Warehouse Automation

Design Document

sddec20-10
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Executive Summary

Development Standards & Practices Used

- MVC style coding in the backend.
- Agile and Test Driven Development practices will be used
- Follow FAA flight regulations on unmanned flight
- Follow IPC standards for PCB design and assembly

Summary of Requirements

- Have some method to take inventory in a warehouse
- Create a module design which can be integrated into different warehouses
- The gathered data must be transmitted to a web server via wireless communication
- Data in the server must be viewable in a web application

Applicable Courses from Iowa State University Curriculum

- CprE 288: Embedded Systems
- ComS 309: Software Development Practices
- ComS 319: Construction of User Interfaces
- EE 333: Electronic System Design

New Skills/Knowledge acquired that was not taught in courses

Most knowledge required in this project has been taught in the courses mentioned above.

Table of Contents

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

1 Introduction

1.1 Acknowledgment

The team appreciates Dr. Rover for choosing us 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, easily 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 of the project.

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 aerial drone 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 proposed solution. 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 an aerial autonomous vehicle 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 an aerial drone with a built-in barcode scanner to scan barcodes. This drone will be operated manually by an operator who will fly the drone across the warehouse to scan barcodes. Data from the drone will be transmitted to the server via wireless communication. A website will also be developed to view the gathered data and run analytics on it.

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. A separate room in Coover hall will be utilized for testing purposes to prevent the risk of harming others in case of an abnormal flight. This room will be emptied out since the drone operators are required to operate at a minimum of 1 meter while the drone is in flight.

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 project requirements are being met through seeking feedback
- **System Requirements:**
    - Design and develop an aerial drone
    - Integrate scanners into the system to scan barcodes
    - Use wireless communication to transmit data from the drone to the server
    - Develop a web application which displays 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 address concerns
    - Weekly team meeting with the faculty advisor to discuss progress and future goals
- **Functional Requirements:**
    - The drone should be able to fly to the height of most warehouses
    - The done must scan barcodes off of pallets
    - 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 drone is not recommended for outdoor use
    - 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
    - The person controlling the drone is well trained
- **Limitations:**
    - A single drone shall operate for a minimum of 20 minutes on a single charge
    - The drone shall be no larger than 300 mm in length
    - The drone shall have a swappable battery
    - The drone shall use a lithium-ion battery
    - The drone shall always operate in the range of a wireless access point

1.7 Expected End Product and Deliverables

The expected end product will be a drone with a charging base station. This drone will be operated through a radio controller. 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 20 minutes. Once on a low charge, the drone will be moved to the base station for charging and will continue once fully charged.

A web application will also be shipped with the drone which will display the data received by the server from the drone. This data will be updated in real-time as items are scanned. 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	**Due**
1	Project Plan	January
2	Research Hardware Components	February
3	Research Software Components	February - April
4	Construct Project Schematics	March
5	Perform Cost Analysis	March
6	Components Ordering	August (originally April, delayed due to COVID)
7	Product Assembly	September
8	Software Testing and Debugging	September - November
9	Hardware Testing and Debugging	September - November
10	Product Delivery	December

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 drone must scan barcodes off of pallets in each aisle of the warehouse. The data from the scanner shall be transmitted to the backend server and this data should be viewable through a web application.

When considering the nonfunctional requirements, a scanner will be integrated into an aerial drone to scan the barcodes. 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 20 minutes 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 will be implemented and continuously assessed to make sure the drone is operating as expected. For IEEE standards would just be to meet FAA standards.

2.2 Design Analysis

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.

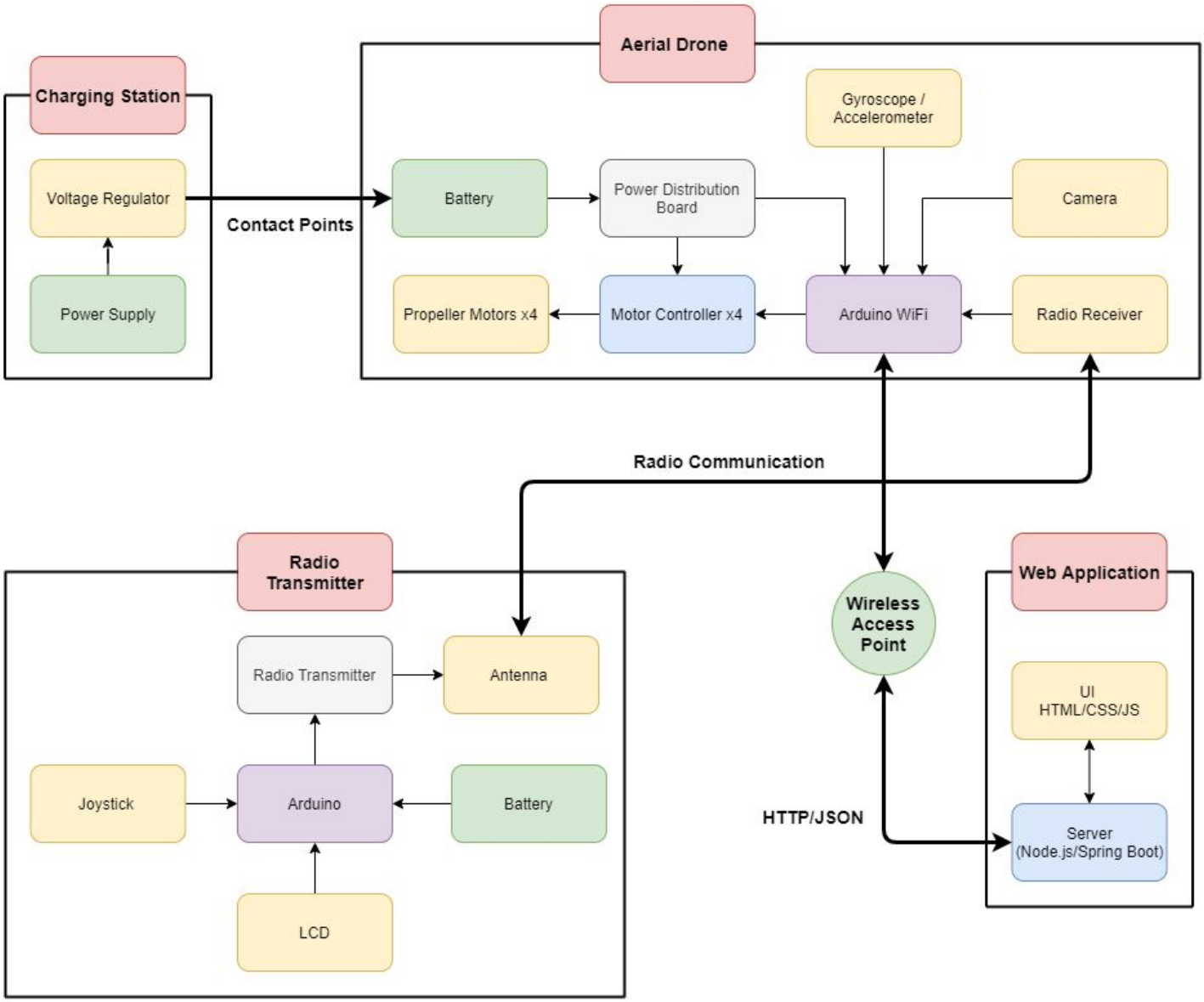
Thus far, the drone project has been working well. The team has been able to do research on all the hardware components with cost analysis. The team is now focused on working on the software side of the development process.

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 that a warehouse setting isn't safe for warehouse workers. Employees reaching high stacked inventory through the help of ladders, which 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 for now.

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.

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 drone 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.

There is also the risk that the drone may damage itself in the event of a crash. This can be mitigated by having extra propellers on hand, using the testing stand, and cutting power to the drone in case things go awry.

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

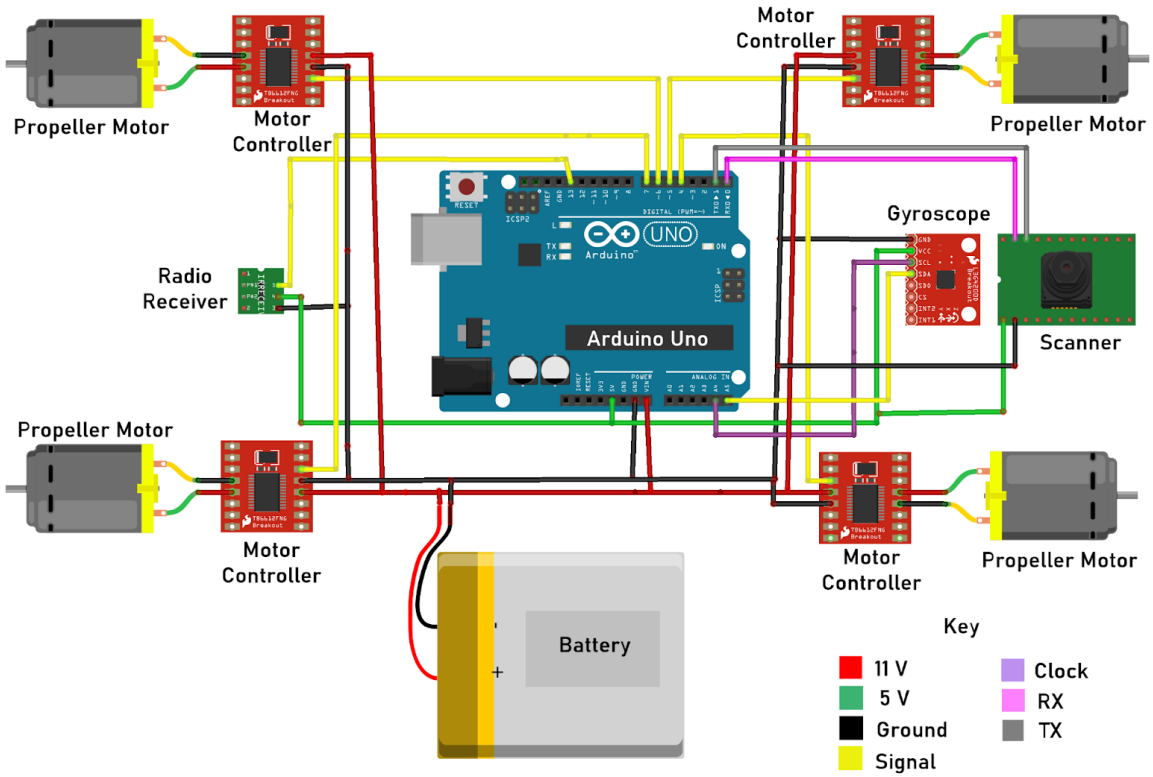
3.6 Project Tracking Procedures

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.

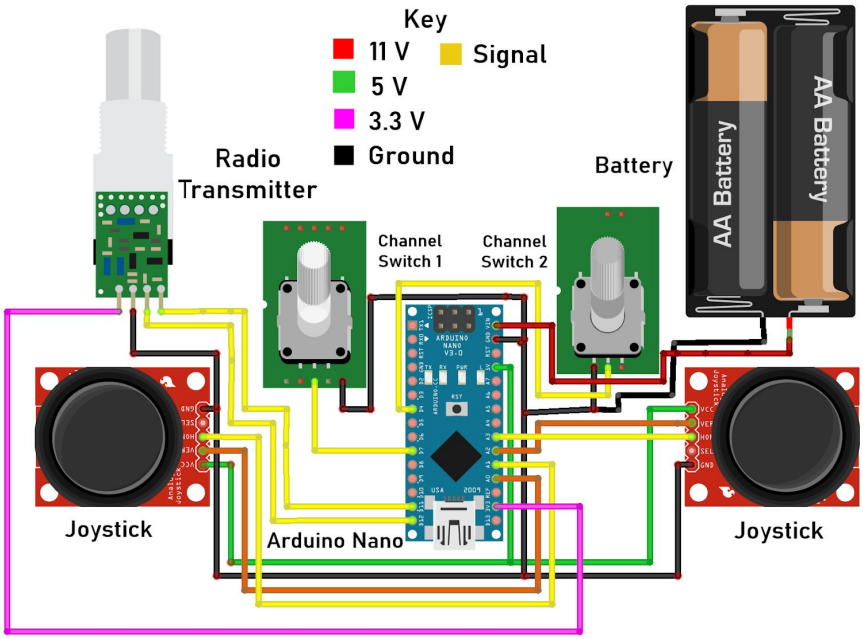
3.7 Expected Results and Validation

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 Circuit:



Expected Controller Circuit:

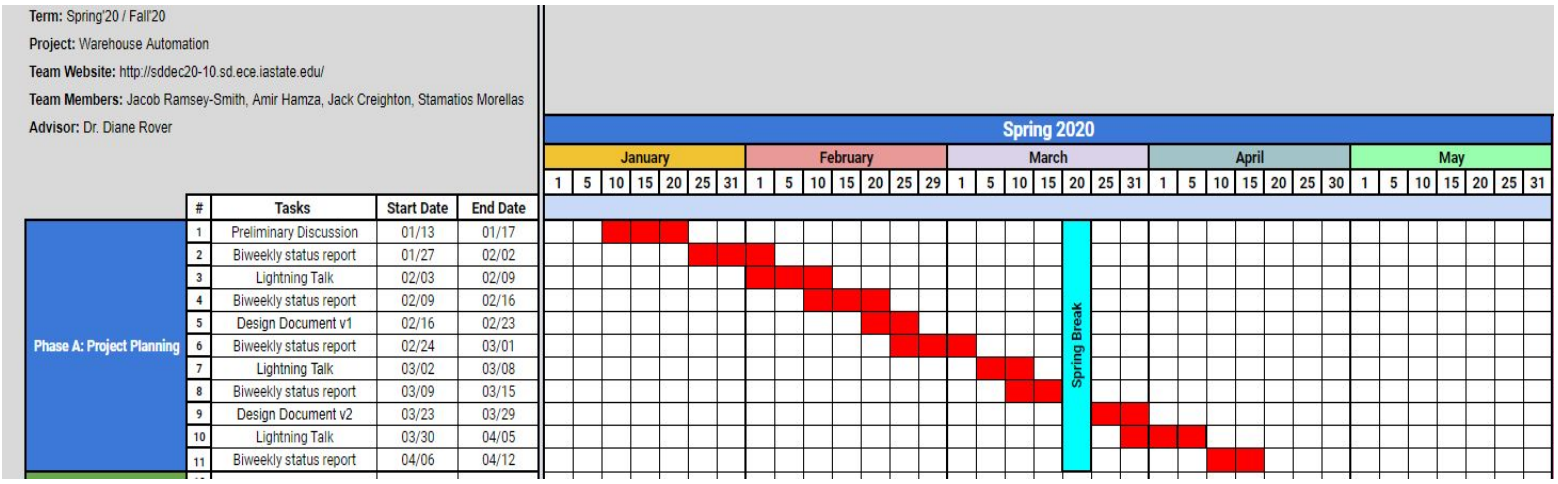


4. Project Timeline, Estimated Resources, and Challenges

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. Next, 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 good 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 having someone manually fly the drone to a barcode and scan it. The team would like to have the drone capable of implementing autonomous docking. If the team meets its preliminary goal of an operational drone, then the autonomous flight will be worked upon.
- Foreseen Challenges:
    - The team has many challenges to face during the duration of this project. One of the hardware challenges would be having a battery for the drone that has enough power for the motors and flight controller, which is simultaneously not too heavy for the drone to lift. 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 the 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 a 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	It 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
    - We 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-Alkal	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

5.1 Interface Specifications

Our team is working on creating simulations in PSpice software for testing our project circuits.

5.2 Hardware and software

Hardware used in the testing phase will consist of:

- The drone and its respective components
- The controller and its respective components.
- The barcode scanner

Individual tests will be performed checking the motor controllers and motors to confirm each one is functioning properly. Then the remote channels will be tested to make sure the Arduino controller is receiving a signal. The barcode scanner needs to be activated when a channel switch is toggled.

Software used in the testing phase will consist of:

- C++ code for the Arduino to control the motor, barcode scanner, and gyroscope.
- Code responsible for sending and receiving signals from the controller.
- Code to send data to the backend from the drone over wifi. This will eventually be used to implement sending data obtained from the barcode
- The UI querying the database. This will test that the database is being updated accurately and the UI is working properly.

5.3 Functional Testing

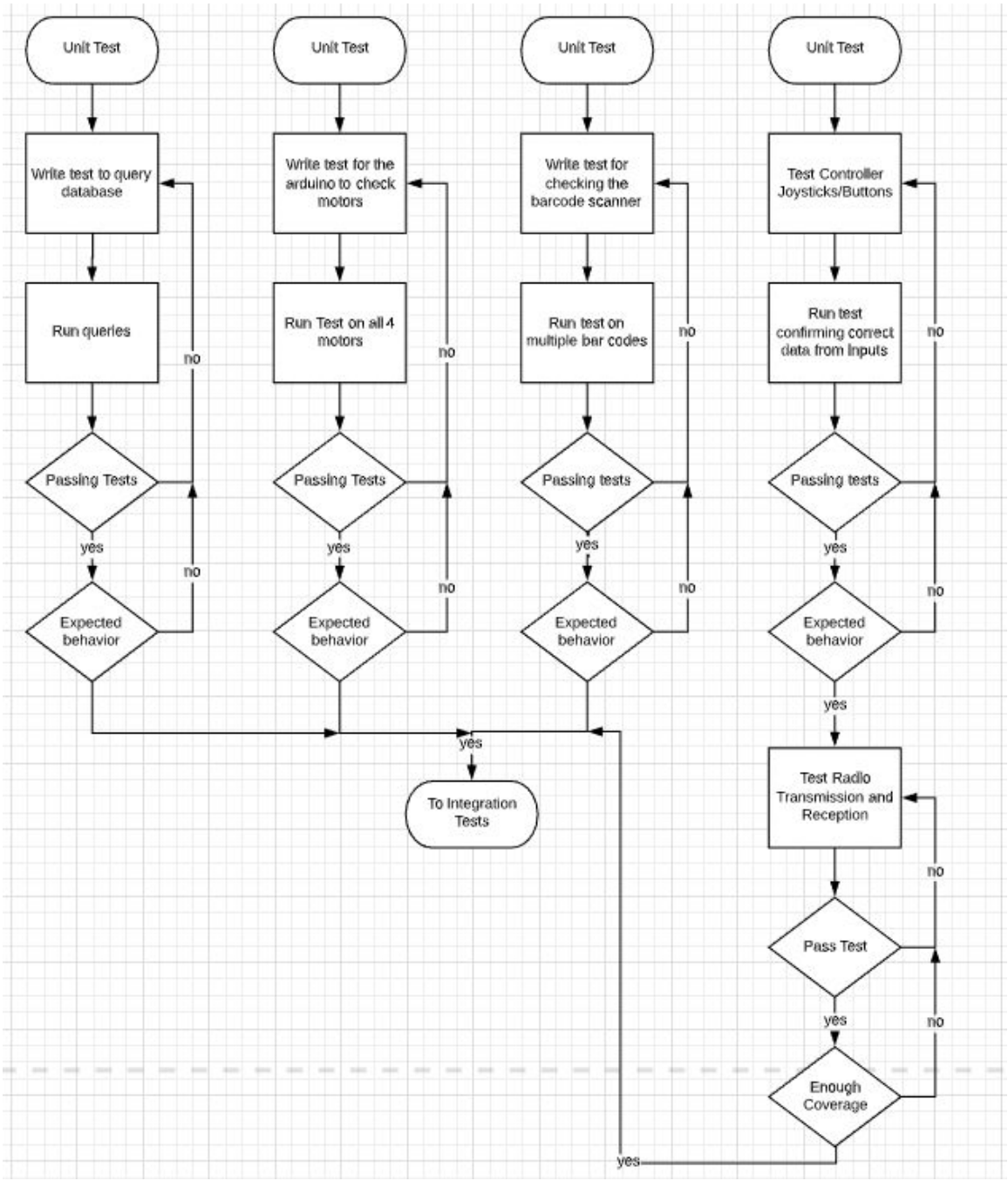
- Initially, the battery will be tested to make sure it works. Then the motors will be hooked up to the battery to confirm each of the motors work.
- Separately the flight controller (the Arduino board) will be hooked up to confirm that works and run unit tests on that with the barcode scanner. This includes a test to confirm the board can receive a signal from the controller.
- Then the flight controller and motors will be hooked up to make sure the whole system is functional.

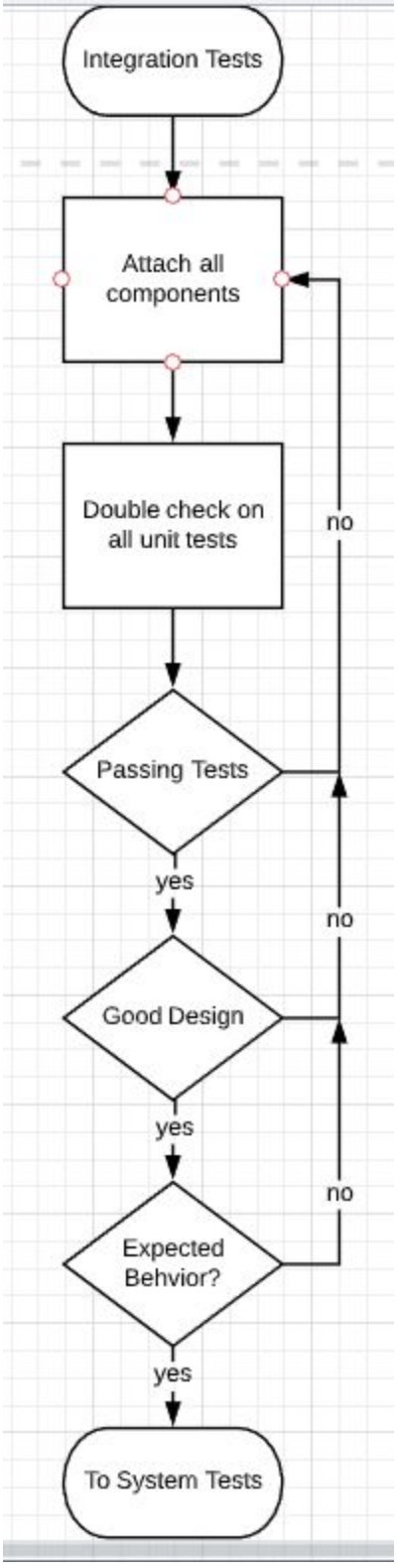
5.4 Non-Functional Testing

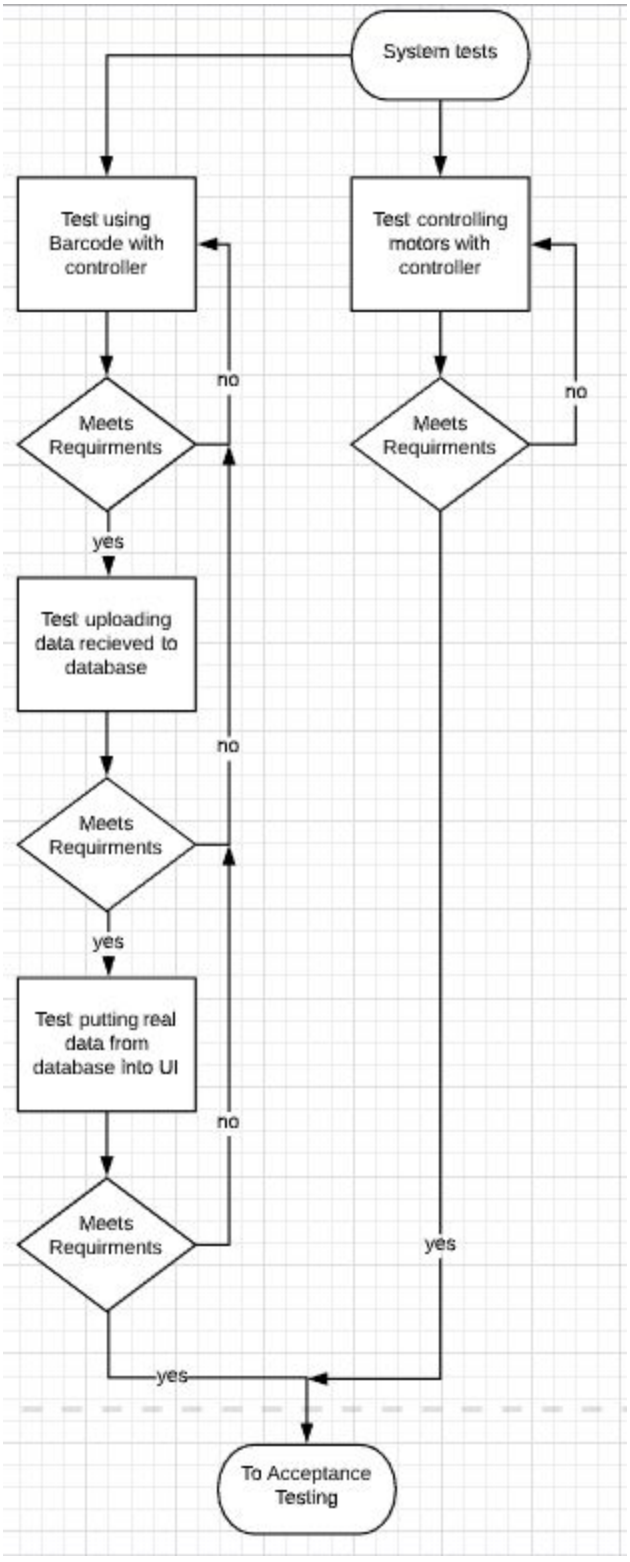
- While testing the motors of the drone, the team must ensure that the motors will be able to lift the drone and hover with no more than half throttle. The purpose of this is to not burn out the motors and ensure longevity of the drone. The drone may also have more equipment attached in the future and the drone must be able to carry that as well.
- During initial flight tests, the drone will be tested using a tether to safely ensure flight capabilities.
- The Drone will also be tested for general usability and if the control setup is easy and intuitive.

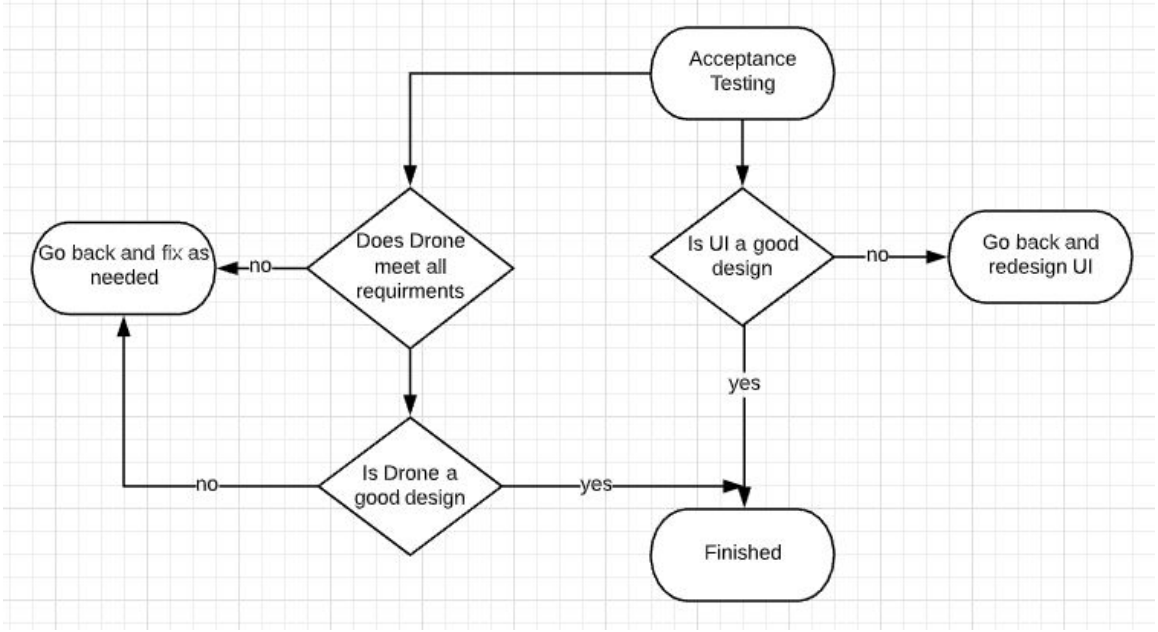
5.5 Process

The following flow diagrams describe the process to test each method indicated in Section 5.2. During the Integration testing stage, additional tests will be done to meet non-functional requirements, such as building a stand with a tether to safely test the drone.




Integration Tests
Attach all components
Double check on all unit tests
Passing Tests
yes
Good Design
yes
Expected Behvior?
yes
To System Tests
no
no
no


System tests
Test using Barcode with controller
Test controlling motors with controller
Meets Requirments
Meets Requirments
yes
Test uploading data recieved to database
Meets Requirments
yes
Test putting real data from database into UI
Meets Requirments
yes
yes
To Acceptance Testing
no
no
no
no
no



5.6 Results

So far we have not had a chance to do any testing because of the COVID-19 pandemic setting us back by a considerable amount. Due to this delay we have not been able to order components and begin assembly of our drone, and therefore have nothing to test on. We have models for our hardware to put together as shown as in section 3.7.

6. Closing Material

6.1 Conclusion

The primary goal of our project is to create an aerial drone capable of scanning barcodes to increase efficiency and safety in a warehouse environment. Our plan is to have the drone be manually operated to scan barcodes, and then the barcodes will then be sent over WiFi to update the database accordingly. We will also develop a web application that allows the user to get current inventory counts, update the database manually, and get certain metrics on products.

The original plan was for a fully autonomous drone, but after researching that plan and consulting with faculty we concluded that approach was not feasible due to cost, time, and circumstantial constrictions. However, we plan on focusing on modular development so that once we have our manually controlled drone functioning transitioning to a more autonomous drone will be easier.

So far we have designed schematics for both the drone and the controller, completed a cost estimate for all the hardware components we will need, and developed high-level software diagrams such as use case scenarios. We have also created a timeline and detailed milestones to help us stay on track when the Fall semester begins.

Our solution surpasses other solutions as the team has found reliable sources stating that drones are more efficient than workers. This is described more in depth in section 3.1.

6.2 References

[1] "Arduino drone brushless flight controller tutorial", *Electronoobs.com*, 2020. [Online]. Available: http://www.electronoobs.com/eng_robotica_tut9.php. [Accessed: 26- Apr- 2020]

[2] J. Brokking, "Brokking.net - Project YMFC-AL - The Arduino auto-level quadcopter - Home.", *Brokking.net*, 2020. [Online]. Available: http://www.brokking.net/ymfc-al_main.html. [Accessed: 26- Apr- 2020]

[3] H. Srivastava, "5 Best Free and Open Source Inventory Management Software", *Blog.capterra.com*, 2020. [Online]. Available: https://blog.capterra.com/the-top-5-free-inventory-software-systems/. [Accessed: 26- Apr- 2020]

[4] J. Schofield, "7 Important Inventory Metrics for Your Warehouse", *System ID Barcode System Blog*, 2020. [Online]. Available: http://www.systemid.com/learn/7-metrics-for-your-warehouse/. [Accessed: 26- Apr- 2020]

[5] S. Stone, "5 Key Warehouse Performance Metrics for an Effective Operation", *Cisco-eagle.com*, 2020. [Online]. Available: https://www.cisco-eagle.com/blog/2016/01/28/5-key-warehouse-performance-metrics-for-an-effective-operation/. [Accessed: 26- Apr- 2020]

[6] M. Lebied, "Inventory Metrics & KPIs – Best Practices Every Manager Should Know", *BI Blog | Data Visualization & Analytics Blog | datapine*, 2020. [Online]. Available: https://www.datapine.com/blog/inventory-metrics-and-kpi-best-practices/. [Accessed: 26- Apr- 2020]

[7] S. Cho, "10 Inventory Metrics You Need to Know - Inventory Management Metrics", Best Inventory Management Software for Small Businesses - EMERGE App, 2020. [Online]. Available: https://emergeapp.net/inventory-reports/10-inventory-metrics-for-smbs/. [Accessed: 26- Apr- 2020]

[8] J. Brokking, "Brokking.net - Project YMFC-AL - The Arduino auto-level quadcopter - Home.", *Brokking.net*, 2020. [Online]. Available: http://www.brokking.net/ymfc-al_main.html. [Accessed: 26- Apr- 2020]

[9] "Arduino radio controller NRF24", *Electronoobs.com*, 2020. [Online]. Available: http://www.electronoobs.com/eng_arduino_tut25_2.php. [Accessed: 26- Apr- 2020]

[10] "DIY Arduino RC Transmitter - HowToMechatronics", *HowToMechatronics*, 2020. [Online]. Available: https://howtomechatronics.com/projects/diy-arduino-rc-transmitter/. [Accessed: 26- Apr- 2020]

[11] "DIY Arduino RC Receiver for RC Models and Arduino Projects", *HowToMechatronics*, 2020. [Online]. Available: https://howtomechatronics.com/projects/diy-arduino-rc-receiver/. [Accessed: 26- Apr- 2020]

[12] "Supply Chain Metrics for Data Driven Leaders", *Klipfolio.com*, 2020. [Online]. Available: https://www.klipfolio.com/resources/kpi-examples/supply-chain. [Accessed: 26- Apr- 2020]

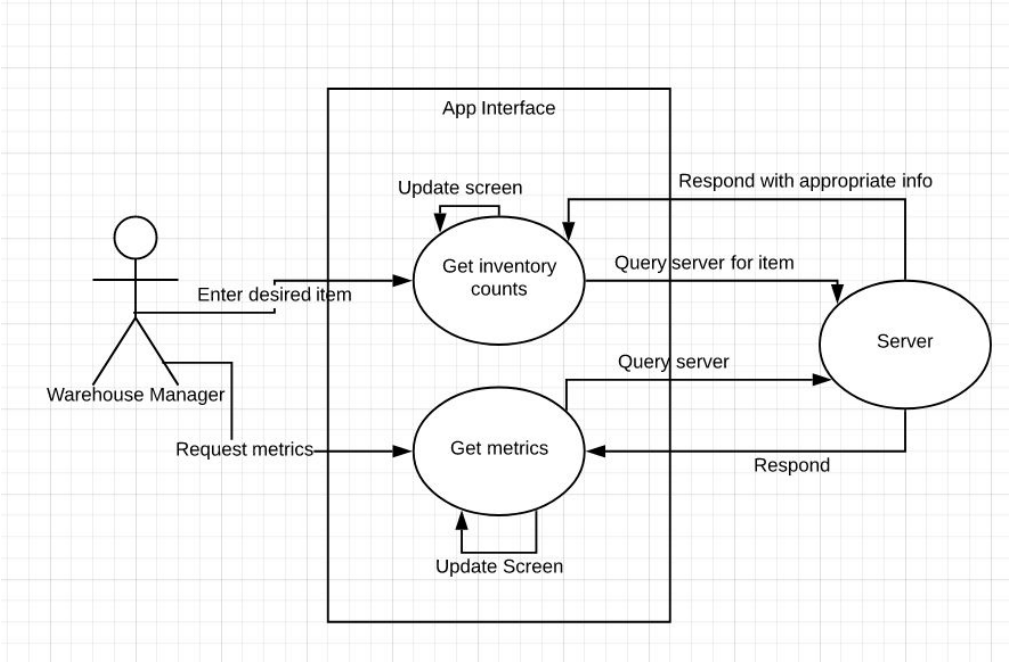
[13] "KPIs to Improve Inventory Management Process | USPS Delivers", *USPS Delivers*, 2020. [Online]. Available: https://www.uspsdelivers.com/10-kpis-that-can-help-improve-your-inventory-management-process/. [Accessed: 26- Apr- 2020]

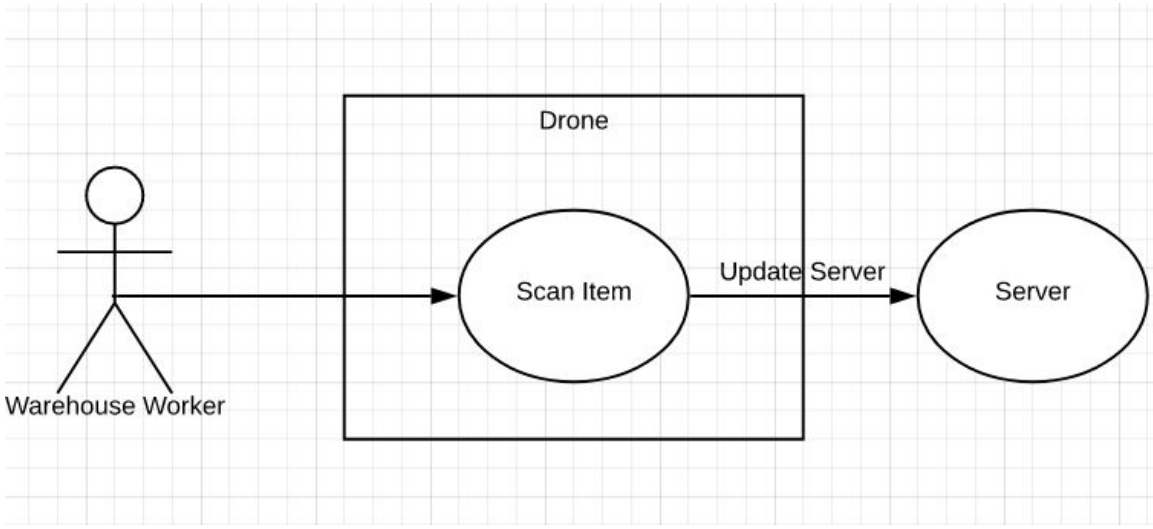
6.3 Appendices

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.

Use Case Scenarios





Relation Between Hardware and Software Overview