Project Deliverable D

GNG 1103

Team D6

"Diamond Hands"

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1.0 Introduction

After our initial client meeting with JAMZ drone delivery on January 27 2021, we compiled and analysed the core needs of our client in order to determine their relative importance. This process is beneficial towards clarifying the overall design requirements helping us to effectively address the problems that they presented us with. Furthermore, we condensed and refined our individual ideas into a practical solution for JAMZ that we wish to further explore.

2.0 Problem Statement

JAMZ drone delivery requires a method of detecting violent shaking that continuously transmits accurate data relevant to the status of the package until delivered to the customer.

3.0 Benchmarking

Table 1: Benchmarking of sensors

Specs/Sensors	MPU 6050 6 Axis Gyro Accelerometer	AdaFruit LSM6DS33 6-DoF	Grove 6 Axis Accelerometer and Gyroscope
Main use	Motion/ tilt sensing	Motion/ tilt Sensing	Motion/ tilt sensing
Size	21 x 16 x 3mm	25 x 25 x 5mm	140 x 85 x 10.3mm
Power usage	3-5v	3-5v	3.3/5v
Weight	2.1g	1.7g	8g
Gyro Data Range	250/ 500/ 1000/ 2000 dps	125/ 250/ 500/ 1000/ 2000 dps	125/ 245/ 500/ 1000/ 2000 dps
Accelerometer Data Range	2/ 4/ 8/ 16g	2/ 4/ 8/ 16g	2/ 4/ 8/ 16 g
Cost	$3.35	$7.54	$13.87

Table 2: Ranking of Sensors

Specs/Sensors	Importance	MPU 6050 6 Axis Gyro Accelerometer	AdaFruit LSM6DS33 6-DoF	Grove 6 Axis Accelerometer and Gyroscope
Main use	3	Motion/ tilt sensing	Motion/ tilt Sensing	Motion/ tilt sensing
Size	3	21 x 16 x 3mm	25 x 25 x 5mm	140 x 85 x 10.3mm
Power usage	1	3-5v	3-5v	3.3/5v
Weight	2	2.1g	1.7g	8g
Gyro Data Range	5	250/ 500/ 1000/ 2000 dps	125/ 250/ 500/ 1000/ 2000 dps	125/ 245/ 500/ 1000/ 2000 dps
Accelerometer Data Range	5	2/ 4/ 8/ 16g	2/ 4/ 8/ 16g	2/ 4/ 8/ 16 g
Cost	4	$3.35	$7.54	$13.87
Total		62	62	50

Green = 3 Yellow = 2 Red = 1

4.0 Design Criteria

4.1 Functional requirements

Table 3: Functional Requirements

	Design Specifications	Relation (=,<,>)	Value	Units	Verification Method
1	Degrees of Freedom	=	6	Degrees	Test
2	Power Draw	<=	5	Volts	Test
3	Communicate with Arduino	=	yes	N/A	Test

4.2 Constraints

Table 4: Constraints

	Design Specifications	Relation (=,<,>)	Value	Units	Verification Method
1	Cost	<	50	$	Estimate, Final Check
2	Operating Temperature	<	40	°C	Test
3	Weight	<	50	g	Test

4.3 Non Functional Requirements

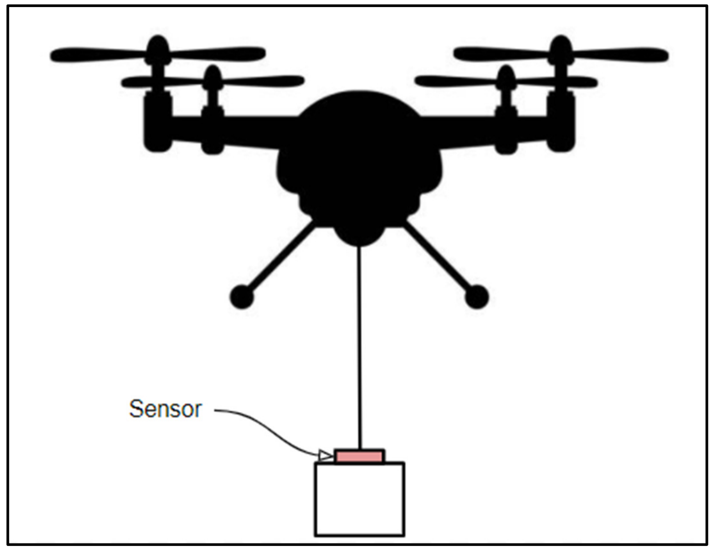
Table 5: Non-Functional Requirements

	Design Specifications	Relation (=,<,>)	Value	Units	Verification Method
1	Size of Sensor	<	10000	mm^3	Test
2	Aesthetics	=	yes	N/A	Test
3	Reliability	=	yes	N/A	Test

5.0 Subsystems

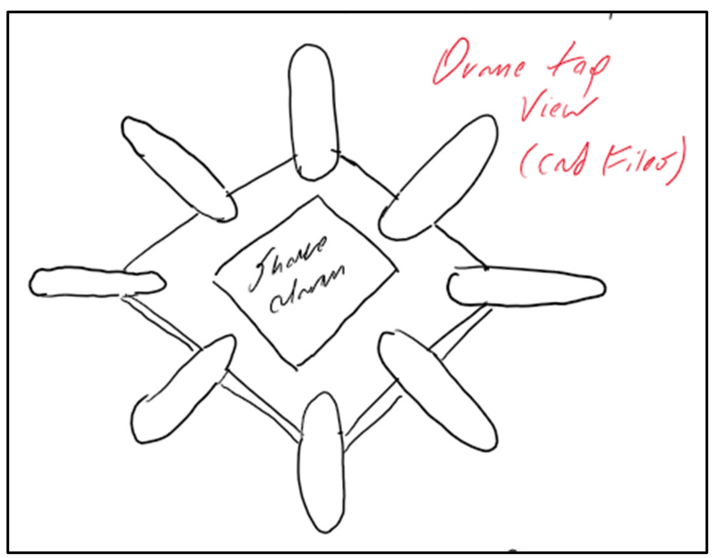
5.1 Location of the Module

5.1.1 - Karsten Lowe



- Module is not fixed to the drone.
- Module containing the vibration sensor is lowered from the tether with the package.
- Module is the point of attachment between the drone and the package.
- The sensor is located with the package until the customer unhooks it means the data is being collected the entire delivery process.
- The part of the process most susceptible to violent shaking is the lowering of the package.

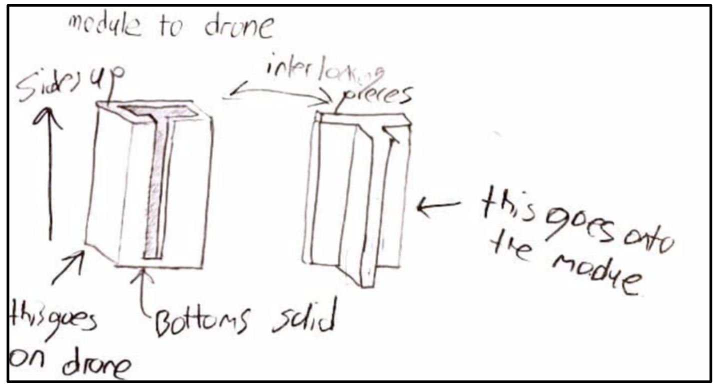
5.1.2 - Connor Harper



- The shake alarm is connected to the top of the drone VIA an arduino microcontroller
- Arduino would be connected to the top of the drone, minimizing the change in centre of gravity of the drone
- The close proximity of the module to the central computer of the drone allows for easy data communication between the violent shake alarm and the main computer
- The location of the module means that the shake alarm is not connected to the package and as a result is not capable of reading the shaking of the package during pickup and dropoff.

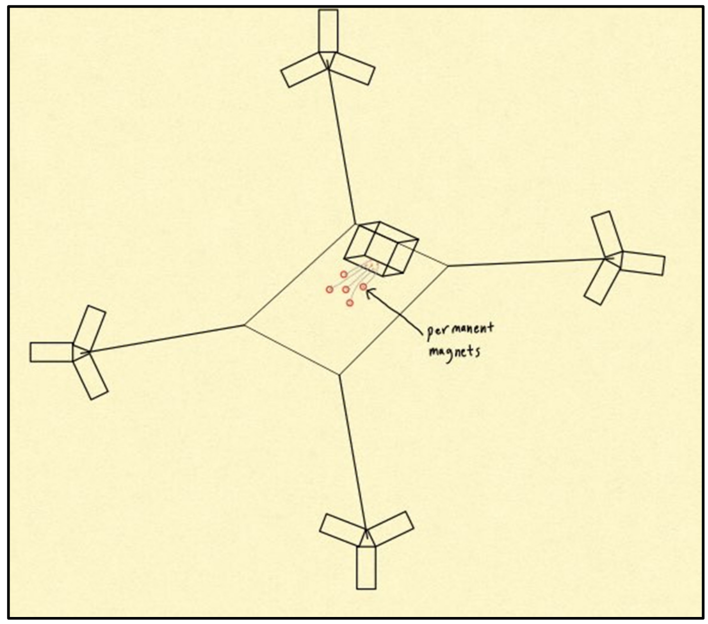
5.1.3 - Jason Clapiz

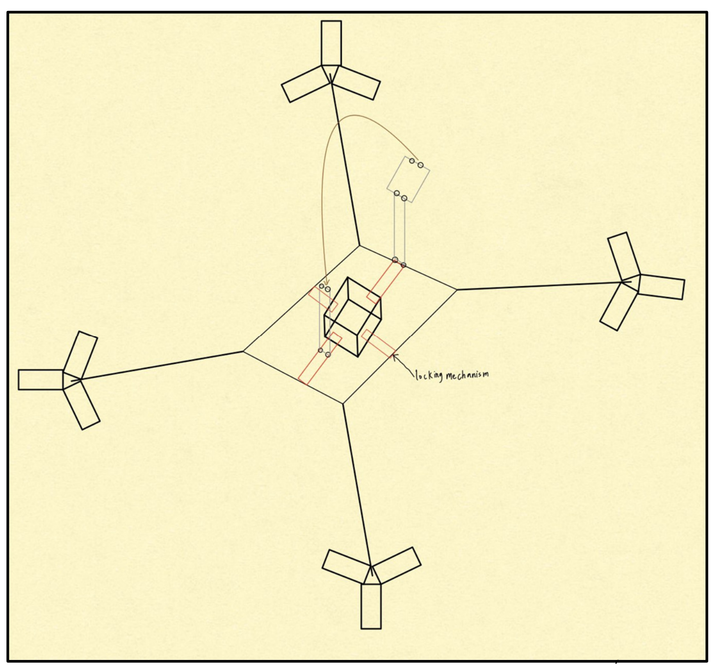
- interlocking
- Almost like puzzle piece so they fit together and slide into place
- Easily removable and replaceable for quick change of sensor if repairs are needed
- Keeps everything solid and stable
- Placed on side of the drone
- gravity and friction keep the two pieces together



5.1.4 - Leo Tan

- All of the electronics will fit inside a case, and the case will be placed on top of the drone or on the hook
- If the case is on top of the drone, then we can either use a wired or wireless transmitter module.
- If the case is on top of the hook, then we have to use a wireless transmitter module.
- Permanent magnets can be glued onto the drone or hook and the bottom of the case, so the case stays connected to the top of the drone or hook.
- The case can also be placed in a pre-made locking mechanism. The locking mechanism will have at least 4 rectangular metal rods that the case will slide onto. Also, there is a latch that prevents the case from vertical movements.

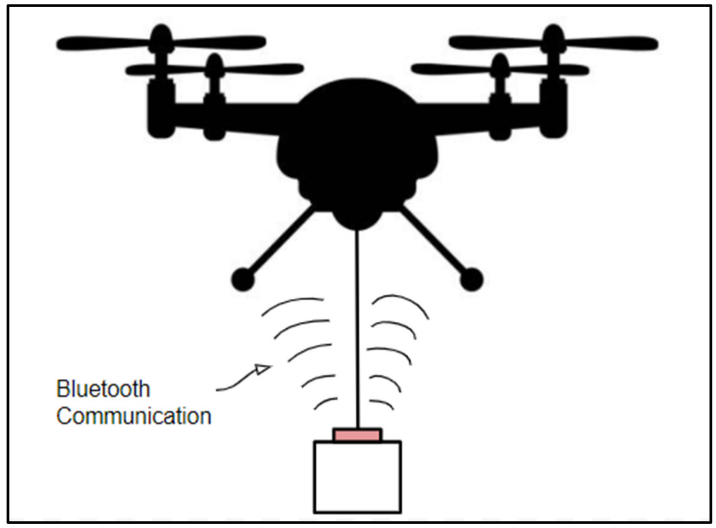




5.2 Data Transmission

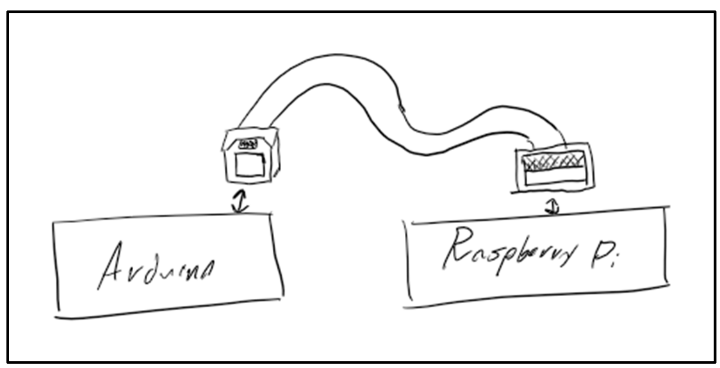
5.2.1 - Karsten Lowe

- Bluetooth communication between the module and the drone.
- Wireless data transfer
- Bluetooth transmitter is located inside the module highlighted in red.



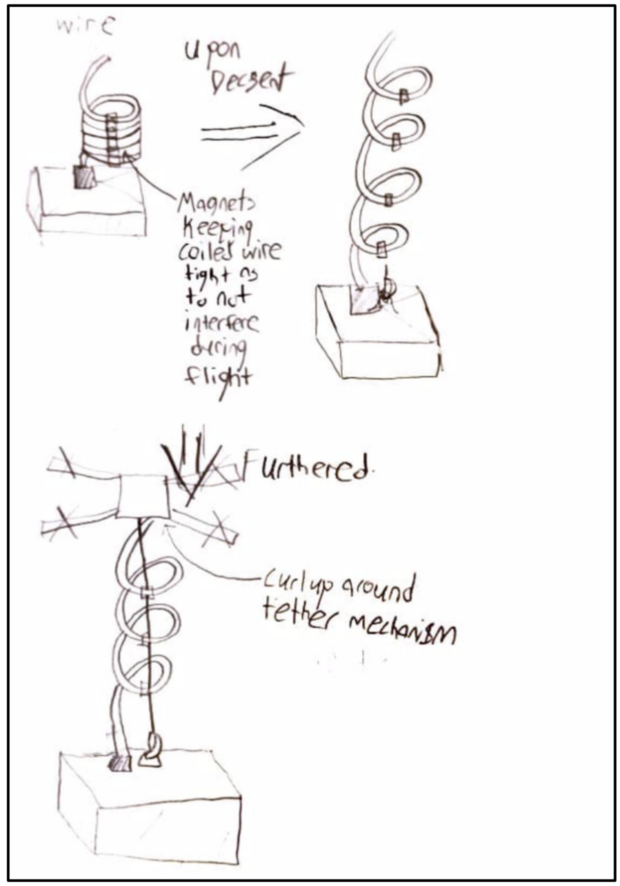
5.2.2 - Connor Harper

- Data transmission would be facilitated by the physical connection of a USB A to USB B cable
- The data would be transmitted from the arduino to the raspberry pi through serial communication
- The physicality of the cable means communication should be fairly streamlined and without interruption.



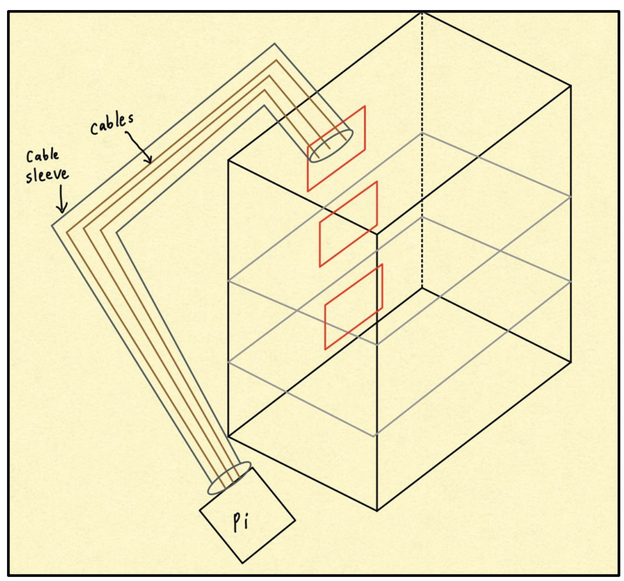
5.2.3 - Jason Clapiz

- Wired: Coiled wire that has magnets so when it retracts back into the drone the wire stays stable
- Curls around tether system keeps everything tight and in place/No flailing wires
- Wire can covered in a braided protective cover



5.2.4 - Leo Tan

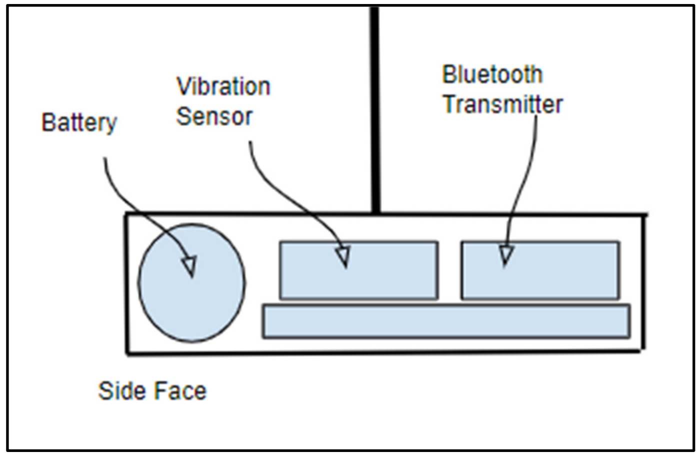
- Wired: We will need a male USB 2.0 Type B connector that connects to the Arduino USB port and a male USB 3.0 Type A connector that connects to the Pi (preferably 3.0).
    - We can only use this option if the case is attached to the top of the drone.
- Wireless: A bluetooth or 4G electronic component will transmit data to the Raspberry Pi.
    - We can use this option whether the case is attached on the drone or on the hook.
    - I honestly prefer this method because we don't have to worry about additional cable sleeve or cable protection just for the wire, and we don't have to worry about figuring out the most efficient and safest cable path to the drone.



5.3 Data Recording

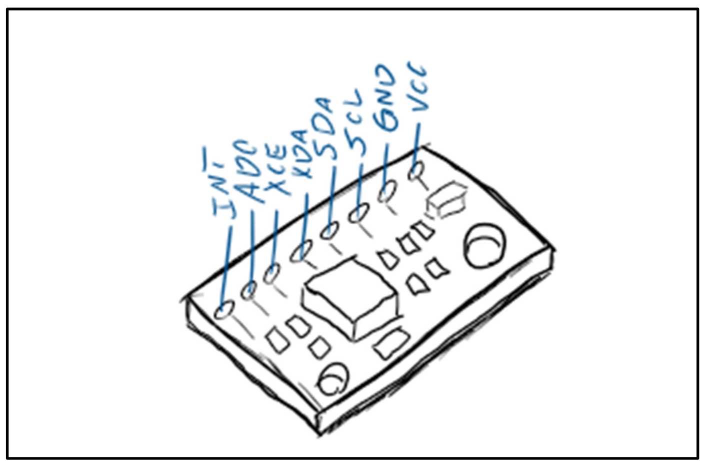
5.3.1 - Karsten Lowe

- There is a 6-axis accelerometer and gyroscope acting as the vibration sensor fixed to an arduino. This will record the targeted data from this project.
- AdaFruit LSM6DS33 6-DoF
- There is also a bluetooth module connected to the arduino to facilitate the data transmission.



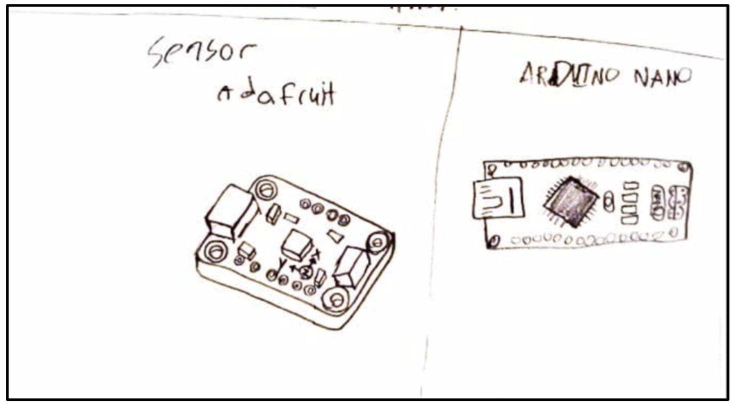
5.3.2 - Connor Harper

- The data recording device consists of a MPU 6050 6 Axis Gyroscope/ Accelerometer
- It offers accurate, cost effective acceleration and tilt data in a small and lightweight package
- Comes ready to interface with arduino and raspberry pi out of the box
- Readily available for bulk ordering
- Many versions of the MPU 6050 exist, if one version does not work, many others are available



5.3.3 - Jason Clapiz

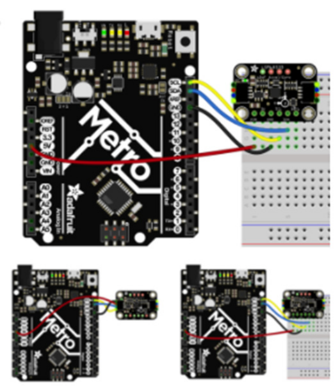
- AdaFruit LSM6DS33 6-DoF
  - Very small compact and lightweight
  - Good data range
  - Already has platform to show how to use it
  - Available in bulk if need be
- Arduino NANO
  - Small and lightweight
  - Cheap
  - Available in bulk if need be



I2C Wiring

Use this wiring if you want to connect via I2C interface

By default, the I2C address is **0x6A**. If you add a jumper from **DO** to **3.3V** the address will change to **0x6B**



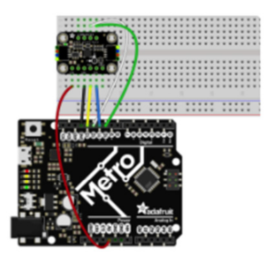
- Connect **board VIN (red wire)** to **Arduino 5V** if you are running a **5V** board Arduino (Uno, etc.). If your board is **3V**, connect to that instead.
- Connect **board GND (black wire)** to **Arduino GND**
- Connect **board SCL (yellow wire)** to **Arduino SCL**
- Connect **board SDA (blue wire)** to **Arduino SDA**

5.3.4 - Leo Tan

- AdaFruit LSM6DS33 6-DoF
  - 6 DOF
  - Small
  - Lightweight
  - Cheap
  - Pre-made libraries that have good synergy with Arduino IDE
  - Can be wired in either I2C or SPI method
  - Can easily fit on top of Arduino Uno in one level (referring to my drawing)
    - I2C
    - SPI
- Ignore this temporarily: We can also buy the proprietary cable connectors from AdaFruit (SparkFun qwiic compatible STEEMA QT)

SPI Wiring

Since this is a SPI-capable sensor, we can use hardware or 'software' SPI. To make wiring identical on all microcontrollers, we'll begin with 'software' SPI. The following pins should be used:

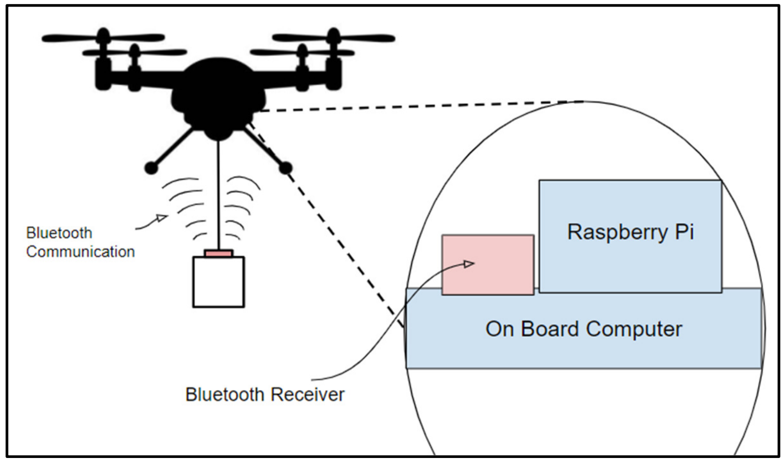


- Connect **Vin** to the power supply, 3V or 5V is fine. Use the same voltage that the microcontroller logic is based off of
- Connect **GND** to common power/data ground
- Connect the **SCK** pin to **Digital #13** but any pin can be used later
- Connect the **DO** pin to **Digital #12** but any pin can be used later
- Connect the **SDA** pin to **Digital #11** but any pin can be used later
- Connect the **CS** pin **Digital #10** but any pin can be used later

5.4 Data Translation

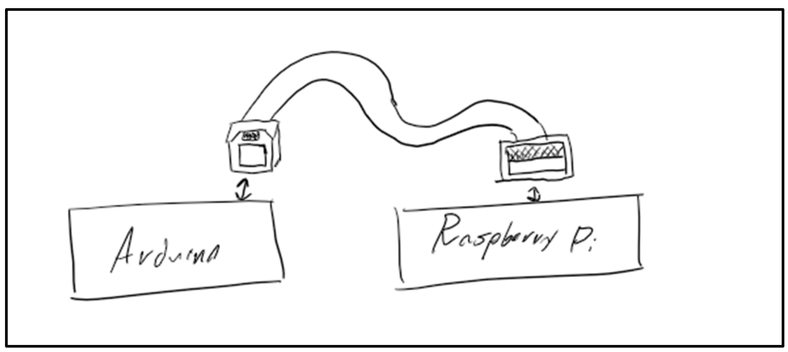
5.4.1 - Karsten Lowe

- Bluetooth receiver onboard will translate the data from the arduino to the raspberry pi.



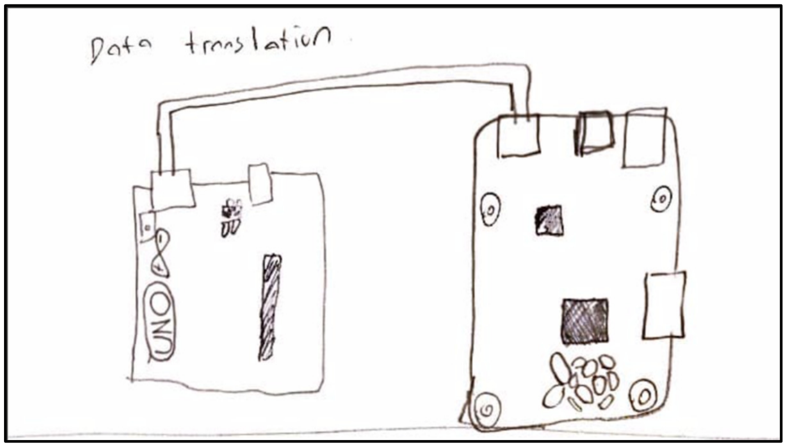
5.4.2 - Connor Harper

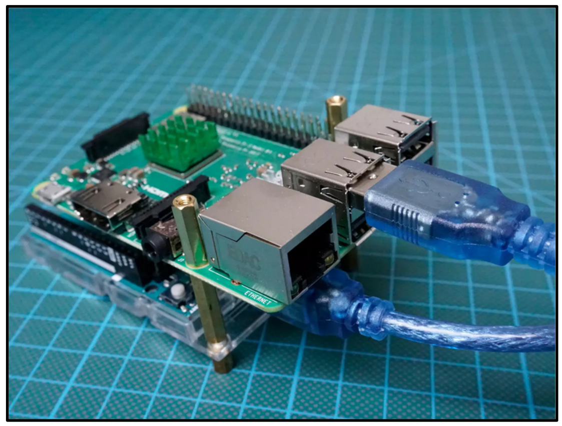
- Data translation between arduino and raspberry pi via the serial monitor is already in use
- It's a simple matter of setting up the communication from both ends and all the arduino has to do is send data via the serial port.
- The raspberry pi then can receive data from the serial port and can then do with the data all it wants.



5.4.3 - Jason Clapiz

- Arduino to Raspberry Pi through a wired proprietary connection
- It is very simple to code something onto the raspberry pi that can read the code from the Arduino
- Because it is a wired connection it is very stable

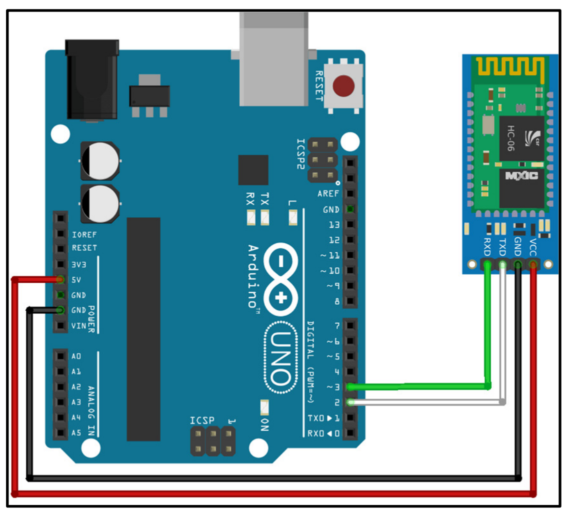




5.4.4 - Leo Tan

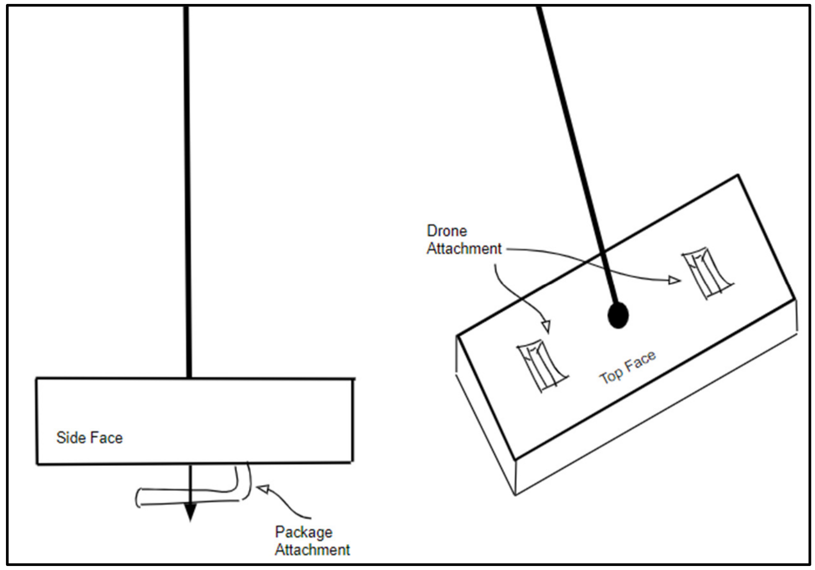
- Wired: We can use a male USB 2.0 Type B cable to a male USB 3.0 (preferably 3.0 over 2.0) Type A cable to connect from the Arduino to the Raspberry Pi.

- Wireless: We will need a separate electronic component that has bluetooth 5.0 (preferable 5.0 over 4.0) or/and 4G capabilities that will be wired up to the Arduino, and we will be able to send info to the Raspberry Pi this way.



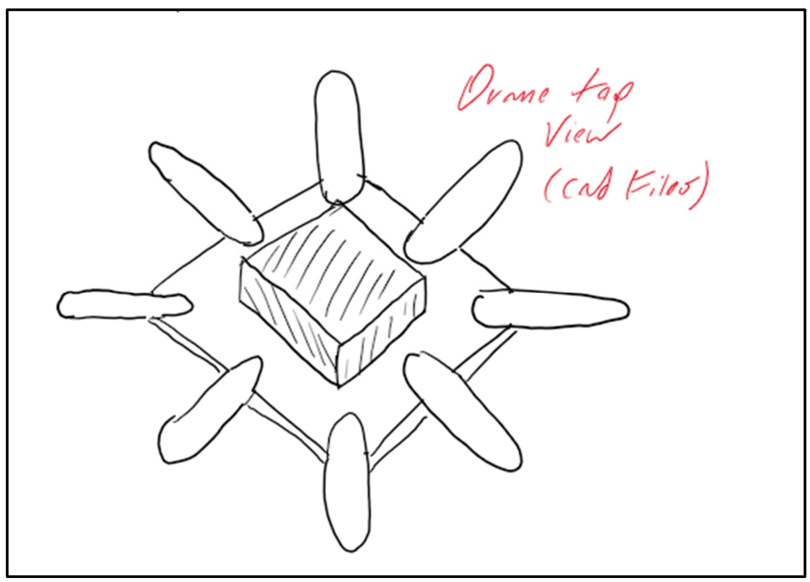
5.5 Case/Housing

5.5.1 - Karsten Lowe



- Module is the connection between the drone and the package.
- There is a hook underneath the module which is released when there is no downward pressure. Similar to the gravity winch used for the tether.
- The top face has 2 attachment points for the drone to securely attach to the module and package.

5.5.2 - Connor Harper



- A 3d printed plastic shell on top of the drone covering the components
- Located on top of the drone covering the arduino and sensors
- Easy to manufacture and replace in the event a shell is damaged or lost for whatever reason.

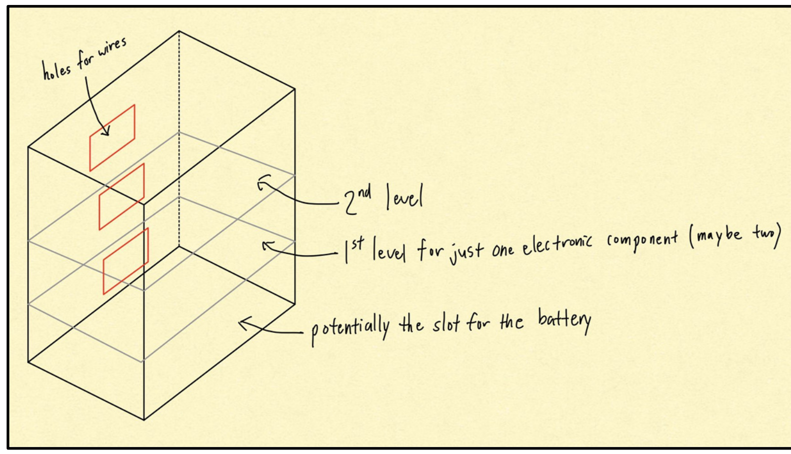
- Low manufacturing cost as well as lightweight compared to other materials
- Main concern is UV damage over time making the shell more brittle and prone to cracking

5.5.3 - Jason Clapiz

- First design: magnets on both the box and the sensor in order to keep things in place and get reliable data. The sensor will come off of the box and retract back up to the drone
- Second design: Nano suction technology (pad) on bottom of the sensor which will adhere to the box
- This does not require anything to be on the box and allows for the box to be disposable

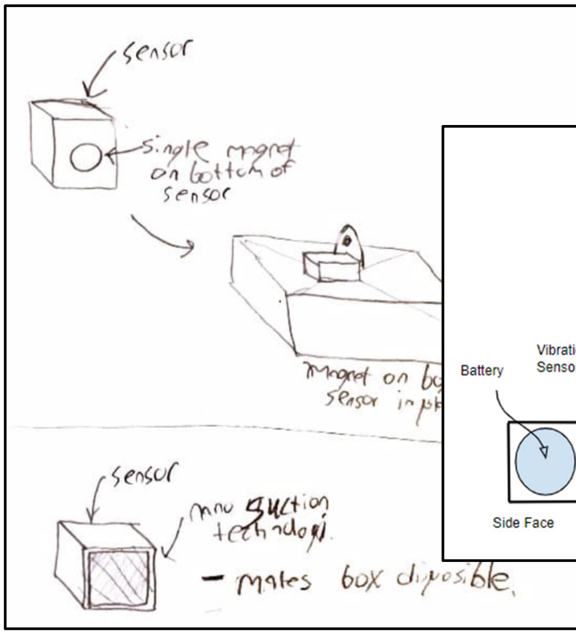
5.5.4 - Leo Tan

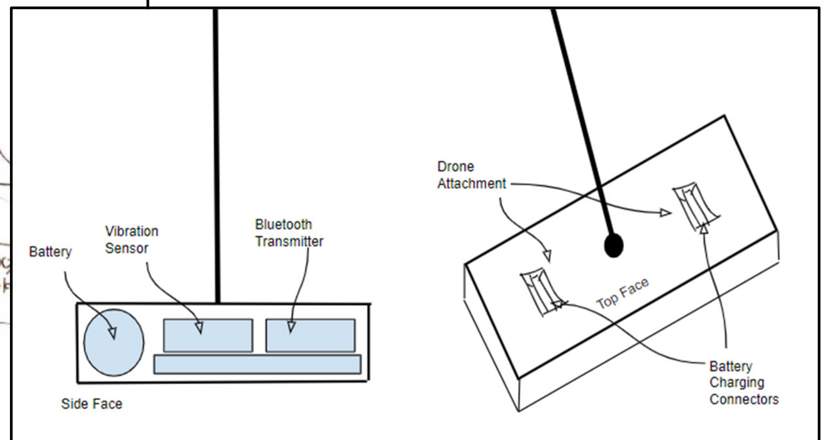
- We should consider using a 3D printed case.
- Cheap
- Easily reproducible
- Quickly reproducible
- Lightweight
- The electronics will be vertically stacked, and a platform will be created for each electronic component.
- The case (which packs all the electronics together and potentially external battery pack) can be attached

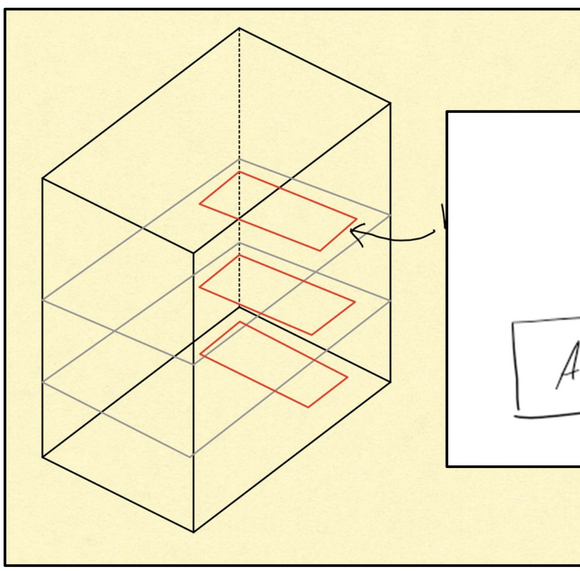


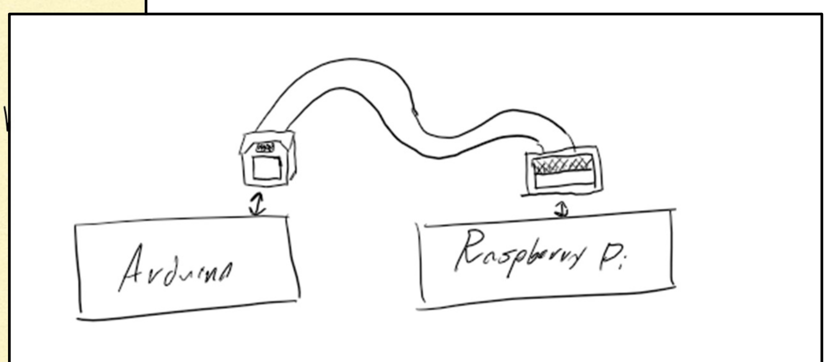
on the top of the drone or on the hook.
    - One case to tightly pack the electronics in a vertical manner
    - A platform for each electronic part to rest on
    - Make sure that the electronics essentially can't move in the horizontal plane and the vertical plane once they're inside the case

5.6 Power Delivery







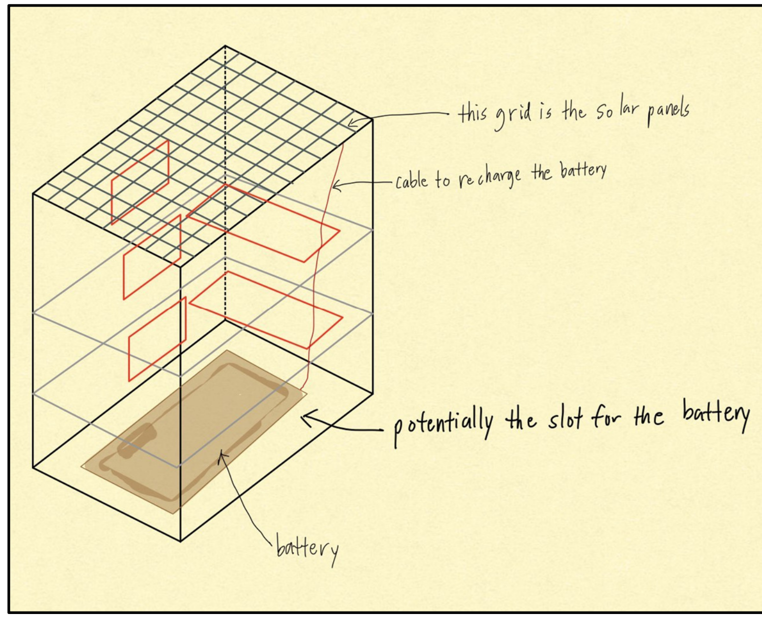


5.6.1 - Karsten Lowe

- Module is powered from a battery which is located inside the housing.
- The battery is charged from the 2 connection pins which attach directly to the drone when in flight.
- The charging is drawn from the drones onboard battery.

5.6.2 - Connor Harper

- Power is delivered to the components via the USB cable from the raspberry pi to the arduino
- The arduino is then capable of running the sensor and other components off 5v / 3.3v power
- The main power source is thus the onboard drone batteries
- This means that there is no independent power source for the arduino and you don't have to manage separate power sources

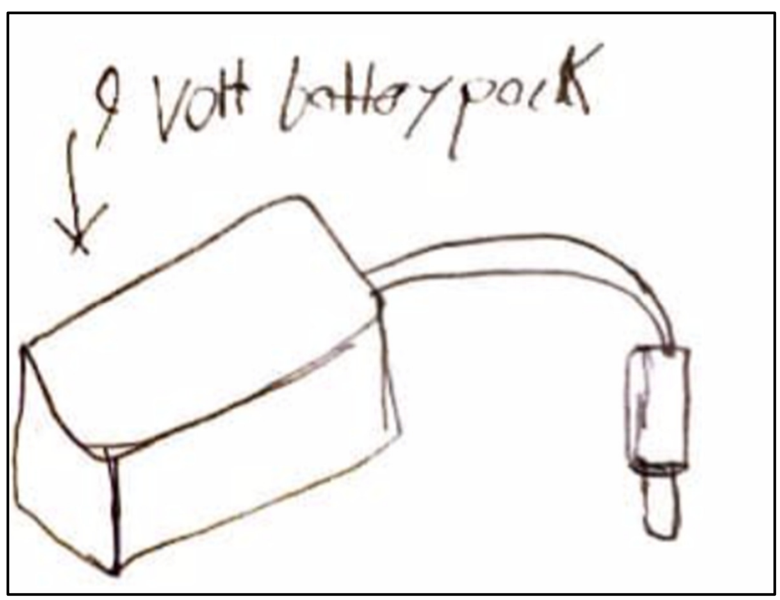


5.6.4 - Leo Tan

- External rechargeable battery pack that is attached to the bottom of the case that will give power to all of the electronics

5.6.3 - Jason Clapiz

- 9-Volt battery to power both the sensor and the module.
- wire connects to the arduino
- Easily Replaceable because all you would need to do is swap out the 9-Volt battery and you have full charge again

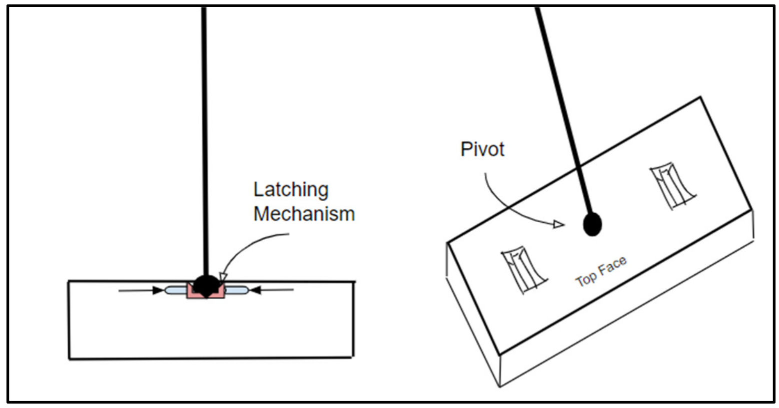


- Solar panels could be attached to the top of the case to recharge the external battery pack

5.7 Desired Response

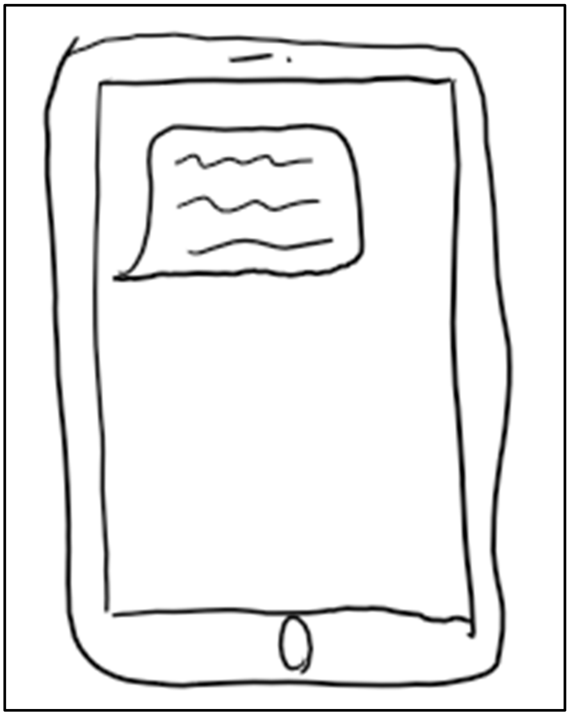
5.7.1 - Karsten Lowe

- In an event where the package is swinging violently and uncontrollably, the latching mechanism will clamp onto the pivot reducing one source of freedom.
- This can be initiated by the arduino if the vibration sensor detects violent shaking.



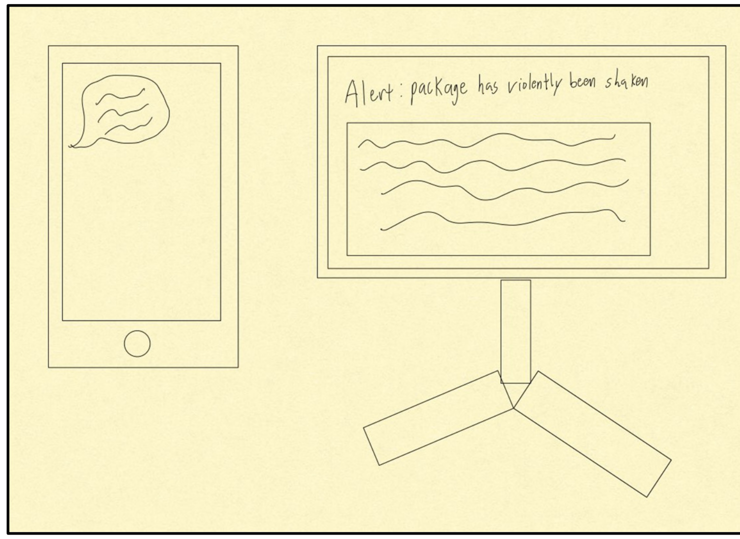
5.7.2 - Connor Harper

- Person placing order received SMS message or notification through app notifying them that the contents of the package have been distrubed
- This operation would be carried out by either an automated system or by the drone operator once sufficient parameters have been met/ exceeded



5.7.3 - Jason Clapiz

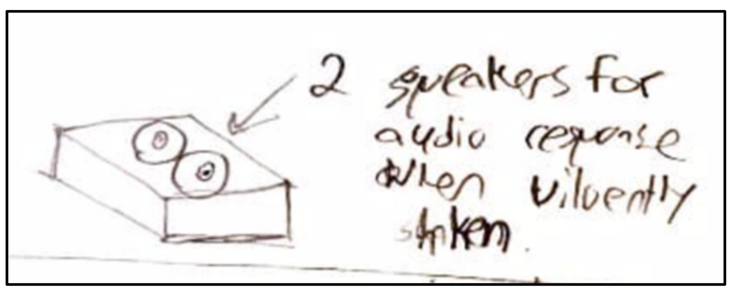
- Two low energy speakers placed on top of the module/ in module housing
- When the sensor detects a violent shake a noise will be transmitted from the speaker alerting anything nearby that something is violently shaking
- The sound could deter something



that is violently shaking

5.7.4 - Leo Tan

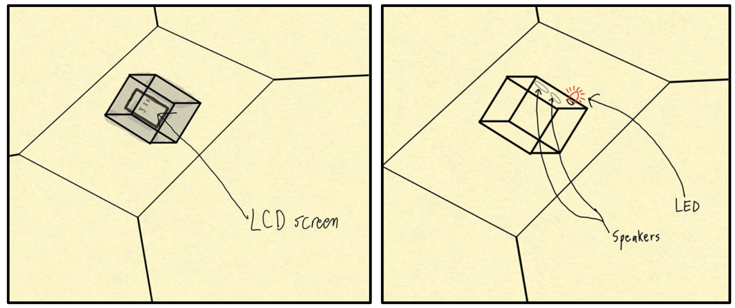
- A text notification will be sent to the customer who ordered the food to notify that his/her food has violently been shaken and might not be in perfect condition, and since data is transmitted to the drone, the drone will hopefully send information to headquarters that the food has



violently been shaken.
- We can also add in a LED that only turns on when the food has violently been shaken and a speaker that plays

sad music to indicate that the food has violently been shaken.

- We can replace the LED and the speaker with a LCD screen to display words such as "Hello, we are sorry that your food might not be in perfect condition because it was shaken around."



6.0 Subsystem Analysis

6.1 Individual Subsystems

Table 6: Subsystem Analysis

Subsystem\ Creator	Karsten Lowe	Connor Harper	Jason Clapiz	Leo Tan
Location of Module	Not fixed to drone, lowered with the package.	Top of the drone, not in contact with the package.	Side of drone using interlocking piece	On top of drone, like at the very top of drone
Data Transmission	Wireless module with a Bluetooth transmitter.	Wired USB type A to USB type B male-male cable.	Coiled wire from the sensor on the package to the module	Wireless 4G module to transmit to Raspberry Pi
Data Recording	AdaFruit 6-axis accelerometer and gyroscope	MPU 6050 6-axis gyroscope and accelerometer.	AdaFruit 6-axis accelerometer/ gyroscope	AdaFruit 6-axis accelerometer/ gyroscope
Data Translation	Bluetooth receiver onboard to Raspberry Pi.	Serial port VIA USB cable.	Serial port VIA USB cable	Raspberry Pi will receive the wireless info from 4G module

Case/ Housing	3D printed plastic case.	3D printed plastic case.	3D printed plastic case.	3D printed plastic case
Power Delivery	Power drawn from 9V battery, recharged by the main battery with the drone's connection points.	Main batteries of the drone VIA USB cable from raspberry pi to arduino.	9-Volt battery connected to arduino	Power drawn from main battery pack of the drone with possibly a step down transformer from high volts to lower volts like 5V
Desired Response	Lock-up mechanism to reduce one pivot point.	SMS or in app notification to client alerting to distrubed contents.	Low energy speakers that emit sound when violently shaken	SMS, in app notification, and LCD screen

6.2 Ranking of Subsystem Solutions

Table 7: Ranking of Subsystem Analysis

Subsystem	Importance (1-5)	Karsten Lowe	Connor Harper	Jason Clapiz	Leo Tan
Location of Module	4	Sensor on the package	Sensor on the drone	Sensor on the package	Sensor on the drone
Data Transmission	3	Wireless Bluetooth	Wired USB	Wired USB	Wireless 4G
Data Recording	5	AdaFruit	MPU 6050	AdaFruit	AdaFruit
Data Translation	3	Bluetooth receiver to Raspberry Pi.	Serial port VIA USB cable.	Serial port VIA USB cable	4G receiver to Raspberry Pi
Case/Housing	1	3D printed plastic	3D printed plastic	3D printed plastic	3D printed plastic
Power Delivery	3	9V Battery	Main battery	Main battery	Solar charged 9V Battery

Desired Response	2	Lock-up mechanism	SMS alert	Speaker on hook	SMS alert LCD display
Total		51	57	59	42

Green = 3 Yellow = 2 Red = 1

6.3 Analysis of General Concepts

Table 8: Analysis of General Concepts

General Concepts	Resulting Design	Advantages	Disadvantages
Karsten Lowe Sensor on Package Wireless	Module (AdaFruit sensor) is not fixed to the drone. Module is the attachment point between drone and package. Module requires a bluetooth transmitter to send data to the onboard computer. Drone requires a bluetooth receiver to translate data from the sensor to the Raspberry Pi. Module requires a secondary battery to deliver power when lowered from the tether.	Sensor is attached to the package for the entire duration of the delivery process. The lowering process is most susceptible to violent shaking, this means the most relevant data is being collected. Bluetooth communication is cheap and capable of transmitting the data from the module to the drone.	Wireless communication is prone to interference and noise. Module must be able to recharge directly from the main battery through connection points or via solar energy. Case housing must also have a secur00000e attachment point underneath to hold the package.
Connor Harper Sensor on Drone Wired	Module is affixed to the top, centre of the drone The Arduino connects to the Raspberry Pi via a USB A-B cable where data is sent through the serial port All components are powered by the drone's onboard battery system The module required a pass through from the Arduino	Cable connection style ensures that the data flow is consistent and interruptions are mitigated Power delivered by the central batteries means power management is simplified Design is simple in nature, reducing	Not recording the shaking of the package itself, just the drone Does not do anything to counteract the shaking of the package Placement of components can cause the drone to become top-heavy

	to the Raspberry Pi to allow for the cable(s) An MPU 6050 is used to record the data A 3D printed plastic shell is used to cover the module Customer receives an SMS message when the package is distrubed	potential sources of error and allowing for easier troubleshooting Shell is cheap and easy to produce	3D printed plastics are susceptible to UV damage over time and would require maintenance and possible replacement intermittently
Jason Clapiz Sensor on Package Wired	Module is not fixed to the drone Module is attached to the package connected to the arduino with a wire which is affixed to the drone Wired connection is through a cable that is coiled to prevent flailing of parts and pieces off the drone The module gets its power directly from the drones battery	A wired connection insures stable and reliable data flow Very simple design with less components to deal with Does not need external power and takes advantage of the drones onboard battery Since the module is directly on the package it can more accurately sense the stability of the contents of the package	external wires can get in the way of other components on the drone or even have the potential to break Must have a secure attachment point on the package Have to be able to get wire back up to the drone after deployment of package
Leo Tan Sensor on Drone Wireless	Module is firmly fixed on the drone. At least one bluetooth module is needed to transmit data from the	Bluetooth transmission means no need for more external wires. Don't need to include	Module has to be 100% firmly fixed onto the drone. Module can not detect violent shaking

	Arduino to the Raspberry Pi. Module will be powered by the main battery of the drone. The Adafruit sensor will be used to record the data. Case material will be 3D printed material. SMS text will be sent to the customer if the package has been shaken.	a separate battery pack for the module. Bluetooth 4.0 and 5.0 modules are cheap, small, energy efficient, and quite reliable in terms of transmitting continuous data. Adafruit sensor has motion and tilt, small, energy efficient, lightweight, really good gyro and accelerometer data range, and reasonably priced unit. SMS text would be reliable since JAMZ will be operating in rural places that hopefully have cellular networks.	during the time in between after releasing the hook. Other external electromagnetic waves could potentially interfere with the bluetooth waves. 3D printed material will break down due to UV damage. Might need to apply a coating material on the 3D printed material for protection. If the rural places have weak cellular networks, then a solution for the desired response category.

6.4 Ranking of General Concepts

Table 9: Ranking of General Concepts

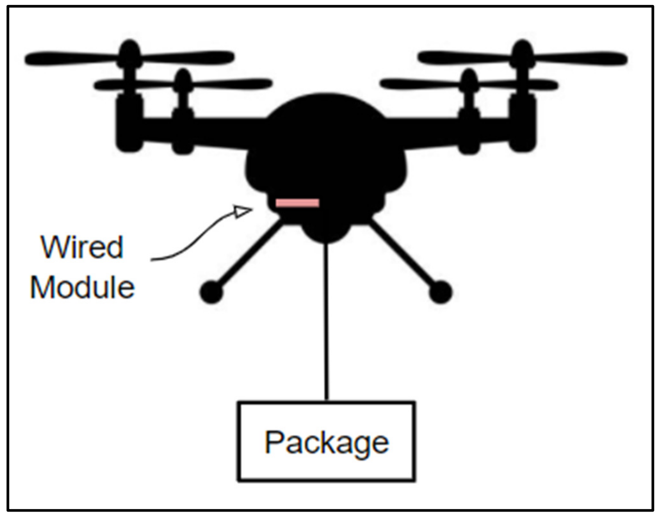
Criteria	Importance (1-5)	General Concepts			
		Wired		Wireless	
Sensor Location		Drone	Package	Drone	Package
Relevance of Data Recorded	5	1	3	1	3
Quality of Data Transmitted	5	3	3	2	2
Consistency of Data Recorded	5	3	3	2	2
Reliability of Data Transmission	4	3	2	1	1
Accuracy of Data Recorded	4	2	3	2	3
Relative Simplicity	2	3	1	2	2
Relative Cost	1	3	1	2	2
Overall Feasibility	4	3	1	2	3
Potential Application Issues	3	3	1	2	2
Total		85	75	62	77

General concepts are comparatively ranked 1 - 3, with 1 being the worst and 3 being the best.

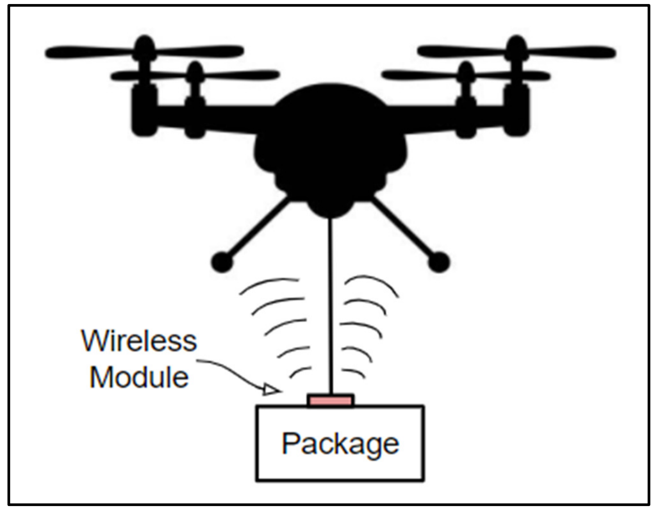
7.0 Conclusion

The two general concepts we would like to further explore are on opposite sides of the spectrum in terms of overall design. We like the **wired, sensor-on-drone** design and the **wireless sensor-on-package** design. Both of these designs have large benefits and drawbacks but the largest difference between them is complexity.

The **wired, sensor-on-drone** design is the most simple design brought forward during the conceptual design process and also the most dependable. Wired designs prove to be accurate, reliable and also cost effective but the level of complexity they can achieve is limited due to the nature of their physicality. The key justification for pursuing wired communication is that JAMZ prioritizes consistent, accurate, and reliable data transmission. Therefore the wired, sensor-on-drone concept maximizes the overall simplicity and the quality of data transfer between the module and the drone.



The **wireless sensor-on-package** design is the most complicated solution brought forward. The wireless design would allow for constant data transmission and provide a more compact and lightweight design as compared to other proposed solutions. Bluetooth modules are small and inexpensive meaning that wireless data transmission between the sensor and the drone is practical and cost-effective. Furthermore, the fact that the sensor is fixed to the package during the entire delivery process ensures that the most relevant data is being collected. By pursuing wireless communication, JAMZ can collect highly relevant data and receive constant feedback with regard to the stability of the package. Therefore the wireless sensor-on-package concept has much greater potential to effectively address the core problem that JAMZ presented us with, convincing us that this design is also worth further exploring.



The desired response mechanism chosen to be further explored for our module is integrating an automated SMS alert sent out to the customer in the event their package is violently shaken. This is beneficial for JAMZ because an alert sent automatically to the customers and clients will proactively disclose any likely problems encountered along the delivery process. Secondly, the concept of a correcting mechanism similar to the lock-up mechanism proposed could be beneficial in attempting to regain control when the package is violently shaking. This being said, the proposed correcting mechanism will not be further explored because of 3 key reasons: The lock-up mechanism that was proposed is not a proven correcting mechanism that can stabilize the package, the lock-up mechanism is complicated and would require further development to fully implement, and the lock-up mechanism is reliant on the sensor being fixed to the package and not the drone.

The two general concepts that we decided **not** to further explore include the wired, sensor-on-package design and the wireless, sensor-on-drone design. This is largely due to the fact that both concepts over-complicate the design and introduce other unnecessary problems.

The wired, sensor-on-package design combines the proven consistency of a wired design with the accuracy of the sensor located on the package. While this design seemed to be the "best of both worlds" solution , many problems arose when scrutinising the design. Many questions such as how the physicality of the design would be implemented with the raising and lowering of the package and the potential weight that could be added to facilitate the return of the cable. Due to the amount of necessary mechanisms that would have to be added to the drone in order to resolve these issues, this concept would be too extensive to complete, outweighing the benefits of this design.

The wireless sensor-on-drone design is a good design in terms of weight savings and modularity of the design, however, the added complexity of a wireless system when compared to the wired seems unnecessary. Potential signal interference, power consumption and added complexity of a wireless system all contributed to our decision to not pursue this proposed design.