# SPARROW

## **S**ensor **P**ackage for **A**dvanced **R**econnaissance and **R**obust **O**perational **W**orkflows


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# Chapter 2 – Project Description

## 2.1 Project Motivation and Background

Search and rescue operations have been around for quite some time, especially after any natural disasters or important cases appear. While humans can perform such search and rescue operations, drones have become better at performing such tasks as viewing the scene from the sky provides a better vision of the surroundings and allows for better searching of the environment for humans in need of help.

To address this challenge and to improve the safety and efficiency of such operation, SPARROW introduces a solution that leverages a communication between the drone and the base station controller where the drone would scan the affected regions and transmit their data over the controller for displaying the feed.

By using computer vision technology, SPARROW can process visual data in real time, detecting any humans in need of help and showcase the situation to the display on the controller. This not only drastically accelerates the assessment phase but enhances safety by reducing the need to physically inspect these hazardous areas.

This integration of computer vision into drone applications represents a progressive approach to disaster management. With SPARROW containing the drone and base station controller working together, this system allows for rapid, data-driven decision-making. This pairing ultimately promises to minimize disruption to any situation affected by a need for search and rescue operation in the wild.

## 2.2 Current Technologies and Existing Projects

**DJI RC Pro**

The DJI RC Pro is a drone controller designed and manufactured by DJI, a leading technology company based in Shenzhen, China. Renowned for producing a wide array of unmanned aerial vehicles (UAVs) used extensively in aerial photography, surveying, and other applications, DJI has become synonymous with innovation and quality in the drone industry. The DJI RC Pro stands out as a versatile and high-performance controller, engineered to be compatible with and control a broad range of DJI's drone products. Our group must consider the design decisions of an industry leader such as DJI so that we may produce a competitive product that attempts to improve areas where the DJI RC Pro is lacking.

One of the standout features of the DJI RC Pro is its advanced communication capabilities. It employs four 2T4R high-gain antenna systems, in combination with O3+ video transmission technology. This combination allows the controller to send and receive information from distances exceeding 15 kilometers, ensuring strong connectivity even in challenging environments. The transmission system operates with a latency of just 120 milliseconds, providing real-time control and feedback essential for precision flying. Additionally, the controller supports video transmission at a resolution of 1080p/60fps, ensuring clear and detailed visuals for the operator.

Incorporating a lithium-ion battery with 5000 mAh at 7.2 V of capacity, the DJI RC Pro is provided with a rated power of 12 watts. The controller is designed for quick recharging, requiring only 1.5 hours to reach full capacity when using a 15-volt USB charger. Once fully charged, the DJI RC Pro can operate continuously for up to 3 hours before running out of battery.

It is because of the DJI RC Pro’s robustness and performance that has made it an industry standard, widely regarded for its ability to support a diverse range of drones while maintaining high-resolution video transmission with minimal latency. This reliability is crucial for professionals who depend on accurate and timely data from their drones and is even more crucial during emergency responses.

However, while the DJI RC Pro excels in many areas, there is always room for improvement and specialization to meet specific needs. This is where SPARROW comes into play. SPARROW aims to build upon the strong foundation provided by the DJI RC Pro, addressing areas where enhancements are necessary. One key focus is increasing the durability of the controller to withstand harsh environmental conditions and the rigors of fieldwork. Additionally, the project seeks to extend battery life, ensuring even longer operational periods without the need for recharging.

Another difference is that SPARROW will emphasize enhancing the autonomous capabilities of the drone system. This includes the development of advanced algorithms and sensors that enable the drone to detect power lines and transformer faults autonomously using computer vision. Such capabilities are particularly critical in post-natural disaster scenarios, where quick and efficient detection of infrastructure damage is essential for restoring services and ensuring public safety. By improving these aspects, SPARROW aims to create a drone controller and system that is not only reliable but also highly specialized for critical tasks in challenging environments during a post-natural disaster event.

**HSE Carrier Ground Control Station (C-GCS)**

The Carrier Ground Control Station (C-GCS) is an advanced control unit developed and produced by Homeland Surveillance & Electronics (HSE), a UAV technology company based in Florida, United States. HSE is known for its innovation in drone technology, specializing in the production of UAVs and drone controllers primarily used by first responders and the agricultural industry. The company’s commitment to creating reliable and efficient UAV solutions has made it a trusted name among professionals who depend on aerial technology for their critical operations. It is important for our group to consider the design decisions of a specialized product such as the HSE C-GCS so that we may improve our product.

The C-GCS stands out as a versatile and powerful ground control station, fully compatible with all HSE drones. This compatibility ensures seamless integration and operation, allowing users to efficiently manage and control their UAVs from a single interface. In addition to supporting HSE's drones, the C-GCS is designed to be easily integrated with other third-party UAV platforms. This flexibility is crucial for users who operate a diverse fleet of drones from different manufacturers, providing a unified control system that simplifies operations and enhances efficiency.

One of the key features of the C-GCS is its advanced communication capabilities. It employs an RFD900 and a TBS Crossfire, two high-performance communication systems that enable the control station to send and receive information at distances exceeding 15 kilometers. This long-range capability is essential for operations that require extensive coverage, such as search and rescue missions, large-scale agricultural monitoring, and post-natural disaster responses.

The C-GCS is powered by a 4S lithium-ion battery with a capacity of 5200 mAh, providing ample power for extended operations. For users who require longer operational periods, the C-GCS offers an optional configuration that allows two batteries to be run in parallel, effectively doubling the capacity to 10400 mAh. This flexibility in power options ensures that the control station can meet the demands of various missions, from short, intensive tasks to prolonged, continuous operations.

The durability and reliability of the C-GCS make it a dependable tool for professionals working in demanding environments. HSE has built the control station to withstand harsh conditions, ensuring that it remains operational even in challenging weather and terrain. This robustness is particularly important for first responders who often operate in extreme conditions and for agricultural users who need reliable equipment to manage their fields effectively.

However, similarly to the DJI RC Pro, the C-GCS, despite its numerous advantages, is still lacking in a few areas where SPARROW seeks to improve. We plan on implementing a mesh network to expand its effective operational range at the cost of higher latency. This makes SPARROW better suited for autonomous, drone fleet surveying of an area, allowing it to quickly identify potential hazards in a fraction of the time a single drone would take.

**Summary**

Examining currently available commercial technologies and past projects relevant to our current product provides valuable insights into our project's potential direction. Understanding existing solutions not only helps us set practical constraints and requirements but also informs us about the areas where we can innovate and improve.

In the case of our current project, we are focusing on two key examples: the DJI RC Pro and the HSE Carrier Ground Control Station (C-GCS). These products highlight different strengths and areas for improvement that are pertinent to our development goals.

The DJI RC Pro serves as a prime example of an industry standard. By analyzing its design, we learned several things about implementing an effective antenna system, which would allow our controller to send information to the drone fleet at distances much further than we initially expected at the start of this project. Additionally, we also recognized some areas we could improve upon, such as the DJI RC Pro’s autonomous capabilities. By implementing a detection algorithm utilizing AI to find and mark potential hazards after a natural disaster and a mesh network to expand the effective range the drone fleet can survey, the autonomous capabilities of SPARROW have dramatically increased.

The HSE C-GCS serves as a prime example of a specialized product, similar to our own. We recognized several design choices in the C-GCS that would allow SPARROW to fulfill its intended purpose at a much higher capacity. One such design choice is its power storage and management system. We intend for SPARROW to have a very high battery life when compared to other products that share a similar purpose. Furthermore, we also want SPARROW to be extremely sturdy so that it can handle even the roughest conditions and still be reliable and efficient. The C-GCS utilizes a sturdy case that allows for larger batteries while still keeping the controller safe from any hazards at the cost of both size and weight.

In conclusion, studying the DJI RC Pro and the HSE C-GCS has provided our group several insights into how we should proceed with our research and has given us a direction to move forward. We should pay special attention to our antenna array as there seems to be the most technical variance between the two products. We should also ensure our autonomous capabilities are sufficient so that our project can effectively meet its goals. By integrating these insights into our design process, we can create a product that not only meets but exceeds several current industry standards, providing innovative solutions for drone control and operations in challenging environments.

## 2.3 Goals and Objectives

The central goal of this project is to develop a drone control station capable of managing communication with a drone sensor package. Deployed in the operation of searching and rescuing, the drone will identify humans in need of help and transmit the video feedback to the base station controller to alert the users. Key objectives for SPARROW include the following:

Overall Goals

- **Communication**: SPARROW must establish and maintain communication between the drone and base station.
- **Fault Detection**: SPARROW must be able to accurately identify humans in need of help throughout the surrounding area.

Objectives

- **Data Transmission**: Transmit data and commands to the drone for effective deployment and operation.
- **Data Reception**: Receive real-time data from the drone, including their findings and operational status.
- **Live Feed Display**: Provide a live video feed from the drones' cameras to allow real-time monitoring and facilitate immediate assessment.
- **Automatic Search and Rescue Detection**: Utilize computer vision to automatically detect humans in the wild without requiring human interference.
- **Automated Drone Recall**: Automatically recall the drone fleet when the battery levels of either drone or controller reaches critical levels to ensure continuous operation.
- **User Interface**: Maximize user interactivity and ease of operation by incorporating a touchscreen display.

Stretch Goals

- **Base Station Charging**: Achieve a system where the base station has a charging station where the drone can autonomously come down and recharge its battery.
- **Payload Deployment**: Achieve a system where the drone package would have room to carry a payload that can be developed in the scene for injured humans spotted in the wild.

**Hardware - Basic Goals**

The core functionality of SPARROW revolves around allowing bi-directional data transmission with the SOAR drones. To achieve this, SPARROW must be equipped with an array of antennas, which are essential to issue commands to the drones and to transfer data between the base station and the drones. Converting electronic signals into electromagnetic waves that establish communication links between transmitters and receivers across free space, the antennas are some of the most crucial components for SPARROW.

In any wireless communication system, the antenna plays a pivotal role in maintaining seamless connectivity. For our project, it's important to select antennas that are capable of operating effectively over long distances. This would not only ensure robust communication but enhances safety by allowing remote fleet control from safer, more secure locations.

Additionally, SPARROW must support a high-resolution display to manage and monitor live video streams from the drones. The display's interface should enable seamless switching between camera feeds, including the regular and infrared views. Additionally, a map feature displaying the GPS locations of each drone within the fleet should be incorporated. This would allow for real-time tracking and situational awareness.

Power management is another critical aspect of the SPARROW design. SPARROW will be equipped with a rechargeable battery designed to provide twice as long as the drone's operational time. This redundancy ensures uninterrupted operation. The battery should also be able to power the controller being charged in order to minimize downtime and remaining consistent functionality.

**Stretch Goal - Base Station Charging**

Integrating an autonomous charging station in our system would allow for a more efficient and sustainable operation of the drone. Utilizing wireless charging technology, the drones would be able to recharge their batteries immediately upon landing, minimizing damage to any physical connectors and preventing overcharging through built-in mechanisms.

Drones will be equipped with an advanced navigation system that incorporates GPS, LiDAR, and computer vision for precise landing. As a drone approaches its battery limit, it should autonomously navigate back to the base station. Upon landing, the charging process will initiate automatically, providing real-time updates on the battery status through a dashboard accessible to the operators to the controller. The station could also feature sensors that monitor the health of the charging station, alerting, alerting operators to any potential maintenance needs. Additionally, the base station could employ renewable energy sources to power the charging station, creating a more sustainable system.

**Stretch Goal - Payload Deployment**

Implementation a system where our drone system with the sensors and cameras would weigh less and leave enough room for our drone to carry a payload, such as medical equipment, to be deployed in the certain situations to allow the human on the ground to take the deployed payload and use it for themselves to aid them before the actual rescue team arrives to help support the injured.

In order for such a situation to be feasible, our other payloads would have to be lighter while still fulfilling their purpose, such as the sensors, cameras, and the drone itself. Due to weight limitations, the drone must be light enough alongside the deployment payload so that it obeys the weight regulations of the drone so that this stretch goal can be achieved. On top of such implementation, our drone would require a GPS on it so that it can autonomously be sent out and seek to rescue humans and deploy the payload on the scene and then be returned back via the return to base protocol.

**Software Goals**

The primary software goal of this project is to develop a network system enabling real-time communication between an autonomous drone tasked with recognizing humans in the field and signaling humans in need of help. The communication will ensure that drones can dynamically share critical data such as video feed and the thermal footage and in order to prevent collisions and optimize coverage, our package will implement autonomous flight software communication to establish connection with the base station. By leveraging this communication framework, the drone will be able to collaboratively identify and report human recognition for efficient and safe inspection processes for a search and rescue operation. The system will include emergency landing and return-to-home protocols, ensuring reliable operation even in challenging environments.

In addition to the network that will be implemented, a main part of the project revolves around the image recognition capabilities to enhance the drones ability to identify and analyze humans in need of help. Using a high-resolution camera and an advanced image processing algorithm, the drones will capture and process real-time images of the scenario to determine whether there is a need for rescue. The image recognition software will be trained to detect humans and automatically report these situations back to the control center with its location. The goal is to significantly improve the speed of human detection, enabling quicker response times and reducing the risk of humans being left outside and unrescued for an extended amount of period.

## 2.4 Required Specifications

Keeping in mind our goals and objectives for this project, we defined the following specifications:

***Table 2.1. Specifications of controller***

| **Physical Qualities** | |
|---|---|
| Maximum Total Weight | 2 kg |
| Minimum Size | 40x40x20 $cm^3$ |
| **Communication System** | |
| Minimum Range | 1 mi |
| Data Rate | 5 kbps |

| | |
|---|---|
| Latency | 100 ms |
| Startup Time | 1 minute |
| **Video Reception** | |
| Maximum Range | 5 mi |
| Data Rate | 10 Mbps |
| Latency | 100 ms |
| **Display** | |
| Minimum Resolution | 720p |
| Minimum Size | 5 in |
| Maximum Size | 13 in |
| Minimum Refresh Rate | 60 Hz |
| Maximum Response Time | 5 ms |
| Minimum Brightness | 400 nits |
| **Video Processing** | |
| Clock Speed | 1.5 GHz |
| Flash Memory | 2 MB |
| RAM | 8 GB |
| Operating Voltage | 5 V |
| Detection Range | 20 m |
| Data Throughput | 500 Mbps |
| **Power System** | |
| Battery Life | 1 hour |
| Voltage Input | 3V - 5V |
| Maximum Current Draw | 500 mA |
| Minimum Power | 15 W |

| | |
|---|---|
| Maximum Power | 30 W |
| Charging Rate | 750 Ah |

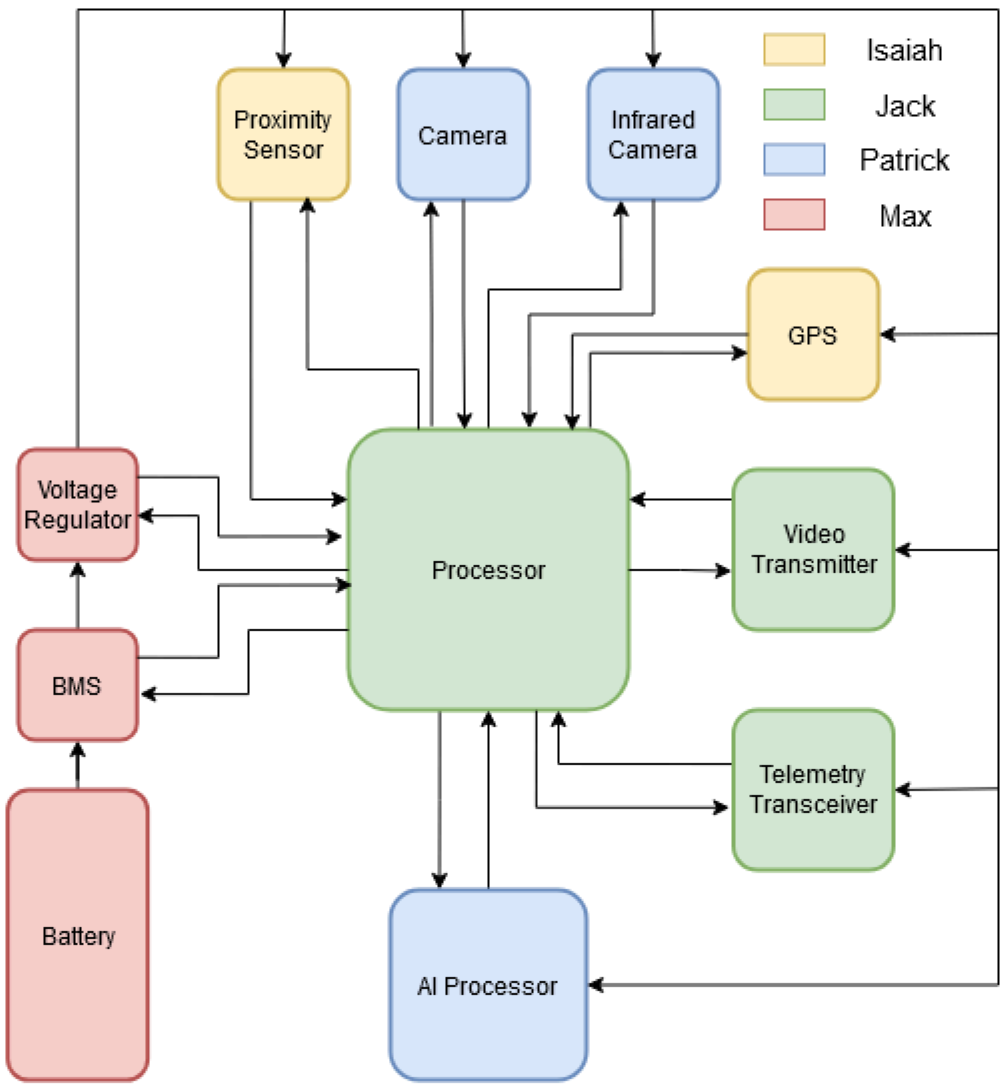



***Figure 2.1.*** *Drone Hardware Block Diagram*

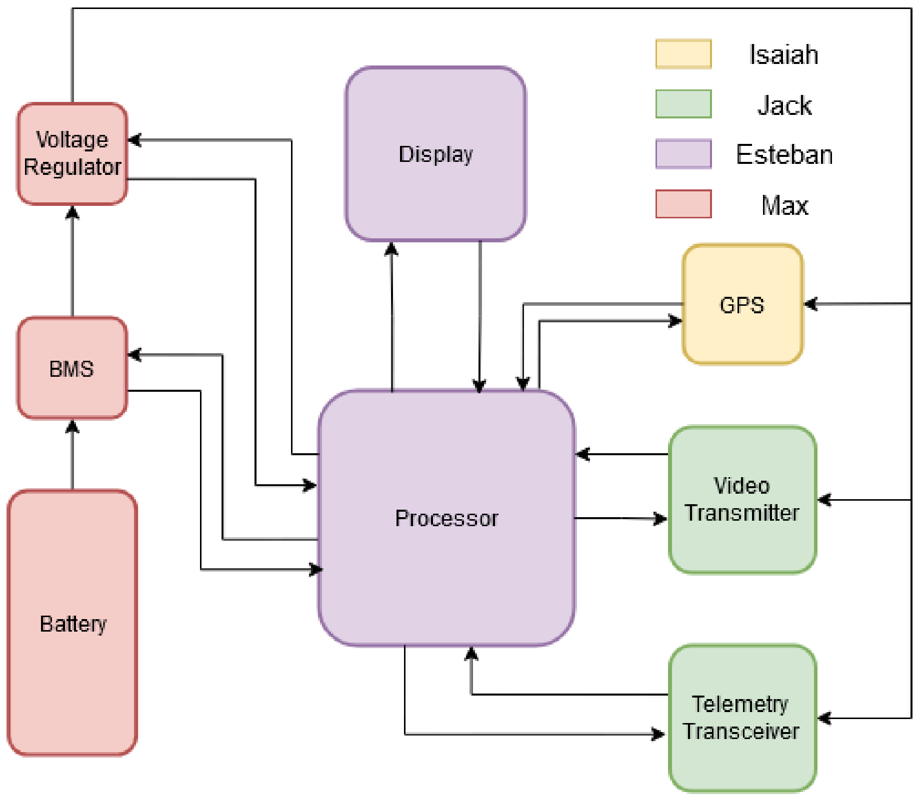



***Figure 2.2.*** *Controller Hardware Block Diagram*

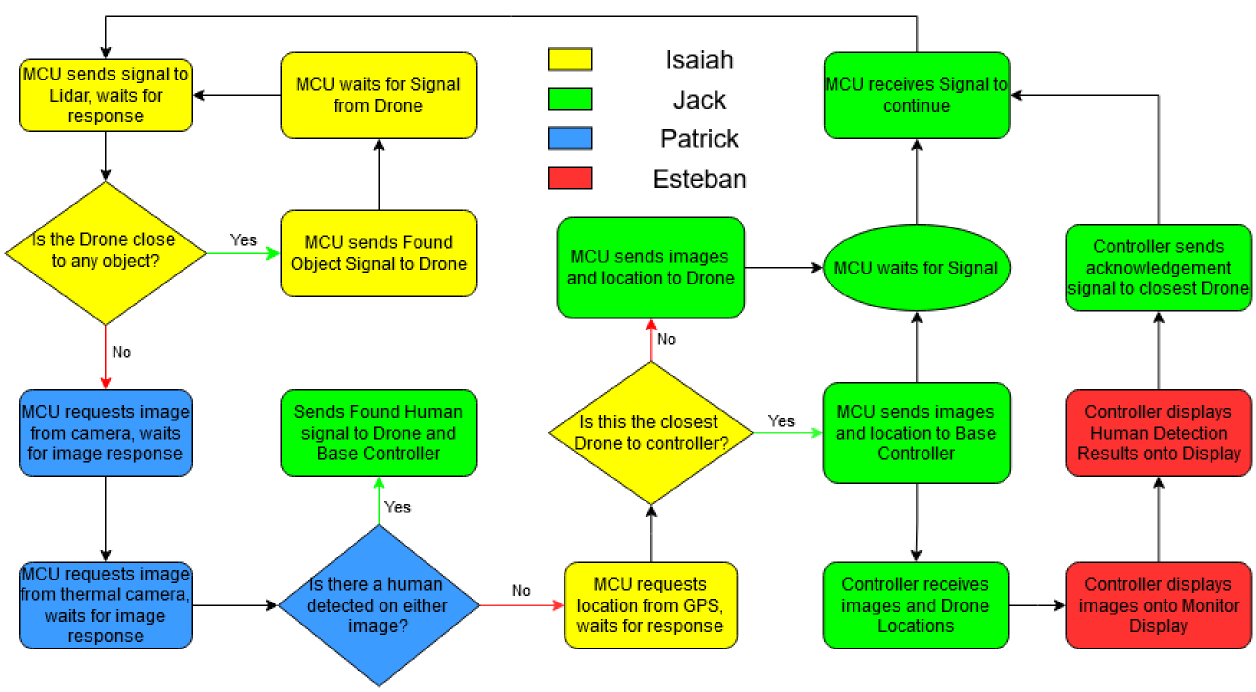


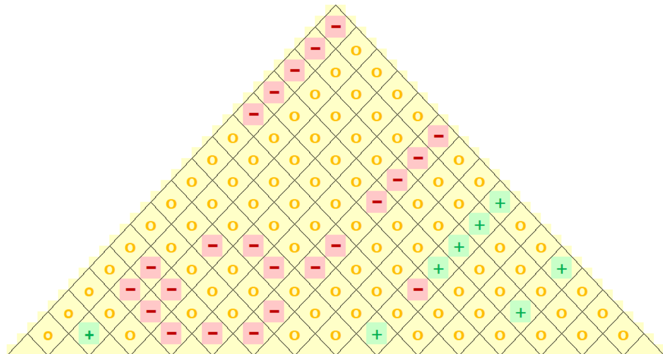

***Figure 2.3.*** *Software Flowchart*

# 2.5 House of Quality

| Correlations | |
|---|---|
| Positive | + |
| Negative | − |
| No Correlation | o |

| Relationships | |
|---|---|
| Strongly Positive | ↑↑ |
| Weakly Positive | ↑ |
| No Relation | ○ |
| Weakly Negative | ↓ |
| Strongly Negative | ↓↓ |

| Direction of Improvement | |
|---|---|
| High | ▲ |
| Low | ▼ |



| Column # | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Functional Requirements / Customer Requirements (Explicit and Implicit) | Direction of Desirability | Package Weight | Controller Weight | Controller Size | Communication Latency | Signal Distance | Battery Life | Charging Rate | Screen Resolution | Accuracy of Detection | CPU Processing Speed | GPU Processing Speed | Detection Distance | Camera FPS | Camera Resolution | Thermal Camera FPS | Thermal Camera Resolution |
| Direction of Desirability | | ▼ | ▼ | ▼ | ▼ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ |
| Affordability | ▲ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ |
| Durability | ▲ | ↓ | ↓ | ↓ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Portability | ▲ | ↓↓ | ↓↓ | ↓↓ | ○ | ↑↑ | ↓↓ | ↓ | ↓ | ○ | ○ | ○ | ○ | ↓↓ | ○ | ↓↓ | ○ |
| Reliability | ▲ | ↑ | ↑ | ↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑ | ↑↑ | ↑ | ↑↑ |
| Compatibility with Drone | ▲ | ○ | ○ | ○ | ↑↑ | ↑↑ | ↑ | ○ | ↑ | ↑↑ | ○ | ○ | ↑ | ○ | ○ | ○ | ○ |
| Forward Compatability | ▲ | ↓ | ↓ | ↓ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↓ | ↑↑ | ↑↑ | ↓ | ↓↓ | ↓↓ | ↓↓ | ↓↓ |
| Ease of Use | ▲ | ○ | ○ | ○ | ↑↑ | ↑↑ | ↑↑ | ↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ |
| Ease of Maintenance | ▲ | ↓↓ | ↓↓ | ↓↓ | ○ | ○ | ↓ | ↓ | ↓ | ○ | ○ | ○ | ○ | ↓↓ | ↓↓ | ↓↓ | ↓↓ |
| Lightweight | ▲ | ↑↑ | ↑↑ | ↑↑ | ○ | ↑ | ↓↓ | ↓ | ↓ | ○ | ○ | ○ | ○ | ↓↓ | ○ | ↓↓ | ○ |
| Storage Capacity | ▲ | ↓↓ | ↓↓ | ↓↓ | ○ | ○ | ↑↑ | ↑ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Communication Range | ▲ | ↑↑ | ↑↑ | ↑↑ | ↓ | ↑↑ | ↓ | ○ | ○ | ↓ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Time-Saving | ▲ | ○ | ○ | ○ | ↑↑ | ↑↑ | ↑ | ↑↑ | ↑ | ↑↑ | ↑↑ | ↑↑ | ↑↑ | ↑ | ↑ | ↑ | ↑ |
| Detection Accuracy | ▲ | ○ | ○ | ○ | ↑ | ○ | ○ | ○ | ○ | ↑↑ | ↑ | ↑ | ↓↓ | ↑↑ | ↑↑ | ↑↑ | ↑↑ |
| Product Efficiency | ▲ | ○ | ○ | ○ | ↑ | ↑↑ | ↑↑ | ↑ | ↑ | ↑ | ↑↑ | ↑↑ | ↑↑ | ↑ | ↑ | ↑ | ↑ |
| Target | | 5 lbs | 2.5 lbs - 5 lbs | Approx. 40x40x20 $cm^3$ | <100 ms | 1 mi - 2 mi | Approx. 2x drone battery life | 500 mA - 1 A | 720 p - 1080 p | 90% | 1.5 GHz | 625 MHz | 50 m | 50 fps | 1080 p | | |

***Figure 2.4** House of Quality*

# Chapter 10 - Administrative Content

## 10.1 Budget

The budget provided for this project by our sponsor Lockheed Martin was $2000, and with this generous amount of budget, we aim to utilize the spending to best potential in order to minimize personal costs from each of the group members while still being able to produce a solid result from this project.

***Table 10.1.*** *Initial budget for project*

| Sub-System | Cost |
|---|---|
| Display | $150 |
| MCU | $1750 |
| Cameras | $1000 |
| Sensors | $500 |
| Communication | $250 |
| Battery | $50 |
| Charger | $35 |
| ***Total*** | $3735 |

## 10.3 Distribution of Work

The distribution of work among the team member's is designed to ensure the project's success. Given the interdependency of each system, it's important for each team member to actively collaborate with each other. Each member's role is not isolated, but linked to the contributions of others. To achieve a functional product, collaboration is essential. This approach ensures that each member remains informed about the design process and understands how their individual contributions integrate with the contributions of others.

***Table 10.3*** *Distribution of work*

| Name | Primary Responsibilities | Secondary Responsibilities |
|---|---|---|
| Jack Gao<br>*Computer Engineering* | Software Implementation | Communication Setup |
| | Website Management | Display Implementation |
| Max Hoffner<br>*Electrical Engineering* | PSU Design and Implementation | Software Implementation |
| | PCB Design | Sensor Implementation |

| | | |
|---|---|---|
| Isaiah McCarty<br>*Electrical Engineering* | Communication Setup | PCB Design |
| | Sensor Implementation | Display Implementation |
| Patrick Rizkalla<br>*Computer Engineering* | Computer Vision | Website Management |
| | Display Implementation | Communication Setup |
| Esteban Venegas<br>*Computer Engineering* | Display Implementation | Computer Vision |
| | Software Implementation | Sensor Implementation |

## 10.4 Milestones

Multiple events and meetings are necessary throughout the project to create a successful project. Once finalizing an idea, we scheduled biweekly meetings to ensure we stayed on track with our deliverables.

***Table 10.4*** *Project Initialization Milestones*

| Start Date | Planned End Date | Required End Date | Task | Description |
|---|---|---|---|---|
| 08/20/2024 | 08/20/2024 | 08/22/2024 | Recruiting | Members Recruited: Jack Gao (CpE), Max Hoffner (EE), Isaiah McCarty (EE), Patrick Rizkalla (CpE), Esteban Venegas (CpE) |
| 08/22/2024 | 08/27/2024 | 08/27/2024 | Brainstorming | Meeting in person to discuss potential ideas and pick one for the project. |
| 08/27/2024 | 08/27/2024 | 09/06/2024 | Initial Document | The first 10 pages of Divide and Conquer |

| | | | | |
|---|---|---|---|---|
| 08/27/2024 | 09/16/2024 | 10/29/2024 | 60-page Milestone | The first half of the document |
| 08/27/2024 | 10/21/2024 | 11/26/2024 | Final Document | The final document for SD1 |

***Table 10.5*** *Project Fabrication Milestones*

| Start Date | Planned End Date | Required End Date | Task | Description |
|---|---|---|---|---|
| 08/27/2024 | 09/09/2024 | 11/08/2024 | Component Selection | Making a tentative budget and bill of materials for core components. |
| 08/27/2024 | 09/09/2024 | 11/26/2024 | System Design | Designing the overall schematic for the project. |
| 09/09/2024 | 10/08/2024 | 11/26/2024 | System Testing | Testing individual components and their compatibility within our project. |
| 09/09/2024 | 09/23/2024 | TBD-SDII | PCB Design | Have specialized PCB designed and ready to be ordered. |
| TBD-SDII | TBD-SDII | TBD-SDII | PCB Testing | Test PCB to make sure it works |

| | | | | |
|---|---|---|---|---|
| TBD-SDII | TBD-SDII | TBD-SDII | Prototype Completion | Complete project |

Throughout the milestones and fabrication of the project, various tasks overlap with each other due to the requirements of this project and some tasks are TBD as we have no insight on them until Senior Design II comes around. This milestone acts as a guideline for reference to a successful project done in a timely manner.