deciding on the most efficient and cost-effective way. Due to the complexity of autonomy, hardware and software requirements are still being discussed and we hope to have a plan of action by the end of the semester. Since the team is still in the planning stage, no testing has been carried out yet. The team wants to ensure a clear vision before any components are ordered and tested.

The team believes that the proposed solution has the potential to improve current warehouse operations. This solution will not only speed up the inventory management process but also save companies millions in the long run through cutting employee costs. The current situation is a warehouse setting isn't safe for the warehouse workers. Employees reaching high stacked inventory through the help of ladders is risky and has resulted in many fatalities. Through our solution, the team believes that the employee will be safer than ever as our drones will be doing most of the high-risk operations in the warehouse.

2.3 Development Process

As Agile and TDD development processes are not mutually exclusive the team will be following both of these development processes. The team chose these processes over the Waterfall development process because they are cyclical which we believe will help create better-written code and better products. They also allow for more flexibility and as a smaller team with no client that is highly desired.

2.4 Conceptual Sketch



3. Statement of Work

3.1 Previous Work And Literature

The company PINC offers an automatic inventory service using aerial drones. From the companies website:

"PINC's UAS (Unmanned Aircraft System) is called PINC AIR, Aerial Inventory Robots™. This warehouse drone solution allows companies to apply drone technology, coupled with advanced optical, RFID, and barcoding sensor capabilities, to significantly improve the operational effectiveness and efficiency of warehouse inventory cycle count.

The warehouse drone can be ordered by the operator to perform automatic inventory checks throughout the facility, accurately identifying inventory in put-away locations, at the frequency of your choosing. Moving the process of information capture into the air provides on-demand checks of logistics inventories and avoids the time, expense, and risk of using a people lift to access difficult to reach locations within the warehouse."
https://www.pinc.com/warehouse-drone-inventory-management/

Our project has many similarities to PINC's product, which we believe to be a positive. Since our project shares many common features with a professional company's product we must be heading in the right direction.
One of the main differences between our drone and PINC's is that our drone will be able to be driven manually while PINC's are fully automated. Our drones are also much cheaper to make because they don't require the many sensors that are needed to build a fully-autonomous drone.

3.2 Technology Considerations

The team initially decided to use a Raspberry Pi and a camera module for the drone. The reason behind this consideration was to do imaging processing on the barcodes of pallets in a warehouse. The team opted for OpenCV, an open-source computer vision library that can be used on a Raspberry Pi. Autonomy was also a big part of the discussion at the beginning of the semester. The approach was to use lidar and transceiver chips for obstacle detection and localization.

With enough research the team soon realized the complexity of the project and implementation of autonomy and image processing become a concern. To address these concerns the team has decided to use an Arduino as a flight computer for the drone. The team was able to find many resources and tutorials online that will give the team a good head start with the project. A scanner module has been chosen instead of a camera since it does the same job with very low processing power over serial communication. The team does plan on implementing partial autonomy through drone docking however this is still a second priority.

3.3 Task Decomposition

The team has divided tasks into two separate entities. The first one is the Gantt chart, a visual of which is posted in the next section of this document. The Gantt chart encompasses all the major tasks and deadlines established by the instructors. The team regularly uses this to make sure it is on track with each milestone. The second is a Trello board that was created for assigning individual

tasks to each team member. Trello has allowed us to keep track of member performance and time contribution.

Task	Start	End
Preliminary Discussion	01/13	01/17
Biweekly status report	01/27	02/02
Lightning Talk	02/03	02/09
Biweekly status report	02/09	02/16
Design Document v1	02/16	02/23
Biweekly status report	02/24	03/01
Lightning Talk	03/02	03/08
Biweekly status report	03/09	03/15
Design Document v2	03/23	03/29
Lightning Talk	03/30	04/05
Biweekly status report	04/06	04/12

3.4 Possible Risks And Risk Management

The main risk is with the cost of making a fully autonomous drone. After the team spoke with Dr. Jones, he estimated the total cost of a sophisticated automated drone could be around $10,000. The team's solution to this is to make a semi-autonomous drone. The drone can be manually flown and capable of scanning inventory but has some autonomous features such as self-docking at a charging station.

Knowledge of technology is also a challenge since the team isn't experienced in this regard. Hence, an extensive amount of time and energy is being contributed to the research.

The drone itself can be a hazard to the operators and people around the fight parameter. Hence a special testing stand will be built to mitigate this hazard. The testing stand will be used to calibrate the drone so that it doesn't go off course. An area will also be reserved in the Coover with proper approval for our drone testing. This will ensure no injuries occur in case of a crash.

3.5 Project Proposed Milestones and Evaluation Criteria

- The key milestones of the project with evaluations are detailed down below.

Tasks	Evaluation
• Drone schematic	• Run a simulation in PSpice to ensure each component is getting the right voltage

• Cost analysis	• Add multiple sources for a single component to ensure the best price
• Test stand	• Ensure the stand is able to withstand the drone downward thrust
• Drone calibration	• Visually test if the drone is drifting away from its stationary point • Visually test whether the drone maintains a balanced fight
• Scanning barcodes	• Test the scanner data being transmitted to the Arduino over serial communication
• Data transmission from the drone to the server	• Ensure that the scanner data is being transmitted to the backend by making POST requests from the Arduino to the backend server
• Backend server API testing	• Prepare Unit testing in Mockito to ensure APIs word before using with the drone

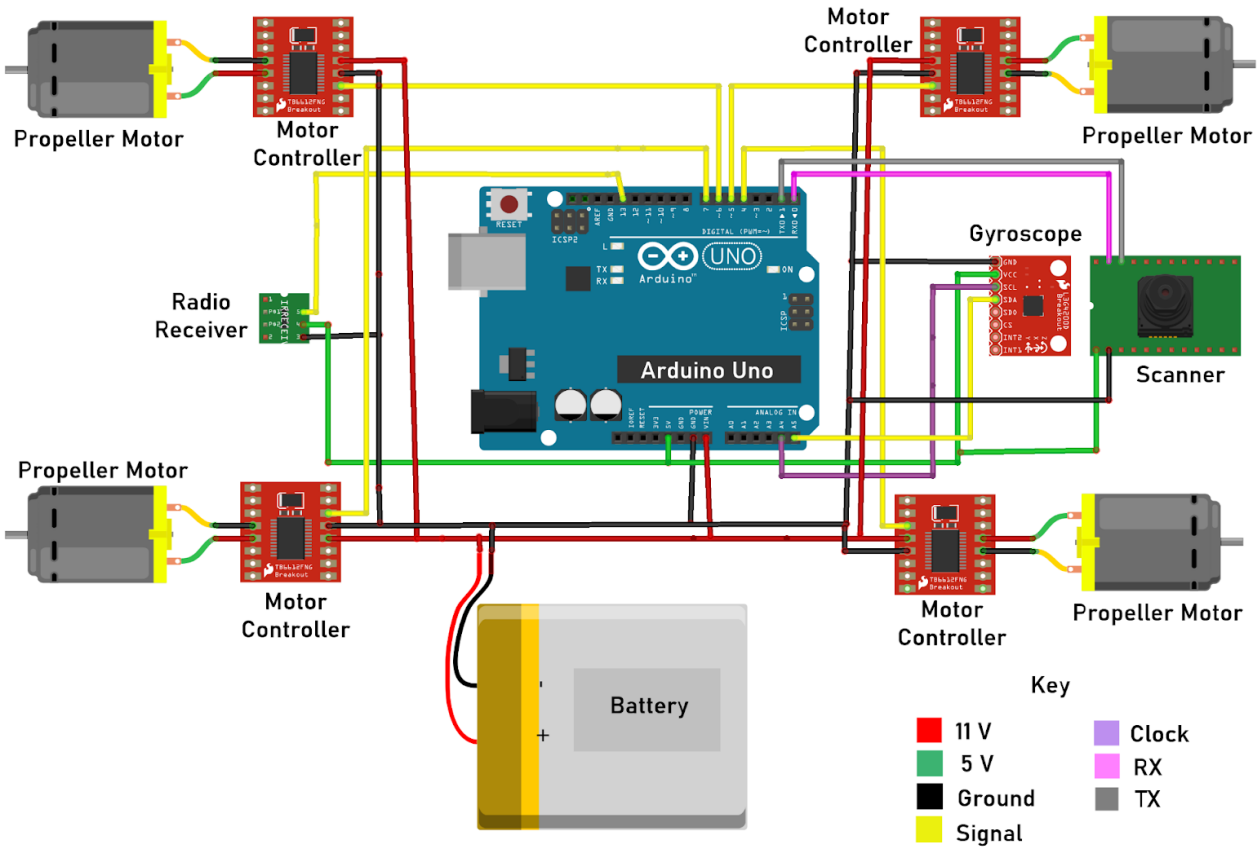
3.6 Project Tracking Procedures

- The team is using a Gantt chart as depicted in section 4.1 to keep track of the project deliverables. As stated before, individual tasks will be tracked using Trello.

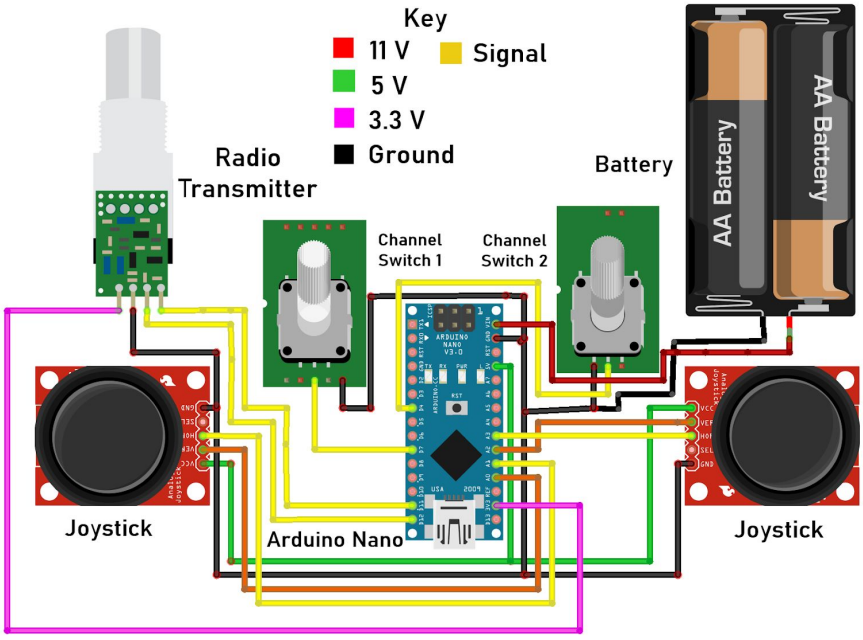
3.7 Expected Results and Validation

- Our final goal is to have a flyable drone that can scan barcodes and dock itself at a charging station. Scanning inventory items will update a database with the total number of each item, its location, and the barcode. To test our project we plan on setting up a mock warehouse to run different scenarios.

Expected Drone Schematic:



Expected Controller Schematic:



4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

- This is the team's Gantt chart with project deliverables. These are the assigned projects throughout the semester with defined due dates. This Gantt chart is part of a whole. It extends into next semester, and can be filled out as needed.

- Additional tasks that need to be accomplished are referenced in section 3.5.
    - The team has already worked some on cost analysis. The next stage would be to use selected components in the drone schematic test and simulate them by April 10th. After this has been established the team would like to start work on data transmission from drone to server. This work may take an extended period of time due to the lack of availability of the drone for testing. Ideally, this would be functional around the end of September. The other task that goes along with this is the backend server API testing. This will need to be set up first along with the server and would ideally be accomplished about a month into next semester. The hardware team would like to have the barcode scanning task done very quickly after receiving parts as it does not require flight capabilities. With the recent transition to online school, it is not entirely clear when we will be putting in our order for parts, but it would be ideal to have this task accomplished before the next semester starts. Drone Calibration will be a task only after the drone is capable of flight. As such we would like this task to be accomplished about a month into next semester, however, to accomplish this task we must first create a stand so that the drone does not fly away during calibration. The team would like to have this task finished early next semester. The team would like to have this task accomplished within 2 weeks of finishing drone calibration.

4.2 Feasibility Assessment

- Realistic Projection:
    - The team would like to have a fully functional drone capable of scanning barcodes and transmitting data over wifi. The minimal requirement the team would like to meet is have someone manually flying the drone to a barcode and scan it. The team would like to have the drone capable of implementing autonomous flight by docking the drone. So if the team meets its preliminary goal, operational drone, then autonomous flight could be implemented.
- Foreseen Challenges:
    - The team has many challenges to face during the duration of this project. Some of the hardware challenges include balancing the weight of the drone with the power needed to power the thrusters to make the drone fly. Another would be that the team has minimal experience soldering, which is a requirement for building the drone. There are several challenges on the software side as well. Ensuring a leveled flight and able to move in the right orientation are a few challenges that will be tackled by the software team. In addition to that, ensuring the drone can send and send information over wifi in real time.

4.3 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be based on the projected effort required to perform the task correctly and not just "X" hours per week for the number of weeks that the task is active

Starting with Design document V2:

Tasks	**Effort Requirements**
Design Document V2	This requires a moderate amount of effort as the team has to correlate and confirm that everyone is on the same page as well as researching necessary materials.
Lightning Talk	This requires a smaller amount of effort. Each person should only need to record about a min. worth of information.
Biweekly status report	This requires a moderate amount of effort. It should be a comprehensive summary of accomplishments over the course of the last 2 weeks.
Drone Schematic	This might be a larger amount of effort. The team must have confirmation the schematic will work if the specific parts are ordered.
Cost Analysis	This will be a smaller amount of effort, but might have to be redone on occasion depending on how well the other tasks go.
Test Stand	This task will require a smaller amount of effort. We just need a simple stand to tether the drone to while we test and calibrate it.

Drone Calibration	This task will require a larger amount of effort. A good portion of work will be required to make sure the drone can be reliably flown to avoid injuries or damaging the drone.
Scanning Barcodes	This will be a smaller amount of effort. Many tutorials exist online and should be fairly simple depending on which barcode scanner we purchase.
Data transmission from drone to server	This will be a smaller amount of effort, sending information over wifi should be a relatively trivial task.
Backend Server API testing	This will be a smaller amount of effort, but testing must be done often to be sure nothing breaks between changes.
Creating UI	This will require a medium to large amount of effort. Designing the UI from scratch gives us a lot of freedom with displaying data; this will require researching the appropriate metrics to display to the user. From a technical standpoint, the admin console is intended to be a responsive web application, so the learning curve of learning a responsive web framework should be the main thing to watch out for here.
Maintaining Inventory Database	Should be a small amount of effort as long as we can properly scan and transmit data to the server.

4.4 Other Resource Requirements

- A room large enough to fly a drone
    - Dr. Rover mentioned she could put in a request to allocate space for our team somewhere.
- Shelves
    - Shelves are needed to simulate a warehouse environment and put goods at different elevations
- Boxes
    - Cardboard boxes or something similar to place barcodes on.
- Barcode printer
    - Will need this to print barcodes to test the scanner. We would like to check in with existing ISU resources to see if one would be available for use.

4.5 Financial Requirements

The team has a $500 budget constraint for our project. The team laid out the items needed to complete our project in a spreadsheet listed here:

						Drone Cost Analysis	
Index	Item	Cost per Item	Shipping	Quantity	Total	Link	Purpose
1	off the shelf drone	$0	$0	1	$0	https://www.madnesscase.com/products/drone-x-pro-wit	temporary drone to practice getting video feed from and scanning barcod
2	Drone Frame	$19.99	$0.00	1	$19.99	https://www.amazon.com/dp/B0776WLHX7/ref=psdc_11	To mount the components on
3	Propeller Motor	$15.99	$0.00	4	$63.96	https://www.amazon.com/powerday-Brushless-Controller	For thrust
4	Gryoscope Sensor	$10.99	$0.00	1	$10.99	https://www.amazon.com/ACROBOTIC-Gyroscope-Acce	For Orientation and balancing
5	Lipo Battery	$33.99	$0.00	2	$67.98	https://www.amazon.com/Zeee-Helicopter-Airplane-Quad	Powering the drone
6	Lipo Battery Charge	$38.99	$0.00	1	$38.99	https://www.amazon.com/Haisito-Charger-Battery-Balan	Charging drone's battery
7	Miscellaneous	$50	$0	1	$50		Wiring, pcb, transistors, capacitors, resistors, heat, heat shrink etc.
8	Arduino Nano		0		0		Borrow from ETG
9	Scanner	$33	$0	1	$33	https://www.aliexpress.com/item/4000161114258.html?s	Scanning barcodes

						RC Controller Cost Analysis	
Index	Item	Cost per Item	Shipping	Quantity	Total	Link	Purpose
1	Transmitter	$10.99	$0.00	1	$10.99	https://www.amazon.com/MakerFocus-NRF24L01-Trans	Transmitting data to the receiver
2	Receiver	$5.99	$0.00	1	$5.99	https://www.amazon.com/Aideepen-Wireless-Transceive	Receiving data from the transmitter
3	2 Joystick	$9.99	$0.00	1	$9.99	https://www.amazon.com/DEVMO-Joystick-Breakout-Co	Controlling the drone
4	Toggle Switches	$8.56	$0.00	1	$8.56	https://www.amazon.com/Gikfun-MTS102-Position-Toggl	Switching between radio channels
5	x4 9V battery	$7.48	$0.00	1	$7.48	https://www.amazon.com/AmazonBasics-Everyday-Alka	Powering the controller
6	Arduino Nano				0		Borrow from ETG
7	Miscellaneous	$30	$0	1	$30		Wiring, pcb, transistors, capacitors, resistors, heat, heat shrink etc.
8	Battery Connector	$4.99	$0.00	1	$4.99	https://www.amazon.com/LAMPVPATH-Battery-Connect	connecting to arduino
9			0		0		

And this leads to our by item break down:

Item	Total Cost
Drone	$285
RC Controller	$78.00
Budget	$500
Remaining	$137

As you can see the team is under budget and plans to use remaining funds to replace parts that might break during construction or testing phases if need be.

5. Testing and Implementation

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or a software library

Although the tooling is usually significantly different, the testing process is typically quite similar regardless of CprE, EE, or SE themed project:

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study for functional and non-functional requirements)
2. Define the individual items to be tested
3. Define, design, and develop the actual test cases
4. Determine the anticipated test results for each test case 5. Perform the actual tests
6. Evaluate the actual test results
7. Make the necessary changes to the product being tested 8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you've determined.

5.1 Interface Specifications

– Discuss any hardware/software interfacing that you are working on for testing your project

5.2 Hardware and software

– Indicate any hardware and/or software used in the testing phase

– Provide brief, simple introductions for each to explain the usefulness of each

5.3 Functional Testing

Examples include unit, integration, system, acceptance testing

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

5.5 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

5.6 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

• This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

-**Modeling and Simulation**: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.

-List the **implementation Issues and Challenges**.

6. Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

6.3 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.