Project Document

Michael Crockett, Shengmei Hu, Brieanna Jeibmann, Bradley Martin

6 May 2022

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1.0 Overview

1.1. Executive Summary

The purpose of this project is to provide a foraging toy that will be able to measure the force produced by the red crossbill (*Loxia curvirostra*) while it forages for seed. The force produced will be then examined to determine different feeding behaviors in risk reward scenarios and how willing they are to work for food. The physical device will be able to hang from the side of a cage and be able to apply a variable force to a hinge that the birds will open for seeds. The goal of this project is to find a way to accurately measure the force produced by the red crossbill so the information can be used for research purposes.

The current state of the project is in the developmental and planning stage. The birds will interact with a hinge by opening it to get food and will be attached to a replaceable extension spring so different forces can be applied to the hinge. A load cell will be attached to the other end of the extension spring to measure the force being applied to the hinge by the birds. The information will then be information sent off to the OSU servers so it can be accessed by the researchers using it. All of the electronics will be enclosed in a plastic box that hooks onto the side of a cage.

The enclosure will be made of a smooth plastic material and will be able to hang on the side of a cage in a way that would make it very difficult for the birds to knock down. A removable plastic cover will be made to go over the top of the enclosure for easy cleaning and to reduce the chance of the internal electronics from getting damaged. There will also be several roosts for the birds to use while they interact with the puzzle so they can get different angles and a steady grip when interacting with the hinge.

The system will send data to the OSU server so it can be stored and later accessed by the researchers via an interface. If any experiments are being conducted out of range for the OSU network a VPN can be used so the data can be sent to the OSU servers.

The system will measure the force produced by the bird with a load cell that is configured to measure the tension of the extension spring because the force of tension being measured by the load cell will be the same as the force of tension being applied to the hinge.

1.2. Team Communication Protocols and Standards

Table 1: Contact Information for Members

Member	Contact Information
Michael Crockett	crocketm@oregonstate.edu
Shengmei Hu	hushe@oregonstate.edu

Brieanna Jeibmann	jeibmanb@oregonstate.edu
Bradley Martin	martbrad@oregonstate.edu

Table 2: Team Members Expected Roles and Contributions

Member	Expected Role	Expected Contributions
Michael Crockett	Research and Design Graphic maker Document Moderator Mechanical Lead	Makes graphics such as timelines Design and implement assigned blocks Adjusts document content to meet required standards
Shengmei Hu	Treasuring Partner Communication Research & Design	Keeps track of budget. Emails project partner for the group. Design and implement part of the system.
Brieanna Jeibmann	Organizational Lead PCB Design Lead	Keeps assignments and workspace organized. Notifies the team of upcoming meetings and assignments. Reviews all final PCB designs before being sent to manufacturing
Bradley Marin	Software Lead Research and Design	Developing of the MySQL server Design and implement part of the system

Table 3: Team Standards and Protocols

Team Standards	
Protocol	**Assessment Parameters**
Participate in checkups and discussions	Members must respond on Discord to relevant agreements by the end of the day, and acknowledge discussions even if they do not contribute much to it.
Missing meetings	Members must notify other members if they are not able to attend meetings before the meeting starts. If they miss the meeting, they should be responsible for catching up through the Discord chat and by asking team members for any other information that was brought up during the meeting.
Use of Discord	Members are expected to check the Discord at least twice a day, morning and evening. The discord should be used to remind members of upcoming meetings and due dates, a place to share ideas, and as a way to share links.
Due Dates	Work should be completed and ready to turn in at least 6

	hours before it is due. Most of the work should be done at least 24 hours before it is due.
Dealing with problems	Members should not be afraid to seek help from each other whenever needed. If issues arise, members should respectfully communicate with the entire group. If a disagreement occurs between members and starts getting out of hand, the members should take some time to cool off and talk about the disagreement and how to resolve it, and if need be another team member to help mediate.
Use of Google Drive	Documents should be properly organized into their folders. All documentation, project work, research, and other artifacts should be shared with the rest of the group through the drive. Give a heads up and/or get permission to delete/edit another person's work through the discord.

Project Partner Communication:
- Primary communication with project partner will be done through email.
- Project partner should be updated weekly through email on progress or if planning for meetings with the partner.
- Project partner is comfortable with in person and zoom meetings.
- Meetings or emails with project partner will be done to discuss ideas/updates on progress, and plan on testing with birds.
- Project partner is an ecophysiologist at OSU and will provide relevant information and access to the crossbill birds.
- Project partner can give information from past mechanical puzzles, but sensors, data visualization, and electronic parts will be left up to the team.

1.3. Gap Analysis

Currently there is no way to measure the force produced by the beak of the red crossbill when it is foraging for food, according to our project partner who specializes in research of the red crossbill. The red crossbill forages in a very different way then most birds, as they shift their lower mandible sideways to pry open conifer cones to extra the seeds. It is assumed that in order to measure the force that these birds produce, we will need a sensor to measure the force and a way to apply a variable force to the puzzle mechanism. The reason for making this is to research how much work a red crossbill puts into getting food and how the difficulty of getting that food can motivate them.

1.4. Timeline/Proposed Timeline

Bird Foraging Puzzle Project

Team Members: Michael Crockett, Shengmei Hu, Brieanna Jeibmann, Bradley Marin   **Project Partner:**   Jamie Cornelius

TASK TITLE	TASK OWNER	START DATE	DUE DATE	STATUS	Fall Term				Winter Term				Spring Term		
					Month 1	Month 2	Month 3		Month 4	Month 5	Month 6		Month 7	Month 8	Month 9
Problem Definition															
Contact Project Partner	Team	10/6/21	10/12/21	Complete											
Research Project Topics	Team	10/6/21	N/A	Complete											
Section 1 Documents	Team	10/8/21	10/22/21	Complete											
Preliminary Design															
Section 2 Documents	Team	10/15/21	10/29/21	Complete											
Create Project Requirements	Team	10/15/21	10/29/21	Complete											
Design Concept Research	Team Individually	10/10/21	12/3/21	Complete											
Section 3 Document	Team	11/05/21	11/19/21	Complete											
Build Proof of Concept (Tech demo)	Team	11/05/21	12/3/21	Complete											
Modular Testing															
Indivdual Block 1 Construction	Team Individually	1/3/22	2/27/22	Complete											
Indivdual Block 1 Verification	Team Individually	2/28/22	3/1/22	Complete											
Indivdual Block 2 Construction	Team Individually	1/3/22	3/13/22	Complete											
Indivdual Block 2 Verification	Team Individually	3/14/22	3/15/22	Complete											
System Level Testing															
Connect blocks to full System	Team	4/1/22	4/15/22	Complete											
Full System Adjustments and Final	Team	4/15/22	5/1/22	Complete											
Full System Verification	Team	5/2/22	5/4/22	Complete											
Presentation Preperation															
Create Poster	Team	4/1/22	5/13/22	Complete											
Poster Presentation	Team	6/3/22	6/3/22	Complete											
Project Closing															
Final Documentation	Team	4/1/22	5/6	Complete											
Closing Tasks	Team	5/3/22	5/6/22	Complete											

Figure 1: Timeline of Project

1.5. References and File Links

1.5.1. References (IEEE)

1.5.2. File Links

1.6. Revision Table

Date	Revisions Made
10/20/2021	Brieanna Jeibmann - Gap Analysis
10/21/2021	Shengmei Hu - Team Communication Protocols and Standards
10/22/2021	Brieanna Jeibmann - Executive Summary
10/22/2021	Michael Crockett - Timeline
10/21/2021	Bradley Martin - Formatting document
10/22/2021	Bradley Martin - Executive summary
10/29/2021	Brieanna Jeibmann - Changed layout of timeline to make it more legible.
11/2/2021	Brieanna Jeibmann - Added to Team Standard for missing a meeting, use of discord, dealing with problems, and use of Google Drive sections. - Added table/figure labels - Added content to the Gap Analysis based on professor feedback. - Adding information on what my expected role and contributions are.
11/11/2021 - 11/12/2021	Brieanna Jeibmann - Added much more information and reworded the Executive Summary.
11/12/2021	Michael Crockett - Revised Timeline
11/30/2021	Brieanna Jeibman - Changed executive summary to match current design
5/6/2022	Brieanna Jeibmann - Updated timeline

2.0 Requirements Impacts and Risks

2.1.Requirements

2.1.1 Measure Force

PPR: Applied force must be measured
ER: The device must be able to take force measurements represented to the nearest +/- 0.1N.
Verification Method:
1. Power on the sensor.
2. Using a 100 gram load, hang it from the sensing plate.
3. Look at the sensor output on the database.
4. If the sensor output is between 0.09 and 0.11N, this requirement is met.

2.1.2 Safety

PPR: System must be safe for both birds and humans.
ER: During operation safety mechanism will prevent hinge from crushing bird or human finger by having at least three hold points in the operating range.
Verification Method:
1. Begin system operation and start lifting hinge.
2. Let go of the hinge and show that it is prevented from falling by the first stop point.
3. Resume lifting hinge and repeat for 2 more stopping points.
4. If three hold points successfully prevent the hinge from falling back to the start position then the requirement is met.

2.1.3 Data Visualization

PPR: System must provide user visual representation of experimental data
ER: Data will be graphically outputted as force over time and must be accessible via the MySQL server.
Verification Method:
1. Go to the OSU hosted webpage ensuring the files of input in the Public_html folder in the network drive.
2. Send sensor data with MySQL queries to the database.
3. Go to the Data Presentation webpage and see that both the graph and table are populated.

2.1.4 Cleanability

PPR: The device must be cleanable and withstand frequent use/cleaning.
ER: Bird waste and grime can be removed from device materials using water and an abrasive instrument.

Verification Method:
1. Apply material similar to bird waste to the system.
2. Wait 30 seconds.
3. Remove material from the system using water and an abrasive instrument.
4. If material has been successfully removed then the requirement is met.

2.1.5 Damage Resilient

PPR: Device must be resilient to bird tampering.
ER: System will have an enclosure that protects electrical components from the birds causing damage due to pecking and scratching.
Verification Method:
1. Scratch enclosure forcefully with fingernails several times.
2. Take 12 quarters and drop them on the enclosure individually from 2 feet above the enclosure to see if any damage occurs.
3. If after testing, the system still functions the same, then the requirement is met.

2.1.6 Mounting

PPR: Puzzle must be mountable to a bird cage.
ER: System will be attachable and removable to the side of a bird cage.
Verification Method:
1. Mount the system to the side of a cage.
2. Wait 30 seconds.
3. Confirm that the system is still attached to the cage.
4. Detach the system from the cage.
5. If successful then the requirement is passed.

2.1.7 Bird Accessibility

PPR: Device must be accessible for the birds.
ER: System will have a perch where the birds are able to hold onto and interact with the puzzle at the same time. The perch will be able to sustain at least 250 grams of weight..
Verification Method:
1. A 0.25kg weight will be hung from the perch for 30 seconds.
2. If the perch withstands the stress of the weight then it passes the requirement.

2.1.8 Budget

PPR: Device must be affordable for mass production.
ER: The system will be produced for less than or equal to the allocated budget of the project by all stakeholders. Current budget allocation 300 dollars.

Verification Method:
1. Before purchasing any component/part they will be considered if the cost is worth it and if there are any possible replacements with the same desidered properties.
2. The part and its total cost will be added to the BOM (Bill of Materials) and the total available budget will be adjusted.
3. Repeat steps for any possible purchase made.
4. If the cost is less then or equal to $300 then this requirement is met.

2.2. Design Impact Statement

2.2.1. Introduction

Our project is a bird foraging puzzle that serves as a mechanism to facilitate and study the foraging behaviors of the red crossbill bird. The device will have a certain threshold of force, which can be adjusted, that the birds' beaks must output in order to obtain food. The system will also be able to display the force applied by the bird. Overall, if successful, this device will be able to be used to study the adaptability and decision making of the red crossbill, and potentially other bird species.

This document serves as an assessment of the negative impacts that our research-based project may have. It will provide insight into the public welfare, cultural, social, environmental, and economic impacts that our project may induce, as well as potential mitigation plans for these impacts. The impacts of technology should be heavily monitored in order to ensure that a project will not have lasting negative effects. Specifically with our project, we are mainly concerned with impacts that come from production and end of life cycle of electronic parts, bird conservation and its relation to the spread of diseases, and how usage of our puzzle may change the behavior of wild birds. From assessment of the potential negative impacts, we hope to devise mitigation strategies in order to ensure our project does not do more harm than good.

2.2.2. Public Health, Safety, and Welfare Impacts

Since the bird foraging puzzle project is focused mainly on the foraging habits of birds, there are not really many obvious direct effects on the general public's health, safety, or welfare. However, since the project is associated with bird conservation, this could be linked to the spread of avian diseases. Conservation of birds may entail movement of bird populations, increase in total bird populations, and other possible ways that avian diseases and viruses can spread. This could affect poultry and gamefowl, or even pets which many people come into contact with. People are susceptible to avian diseases such as avian influenza, thus harming public health[1]. Most people consume products that use poultry and gamefowl, such as meat and eggs, and thus if not properly handled, these foods could also potentially make people sick.

However, conservation in general is associated with protecting the environment and thus keeping air and water clean. Healthy bird populations are a good indicator for an ecosystem that is doing well, so the overall environmental health goes up. Foraging birds are a fundamental contributor of ecosystem health, as they are able to induce forest growth by spreading plant and tree seeds, prevent insect populations from destroying plants, and serve as food for higher up predators. Birds play a large part in helping to create less fire susceptible and flood prone areas.

Besides contributing towards healthier ecosystems, birds also serve as a warning for the occurrence of disease outbreaks. While the spread of disease through bird populations serves as a risk towards public health, the resulting mass deaths of birds can also serve as a warning towards disease outbreaks, allowing the public to prepare against diseases accordingly. For example, in the northeastern United States, crow deaths helped health authorities identify a West Nile virus outbreak. The monitoring of bird populations may be used as a surveillance tool against the spread of disease[9]. Therefore, these factors of bird conservation can serve to mitigate the risks of avian diseases and general public health and safety could be positively impacted by bird research and conservation.

As with all electronic systems, production of parts used in the system produces a carbon footprint that contributes to climate change. End of life cycle also likely means that the device will be disposed of into landfills in developing countries which contributes to pollution and negatively impacts human populations. Landfills can pollute water systems, take up land, and contribute to poor air quality, which is a detriment to the overall health of humans. Even parts that are recycled can have a negative impact on the local people's health. In developing countries, recycling of electronic parts is not regulated, and includes methods such as acid baths or open-air burning which "can expose workers to high levels of contaminants such as lead, mercury, cadmium and arsenic, which can lead to irreversible health effects, including cancers, miscarriages, neurological damage and diminished IQs [2]." These recycling methods also pollute the air, water, and soil, thus contributing to a worsening global public health due to the degradation of the environment. Our system will feature a microcontroller, load cell, and power supply, which means that our project will have electronic parts that will eventually contribute to the environmental issues associated with the end of life cycle.

The production cycle of electronics can also have a large impact on the environment. "Producing a chip required 3.5 pounds of fossil fuels, nearly a quarter pound of chemicals, about 70 pounds of water and 1.5 pounds of gasses such as nitrogen [10]." Due to the nature of our project, it is very likely that it may be mass produced for the study of birds. Though the size of the system is small, the weight of the materials required and emissions generated is very large in comparison. However, our project can be stripped apart and its electronic components would be reusable on their own, which may help to mitigate the environmental issues associated with the end of life cycle as well as production cycle.

2.2.3. Cultural and Social Impacts

Since birds are often indicator species [3], i.e. bird population health and behavior positively correlates with the health of an ecosystem, this could help in conservation efforts. It is a potential tool for climate change activists to provide more information on how humans are impacting the environment. Since climate change is a large social issue in this day and age, bird research would have an impact on the social movement of environmental conservation and climate change awareness. Of course, due to the polarization of the topic of climate change, this would also lead to more argument and divisiveness on both sides of the topic, which may be seen as a negative impact on the unity of society.

Bird watchers and animal enthusiasts would likely be impacted by this device, as it will provide more opportunities for research into wild birds. Due to the nature of the research associated with the device, wild birds may exhibit behavioral changes. The birds that will be the focus of the research will be wild caught, taught to use the puzzle for the research period, interact directly with people, and eventually released back into the environment. But it is possible that they will pass their new behavior to other wild birds, as altered behavior can persist in wild birds [11]. This could negatively impact those who enjoy outdoor activities such as

bird watching, hiking, falconeering, camping, and more, as the birds could display unnatural behavior and even be less fearful of humans. Birds play a fundamental part of outdoor scenery, as many people associate bird song with nice days. But since the project will contribute to a better understanding of birds and aid in conservation efforts, bird conservation overall may mitigate the smaller issues created by the research.

The foraging puzzle could even be further developed into an enrichment tool for birdkeepers, aviaries, and zoos. Captive birds are more likely to be active when they are able to interact with objects that may stimulate their brains. "Enrichment allows animals to demonstrate their species-typical behavior, gives them the opportunity to exercise control or choice over their environment and enhances their well-being [4]." Proper and responsible birdkeepers would be more than happy to have access to a tool that helps improve the life of the birds that they keep in captivity. This could also aim to help eventually mitigate the behavioral issues created by interacting and researching the birds. If designed to look more like a pine cone, our project will allow for full species typical behavior for the researched birds.

2.2.4. Environmental Impacts

As stated above, electronic part production which has a carbon footprint and end of life stages with poor disposal methods can negatively impact the environment since production and disposal both contribute to pollution of the environment. All electronics face an end of life phase, in which the electronic is nearing the end of their useful life, and are discarded. Discarded electronics often end up being shipped to developing countries where they end up in landfills, and their parts are either recycled or left to degrade and leach into the environment. "Between 250,000 tonnes and 1.3 million tonnes of used electrical products are shipped out of the EU every year, mostly to West Africa and Asia [6]." Unregulated and dangerous recycling methods such as acid baths or open-air burning that are often used in these countries and thus have a huge impact on local ecosystems and even global environment [2]. But, as stated above, the individual parts specific to our project can be taken and reused in other systems. This can help to mitigate the electronic waste produced by our project, though eventually it will contribute to the issues of pollution and climate change.

However, the contribution towards research and conservation of birds by this project can help mitigate the environmental issues created by its production and end of life cycle. Research on birds and their adaptivity is a good way to learn more about the health and behavior of an ecosystem. A healthy bird population is a large indicator to whether an ecosystem is doing well or not [3]. Conservationists and climate change activists would likely look towards how a foraging population such as the red crossbill is adapting to changes in their environment to understand how human driven environmental changes are affecting an ecosystem. Therefore a mechanism that is able to test and monitor a bird's behavior would be a good tool to use in understanding how climate change and other human driven factors are affecting the natural world.

Furthermore, learning about the adaptivity and behavior of this specific bird species, the red crossbill, can serve as a good model for the future understanding of the general adaptivity and behavior of other birds, or even other animal groups. With climate change, "These new living conditions may lead organisms to extinction, but they can also offer them new opportunities depending on how they respond (or not) to these changes [5]." This type of research is important when many animal species are facing the threat of extinction and loss of biodiversity is becoming an ever greater problem. Humans have a severe impact on the environment, no matter the location or scenario, so it is a good idea to understand how animals will adapt to the changes caused by humans with the ever increasing global population of

humans. Research on behavioral changes in animals can help predict future outcomes, and thus allow us to devise plans to minimize the negative impacts of humans.

2.2.5.Economic Factors

As the device could be used as a tool to facilitate the push for more climate change and conservation legislation, this would likely affect the logging and farming industry. Non-sustainable logging (where trees are not replanted) is a large contributing factor to deforestation, which is an issue that is seen by many as something that negatively impacts the environment. Even with sustainable logging, "The creation of logging roads also greatly impacts the aquatic systems on the forest by introducing increased erosion and sedimentation into the area [7]." Thus restrictions could still be made on logging, therefore negatively affecting the economy. Farming is also another industry that could be harmed by conservation, since it is also an industry that requires a lot of land and thus contributes to deforestation and loss of biodiversity. Restrictions on land use for farming would negatively impact much of the US economy as farming is a huge industry and everybody depends on farming to source their food.

Device production can contribute to the ongoing chip shortage, as the system requires a microcontroller to process data and control the puzzle. Since the device is intended for mass production, this further increases its impact on the chip shortage and ballooning chip prices. Since microprocessor chips are used in all electronics, and therefore have a huge impact on many industries [8], this project would be contributing to a larger problem in the economy.

2.2.6.Conclusion

Our system has several potentially negative impacts. Some are more obvious than others, but impacts are mostly indirect. This research based project may have a butterfly effect, though due to the nicheness of our project, it is unlikely that our project will have any lasting, large-scale effects, and larger effects may be mitigated by potential positive impacts.

Since our project is mostly associated with bird study and conservation, most of the projected impacts are connected to the environment. With all electronics, there is a negative impact of contribution to electronic waste from discarded parts, and it is no different for this project. It contributes to the growing concern of electronic waste, which directly harms the environment by polluting the air, water and soil. Electronic waste also harms public health, due to the unregulated management of waste that exposes workers and locals to unsafe chemicals. Pollution of the environment also leads to an overall negative effect on global public health as well.

In terms of conservation and research, the research associated with this project can facilitate the social movements of conservation and climate change awareness, which will cause social divisiveness due to the polarized nature of climate change. Industries such as farming and logging tend to not benefit from conservation efforts and legislation, thus negatively affecting the economy as well as contributing to more social divisiveness. It may also negatively impact those who enjoy experiencing outdoor activities and the natural world, as the research associated with our project may induce behavioral changes in wild birds.

Nevertheless, our team hopes to minimize the negative impacts of our device, as that is the responsibility of us as engineers. Our project will attempt to minimize the negative impacts listed above by:

- Taking extra caution in not wasting electronic parts by making sure that the design does not need to be revised and rebuilt with new parts.
- Reusing electronic parts in other potential projects to minimize the production and end of life cycle waste.
- Create a device that facilitates species-typical behavior, reducing risk of introducing behavioral changes to wild populations.
- Contribute to research and conservation efforts that will aid in monitoring the environment and help create plans to minimize environmental changes induced by humans.

Though some of the potential negative impacts of this project are out of our hands, due to how dependent they are on many factors, as well as how large scale they may be, we may not be able to do much to address those issues. But we will attempt to mitigate the negative contributions and impacts of our project as much as possible throughout the design and development of our project.

2.3.Risks

Table 5: Risk Assessment and Action Plans

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance Indicator	Responsible Party	Action Plan
R1	Injury of Birds	Safety	2%	Very High	Birds injured or not	Full Team	Review design of what went wrong and modify design to negate risk.
R2	Parts don't arrive	Timeline	30%	High	Having parts or not	Part orderer/Team	Reassess timeline, find replacement parts
R3	Communication with OSU server fails	Technical	20%	Medium	Data is not available	Bradley (Software lead)	Troubleshoot system to find flaw or issue
R4	Birds damage puzzle	Technical	20%	Medium	Function of device unaffected by prolonged bird exposure	Block champion for damaged block	Replace and reinforce damaged parts.
R5	Going over budget	Cost	10%	Low	Cost of project is over $300	Shengmei	Talk to project partner about cost and devise a solution.
R6	Components become damaged and become unusable	Technical	5%	Low	Part produces smoke	Block champion for respective block	Immediately order a new part if there are no spares. Review the design and setup to determine what caused the problem.
R7	Mechanical component operational testing failure	Technical	10%	Low	Mechanical part fails during course of operations	Michael	If part is store bought, immediately purchase replacement. If a part is custom built then

					and is no longer functional		immediately begin remaking it as soons as possible to resume operations.
R8	Basing design specifications off of inaccurate possible force output range estimates	Technical	30%	Medium	Forces that the birds produce being outside the range that the system can measure or force required to beat the puzzle being too difficult/easy.	Mechanical Part: Michael Force Sensing: Shengmei	Adjust estimated force range based on circumstances. Replace any parts with parts that function within new force estimates.

2.4.References and File Links

2.4.1.References (IEEE)

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2.4.2. File Links

2.5. Revision Table

| Date	Revisions Made
10/23/2021	Brieanna Jeibmann - set up section 2 layout
10/27/2021	Shengmei Hu - Risk Table and Requirements
10/27/2021	Brienna Jeibmann - Risk Table and Requirements
10/27/2021	Michael Crockett - Risk Table and Requirements
10/27/2021	Bradley Martin - Risk Table and Requirements
11/2/2021	Brieanna Jeibmann - Fixed numbering on table
11/12/2021	Shengmei Hu - Revised Risk Table and Requirements
11/12/2021	Michael Crockett - Revised Requirements
11/12/2021	Brieanna Jeibmann - Revised Requirements
11/12/2021	Bradley Martin - Revised Requirements
11/30/2021	Brieanna - Reformatted Requirements along with fixing ERs and added a risk to the risk table.
12/1/2021	Brieanna - Fixed the System Verifications
12/1/2021	Michael Crockett - Added to and revised risk table
12/2/2021	Brieanna - Made the System Verifications numbered steps and reformatted section 2.1
12/3/2021	Bradley - Revised verification methods
12/3/2021	Michael Crockett - Revised verification methods
4/20/2022	Team - Revised engineering requirements/testing process.
5/5/2022	Team - Added Impact Assessment section. Used Shengmei Hu's because of the good feedback she received on it and covers a lot of the same points made amongst other team members' papers. Also added the references for the Impact Assessment sections to the references.

3.0 Requirements Impacts and Risks
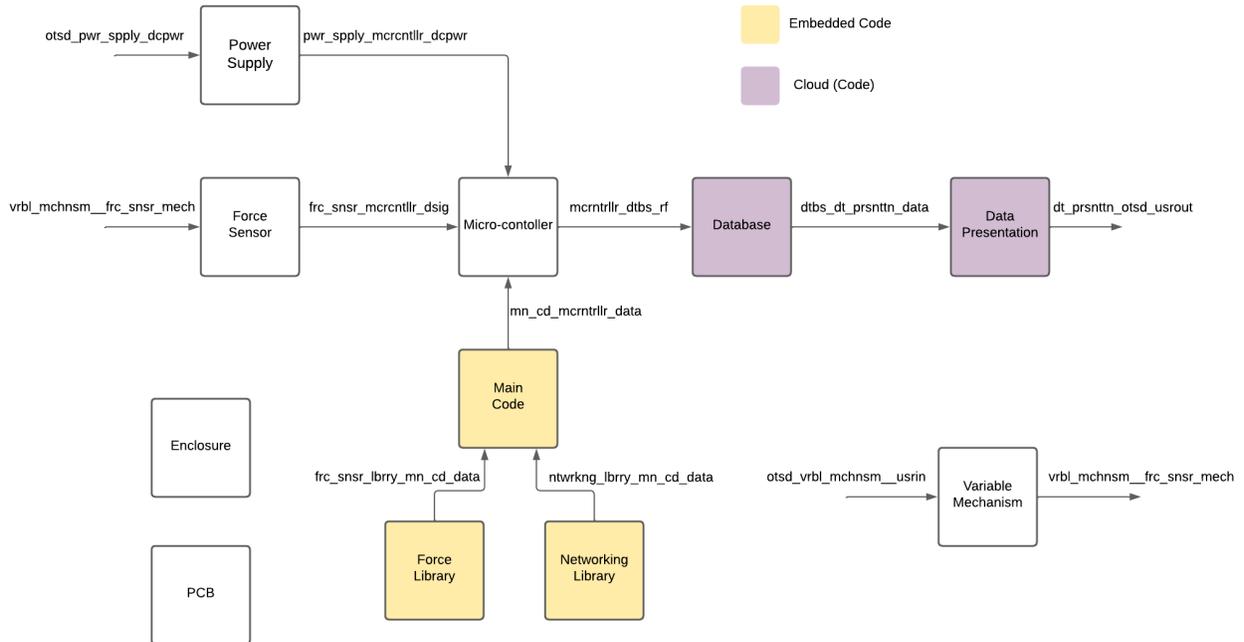
3.1.Block Diagram
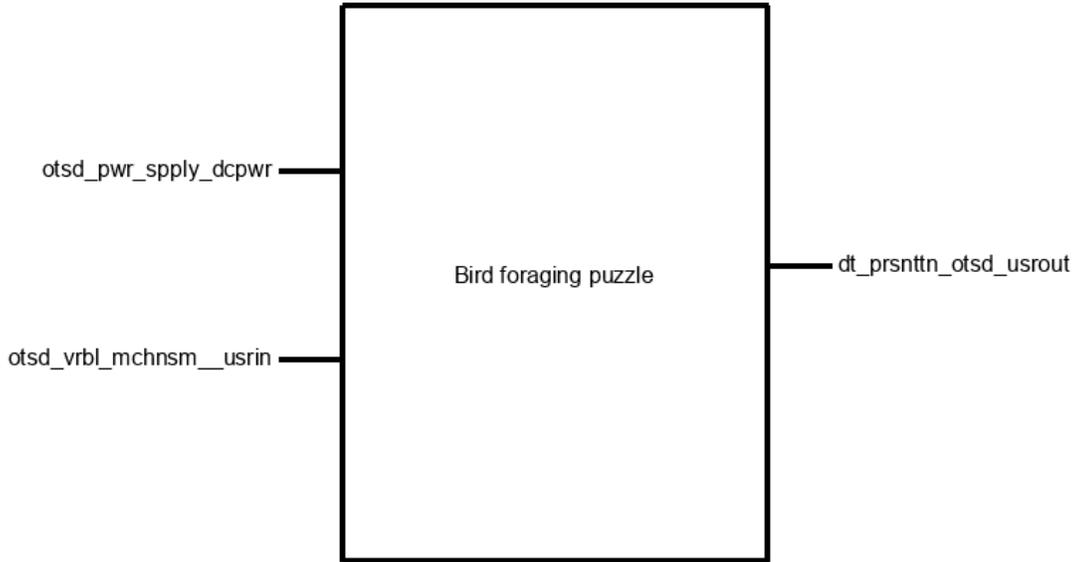
Figure 2: Black Box Diagram

Figure 3: Top-level Block Diagram

3.2.Block Descriptions

Block	Description
PCB	The PCB will contain the routing for the power supply and microcontroller blocks. Even though this block does not have any interfaces of its own it has connectors leading to other parts of the system along with on board routing to connect the microcontroller block to the power supply block. It has a molex connector for the external power supply and a 4 terminal screw connector to attach the PCB to the force sensor block. The force sensor will be connected to the 3.3V, GND, and two GPIO pins on the microcontroller.
Power Supply	Takes in an external power source and outputs a specific voltage as required to power the force sensor and the Adafruit HUZZAH32 - esp32 feather microcontroller.
Micro-controller	Contains the main code block for the force sensor block needed to run it along with the code to send the data collected by the force sensor to the server so it can be accessed later.
Force sensor	In order to measure the force, a pressure sensor block must be included for this project. This block consists of a strain gauge and load cell amplifier. As force applied to the strain gauge changes, the strain gauge outputs changes in resistance, oftentimes less than an ohm, which is then enhanced by the load cell amplifier into a value that can be measured more accurately. This force data is then sent to the microcontroller.
Variable Mechanism	The variable mechanism block is the primary mechanical operation block. Michael is responsible for completing this block. Importantly, this block accomplishes a number of crucial system functions including providing a changeable level of resistance that the bird will attempt to overcome. Primary components include the hinge, variable force springs and the mechanism stopper. The hinge is the point of contact for the bird to forage and the variable force resisting against the bird's attempts to move the hinge will be applied by the springs of varying levels. Safety is critical and the stopper component of the mechanism prevents the hinge from injuring the birds.
Database	The purpose of this block is to create a database to store all of our sensor values. The database will be created using MySQL and be hosted on the OSU engineering servers, The management of the database will use MySQL queries sent from a PHP script to create and delete tables. This block will also handle taking in the values from the force sensor that the microcontroller will then be transmitting over wifi. The data from the database will then be output to a website in the form of a table and graph via the data presentation block. With the data again being transmitted using MySQL queries.

Enclosure	The enclosure block is a very crucial and necessary part of the system. Overall the purpose of the enclosure block is to protect and house the electronic components of the system. CAD software is used to create a 3D model based on the needed specifications of the project. The model will then be 3D printed. It will be in at least two pieces so that it is openable, but when together the enclosure will protect the electronics from damage. A high priority for the project is that the system is well protected from outside elements. The components that will be enclosed include the PCB and the force sensor. Two openings will be present on the outside of the enclosure. One is for a power cable and the other is for the connection of the variable force mechanism to the force sensor.
Data Presentation	The purpose of this block is to create a visual representation from the data collected from our system sensors. PHP is used to create a website using the OSU domain. Within the backend of the website queries to a MySQL database will be checked for updates. Updates to the database will occur whenever the system sensors are switched on, if no force is applied to the sensor then a value of 0 will be sent to the database. Once the data has been retrieved from the database it will be parsed into a json file and read again by a javascript program running chartjs to make a line graph. A table with the force value and timestamp will be present below the table as well.
Main Code	The system requires the ability to measure and process data on the applied force of a bird's beak over varying amounts of time, as well as the ability to send this data to an online database through a wireless connection. In order to receive sensor data, process it, and send this data to the database, a main code block must be included for this project that integrates the force sensor library and networking library. This block will connect to WiFi in order to send data to the database block. It will take in sensor data from the sensor block, expected to be in grams, and convert these values into force values in Newtons.
Force Library	This block is the code needed to translate the analog signal from the force sensor into a unit of force, Newtons.
Networking Library	This block is the code needed for the system to communicate with the database and send over the force measurements.

3.3. Interface Definitions

Interface	Properties
vrbl_mchnsm__frc_snsr_mech	**Other**: Min Force (N), 0 N **Other**: Time (s), 10 sec **Other**: Max Force (N), 4 N

frc_snsr_mcrcntrllr_dsig	**Other**: Force Range, 0 - 4 N **Other**: Sample Rate: 10 SPS **Vnominal**: 3.3 V
mcrcntrllr_dtbs_rf	**Other**: Esp32 signal for creating a MySQL table **Other**: Esp32 signal for adding data to a table **Other**: Esp32 signal for deleting a table
otsd_pwr_spply_dcpwr	**Vmax**: 12V **Vmin**: 8V **Ipeak**: 1.5A
pwr_spply_mcrcntrllr_dcpwr	**Inominal**: 1.5A **Ipeak**: 1.9A **Vnominal**: 5V **Vripple**: 260mVpp
otsd_vrbl_mchnsm__usrin	**Other**: Hinge Safety Positions: Mechanism has a least 3 safety positions in hinge operating range **Other**: Custom spring sizes: 4 different sizes **Other**: Multimedia Materials: Primary mechanism components are made of metal and 3D printed plastic. **Type**: Mechanism Operational Hinge Range 0 to at least 45 degrees
dtbs_dt_prsnttn_data	**Other**: Time delay: pulls info from database in 5 seconds of refresh **Other**: Webpage configured on OSU namespace **Protocol**: MySQL queries
dt_prsnttn_otsd_usrout	**Type**: JSON File **Type**: Table of Force vs Time **Type**: Graph of Force vs Time
frc_snsr_lbrry_mn_cd_data	**Other**: scale.tare(): Assuming there is no weight on the scale, resets the scale to 0 **Other**: scale.set_scale(): Sets the calibration factor, which depends on units. Expected input of (-1740.0) **Other**: scale.get_units(): Gets the mass measurement from the sensor.
ntwrkng_lbrry_mn_cd_data	**Other**: blink(): Blinks the microcontroller LED at least once **Other**: wifi.status(): Returns the WiFi connection status (0 = connected, 1 = not connected) **Other**: connectToWiFi(): Attempts to connect to a WiFi network using a given network name and password

mn_cd_mcrcntrllr_data	**Datarate**: Expected 10 samples per second, one measurement every 0.1 seconds. **Messages**: float force: outputs the force measurement calculated using weight measurement. Expected 0 - 4 N. **Other**: Time: Real data must be output for at least 10 seconds uninterrupted

3.4.References and File Links

3.4.1. References (IEEE)

[1] L. Ada, "Adafruit HUZZAH32 - esp32 feather," *Adafruit Learning System*. https://learn.adafruit.com/adafruit-huzzah32-esp32-feather. [Accessed: 01-Dec-2021].

[2] S. Al-Mutlaq and Alex, "Load Cell Amplifier HX711 Breakout Hookup Guide," *Sparkfun*. https://learn.sparkfun.com/tutorials/load-cell-amplifier-hx711-breakout-hookup-guide?_ga=2.201734289.1614258175.1638296987-194100810.1637691443. [Accessed: 02-Dec-2021].

3.4.2. File Links

3.5.Revision Table

Date	Revisions Made
11/17/2021	Brieanna - Made first draft of the block diagram
11/17/2021	Shengmei - Interface Definitions
11/18/2021	Michael - Block Descriptions
11/18/2021	Shengmei - Block Descriptions
11/19/2021	Brieanna - Block and Interface Definitions
11/30/2021	Brieanna - Interface properties and re-did some of the definitions. Added References used to determine interface properties.
12/1/2021	Brieanna - Updated block diagram and new interface properties to match with expected format.
12/2/2021	Brieanna - Made a new block diagram based on input from Don. Added black box diagram. Added new interface definitions and moved

	properties from the Block Diagram Entry site. Added description for new blocks.
12/3/2021	Brieanna - Added more interface properties.
12/3/2021	Bradley - Updated block description and interface definitions.
12/3/2021	Michael - Updated block descriptions and interface definitions
4/8/2022	Brieanna - updated top-level block diagram, black box diagram, block descriptions, and interfaces.

4.0 Block Validations

4.1.Power Supply Block Validation

4.1.1.Description

The power supply is a voltage regulator that takes in an 8V-12V external power supply and outputs a 5V. This voltage is used to power the Adafruit HUZZAH32 - esp32 feather micro-controller board along with any other attachments to the board. The Adafruit HUZZAH32 has its own 5V to 3.3V regulator that is used to power the force sensor and the networking functionality that the board is designed to do.
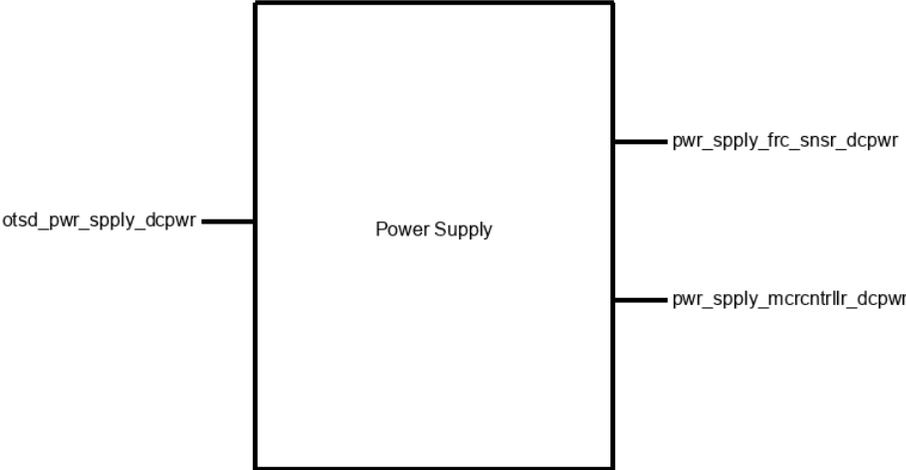
4.1.2.Design
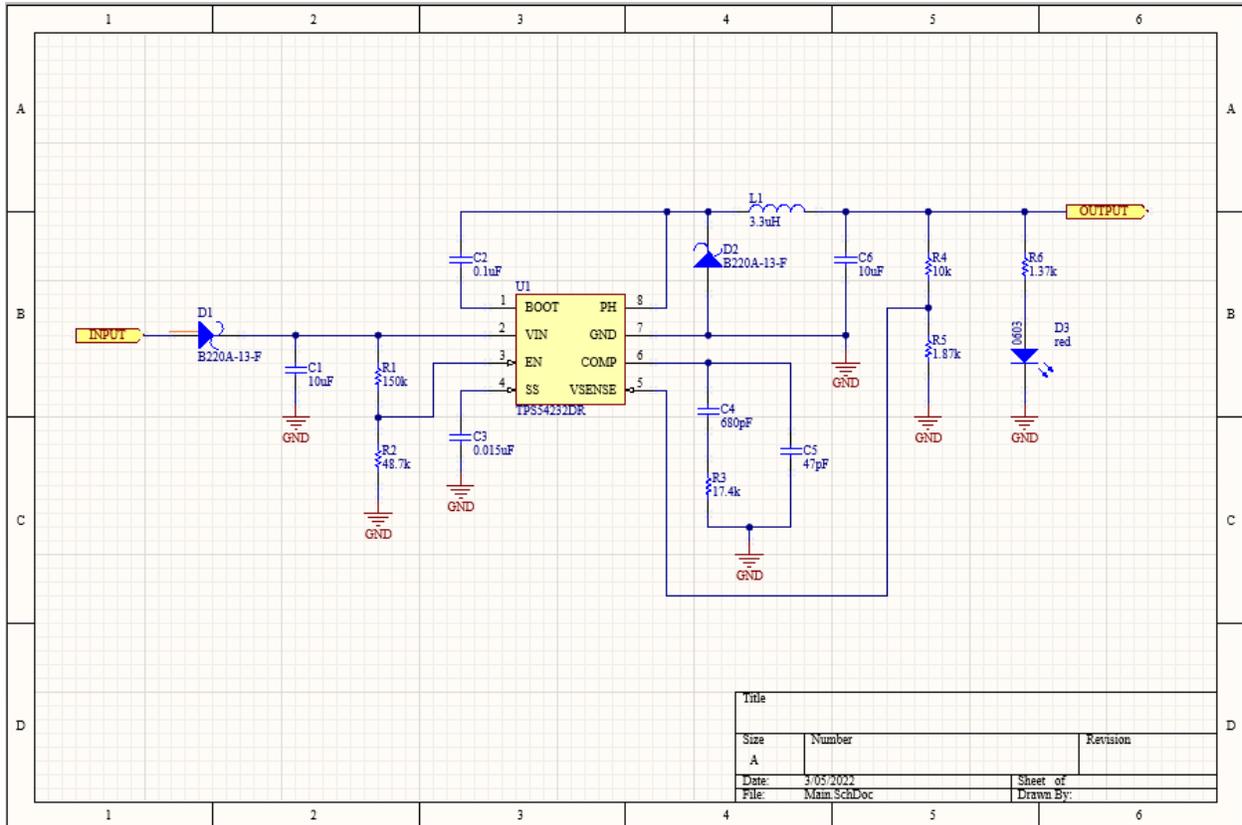

Figure 4: Black Box Diagram for Power Supply

Figure 5: Power Supply Schematic

Link to schematic part BOM

4.1.3. General Validation

This block is based on a typical application schematic from the TPS54232 datasheet, figure 10. This chip is currently available and is being restocked making it a good candidate for a project that will have its final product be produced multiple times. The schottky diode, the typical application schematic uses, B220A, is also instock with all other calculated passive components being either retally available or replaceable with equivalent parts.

Building this block will require wide traces for higher current and allow for better heat dissipation of the chip. This means that the PCB layout will be designed as close as possible to that of the recommended layout in figure 23 of the TPS54232 datasheet. Having the PCB layout being as close as possible to the recommended layout minimizes excessive capacitive coupling leading to a more accurate output voltage.

The LED D1 is not in the original typical application schematic, figure 10. It was added as an indicator LED to indicate that the converter is outputting a voltage and that is it being powered on.

The EN pin on the chip is constantly being supplied power to keep the chip on/enabled. The circuit is designed to stay on as long as a power supply is being inputted into the circuit.

The diode D3 is a reverse protection diode to keep the circuit safe in case of a negative, or reverse, voltage is applied to the input voltage.

4.1.4. Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?

otsd_pwr_spply_dcpwr : Input

Ipeak: 1.5A	This was derived by estimating how much current would be provided by the output to make a one to one ratio.	The TPS54232 is able to have a max input current up to 6 amps on the VIN pin where the input voltage is supplied. .
Vmax: 12V	This was derived by basing the design to run off of a 12V wall adapter.	The TPS54232 is able to handle up to 30 volts, as shown in section 7.1 of the datasheet.
Vmin: 8V	This was derived by the possibility of using a lower voltage wall adapter or a battery pack.	The TPS54232 is able to handle up to -0.3 volts, as shown in section 7.1 of the datasheet.

pwr_spply_mcrcntrllr_dcpwr : Output

Inominal: 200mA	This was derived by how much current is needed to continuously power the ESP32.	The Adafruit HUZZAH32 - ESP32 Feather draws a continuous current of 200mA in order to power it which can be found under the Power Supplies section of the datasheet.
Ipeak: 1A	This was derived by the option to power the board with a USB cable.	The Adafruit HUZZAH32 - ESP32 Feather gives the option to power it with a 5V 1A USB wall adaptor under Options in the datasheet. This means that it should not draw more than 1 amp at any given time even if it never needs to draw this much current. This will ensure there is plenty of

		available current for the microcontroller.
Vnominal: 5V	This is the voltage needed to power the microcontroller.	The USB pin on the Adafruit HUZZAH32 - ESP32 Feather microntoller connects to the power supply of the micro USB jack which is then fed into an on board 3.3V regulator.
Vripple: 260mVpp	This was chosen as it is a small margin off of what the expected nominal voltage should be.	The voltage ripple will be so small that it should not damage the HUZZAH32 - ESP32 Feather by having too strong of a voltage.

4.1.5. Verification Plan

This is a stress test on the system. If it can reliably output 1.5 amps then it should be able to handle the current draw from the actual components.

1. Using a variable power supply, attach the power and ground leads to the input of the circuit. Set the voltage of the power supply to 12 volts, but do not turn it on yet.
2. Attach the output of the circuit to a variable load having it set to draw 1.5 amps.
3. Power on the voltage to the circuit can monitor the variable power supply for how much current it is drawing and how much voltage it is getting. Should be 1.5 amps and 5 volts.
4. Repeat step 3 going down 1 volt each time on the variable voltage supply until 8 volts.
5. If the variable power supply continuously draws 1.5 amps at 5 volts then the circuit is working as expected.

4.1.6. References and File Links

4.1.6.1. References (IEEE)

1. "Adafruit HUZZAH32 - ESP32 feather - adafruit industries." [Online]. Available: https://cdn-learn.adafruit.com/downloads/pdf/adafruit-huzzah32-esp32-feather.pdf.
2. "Adafruit HUZZAH32 - ESP32 Feather Schematic," *Adafruit Learning System*. [Online]. Available: https://cdn-learn.adafruit.com/assets/ assets/000/041/630/original/ feather_schem.png.
3. "HX711 Datasheet." [Online]. Available: https://cdn.sparkfun.com/assets/b/f/5/a/e/ hx711F_EN.pdf .
4. "Micro Load Cell (0-5kg) - CZL635 Datasheet." [Online]. Available: https://www.robotshop.com/media/files/pdf/datasheet-3133.pdf.
5. "TPS54232 2-A, 28-V, 1-MHz, step-down ... - texas instruments." [Online]. Available: https://www.ti.com/lit/ds/symlink/tps54232.pdf.

4.1.7.Revision Table

Date	Revisions Made
1/4/2022	Brieanna - Generated format, added diagrams, added references, and wrote the general validation section.
1/5/2022	Brieanna - Wrote validation plan section and some of the interface validation section. Along with adding some references.
1/7/2022	Brieanna - Completed the interface validation section.
1/18/2022	Brieanna - Added a small detail for clarification in General Validation. Changed the reason why my design will work for Ipeak in otsd_pwr_spply_dcpwr : Input.
1/21/2022	Brieanna - Updated pwr_spply_frc_snsr_dcpwr: Output and pwr_spply_mcrcntrllr_dcpwr : Output.

4.2 Force Sensor Validation

4.2.1.Description

In order to measure the force, a pressure sensor block must be included for this project. This block consists of a strain gauge and load cell amplifier. As force applied to the strain gauge changes, the strain gauge outputs changes in resistance, oftentimes less than an ohm, which is then enhanced by the load cell amplifier into a value that can be measured more accurately. This force data is then sent to the microcontroller.
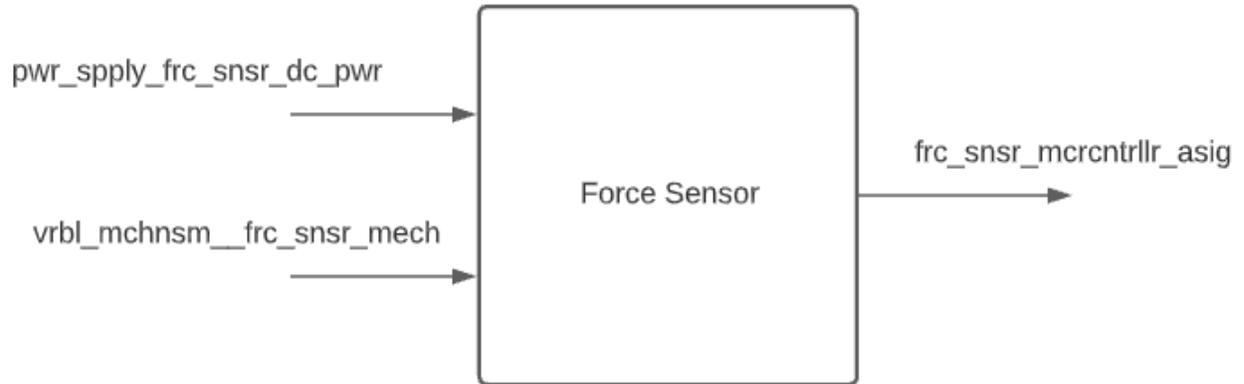
4.2.2.Design

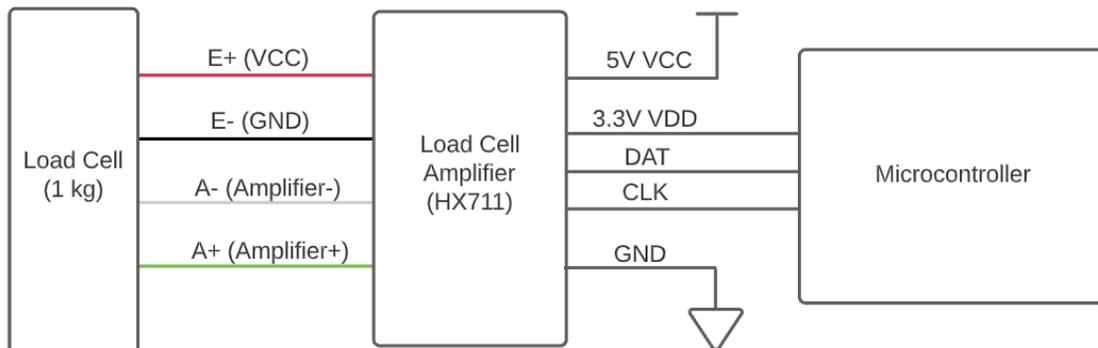Figure 6: Black box diagram of the force sensor block.

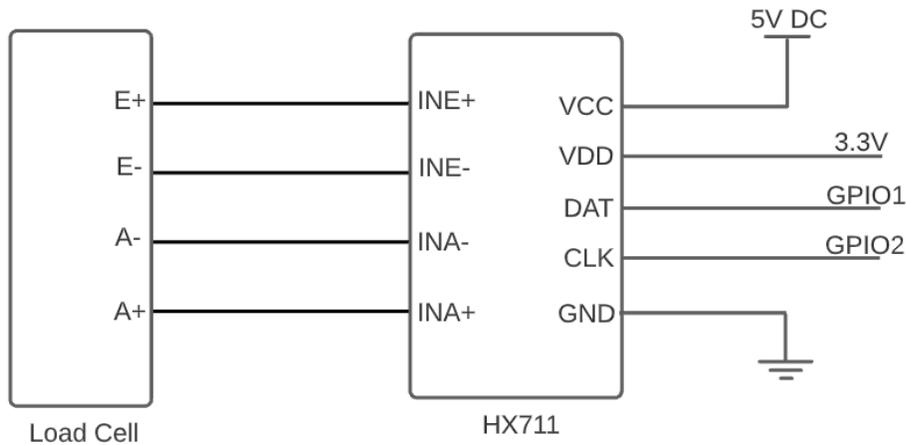Figure 7: Wiring diagram of the force sensor block.

Figure 8: Schematic of force sensor block.

4.2.3. General Validation

The purpose of this block is to measure the force applied by the bird's beak. This data will be continuously measured and output to the microcontroller. The strain gauge that will be used for this block has a load capacity of up to 1 kg, and therefore can measure force up to approximately 10 N, accurate within 0.1 N. This block will fulfill the force measurement requirements, and is directly related to the requirements for adjusting the force threshold and data visualization.

The cost to build this block is ~$15, which allows for the possibility of use in mass production of this particular block. Parts are readily available online, and as shown in the wiring schematic, the block is very easy to assemble. This makes this particular block well suited for the project, as the purpose of the system is to be used in a research scenario by users unfamiliar with electrical systems.

4.2.4. Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
vrbl_mchnsm__frc_snsr_mech: Input		
Other: Force Max (N), expecting a	This maximum was chosen based on data taken in experiments on	Per the HX711 datasheet; sensor is accurate for up to 1kg loads, equal to approximately 10 N of force.

maximum force of 10 N	bite forces for several finch species.	
Other: Force Min (N), expecting a minimum force of 0 N	The minimum is chosen because the sensor should read 0 N of force when no force is applied.	Per the HX711 datasheet; sensor is accurate for up to 1kg loads, equal to approximately 10 N of force.
Other: Time Interval (s), variable force will be measured for 10 sec	Continuous data will be taken for a length of 10 seconds, as it is expected that the bird will interact with the mechanism for no longer than 10 seconds.	Per the HX711 datasheet, the sensor is able to continuously take and output data for as long as needed.

frc_snsr_mcrcntrllr_dsig: Output

Sample Rate: 10 SPS	The 100 ms frequency was chosen because the project partner requested that force data be taken at 0.1 second intervals.	Per the HX711 datasheet, the sensor is able to be set to 10 samples per second (1 sample per 100 ms) or 80 samples per second (1 sample per 12.5 ms).
Force Range, 0 - 4 N	This range was chosen based on data taken in experiments on bite forces for several finch species.	Per the HX711 datasheet; sensor is accurate for up to 1kg loads, equal to approximately 10 N of force.
Vnominal: 3.3 V	The operating voltage of the system will be 3.3 V, as this is what the microcontroller provides.	Per the HX711 datasheet; operation supply voltage range for the amplifier: 2.6 ~ 5.5V. Per the ESP32 Feather datasheet; uses 3.3V logic.

4.2.5. Verification Plan

1. For vrbl_mchnsm__frc_snsr_mech:
   a. Implement block using Arduino Nano microcontroller instead of ESP32 Feather, for testing purposes only.

b. Use a simple program to output force to the serial monitor.
c. Use an object of known mass 1 kg as a value for vrbl_mchnsm__frc_snsr_mech: If the output force on the serial monitor is within 0.2 N of the calculated value for 1 kg (9.8 N), the block proves the force maximum property.
d. When no mass is applied for vrbl_mchnsm__frc_snsr_mech, and the output force on the serial monitor is less than 0.1 N, the block proves the force minimum property.
e. Change the masses applied to vrbl_mchnsm__frc_snsr_mech between 0-1kg for 10 seconds. If the output force changes through a range of 0 - 10 N, then the block proves the continuous time interval property.

2. For frc_snsr_mcrcntrllr_asig:
a. Implement block using Arduino Nano microcontroller instead of ESP32 Feather, for testing purposes only. VDD will be connected to the 3.3V pin on the Arduino Nano.
b. Use a simple program to output force to the serial monitor.
c. Use an object of known mass 1 kg as a value for vrbl_mchnsm__frc_snsr_mech: If the output force on the serial monitor is within 0.2 N of the calculated value for 1 kg (9.8 N), the block proves the force maximum property.
d. When no mass is applied for vrbl_mchnsm__frc_snsr_mech, and the output force on the serial monitor is less than 0.1 N, the block proves the force minimum property.

4.2.6. References

4.2.6.1. References (IEEE)

4.2.6.1. File Links

[1] HX711 Datasheet: https://www.digikey.com/htmldatasheets/production/ 1836471/ 0/0/1/hx711.html
[2] ESP32 Feather Datasheet: https://www.espressif.com/sites/default/files/ documentation/esp32-wroom-32_datasheet_en.pdf

4.2.7. Revision Table

Date	Revisions Made
1/5/2022	Shengmei Hu - Created and formatted document
1/6/2022	Shengmei Hu - Added to interface tables
1/20/2022	Shengmei Hu - Added schematic for system in section 4.1.2
1/21/2022	Shengmei Hu - Added more properties to section 4.1.4
1/21/2022	Shengmei Hu - Revised testing process and added more testing for new

	properties in section 4.1.5

4.3.PCB Block Validation

4.3.1.Description

The PCB will contain the routing for the power supply and microcontroller blocks. Even though this block does not have any interfaces of its own it has connectors leading to other parts of the system along with on board routing to connect the microcontroller block to the power supply block. It has a molex connector to connect to the external power supply and a 4 terminal screw connector to attach the PCB to the force sensor block. The force sensor will be connected to the 3.3V, GND, and two GPIO pins on the microcontroller.
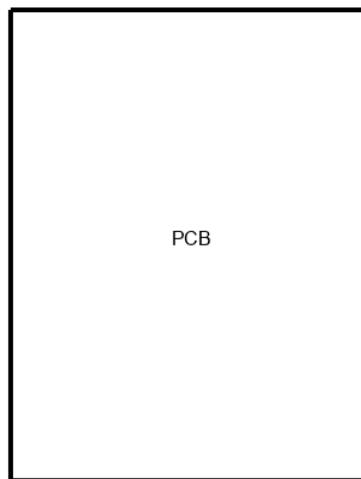
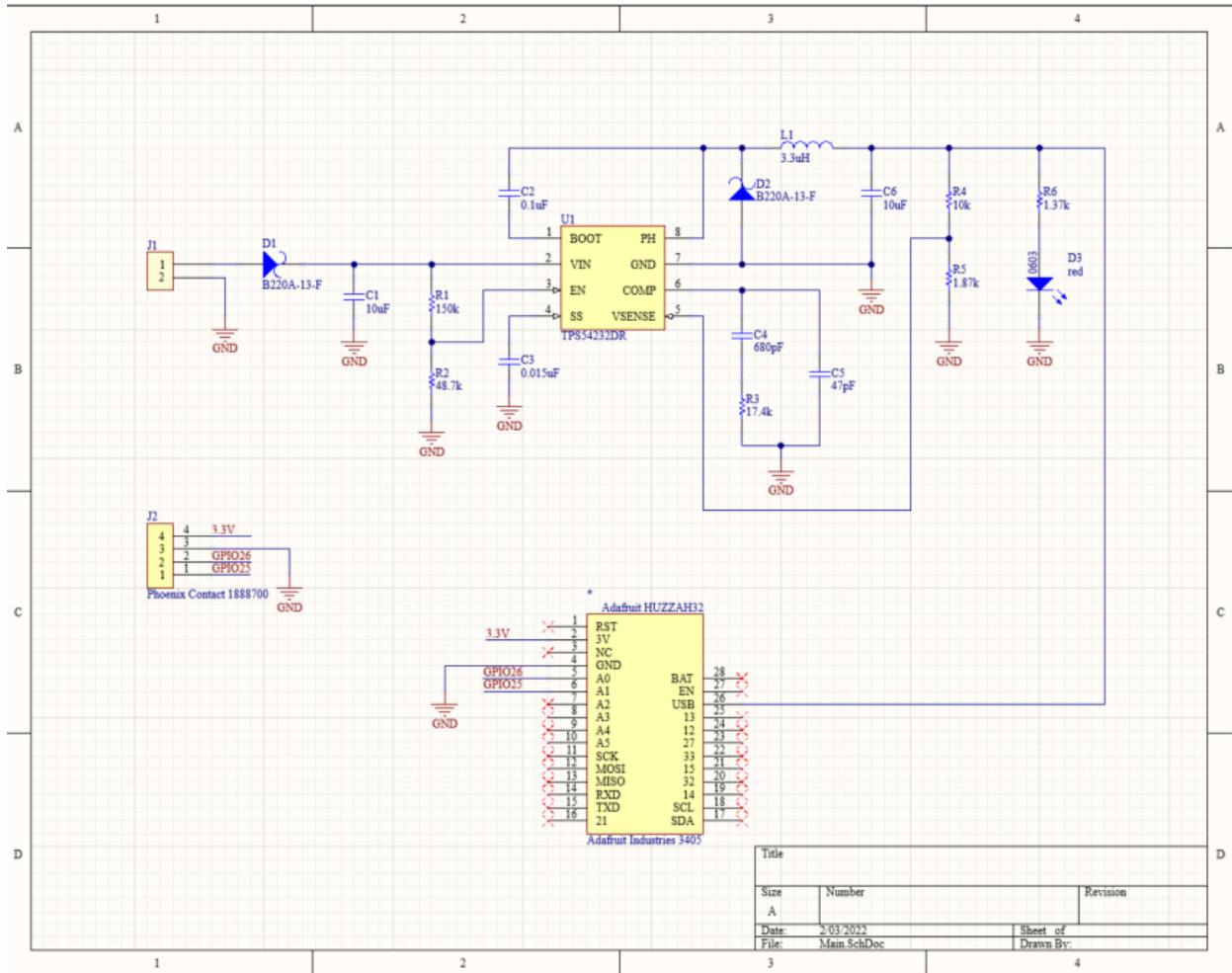### 4.3.2.Design

PCB

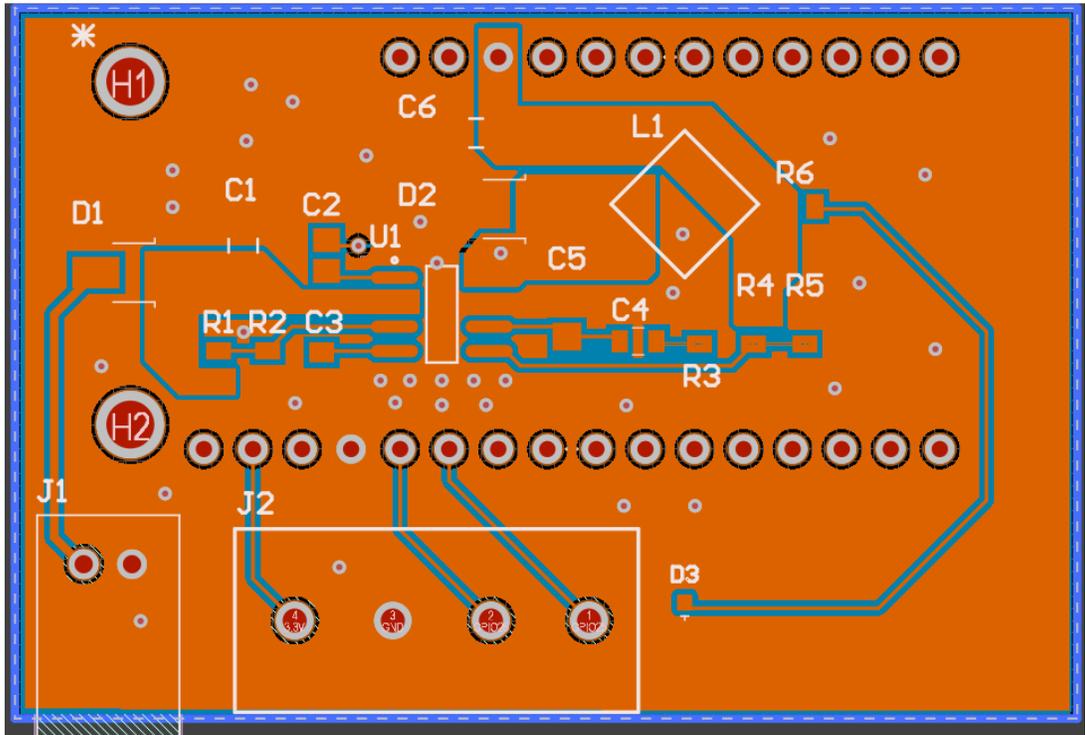Figure 9: Black Box Diagram for PCB

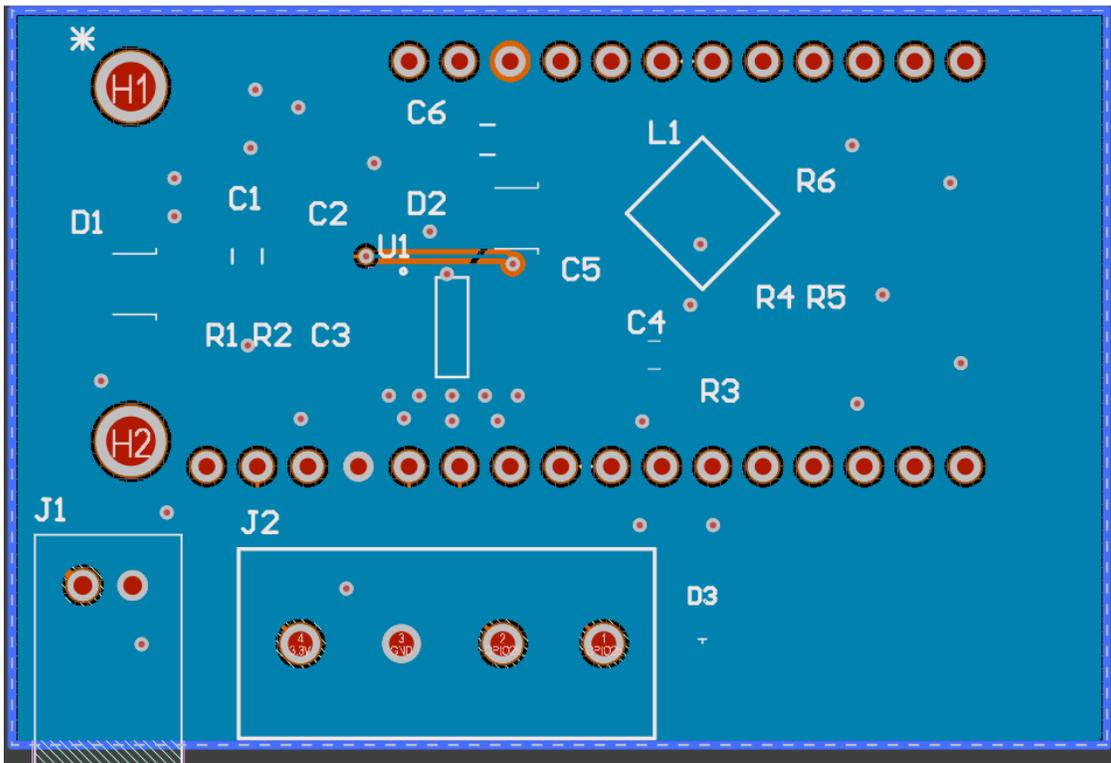Figure 10: Schematic

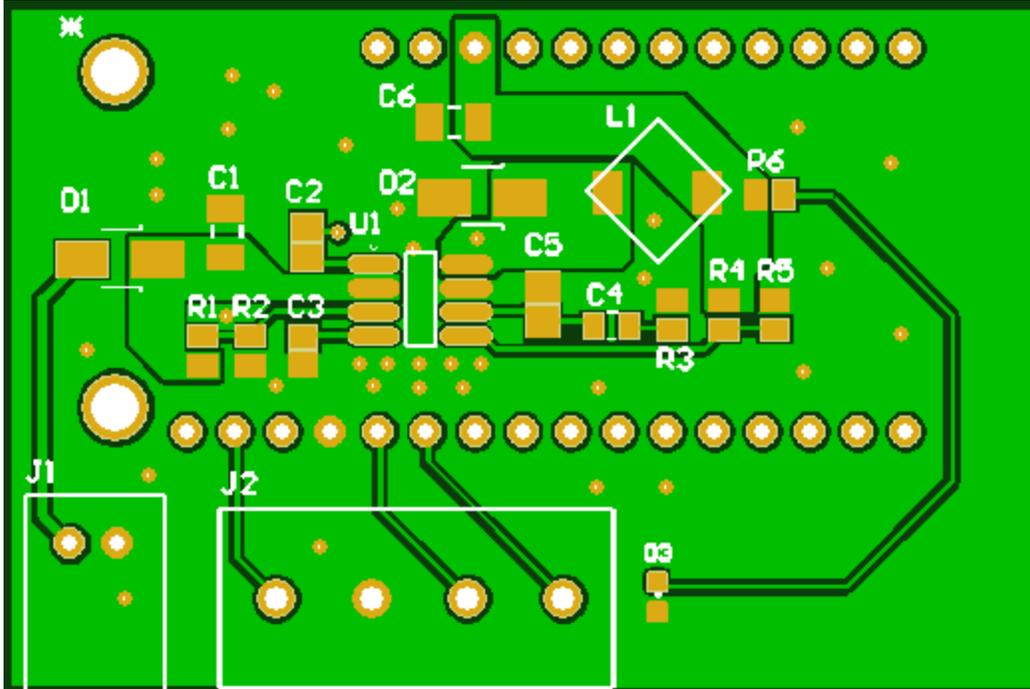Figure 11: Top layer of PCB layout

Figure 12: Bottom layer of PCB layout
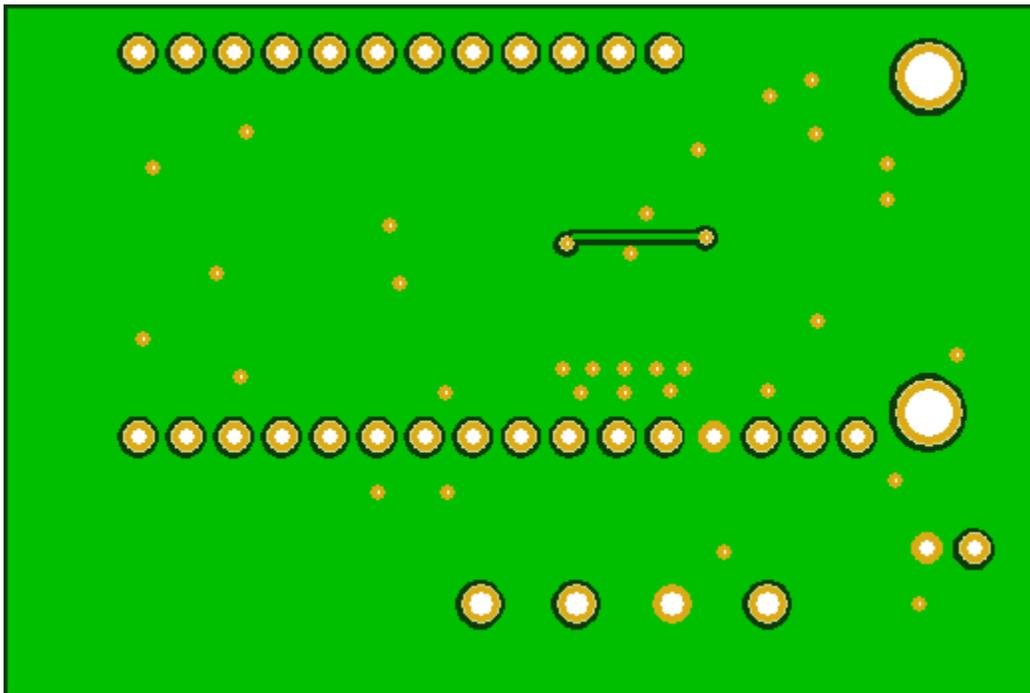
Figure 13: Top view of Gerber file generated PCB

Figure 14: Bottom view of Gerber file generated PCB

Bill of Materials Link

4.3.3.General Validation

All of the connectors leading to other blocks or off board components are one side of the board. This is so that only one side of the board needs space margin for wires to the board when it is inside of the enclosure.

The 2 pin molex connector was chosen as the power supply input was due to the impossibility of a user putting in the connector backwards—essentially applying reverse voltage. The wires attaching the female part of the molex will then lead to the desired female connector for the external power supply. Having the external power supply input connector attached to wires that lead to the board will allow for optimal placement of the input with respect to the enclosure.

The 4 terminal screw header was chosen to connect the PCB to the force sensor block so the connections can be secure and easy to install/uninstall the wires. The terminal connects to the 3.3V, GND, and two GPIO pins on the microcontroller. The GPIO pins chosen were A0 and A1 due to their close proximity of 3.3V leading to shorter and cleaner routing traces [1].

The microcontroller block was bought as a pre-made unit due to it having a networking feature and that the components used for it are extremely difficult to solder by hand. So instead female receptacle headers will be installed on the board so that the microcontroller can be easily installed by putting its male header pins into the sockets [1].

The amplifier for the force sensor was not included on the routing for the PCB as the chip for it was unable to be located as a separate purchasable unit. The amplifier module for the force sensor also likely handles sensitive signals and is specifically designed to mitigate noise.

The thick pad traces used in the power supply layout are based off of figure 23 in the TPS54232 datasheet [3]. These pads were made using polygon pours. The trace leading from the external power supply has a trace thickness of 20mil of 1oz copper allowing the trace to handle an estimated 1.5A of continuous current. All other traces on the PCB have a thickness of 10mil of 1oz copper that can handle 1A of continuous current [2].

The ground pours across the entire upper and lower layers of the board help to reduce any noise by adding shielding. These large ground planes also help dissipate heat generated by the TPS5232 as explained in its datasheet [2]. Both ground pours will be connected with numerous vias that are placed in different locations on the board to ensure the two ground planes have good connections.

4.3.4.Interface Validation

This section is intentionally left blank for PCB formatting.

4.3.5.Verification Plan

1. Supply a 12V supply to the power connector on the PCB. Using a digital multimeter, measure the voltage at the USB and 3V pins on the microcontroller. If the USB pin reads 5V with 260Vpp ripple and the 3V reads 3.3V, then it works as expected.
2. Use the digital multimeter to perform a continuity test between the pins on the microcontroller and the connector terminals to ensure that they are connected. Test the microcontroller pins 3V, GND, A0, and A1.

4.3.6. References and File Links

4.3.6.1. References (IEEE)

[1] "Adafruit HUZZAH32 - ESP32 feather - adafruit industries," *Adafruit*. [Online]. Available: https://cdn-learn.adafruit.com/downloads/pdf/adafruit-huzzah32-esp32- feather.pdf.
[2] S. Patel, "PCB trace width vs current table," *Candor Industries*, 07-Oct-2021. [Online]. Available: https://www.candorind.com/pcb-trace-width-vs-current- table/.
[3] "TPS54232 2-A, 28-V, 1-MHz, Step-Down DC-DC Converter With Eco-Mode," *Texas Instruments*. [Online]. Available: https://www.ti.com/lit/ds/symlink/ tps54232.pdf.

4.3.6.1. File Links

[1] Bill of Materials Link

4.3.7. Revision Table

Date	Revisions Made
1/31/2022	Brieanna - Generated template, added PCB black box diagram, and included reference and file links.
2/2/2022	Brieanna - Added verification plan.
2/4/2022	Brieanna - Added schematic, layout, and general validation.
2/15/2022	Brieanna - Put Reference and File Links in IEEE format. Add new and updated figures in the Design section. Added a few details to General Validation.
2/17/2022	Brieanna - Added new reference and information to General Validation for trace width.
2/18/2022	Brieanna - Added Bill of Materials

4.4.Main Code Validation

4.4.1.Description

The system requires the ability to measure and process data on the applied force of a bird's beak over varying amounts of time, as well as the ability to send this data to an online database through a wireless connection. In order to receive sensor data, process it, and send this data to the database, a main code block must be included for this project that integrates the force sensor library and networking library. This block will connect to WiFi in order to send data to the database block. It will take in sensor data from the sensor block, expected to be in grams, and convert these values into force values in Newtons.
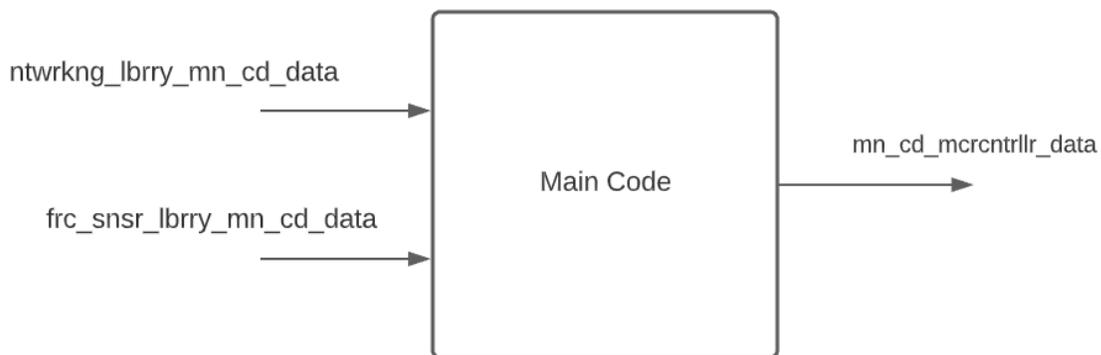
4.4.2.Design

ntwrkng_lbrry_mn_cd_data

frc_snsr_lbrry_mn_cd_data

Main Code

mn_cd_mcrcntrllr_data

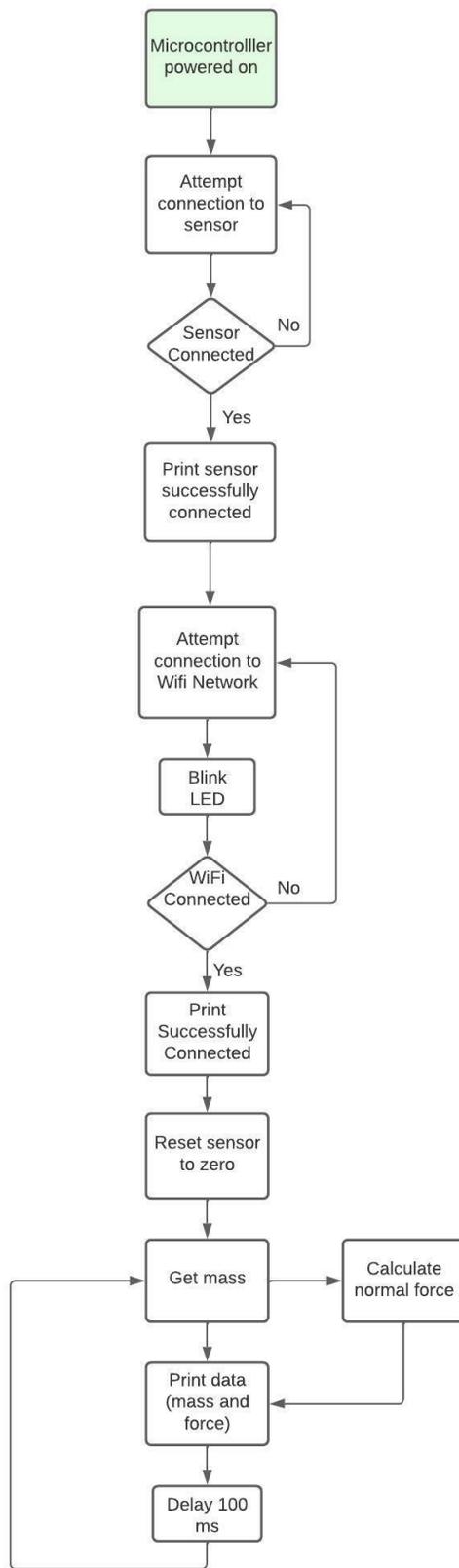Figure 15: Black box diagram of the main code block.

Figure 16: Main code flowchart.

4.4.3.General Validation

The purpose of this block is to collect data from the force sensing block, process it, and be able to send it to the database block wirelessly. Therefore, this code block requires the integration of the force sensor library as well as network library in order to both take data and connect to the internet. Using the networking library, the code will establish a connection to a WiFi network in order to send data to an online database. Using the HX711 (force sensor) library, it will accept mass values (using a calibration factor that outputs grams) from the sensor every tenth of a second and convert each value into newtons of force using the gravitational constant (F = m * g).

This block uses two libraries in the Arduino IDE, since the microcontroller used in the system is an ESP32 and thus requires Arduino IDE. There is no cost to build this block, besides requiring the microcontroller and force sensor blocks for testing and intended operational purposes.

4.4.4 Block Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
ntwrkng_lbrry_mn_cd_data: Input		
Other: connectToWiFi(): Attempts to connect to a WiFi network using a given network name and password	We wanted to encapsulate all of the WiFi functions into one library so it could be tested independently.	This is the function call used in the "Attempt to Connect" in the Design Details flowchart.
Other: wifi.status(): Returns the WiFi connection status (0 = connected, 1 = not connected)	We wanted to encapsulate all of the WiFi functions into one library so it could be tested independently.	This is the function call used in the "Check connection" in the Design Details flowchart.

Other: blink(): Blinks the microcontroller LED once	We wanted a physical method of checking if the microcontroller is currently attempting a wireless connection	This is the function call used in the "Blink" in the Design Details flowchart. The microcontroller's LED can be checked.

frc_snsr_lbrry_mn_cd_data: Input

Other: scale.set_scale(): Sets the calibration factor, which depends on units. Expected input of (-1740.0)	We wanted to encapsulate all of the force sensor functions into one library so it could be tested independently.	This is the function call used in the "Calibrate sensor" in the Design Details flowchart.
Other: scale.get_units(): Gets the mass measurement from the sensor.	We wanted to encapsulate all of the force sensor functions into one library so it could be tested independently.	This is the function call used in the "Get mass" in the Design Details flowchart.
Other: scale.tare(): Assuming there is no weight on the scale, resets the scale to 0	We wanted to encapsulate all of the force sensor functions into one library so it could be tested independently.	This is the function call used in the "Reset to zero" in the Design Details flowchart.

mn_cd_mcrcntrllr_data: Output

Messages: float force: outputs the force measurement calculated	This range was chosen based on data taken in experiments on bite forces for several finch species.	Per the HX711 datasheet; sensor is accurate for up to 1kg loads, equal to approximately 10 N of force.

using weight measurement. Expected 0 - 4 N.		
Datarate: Expected 10 samples per second, one measurement every 0.1 seconds.	The 100 ms frequency was chosen because the project partner requested that force data be taken at 0.1 second intervals.	Per the HX711 datasheet, the sensor is able to be set to 10 samples per second (1 sample per 100 ms) or 80 samples per second (1 sample per 12.5 ms).
Time: Data must be able to be collected for at least 10 seconds uninterrupted	A 10 second interval was chosen as the birds are expected to spend less than 10 seconds interacting with the puzzle.	Per the HX711 datasheet, the sensor is able to be set to continuously take data as long as a connection is established.

4.4.5.Verification Plan

The ESP32 must be connected to the force sensor in order to test for the force sensor library. While the microcontroller will be connected to a computer through USB for powering purposes during testing, the microcontroller will still be able to independently connect to WiFi.

1. For ntwrkng_lbrry_mn_cd_data:
   a. Implement block using ESP32 Feather.
   b. Call function to connect to wifi using credentials set in the code.
   c. Check LED to see if blink() is indicating an attempt to connect.
   d. Check wifi connection using wifi.status().
   e. If wifi.status() returns 0, the microcontroller has successfully connected to the network and proves the library was used correctly.
2. For frc_snsr_lbrry_mn_cd_data:
   a. Implement force sensor block with ESP32 Feather. The pwr_spply_frc_snsr_dcpwr input will be connected to the 3.3V pin on the ESP32.
   b. To check if scale.tare() and get_units() works, enable the sensor block with no mass. Check if mass reading is zero. Add known mass and check that mass reading changes to correctly match the known mass within 2 g.
   c. Restart the force sensor block with mass still on the sensor. If after restarting, the force reading changes to 0, then scale.tare() is working properly.

d. Restart the force sensor block with no mass on the sensor. Perform mass check with 400 g of mass and 500 g. If readings are accurate within 2 g, get_units is working correctly.

3. For mn_cd_mcrcntrllr_data:

   a. Implement force sensor block with ESP32 Feather. The pwr_spply_frc_snsr_dcpwr input will be connected to the 3.3V pin on the ESP32.

   b. To check if force calculation is correct, enable the force sensor block with no mass. Check if force reading is zero. Add known mass and check that force reading changes to correctly match the calculated force using known mass within 0.05 N.

   c. Restart the force sensor block with no mass on the sensor. Perform check with 4 N (408 g of mass), and > 4 N (408 g + another object). If readings are accurate within 0.05 N, then the code correctly processes mass units into force.

   d. Check using timestamps that force is being output 10 times per second. If a reading is given ~ every 0.1 seconds, then the sampling rate is correct.

4.4.6 References and File Links

4.4.6.1. References (IEEE)

4.4.6.2. File Links

[1] HX711 Datasheet: https://www.digikey.com/htmldatasheets/production/1836471/0/0/1/hx711.html

[2] ESP32 Feather Datasheet: https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32_datasheet_en.pdf

4.4.7. Revision Table

Date	Revisions Made
2/18/2022	Shengmei Hu - Revised revision table to be in the correct order
2/18/2022	Shengmei Hu - Revised testing process to include new properties
2/17/2022	Shengmei Hu - Added more interface properties to table
2/17/2022	Shengmei Hu - Revised block overview and code flowchart
2/4/2022	Shengmei Hu - Added to interface tables and flowchart
2/3/2022	Shengmei Hu - Created and formatted document

4.5. Database Block Validation

4.5.1.Description

The purpose of this block is to create a database to store all of our sensor values. The database will be created using MySQL and be hosted on the OSU engineering servers, The management of the database will use MySQL queries sent from a PHP script to create and delete tables. This block will also handle taking in the values from the force sensor that the microcontroller will then be transmitting over wifi. The data from the database will then be output to a website in the form of a table and graph via the data presentation block. With the data again being transmitted using MySQL queries.
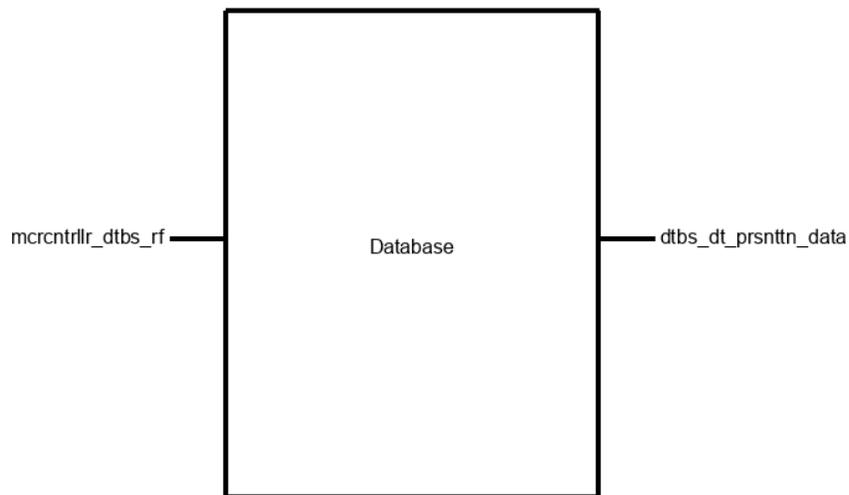
4.5.2.Design

mcrcntrllr_dtbs_rf — Database — dtbs_dt_prsnttn_data

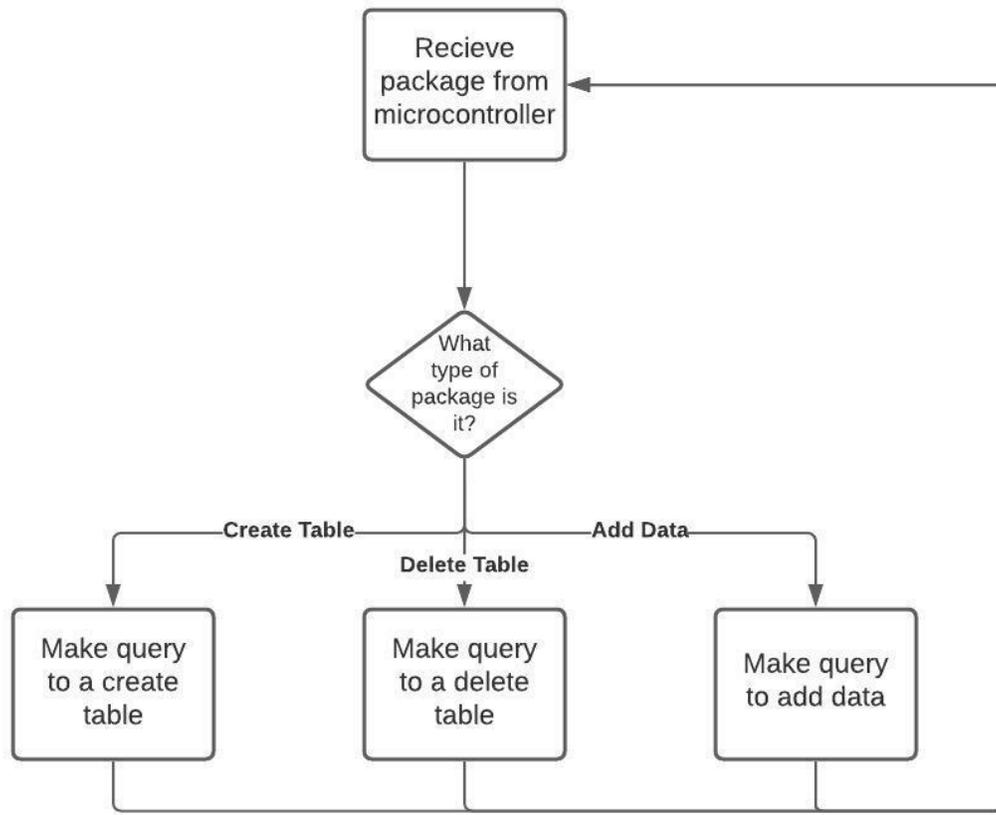Figure 17: Black Box of Database Block

Figure 18: Database Flowchart

4.5.3. General Validation

A database is needed as an intermediate step between the sensors sending data and being presented for the end user to view. Our project partner runs a lab here at OSU and therefore has access to all the services. Using a MySQL database that is both run and presented on the OSU servers and domain was an efficient and familiar way to accomplish this. The database receives updates from the microcontroller only periodically because the force does not need to be seen in real time. The data presentation block only updates whenever the website has been refreshed, so only periodically sending data in packages is much more efficient.

4.5.4. Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?

dtbs_dt_prsnttn_data : Output

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
Other: Time delay: pulls info from database in 5 seconds of refresh	This leaves room for the web page to refresh with any updated values from the database.	The data does not need to be real time and the presentation is for analysis more than monitoring.
Other: Webpage configured on OSU namespace	Web page hosted by OSU so data can be accessed anywhere.	The Lab Members can access the data without needing extra proprietary equipment to the system.
Protocol: MySQL queries	Queries are used as the main way to transfer data from the database.	Queries are called to send data to the backend of the webpage to eventually populate the graph and table outputs.

dt_prsnttn_otsd_usrout : Input

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
Other: esp32 signal for creating a MySQL table	The database needs a container to store whatever data is sent over.	The database cannot store data without a table first being created telling the database where to store it. The microcontroller will signal that a table needs to be created because the system is preparing to send data.
Other: esp32 signal for deleting a table	In order to not store unnecessary data, deleting tables once finished is being used.	The data stored in the database will remain there unless the memory is freed. The system telling the database when it is finished will ensure that memory is efficiently used.

Other: esp32 signal for adding data to a table	The force data is communicated over wifi to be stored in the created tables.	The database needs a way to distinguish where data can be stored once a table is created. The microcontroller will send the signal over wifi along with where it needs to be stored.

4.5.5. Verification Plan

1. Create an artificial microcontroller.
2. The microcontroller will send out 3 different test signals.
3. Send a signal to create a table and check phpmyadmin for confirmation.
4. Send a signal to add data to a table and check phpmyadmin for confirmation.
5. Send a signal to delete table/data and check phpmyadmin for confirmation.

4.5.6 References and File Links

4.5.6.1. References (IEEE)

4.5.6.2. File Links

[1] "Welcome to ESP8266 Arduino Core's documentation!¶," *Welcome to ESP8266 Arduino Core's documentation! - ESP8266 Arduino Core documentation*. [Online]. Available: https://arduino-esp8266.readthedocs.io/en/latest/. [Accessed: 05-Feb-2022].

4.5.7. Revision Table

Date	Revisions Made
2/4/2022	Bradley Martin - Initial Commit
2/18/2022	Bradley Martin - Changed Interface Properties
3/6/2022	Bradley Martin - Added to Project Document

4.6. Data Presentation Block Validation

4.6.1. Description

The purpose of this block is to create a visual representation from the data collected from our system sensors. PHP is used to create a website using the OSU domain. Within the backend of

the website queries to a MySQL database will be checked for updates. Updates to the database will occur whenever the system sensors are switched on, if no force is applied to the sensor then a value of 0 will be sent to the database. Once the data has been retrieved from the database it will be parsed into a json file and read again by a javascript program running chartjs to make a line graph. A table with the force value and timestamp will be present below the table as well.
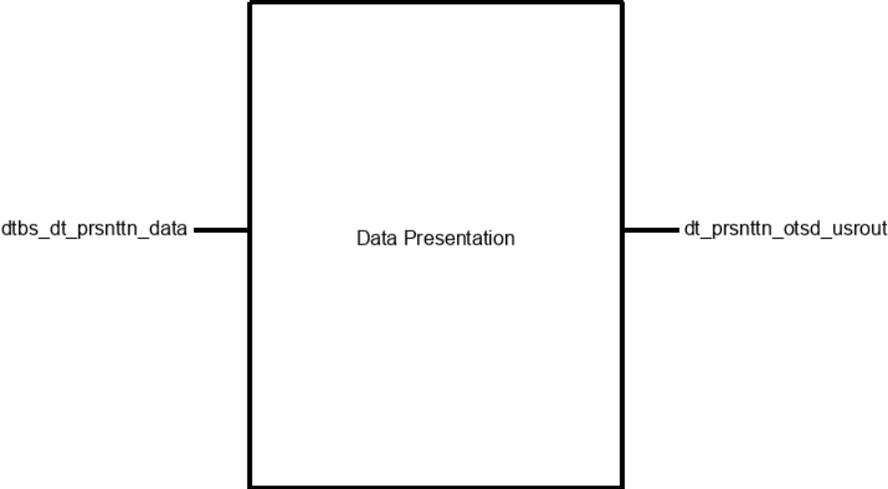
4.6.2.Design
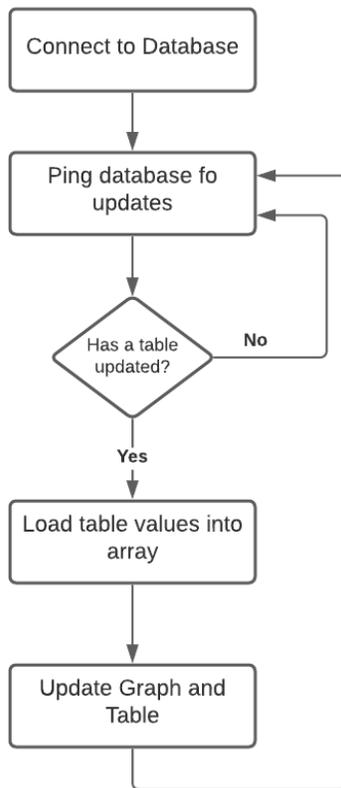

Figure 19: Black Box of Block

Figure 20: Data Presentation Flow Chart

4.6.3. General Validation

A website for data viewing was chosen based on the ease that it could be accessed on by the lab staff this is designed for. Instead of adding another piece of equipment that would be proprietary to the system we opted for a more universal approach. Both a graph a table are present for a sensor so that the force can be better comprehended visual with the graph, and then have more detail from the table if need be.

4.6.4. Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?

dtbs_dt_prsnttn_data : Input

Other: Time delay:	This leaves room for the web	The data does not need to be

pulls info from database in 5 seconds of refresh	page to refresh with any updated values from the database.	real time and the presentation is for analysis more than monitoring.
Other: Webpage configured on OSU namespace	Web page hosted by OSU so data can be accessed anywhere.	The Lab Members can access the data without needing extra proprietary equipment to the system.
Protocol: MySQL queries	Queries are used as the main way to transfer data from the database.	Queries are called to send data to the backend of the webpage to eventually populate the graph and table outputs.

dt_prsnttn_otsd_usrout : Output

Type: Graph of Force vs Time	A way to visually present the data was needed.	Our project partner asked for a quick visual way to analyze data.
Type: Table of Force vs Time	A way to see detailed data at specific points was needed.	Timestamps and data directly from the sensors is presented.
Usability: JSON File	Configuration of the graph requires the data to be formatted in a JSON file.	As noted in chart.js API documentation and tutorials, a JSON file is used to parse through data to create a graph.

4.6.5. Verification Plan

1. Go to the OSU hosted webpage ensuring the files of input in the Public_html folder in the network drive.
2. Create a webpage for an artificial sensor with MySQL queries to send data to the database.
3. Also using MySQL queries call data to be sent to an output JSON file.
4. Using the Public_html folder in the network drive, ensure the JSON file has been created with the expected values.
5. Go to the Data Presentation webpage and see that both the graph and table are populated with the correct values.
6. Enter more data into the artificial sensor to be stored.
7. Start a timer and refresh the data presentation page
8. Time must be less than 5 sec for the page to refresh with new values.

4.6.6. References and File Links

4.6.6.1. References (IEEE)

[1] Chart.js - v3.7.0, https://www.chartjs.org/docs/latest/api/, Last accessed 1/21/2022

[2] MySQL 8.0 Reference Manual, https://dev.mysql.com/doc/refman/8.0/en/, Last accessed 1/8/2022

4.6.6.2. File Links

4.6.7. Revision Table

Date	Revisions Made
1/8/2022	Bradley Martin - Initial Commit
1/20/2022	Bradley Martin - Changed Interface definitions
1/21/2022	Bradley Martin - Added more Interface definitions
1/22/2022	Bradley Martin - Changed Verification Plan
3/6/2022	Bradley Martin - Added to Project Document

4.7. Variable Mechanism Validation

4.7.1. Description

The variable mechanism block is the primary mechanical operation block. Michael is responsible for completing this block. Importantly, this block accomplishes a number of crucial system functions including providing a changeable level of resistance that the bird will attempt to overcome. Primary components include the hinge, variable force springs and the mechanism stopper. The hinge is the point of contact for the bird to forage and the variable force resisting against the bird's attempts to move the hinge will be applied by the springs of varying levels. Safety is critical and the stopper component of the mechanism prevents the hinge from injuring the birds.
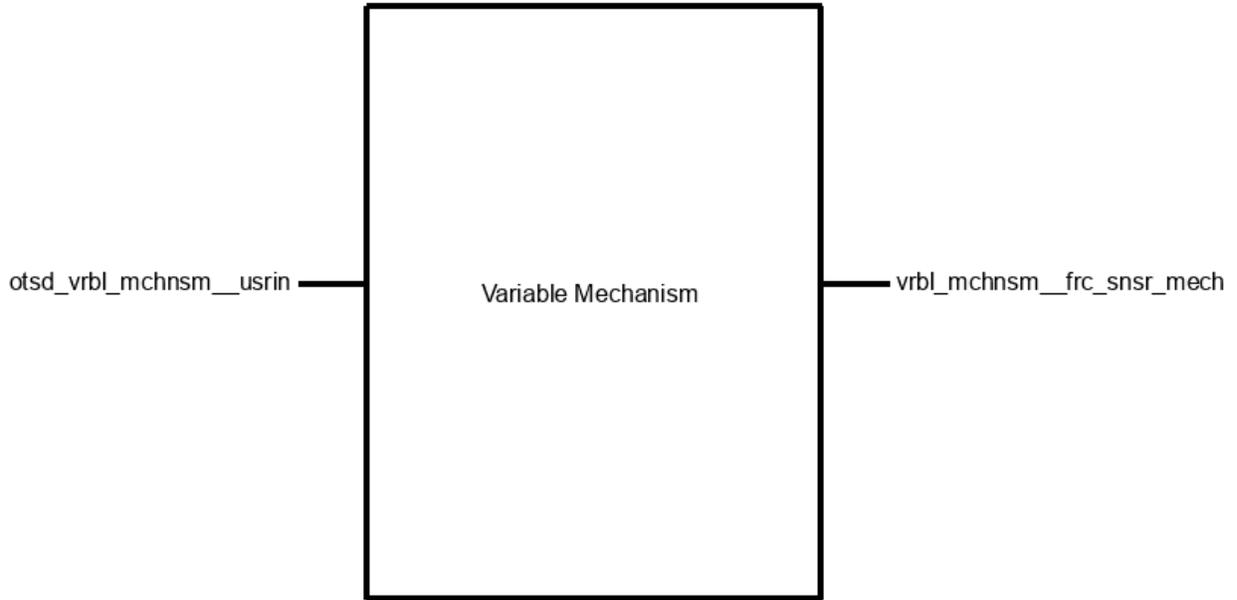
4.7.2. Design

Figure 21: Black Box Diagram

otsd_vrbl_mchnsm__usrin → Variable Mechanism → vrbl_mchnsm__frc_snsr_mech
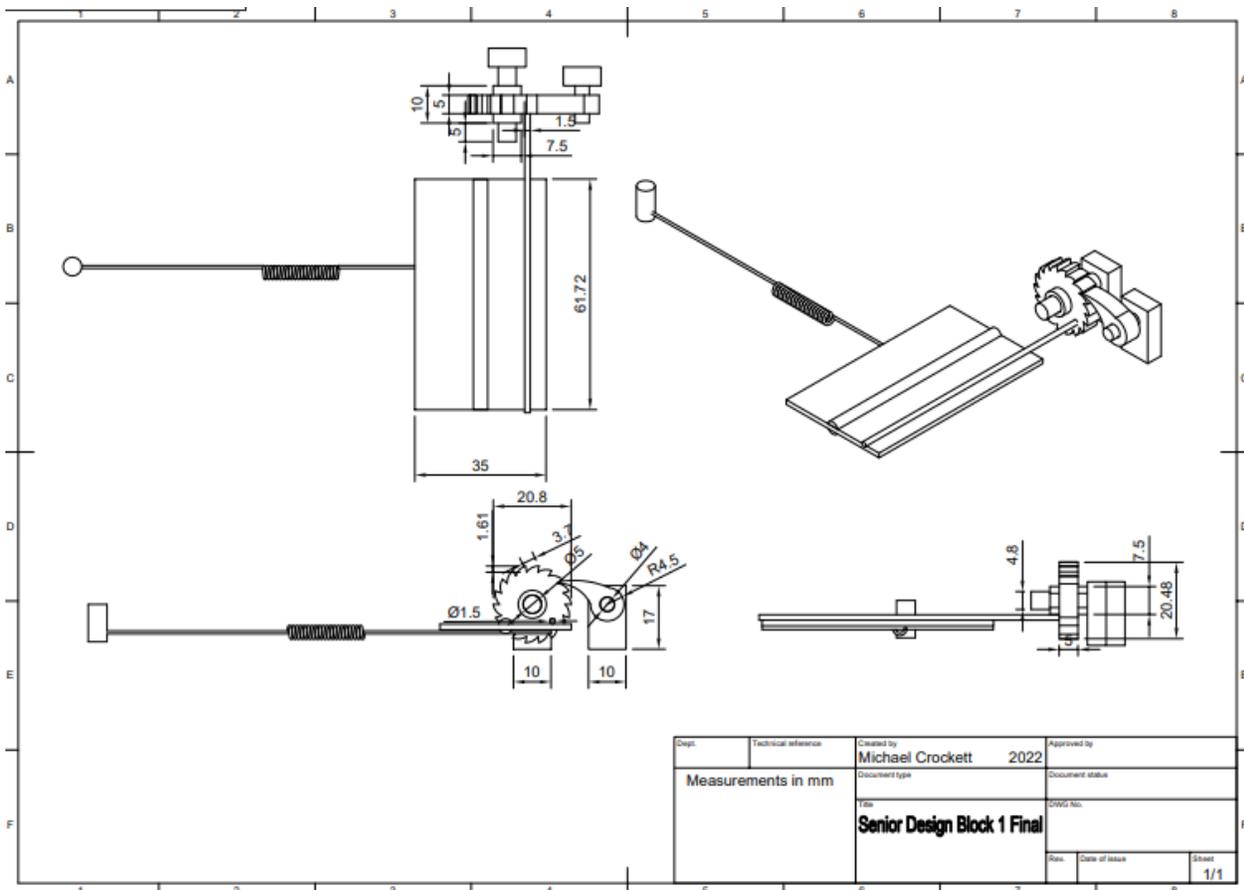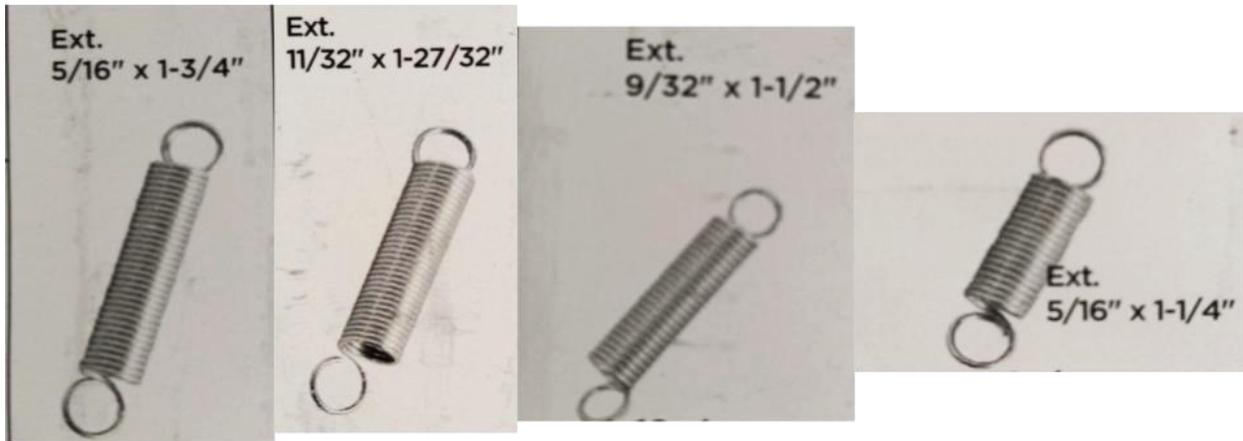

Figure 22: Mechanism Drawing

Figure 23: Purchased Spring Sizes

4.7.3. General Validation

The variable mechanism block is a very important block in the overall system and its design details were made with accomplishing the project goals. This block contains the mechanical mechanism responsible for physical operation of the system. Components in the block such as the hinge, variable force springs, and the mechanism stopper directly address the purpose of the block and overarching goals of the system.

This design addresses many of the overall project concerns as efficiently as possible. Chosen components are all common and relatively low cost to purchase or produce via 3D printing. Simplicity was made a design priority so that the physical mechanism can be easily understood and operated. This block must reliably operate and allow the bird to use its foraging method in a safe manner. In order to ensure the reliable operation the design has been tweaked and modified to maximize simplicity and effectiveness. This block is key to the system operation and the other block will be built off of it physically. The physical sizing and configuration is heavily influenced by the other parts of the system that will be added onto this mechanical base. Possible impact from the system has been seriously considered in the design of this block and has led to a more streamline block.

4.7.4. Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
otsd_vrbl_mchnsm__usrin: Input		
Other: Custom spring sizes: 4 different sizes	The number of different springs was set to 4 in the system requirements to allow for difficult variation. So four different springs are needed for this block.	Four different springs for the system were purchased and the sizes are detailed in the design section (Figure 3).

Type: Mechanism Operational Hinge Range 0 to at least 45 degrees	The range of movement for the hinge mechanism must be large enough that the bird would have sufficient access to a food reward underneath it. The bird can likely access it with a small opening, but having the ability for more access makes the system more friendly to the birds. A minimum of 45 degrees of access ensures that the birds can raise the hinge to point that they can easily access the reward if they are successful.	The hinge has a range of 135 degrees when unattached to any mechanisms. When the variable force and safety stopper components are attached the range of movement is more limited and difficult. The gear is scaled to the hinge and has a rod connecting with the hinge. As a result the hinge movement is restrained by its physical connection to the gear, but they are well aligned and a range of at least 90 degrees should not face any issues well larger than the needed range. The mechanics of the variable spring may affect the range slightly, but the way the block is set up should lead to that effect being minimal as the spring would not be over stretched at a range even higher than 45 degrees.
Other: Hinge Safety Positions: Mechanism has a least 3 safety positions in hinge operating range	The increments that the hinge must be not too far apart to maximize the bird's safety. Having at least 3 is the operating range demonstrates that they are frequent enough to protect the bird.	From the design mechanical drawing it can be seen that the gear has 18 points (Figure 2) at which the latch can be positioned to stop the movement of the hinge. Within the operational range of the hinge the latch would pass more than 3 of the stop points.Therefore the minimum of 3 can be met.
Other: Multi-medium Materials: Primary mechanism components are made of metal and 3D printed plastic.	The materials were chosen for several factors. Metal was used for strength and durability. Plastic was used in order to use 3D printing manufacturing of custom parts.	The hinge is the primary component made of metal. Plastic is used for all of the safety stopping mechanism components. So both metal and 3D printed plastic make up the primary material for components.

vrbl_mchnsm__frc_snsr_mech: Output

Other: Force Max (N), Max force of 10 N	This value is the amount of force that a user is outputting to lift the hinge. The value must meet this minimum so that the puzzle provides a challenge to the bird. The value is based on estimations of bird output	This force requirement should be produced based on the component specifications. The amount of force required to lift the hinge can be adjusted by changing the spring size to result in higher tension and more force on the hinge. Using a sufficiently sized variable force spring the mechanism can require

	force potential created from knowledge of this bird's particular foraging method.	the user to exert 10 newtons of force as the maximum force needed to move the hinge.
Other: Force Min (N), Minimum force of 0 N	At points when the user is not exerting force the mechanism would be outputting 0 N so that is the minimum of the range.	The block can meet this requirement because when no input is exerted a force of 0 N should be measured since no movement is occurring.
Other: Time (s) 10 sec	The mechanism should be able to output force for at least a 10 second period so that the larger system has sufficient data to process.	Due to the mechanical design of the block (Figure 2), during operation the mechanism is always outputting a force so it can easily output force over a 10 second period.

4.7.5.Verification Plan

Process Steps:
1. Setup of system: Confirm all components are present and in the correct position.
2. Show all 4 four variable force springs are available as required by the property "Custom spring sizes: 4 different sizes" from interface otsd_vrbl_mchnsm__usrin.
3. Look over the system to confirm the property "Multi-medium Materials: Primary mechanism components are made of metal and 3D printed plastic." from interface otsd_vrbl_mchnsm__usrin by checking the materials of primary block components.
4. Begin slowly raising the hinge using a hand to simulate the operation of the block.
5. Continue raising the hinge.As the stopper mechanism latch passes each gear tooth, release the hinge to demonstrate the locking point as required by property "Hinge Safety Positions: Mechanism has a least 3 safety positions in hinge operating range" from interface otsd_vrbl_mchnsm__usrin. Do this three times at different safety points.
6. Continue raising the hinge until it reaches a 45 degree angle as required by "Type: Mechanism Operational Hinge Range 0 to at least 45 degrees" from interface otsd_vrbl_mchnsm__usrin.
7. Cease input and reset system.
8. Attach Force Sensor Block and any needed test components.
9. Begin second test run with force sensor block operating.
10. Start applying input to hinge. Raising it very slowly (approximately 4 degrees a second). Continue until the hinge reaches 45 degrees which will take slightly more than ten seconds. This test cycle length is needed to validate the output property "Time (s) 10 sec" in the interface vrbl_mchnsm__frc_snsr_mech.
11. Stop input and conclude test run 2.

12. View data from Force Sensor block testing showing max and min outputs to validated property "Force Max (N), Max force of 10 N" and property "Other: Force Min (N), Minimum force of 0 N" from the interface vrbl_mchnsm__frc_snsr_mech.

4.7.6.References and File Links

4.7.6.1.References (IEEE)

No outside references used.

4.7.6.2.File Links

[1] Variable Mechanism Bill of Materials: https://docs.google.com/spreadsheets/d/1Tx004zRzS28E5MIpYthVcgeTyq-tRGWPWpoqP9SyZu8/edit?usp=sharing

4.7.7.Revision Table

Date	Revisions Made
1/7/2022	Michael Crockett - Added new interface properties to 4.1.4 table
1/14/2022	Michael Crockett - Updated Mechanical Diagram
1/18/2022	Michael Crockett - Revision of properties
1/20/2022	Michael Crockett - Revision of properties
1/21/2022	Michael Crockett - Revision of interfaces and properties
1/21/2022	Michael Crockett - Revision of block test properties
1/21/2022	Michael Crockett - Added figure 3
1/21/2022	Michael Crockett - Updated reference files in file section
1/21/2022	Michael Crockett - Updated Block Diagram

4.8.Enclosure Validation

4.8.1.Design

The enclosure block is a very crucial and necessary part of the system. Overall the purpose of the enclosure block is to protect and house the electronic components of the system.

CAD software is used to create a 3D model based on the needed specifications of the project. The model will then be 3D printed. It will be in at least two pieces so that it is openable, but when together the enclosure will protect the electronics from damage. A high priority for the project is that the system is well protected from outside elements. The components that will be enclosed include the PCB and the force sensor. Two openings will be present on the outside of the enclosure. One is for a power cable and the other is for the connection of the variable force mechanism to the force sensor.
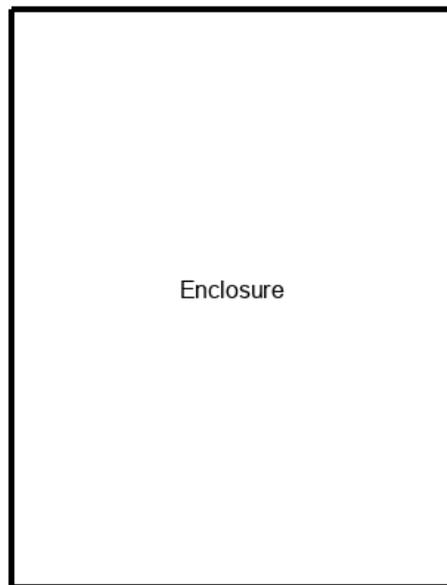
4.8.2. Design
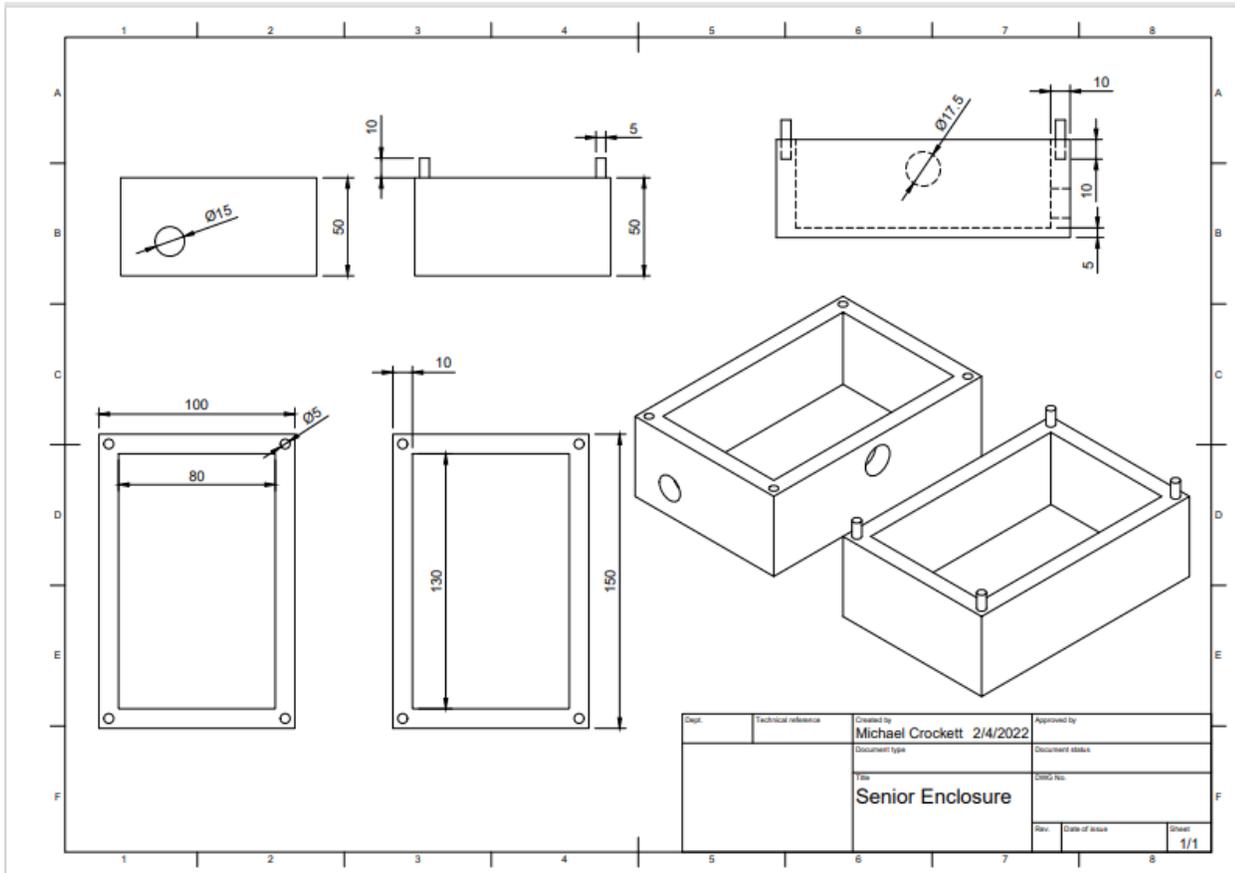

Figure 24: Black Box Diagram

Figure 25: Mechanism Drawing (Measurements in millimeters)

Table 6:Provided Component Dimensions

Component:	Provided Imperial Measurements (Inches)	Measurements converted to metric (Millimeters)
Load Cell	(4 by 0.75 by 0.75)	(101.6 by 19.05 by 19.05)
Additional Load Cell Module	(1 by 1 by 0.5)	(25.4 by 25.4 by 12.7)
PCB	(1.5 by 2.5 by .5)	(38.1 by 63.5 by 12.7)

4.8.3.General Validation

The enclosure block is a critical component of the system and it has been designed to meet the protective needs of the system. The enclosure block is designed in CAD and will be 3D printed. Using CAD software provides lots of flexibility in the design work and makes the process very effective. 3D printing was chosen for manufacturing the block for a number of reasons. It is the easiest way to manufacture the block. It is also very quick to complete and low cost. 3D printed material meets the needs of blocks in terms of durability and utility. This block must protect components from things like water and dust. The 3D printed plastic is strong enough to provide protection to the components and is overall the most effective material choice in this case.

The enclosure will be made in two pieces for both ease of manufacturing and use. It will use a peg connection at each corner to securely connect the two pieces, but this method also also for easy access to the system when needed while not compromising protection. The design size is based on all provided dimensions for the components that will be housed in the enclosure. The dimensions are in millimeters. If some size change occurs, a change can quickly be made by adjusting the design and printing a new model. The components inside the enclosure will be secured using velcro patches. Velcro will keep components from moving while also providing flexibility and ease of use.

4.8.4. Interface Validation

This Enclosure block has no interfaces with other blocks and therefore no interface properties.

4.8.5. Verification Plan

Process Steps:
1. Create and 3D print Enclosure.
2. Place housed components or analogs of the same size in the enclosure.
3. Show that they are successfully mounted and all components fit in the enclosure.
4. Shake and move the enclosure.
5. Show that components are still in place.

4.8.6. References and File Links

4.8.6.1. References (IEEE)

No outside references used.

4.8.6.2. File Links

[1] Enclosure 3D STL File: https://drive.google.com/file/d/1yo4Vk550FTVWo4DLQZdKz_FifdZM5KTQ/view?usp=sharing

4.8.7. Revision Table

Date	Revisions Made
2/1/2022	Michael Crockett - Created Document
2/4/2022	Michael Crockett - Added updated mechanical drawing
2/18/2022	Michael Crockett - Added component size table to design section
2/18/2022	Michael Crockett - Updated General validation description
2/18/2022	Michael Crockett - Updated Overview description

5.0 System Verification Evidence

5.1.Universal Constraints

5.1.1.The system may not include a breadboard

All electrical circuits used in the system are confined to being on PCBs and are interconnected with wires that can also disconnect.

Figure 26: Inside view of enclosure of electronics

5.1.2.The final system must contain both of the following: a student designed PCB and a custom Android/PC/Cloud application

The system contains two PCBs, a student designed one and a pre-made module amplifier for the force sensor. The force sensor deals with small sensitive signals making it not ideal to try and route in the chance of interference with the signal, along with not being able to to find the chip for the circuit, it was decided to buy a pre-made module. The student-made PCB contains the routing for the power supply and is connected to the pre-made ESP32 module that slots into the board and contains the microcontroller and networking circuits.

The cloud application is done using a web server and database hosted using OSU resources. The database is hosted on the OSU engineering servers which can be accessed only through OSU networking. The webserver is the portal for which all communication is done with the database. The web server uses MySQL queries to communicate with the database to modify tables. The web server also has PHP programs to present the data from the database in the form of a line graph and table for the end user.
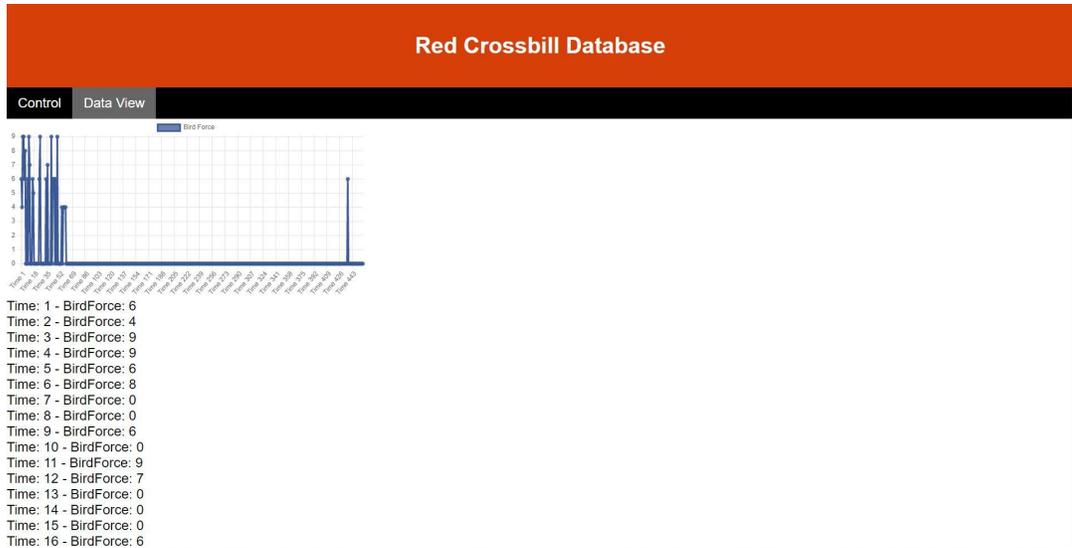
Figure 27:

5.1.3. If an enclosure is present, the contents must be ruggedly enclosed/mounted as evaluated by the course instructor

All electrical components are enclosed in the enclosure. These included the PCB and the force sensor. These components are mounted inside the enclosure using velcro in order to keep them in place. The enclosure protects the components from outside elements.
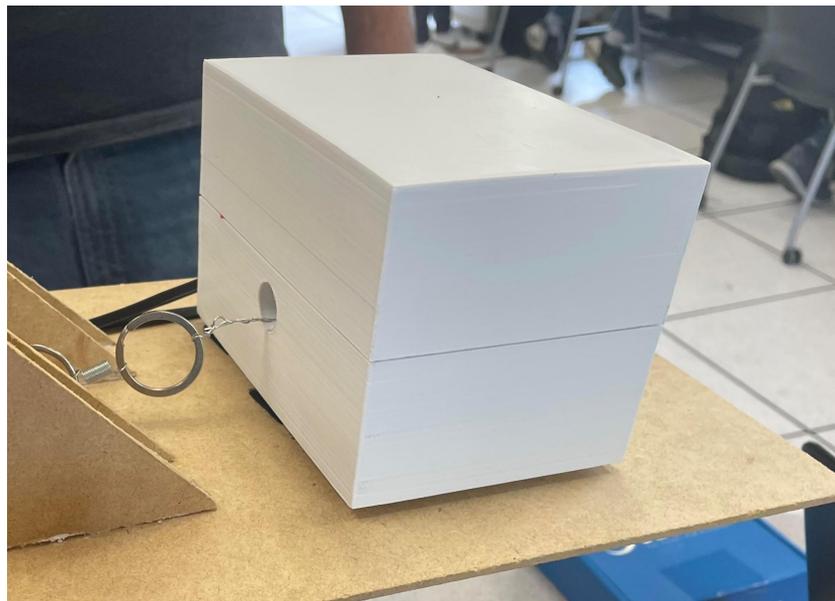

Figure 28: Outside image of the enclosure

5.1.4. If present, all wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors

All wires that connect to the PCB use connectors. On the student-made PCB, the external power supply connects to it with a 2 pin molex connector and the force sensor has a 4 pin screw terminal. The external power supply connects to the circuit with a barrel jack located at an opening to the enclosure.

Figure 29: All boards are connected to wires using connectors.

5.1.5. All power supplies in the system must be at least 65% efficient

The TPS54232 buck converter is an efficient step-down converter as can be seen by the graph below. Even though the graph is for an output voltage of 3.3V and the one in the system outputs 5V, the efficiency shown is always above 70% and having the output of 5V should make it slightly more efficient. The TPS54232 also has an eco-mode that allows for high efficiency at lower output currents at 100mA and below.
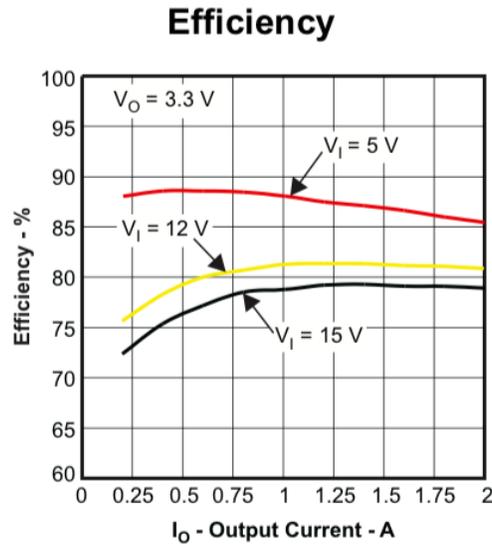
Efficiency

Figure 30: TPS4232 efficiency graph

5.1.6. The system may be no more than 50% built from purchased modules.

The system uses three premade modules, the HX711 load cell amplifier, the 1kg load cell, and the ESP32 microcontroller board. All other parts of the system were designed by the team including the mechanical elements and the database.

5.2. Measure Force

5.2.1. Requirements

PPR: Applied force must be measured.
ER: The device must be able to take force measurements represented to the nearest N.

5.2.2. Testing Process

Preparation:
1. Remove system from cage and mount.
2. Attach an object of known weight to the end of the load cell using rope, string, or wire.
3. Power on the system and run calibration code.
4. Hang the object vertically.
5. Make sure the weight shown matches the known weight to the nearest 10 grams. Adjust calibration factor as needed.

Verification Method:
1. Place the system back into normal operation position. Make sure the hinge is closed.
2. Power on the system.
3. Check that the force output is at 0 N, +/- 0.2 N.
4. Lift hinge.
5. Check that the force output has increased by at least 0.5 N, but no more than 4 N. If so,

this requirement is met.

5.2.3.Testing Evidence

Preparation Test:
https://drive.google.com/file/d/1QuIhGG8j_TxRs3McXPUenLegslKCWkYp/view?usp=sharing
Force Sensor Test:
https://drive.google.com/file/d/1ScAtfYYY1h6jDZMf_N6oGVZKYhVaVu2u/view?usp=sharing

5.3.Safety

5.3.1.Requirements

PPR: System must be safe for both birds and humans.
ER: During operation safety mechanism will prevent hinge from crushing bird or human finger by having at least three hold points in the operating range.

5.3.2.Testing Process

1. Begin system operation and start lifting hinge.
2. Let go of the hinge and show that it is prevented from falling by the first stop point.
3. Resume lifting hinge and repeat for 2 more stopping points.
4. If three hold points successfully prevent the hinge from falling back to the start position then the requirement is met.

5.3.3.Testing Evidence

Safety test video link:
https://drive.google.com/file/d/1oUEFsaRPDdVA06NjgRgpP6Ju5TzM1gf7/view?usp=sharing

5.4.Data Visualization

5.4.1.Requirements

PPR: System must provide user visual representation of experimental data
ER: Data will be graphically outputted as force over time and must be accessible via the MySQL server.

5.4.2.Testing Process

1. Go to the webpage ensuring the files are in a Public_html folder running on the cloud.
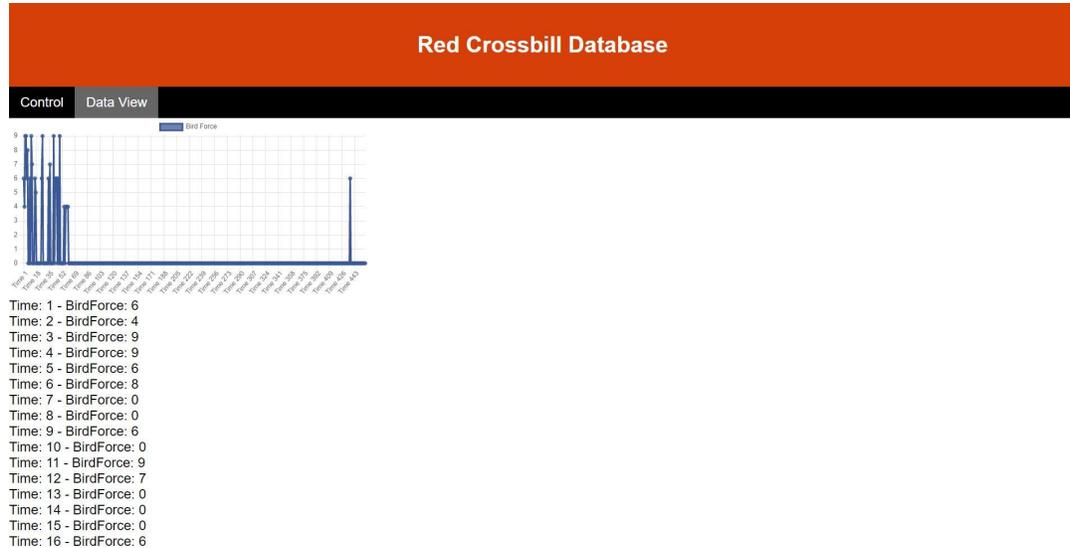2. Use MySQL queries to connect to the database.

3. Go to the Data Presentation webpage and see that both the graph and table are running with no errors.

5.4.3. Testing Evidence

Webpage link:
https://web.engr.oregonstate.edu/~martbrad/ECE_Senior_Design/Graphics_Display.php

Screen:

5.5. Cleanability

5.5.1. Requirements

PPR: The device must be cleanable and withstand frequent use/cleaning.
ER: Bird waste and grime can be removed from device materials using water and an abrasive instrument.

5.5.2. Testing Process

1. Apply material similar to bird waste to the system.
2. Wait 30 seconds.
3. Remove material from the system using water and an abrasive instrument.
4. If material has been successfully removed then the requirement is met.

5.5.3. Testing Evidence

Cleanability test video:
https://drive.google.com/file/d/1-XNvTQGierpayieimtAunxxJJ4f60f7h/view?usp=sharing

5.6. Damage Resilience

5.6.1. Requirements

PPR: Device must be resilient to bird tampering.
ER: System will have an enclosure that protects electrical components from the birds causing damage due to pecking and scratching.

5.6.2. Testing Process

1. Scratch enclosure forcefully with fingernails several times.
2. Take 12 quarters and drop them on the enclosure individually from 2 feet above the enclosure to see if any damage occurs.
3. If after testing, the system still functions the same, then the requirement is met.

5.6.3. Testing Evidence

Scratch and Pecking Tests:
https://drive.google.com/file/d/1sDfXfvF1ivn1_6qrbdGw00pSneP3cu6P/view?usp=sharing

5.7. Mounting

5.7.1. Requirements

PPR: Puzzle must be mountable to a bird cage.
ER: System will be attached and removed from the side of a bird cage.

5.7.2. Testing Process

1. Mount the system to the side of a cage.
2. Wait 30 seconds.
3. Confirm that the system is still attached to the cage.
4. Detach the system from the cage.
5. If successful then the requirement is passed.

5.7.3. Testing Evidence

Mounting video Link:
https://drive.google.com/file/d/17UzDBN2qhpvI6jNu4El9tgHlve5jycc2/view?usp=sharing

5.8. Bird Accessibility

5.8.1. Requirements

PPR: Device must be accessible for the birds.
ER: System will have a perch where the birds are able to hold onto and interact with the puzzle at the same time. The perch will be able to sustain at least 250 grams of weight.

5.8.2. Testing Process

1. A 0.25kg weight will be hung from the perch for 30 seconds.
2. If the perch withstands the stress of the weight then it passes the requirement.

5.8.3. Testing Evidence

Bird Accessibility test link:
https://drive.google.com/file/d/1RlBV0kqEfH5Gh7A0hyk9_rajHQa2-goy/view?usp=sharing

5.9. Budget

5.9.1. Requirements

PPR: Device must be affordable for mass production.
ER: The system will be produced for less than or equal to the allocated budget of the project by all stakeholders. Current budget allocation 300 dollars.

5.9.2. Testing Process

1. Before purchasing any component/part they will be considered if the cost is worth it and if there are any possible replacements with the same desidered properties.
2. The part and its total cost will be added to the BOM (Bill of Materials) and the total available budget will be adjusted.
3. Repeat steps for any possible purchase made.
4. If the cost is less then or equal to $300 then this requirement is met.

5.9.3. Testing Evidence

The included bill of materials includes the purchase totals for the electrical and mechanical components.
Bill of Materials - BOM

5.10.References and File Links

5.10.1.References (IEEE)

[1] "TPS54232 2-A, 28-V, 1-MHz, step-down ... - texas instruments." [Online].
      Available: https://www.ti.com/lit/ds/symlink/tps54232.pdf.

5.10.2.File Links

5.11.Revision Table

Date	Revisions Made
3/6/2022	Brieanna - Universal Constants and Requirements
3/6/2022	Shengmei - Edited force sensor block validation to fit current interfaces on block diagram tool, project requirements
3/6/2022	Michael - Edited Damage Resilience Test Process
3/6/2022	Bradley - Edited Database and Data presentation block validations project requirements
3/12/2022	Michael - Added more testing evidence
4/20/2022	Team - Revised Engineering requirements/testing methods.
5/2/2022	Team - Went through testing process and filmed videos for testing evidence
5/2/2022 - 5/3/2022	Team - added video links to testing evidence sections

6.0 Project Closing

6.1.Future Recommendations

6.1.1.Technical Recommendations

System mechanism could have been designed more effectively to better meet the needs of the project. The current mechanism meets the functionality needs of the system, but is a bit cumbersome and clunky. A mechanical engineer with experience in mechanical design would have been very helpful in improving this part of the project as they could produce a more streamlined version.

The current mounting system does function properly, but it is not an ideal set up.The fitting is a bit loose and the number of positions that the system can be mounted in is limited. The mounting of the system could be much more adaptable and secure with a more thorough design/planning. This is another situation where the skills of a mechanical engineer would be invaluable. Ideally the system should be able to mount to a variety of different cages in a number of positions and with a more flexible mounting design, this could be done

In the system's current configuration the ESP32 sends a POST request every time the sensor is updated. The sensor is set up to take a sample every 100ms for 10 samples a second. This is an inefficient way of sending data especially only for one module. The database is also hosted on the OSU webpage which seems to block communication with it even with HTTPS requests. For the amount of systems setup a more local application for viewing and analyzing data would have been a better approach. Adding network communication adds unneeded complexity to the system and adds a stipulation that the system needs internet connectivity to function. Using a local application increases versatility and localizes where all the data is being sent. From there if a database is really wanted it can then be sent for storage if a trial is deemed so.

The force sensor operates and takes force measurements in the intended manner, but the accuracy of the measurements can be improved upon. In our current setup, one end of the load cell is secured to the enclosure using tape and velcro. Due to how the load cell functions, in which minute shifts between one end of the load cell and the other end are output to the microcontroller as force data, the current mounting set up affects the accuracy to a certain degree. In order to get more accurate data, one end of the load cell should be rigidly mounted to the enclosure using, for example, a screw.

When expanding the system for multiple puzzles to be used at once, only one microcontroller, PCB, and power supply will be needed. The microcontroller used, the ESP32, has 36 GPIO pins, and only 1 GPIO pin is required for data collection from each additional force sensor, as the clock pin for each additional sensor can be wired together or "shared" as one GPIO pin on the microcontroller [1]. The code for the larger system would also need to be adapted for the additional sensors. The PCB would need to be adjusted and additional connectors added to allow for the other GPIO pins to be used. The entire system is able to be powered by a single power supply, so all force sensors will need to share a connection to VOUT and GND. As for kept blocks for the additional systems, there are some recommendations for reducing costs on those blocks in section 6.1.2.

6.1.1.1.References (IEEE)

[1] "Adafruit HUZZAH32 - ESP32 feather - adafruit industries," *Adafruit*. [Online]. Available: https://cdn-learn.adafruit.com/downloads/pdf/adafruit-huzzah32- esp32- feather.pdf.

6.1.2.Global Impact Recommendation

Creating the system out of more sustainable materials would lessen the project's environmental impact, especially in the event where the system is produced in larger numbers. The system uses lots of electronic components that use rare metals and are environmentally unfriendly to mine. Many of those components could be removed in a more streamlined system. The primary mechanical components are wood, plastic and metal. The use of the wood makes the project more environmentally friendly than it could be, but the significant use of plastic dramatically increases the negative environmental impact of the system [1]. Overall designing the system with sustainable materials in mind and limiting the use of environmentally unfriendly material can reduce the impact of the system.

If the system were to be used in conjunction with itself (i.e. 2+ systems), only certain parts would need to be "copied:" the variable mechanism (i.e. the hinge and safety mechanism), the enclosure/mount/perch, and the force sensor. For the enclosure, 3D printing each enclosure would be an additional $50. Additional systems also would require smaller enclosures since the power supply, microcontroller, and PCB are shared between systems. Therefore, the enclosure could be downsized, reducing printing prices and plastic use. A cheaper alternative would be using a plastic tupperware container with holes drilled for wires.

6.1.2.1.References (IEEE)

[1] E. Olivetti, "Toward a sustainable materials system - science.org," *Toward a sustainable materials system*. [Online]. Available: https://www.science.org/doi/10.1126/science.aat6821. [Accessed: 06-May-2022].

6.1.3.Teamwork Recommendations

There are many ideas and thoughts that can trail out in a large project like this. Keeping a detailed schedule of tasks that need to be completed and where the progress stands in those tasks keeps the group informed. This disallows any confusion of who is working on what so that next steps can be planned for. The main benefit to this is when different blocks rely on each other for functionality then the relying blocks know when they can test their blocks.

Integration is a key step in the project process and can always be done more effectively. The integration of this project got off to a slow start and that limited the ability to test the system and resulted in less testing overall that could have helped produce a better system [1]. Integration should get started as soon as possible in order for the team to see how all the system components function together and produce a better result. It also allows for issues with the overall system to be spotted earlier which gives the team more time to resolve them.

6.1.2.1. References (IEEE)

[1] D. Anthony, "15 simple ways to improve team communication," *Workzone*, 26-Apr-2022. [Online]. Available: https://www.workzone.com/blog/team- communication/. [Accessed: 06-May-2022].

6.2. Project Artifact Summary with Links

6.2.1. Database and Data Presentation Code

Code used for making the database and presenting the data on a website.
Code

6.2.2. Main Code

Code used for the ESP32 microcontroller in the system. Contains the code for the force sensor and networking with the database.
Code

6.2.3. PCB

Gerber and NC Drill files in a zip for ordering. There is also a copy the of the schematic file and a BOM generated in CircuitMaker.
PCB

CircuitMaker project
CircuitMaker

6.2.4. Enclosure

CAD and stl files for 3D printing the enclosure along with mechanical drawings.
CAD

6.2.5. Mechanism

CAD and stl files for 3D printing the mechanism along with mechanical drawings.
CAD

6.3. Presentation Materials

Poster used for the 2022 Engineering Expo.
Poster