DEPARTMENT OF
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Incubator for Infant Wildlife

BME 400 - Preliminary Report

10/11/2023

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Team Members:

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Abstract

Wildlife rehabilitation is a noble cause to participate in. The process to become a rehabilitation expert requires licensing, and often everyday people do not know how to best care for wildlife they come across. Rehabilitation can be an expensive process, and many times non-profit organizations do not have the funds to buy all the necessary resources. One of the key resources that is used in rehabilitation, is an incubator. As such the wildlife incubator must be low cost, while also durable, modular, easy to clean, and precise in temperature control. It is essential to create an incubator that is more accessible and accommodating for those interested and passionate about wildlife rehabilitation but may lack the financial resources to purchase components currently available in the market. The team's current solution involves division of the design into three main components: humidity, temperature, and external. The main goals for this semester include creating the different components through trial and error and finding a way to combine all of the internal components into the external design. To ensure proper functionality, the team will be conducting testing on each component to ensure longevity and accuracy. Additionally, client evaluation will be conducted frequently to ensure that the design and development match client needs. With the team's efforts, a low cost and functional incubator will be created by the conclusion of the semester to be tested and receive critical feedback prior to the next semester.

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I. Introduction

Motivation

The broad objective of this project is to create accessibility around wildlife rehabilitation. The goal of wildlife rehabilitation is to treat sick, injured, orphaned, and otherwise distressed wildlife, and to release them back into their natural habitat [1]. Most states require that people who participate in wildlife rehabilitation are licensed, so as to ensure that qualified care is provided to animals in a humane way [2].

This project specifically focuses on the rehabilitation of orphaned mammals and birds. Many of these animals are neonates or nestlings who are too young to regulate their own body temperature. As a result, these animals require supplemental heat to survive. There are a number of wildlife incubators on the market today, but have a high price point that can be difficult to achieve for private parties that are passionate about saving lives. Due to the lack of budget friendly incubators, it becomes difficult for these people to pursue their own wildlife rehabilitation efforts.

Existing Devices and Current Methods

There are a number of wildlife incubators on the market right now, but none are at the price point expected for this project. Incubators at a lower price point do not completely satisfy the client's requirements. One of the main manufacturers of incubators is Brinsea. They offer a number of different incubators with varying capabilities and sizes. The TLC-50 Zoologica II is 25" x 18" x 14", with many electrical components [3]. These components include accurate digital temperature control with a screen for adjustments, alarms that signify temperatures that are too high or too low, automatic humidity control, air filtration and exchange, and variable fan speeds. While all of these components are very advanced and offer effective utilization, the price point is $1199.99 when buying directly. This is a very high cost version of what the team aims to achieve. Another offering by Brinsea is the TLC-30 Eco, which is 9.5" x 9.5" x 6.5", with similar components [4]. However, this incubator is significantly smaller than what is expected to be created by the team. Additionally, this incubator does not include humidity control, and is also at a higher price point of $309.99 when buying directly. This company also offers other types of incubators, however these two were the most similar to what the team hopes to achieve with this project.

Problem Statement

Wildlife rehabilitation often includes caring for neonatal wildlife who are unable to control their own body temperature, thus the incubator must provide supplemental temperature control. Although private parties frequently contribute to wildlife rehabilitation efforts, they do not have enough financial resources required to purchase an incubator. As such the wildlife incubator must be low cost, while also durable, modular, easy to clean, and precise in temperature control. It is essential to create an incubator that is more accessible and accommodating for those interested and passionate about wildlife rehabilitation but may lack the financial resources to purchase components currently available in the market.

II. Background

Relevant Biology and Physiology

Many of the wildlife that is brought into rehabilitation centers is infant wildlife. It has been noted that infants that are altricial have physical limitations because heat loss overwhelms their heat production [5]. Heat regulation also significantly differs in animals based on gender, season and aging [6]. Additionally humidity regulation is a large factor in the design of the incubator as well. This is because it is imperative to control relative humidity. It is not necessary to control it as narrowly as temperature for most mammals, and typically an acceptable range is between 30%-70% for most mammals [7]. Due to the infantile nature of the wildlife that will be housed in the incubator, 60%-70% humidity is preferred. For rehabilitation purposes, rehabbers must provide an adequate environment for animals which includes fresh air, auxiliary ventilation when ambient temperature exceeds 85°F. Additionally, lighting should allow for inspection and cleaning but should not distress animals [8]. Because the incubator developed will be usable to most infant wildlife, it is not necessary to include specific physiological parameters for all species of infant wildlife that can be housed within.

Client Information

The client, Dr. Mark Stelford is the Vice President and Treasurer of a nonprofit organization– Oaken Acres Wildlife Center. This organization has been providing wildlife care for over 30 years and since its inception, has taken in more than 11,000 animals.

Design Specifications

The dimensions of the incubator should be 18" x 18" x 18" and break into a box that is 20" x 20" x 8" or smaller for shipping. The incubator should also cost less than $100 per unit to manufacture, including assembly. There should be modular parts included to allow for easy replacement. To adhere to biological needs of the wildlife, the incubator should also maintain a temperature of 95°F with a buffer of +/- 2°F. Additionally, the incubator should include the ability to increase the humidity up to 60% without the need of additional sealing. There can be the inclusion of a separate sealable part to allow the incubator to reach up to 70% humidity. For safety reasons, there should be no accessible electronics close to where the wildlife is housed within the incubator, and there should be no sharp edges on the interior surface. The shelf life for this product should be 10 years, but can include replaceable parts such as electronics which may not be able to withstand consistent use for the full lifetime of the product. Additionally the product should be able to withstand regular operational use and a cleaning regime. These include the transport and regular removal of the incubator and its modular parts; sustained wait load from animals on the modular parts; scrubbing and cleaning using high temperatures and/or chemicals on the incubator and its parts; and exposure to humid conditions.

III. Preliminary Designs

Humidity Control

1. All-In One Pre-Built Humidifier

The all-in one pre-built humidifier is a commercial-grade humidifier that has been adapted for integration within the incubator system. We have selected a specific model from HUMI-CARE, which unfortunately does not provide detailed information on the margin of error in humidity sensing. However, the manufacturer assures the accuracy of this humidifier. Compact and portable, this humidifier is designed for easy insertion and removal from the incubator, to ensure convenient maintenance and cleaning.

2. Team-Built Water Atomizer and Humidity Sensor Circuit

The team-built Water atomizer and humidity sensor circuit is designed to incorporate a DHT22 humidity sensor with a margin of error of +/-5%. Humidity generation would be managed by a Grove water atomizer circuit, under the precise control of an Arduino.

3. Ultrasonic Nebulizer and Integrated Circuit (IC) Type Humidity Sensor

The ultrasonic nebulizer and Integrated circuit (IC) type humidity sensor will manage and measure the relative humidity within the incubator environment. The ultrasonic nebulizer creates an aerosol under ambient conditions, while the Integrated Circuit (IC) type humidity sensor measures the relative humidity. If the measured humidity falls below a predetermined humidity value, the ultrasonic nebulizer activates, converting sterilized water into fine water particles to elevate the humidity level. The accuracy of the sensor is +/-2% at 25°C [9].

Temperature Control

1. Feedback Heater with Bed Detection

The feedback heater with bed detection consists of a heating detection element embedded within the animal bed at the base of the incubator. This aims to get a more accurate reading of the wildlife's body temperature. A feedback system, integrated with a microcontroller, interprets the detected temperature. Depending on whether the temperature falls within the predetermined range, the system activates or deactivates the heating element to maintain optimal temperature.

2. Feedback Heater with Ambient Air Detection

The feedback heater with ambient air detection is similar to the first design, except for the placement of the temperature sensing element. In this variant, the sensor protrudes from the interior walls of the incubator, measuring the ambient air temperature to initiate the heating feedback loop.

3. Modified Arduino Thermistor

The modified arduino thermistor utilizes our design team's existing familiarity with temperature sensing. This design is heavily based on our previous experience with thermistor fabrication coursework. We will designate an Arduino Uno as the microcontroller, using its Serial Monitor function for consistent temperature readouts. The relay Control will be performed by another robust Arduino product, the Beefcake Relay Control Hookup. This design is not only easily programmable but also compatible with various thermistors. The PTC Ceramic Heating Plate will be tasked with the execution of the heating on or off functions, further enhancing the system's efficiency and reliability. Overall, this design optimizes both ease of use and convenient sourcing of components.

Materials

1. 3D printing with Acrylonitrile Styrene Acrylate (ASA)

ASA is an alternative to ABS that performs exceptionally well in various outdoor environments and climates. It exhibits robust chemical resistance, ensuring durability against bodily fluids, humidity, or cleaning supplies. Furthermore, ASA is improved with superior UV resistance, allowing for outdoor storage without compromising its integrity. Despite these advanced characteristics, ASA remains an economically priced material.

2. 3D printing with Chlorinated Polyethylene (CPE+)

CPE+ has substantial thermal and chemical resistance, ensuring durability across diverse climates. Its exceptional strength enhances its resilience, effectively withstanding potential damage caused by animals. However, the elevated mechanical properties that provide these advantages also increase the complexity of manufacturing, making CPE+ a more costly material option.

3. Injection molding with Polylactic Acid (PLA)

PLA is cost-effective and can be quickly manufactured, making it an ideal choice for prototyping and test prints. However, it lacks the resilience to diverse temperature and chemicals compared to other materials, rendering it less suitable for the final product.

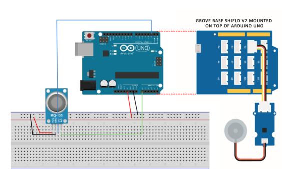
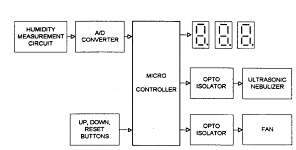
4. Injection molding with Polypropylene (PP)

PP distinguishes itself among the four materials by being recognized as a food-grade plastic, offering a more environmentally friendly option. PP is also relatively lightweight, and has very good chemical and heat resistance, making it an excellent choice for thermal insulation. In addition, PP shows extremely low water absorption, meaning it can support humidity control [10].

IV. Preliminary Design Evaluation

Design Matrix

1. Humidity Control

Criteria	Design 1: All-In-One Pre-built Humidifier 	Design 2: Team-Built Water Automizer and Humidity Sensor Circuit 	Design 3: Ultrasonic nebulizer and Integrated circuit (IC) type humidity sensor 
Accuracy (25)	3/5 (15)	3/5 (15)	4/5 (20)
Ease of	5/5 (20)	2/5 (8)	3/5 (12)

Instrumentation (20)			
Practicality within an Incubator (20)	3/5 (12)	2/5 (8)	2/5 (8)
Usability (15)	3/5 (9)	1/5 (3)	5/5 (15)
Safety (10)	2/5 (4)	3/5 (6)	3/5 (6)
Cost (10)	1/5 (2)	4/5 (8)	3/5 (6)
Total (100)	62	48	67

Table 1: Humidity Preliminary Design Matrix

The designs were evaluated based on multiple criteria including accuracy, ease of instrumentation, practicality within an incubator, usability, safety, and cost. Accuracy is ranked the highest because minimizing the error of the humidity sensor and effective humidity control is the most important criterion emphasized by the team's client. Ease of Instrumentation is the second most important criterion, reflecting the degree of simplicity and efficiency with which the humidifier control, sensors, and humidifier itself can be implemented into the incubator system, considering the time constraints of the semester. Practicality within an incubator refers to how safe and robust the system is to regular cleaning; its ability for water level maintenance; and the realisticness that this humidifier system could be incorporated into an infant wildlife incubator. Usability refers to the ease of changing the humidity, access controls, and ease of refilling the water basin. Safety refers to the system's ability to safeguard against harm to the user and the infant wildlife it will be sustaining. Finally, cost is how affordable the system is– which while the lowest due to constraints of the semester, is important for a non-profit organization. The ultrasonic nebulizer and IC-type humidity sensor design received the highest score primarily because it has highest accuracy, within a +/- 2% range. Additionally, the nebulizer automatically controls the humidity, reducing the need for frequent user intervention, and the water basin is easy to refill.

2. Temperature Control

Criteria	Design 1: Feedback Heater with Bed Detection.	Design 2: Feedback heater with Ambient Air Detection	Design 3: Modified Arduino Thermistor
Safety (25)	3/5 (15)	5/5 (25)	4/5(20)
Temperature	3/5(12)	4/5 (16)	5/5 (20)

Control Capability (20)			
Durability (20)	5/5(20)	4/5(16)	4/5(16)
Cost (15)	2/5(6)	3/5(9)	5/5(15)
Feasibility (10)	4/5(8)	3/5(6)	5/5(10)
Replaceability (10)	3/5(6)	4/5(8)	5/5(10)
Total (100)	67	80	91

Table 2: Temperature Preliminary Design Matrix

The most important factor in our design is safety. This is ranked highly because it is essential to ensure that the heating and electronic elements are not in reach of the animals. Thus to provide the incubating function in the most effective way, the incubator must provide heating without injuring the animals housed inside. Temperature control is also significant as the infant wildlife requires a temperature of 95°F with a buffer of 2 degrees. This temperature range is vital to ensure that the infant wildlife are warmed to proper body temperature. Durability is important because the incubator itself must last 10 years but the electrical components can be replaced infrequently, as needed. Cost is also a significant factor because the entire incubator, including assembly, must be within $100. Feasibility is important because the prototyping should represent the actual assembly of the final product, which will be done by employees at the rehabilitation center. This requires the design to be accessible and feasibly created for people with no experience. Finally, replaceability requires that the electrical components are easy to replace during the lifetime of the incubator. The modified arduino thermistor design received the highest score in most of the criteria, except for safety and durability. This makes the design the optimal choice for temperature control based on our criteria.

3. Materials

Criteria	Design 1: 3D Printing - ASA	Design 2: 3D Printing - CPE	Design 3: Injection Mold - PLA	Design 4: Injection Mold - PP
Temperature Support (25)	4/5 (20)	5/5 (25)	3/5 (15)	5/5 (25)
Water/Weather Resistance (25)	5/5 (25)	4/5 (20)	2/5 (10)	4/5 (20)
Strength/Durability (20)	3/5 (12)	5/5 (20)	5/5 (20)	3/5 (12)

Cost(15)	5/5 (15)	2/5 (6)	4/5 (12)	3/5 (9)
Weight (10)	4/5 (8)	3/5 (6)	2/5 (4)	5/5 (10)
Safety (5)	2/5 (2)	3/5 (3)	2/5 (2)	5/5 (5)
Total (100)	80	80	63	81

Table 3: Materials Preliminary Design Matrix

In contrast to the other matrices, this matrix evaluated materials rather than designs. The criteria for this matrix include temperature support, water and weather resistance, strength and durability, cost, weight and safety. The first and highest weighted of the criteria is temperature support. This is due to the fact that the incubator must maintain a constant temperature to support the body temperature of the animal that the incubator is housing. The second criterion, which is tied for highest weight is water and weather resistance. This is because not only should the incubator support humidity control, but it could be used around the world, and may be stored in places where climate is not controlled. The next criterion is strength and durability. Not only must the incubator be able to withstand the weight of infant wildlife, it must also be resistant to damage from the animal. The incubator should also be able to be used for a long period of time. The cost criterion simply refers to the cost of the material itself. While the incubator must be a reasonable price, the effectiveness of it in nurturing infant wildlife is of higher importance. The second to last criterion is weight. When choosing a material and creating a design, weight will play a factor in both ergonomics when handled by people, as well as shipping costs. The final criterion is safety. While the safety of the animal is of utmost importance, the safety of the material itself does not make a significant difference, as it will not be used as a food storage device. With a high Vicat Softening Point and low moisture absorption, polypropylene scored exceptionally in the two highest weighted criteria, temperature resistance and water/weather resistance [10]. In addition, PP is reasonably priced, and has a good Shore hardness, meaning it will handle scratches from incubated wildlife well. Due to these evaluations of polypropylene, it has been chosen by the team as the material to be used for the apparatus shell.

Proposed Final Design

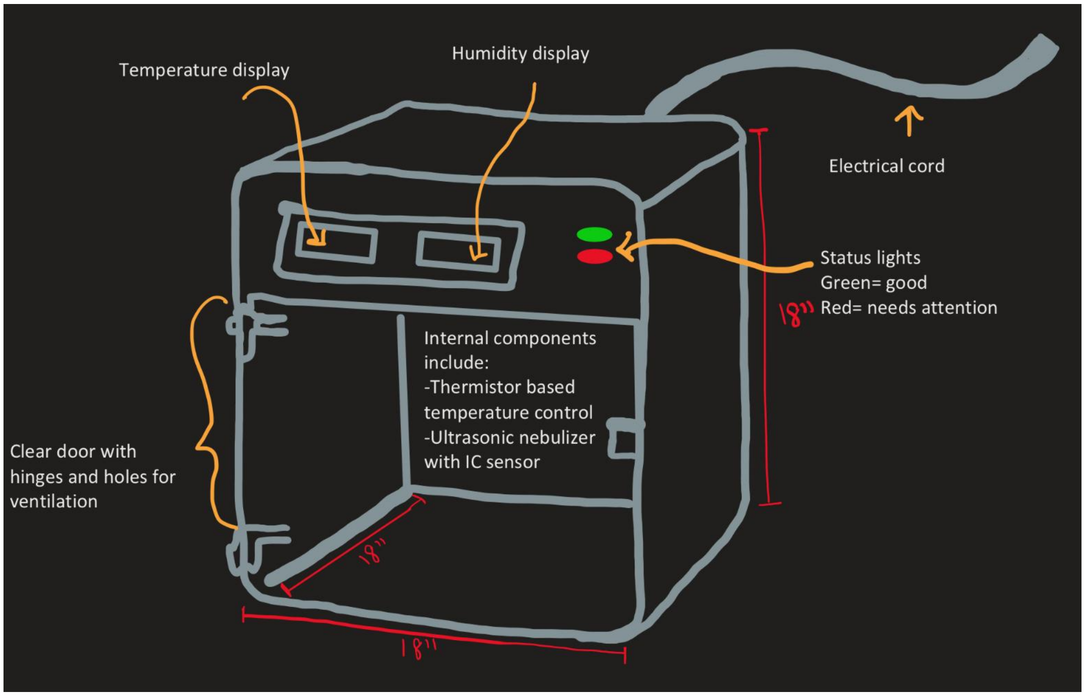


Figure 1: Proposed Final Design combining all three parameters; humidity, temperatur, and materials

The dimension of the incubator is 18" by 18"X18"X18". The design will be made of injection-molded PP, a material that received the highest score in our materials preliminary design matrix. Two displays will be incorporated to show measured temperature and humidity values respectively, enhancing the ease of monitoring. Status light, specifically red light, will indicate if attention is needed, ensuring timely interventions. The incubator will feature a clear door to facilitate easy visibility of the infant wildlife inside. It will also be equipped with hinges and holes to ensure proper ventilation, promoting a safe environment. Internally, the incubator will integrate a thermistor-based temperature control system and an ultrasonic nebulizer with an IC-type humidity sensor to maintain optimal conditions.

V. Fabrication/Development Process

Materials

The team has plans to primarily focus on fabricating working electrical components, prior to making the physical structure of the incubator. Some materials that will be needed for the creation of the humidifier component are a microcontroller (most likely an arduino), compatible humidity and temperature sensors, a nebulizer, a fan, and other typical electronics components such as a breadboard, resistors, and wires. The microcontroller will allow the design team to communicate with the circuit and control it with software. The humidity and temperature sensors will allow for detection of these variables and correction. A nebulizer in the humidifying mechanism that will add water vapor to the incubator environment. A fan will disperse the humidity. Finally the typical electrical components will allow for proper instrumentation.

Materials needed for the temperature sensor include a thermistor if the humidity sensor we get does not have temperature sensing capabilities and has the same basic electrical components as the humidifier. Additionally, a serial monitor, LEDs, and potentially a buzzer for the alert system should be procured. The thermistor is an effective temperature sensor alternative. Additionally, the serial lights, LEDs and buzzer will be able to display and communicate the status of the incubator. Finally, for the materials needed for the outside of the incubator we can use something simple that lacks a plastic bin for temporary use until we are able to fabricate the external components through injection molded polypropylene.

Methods

There are not many methods involved for the creation of the incubator. The electrical components will be made through instrumentation. The injection molding will be the other method utilized for fabricating the incubator external components.

Testing

Testing will be performed on the electrical components initially. The systems will be run for extended periods of time and be cross referenced with an external thermometer and humidity sensor. Humidity and temperature levels will be stored in the arduino temporarily in order to be plotted in the future.

VI. Results

In the end, we hope to plot the humidity and temperature levels and see a trend in the amount of error seen in our temperature levels and to see if it fulfills client requirements.

VII. Discussion

Over the course of the group's research and logistics meetings concerning the use and fabrication of this incubator, it was found that there is a main ethical concern. For human infants, incubators are designed especially for their needs. In contrast, a wildlife incubator may be used for infants of several species. There is concern that the last of specificity for certain species may lead to poorer recovery results than if the incubator was made with certain species in mind.

In the electrical component testing, the team has outlined their processes to interpret results. Through utilizing serial monitor data from the duration of testing time that reports data points on humidity and temperature, the team may draw conclusions. It is expected that we may see errors such as the temperature and humidity systems taking much longer than a desired time to reach the thresholds desired once they are initialized. It might also be observed that the temperature of humidity systems may hover outside the desired ranges. The team will likely have to increase the sensitivity of the systems if this is the case. The largest error that may be observed is that the temperature and humidity systems may never remain in the desired ranges, or at least not for any satisfactory amount of time. The team will perform circuitry analysis and develop a greater understanding of their component fail points if this is our testing result data.

Potential sources of error the team is aware of now lie mostly in the ambiguity of the final design at this point of the prototyping. The insulation quality of the final design is not known, so placing our electrical components in simulated insulators or the like may not yield data that is highly accurate. This may achieve more of a proof-of-concept appropriate result than a highly accurate and usable one.

VIII. Conclusions

The wildlife infant incubators on the market today are too expensive for many of those who run wildlife rehabilitation centers, such as the team's client. The team was tasked with creating an incubator that is durable, safe, precise in its temperature and humidity controls, and affordable. This project aims at improving accessibility in wildlife infant treatments.

The team was able to outline a design that should meet the client's criteria. The design utilizes simple and affordable arduino controls. These controls will read the temperature within the incubator, report it back to a microdevice that records these readings in a serial monitor, and trigger a heating element. The heating element will turn on if the temperature has fallen below 93^{O} F, and will turn off if the temperature has risen above 97^{O} F. The incubator is also equipped with a humidity control system. The team selected the Ultrasonic nebulizer and Integrated circuit (IC) type humidity sensor. The ultrasonic nebulizer creates an aerosol at ambient conditions and an Integrated Circuit (IC) type humidity sensor to measure the relative humidity of the incubator environment. If the predetermined relative humidity value is higher than the measured values, the ultrasonic nebulizer converts sterilized water into fine water particles. The accuracy of the sensor is +/-2% at 25°C. Finally, the team selected a model for the outside of the incubator. The team began by researching four materials, but of them, chose PP. This is because, of the 4 materials, PP is considered a food-grade plastic, and is much safer for the environment when compared to the other materials. As a material, PP is also relatively lightweight, and has good resistance to chemicals and heat, and thus will work well for thermal insulation. It should be safe for the infant wildlife contained within it.

So far, the team has been establishing what testing methods would and would not work. The team has decided that, due to the limited budget being worked with, a relatively affordable apparatus acting as the outside of the incubator will be used during the testing process. Thus, the final product's apparatus construction will not take place until the electrical components are more finalized.

Future work includes the construction and testing of the humidity and electrical components. The team will likely utilize previous coursework in order to construct the code needed for these components.

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X. Appendix

A. Product Design Specification (PDS)

Wildlife Incubator: PDS

9/22/2023
Client: Mark Stelford
Advisor: Dr. Wally Block
Team Members: Loukia Agoudemos, Erwin Cruz, Sophia Finn, Seyoung Selina Park, and Tanishka Sheth

Function:

Wildlife rehabilitation often includes caring for neonatal wildlife who are unable to control their own body temperature, thus the incubator must provide supplemental temperature control. Although private parties frequently contribute to wildlife rehabilitation efforts, they do not have enough financial resources required to purchase an incubator. As such the wildlife incubator must be low cost, while also durable, modular, easy to clean, and precise in temperature control. It is essential to create an incubator that is more accessible and accommodating for those interested and passionate about wildlife rehabilitation but may lack the financial resources to purchase components currently available in the market.

Client requirements:

I. Dimensions should be 18” x 18” x 18” and break down into a box that is 20” x 20” x 8” or smaller for shipping purposes
II. The incubator must be under $100/unit to manufacture
III. The incubator should involve modular parts that allow for easy replacement
IV. The incubator must maintain a temperature of 95°F with a buffer of +/- 1-2 degrees

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements*:

I. The incubator should be durable enough to easily withstand regular operational use and cleaning regimen. This may include:
   A. Transport/regular removal of the incubator and its modular parts.
   B. Sustained weight load from animals on the modular parts.
   C. Scrubbing and cleaning using high temperatures and/or chemicals on the incubator and its parts.
   D. Exposure to humid conditions

II. Incubator door:
   A. Should be large enough to insert and remove modular parts.

B. Should allow for easy access for cleaning.
C. Should allow for easy access to the water basin for humidity control.
D. Should allow for easy access to the animal inside.
E. Should be transparent to allow for observation of the animal inside.

III. The bottom of the incubator should be a 4 inch deep "tray" with smooth sides to make it easy to clean.

IV. The base of the incubator should have indentations that will allow secure placement in a rack, enabling stacking of multiple incubators.

V. Humidity control
A. There must be a spot to put water for humidity control.
B. There should be an obvious alert system to indicate when water needs to be added to the system, or if the humidity level is outside of desired ranges.
C. Should have the ability to increase humidity up to 60% without additional sealing on the door.
1. The ability to increase to 70% humidity is ideal.

b. *Safety*:

I. There should be no sharp edges on the interior surface to ensure the safety of the wildlife inside of it.

II. The incubator should be assembled with seals / bolts that are smooth on the inside of the incubator for easy cleaning and safety of the wildlife inside of it.

III. Accurate temperature and humidity control for the safety of the wildlife.

IV. Should have failure alerts and fail-safes.

c. *Accuracy and Reliability*:

I. Accurate temperature control inside the incubator with a typical range of 90°F to 100°F and temperature of the incubator needs to be within 1 to 2 degrees of the target temperature set by the user.

II. Humidity control should have a maximum error of 5% of the displayed humidity.
A. A 3% error is ideal.

d. *Life in Service*:

I. It is preferred that the incubator has a life in service similar to current products on the market. This is typically defined as 1-3 years.

e. *Shelf Life*:

I. The incubator will be stored in a storage unit that does not include climate control and thus the components should be able to withstand being in a variable environment.

f. *Operating Environment*:

I. The user should be able to store this incubator in a storage unit that isn't climate controlled in Arizona or Minnesota and they should expect it to work when they bring it into a climate controlled building.

g. *Ergonomics*:

I. The incubator should allow for easy access to the animal, as employees will be checking on the animals frequently.

II. The incubator should be easy to carry and be lightweight such that employees can move it from the shelves that it will be stored on.

III. Electronics must be housed within the incubator at a height such that the animals cannot reach them.

h. *Size*:

I. The outside assembled dimensions of the incubator should be 18" x 18" x 18".

II. The unit should ideally be able to be broken down into a box that is 20" x 20" x 8" or smaller for shipping.

i. *Weight*:

I. OSHA requirements typically recommend that workplaces do not allow carrying of equipment over 35 lb. Many kinds of newborn livestock, such as sheep, weigh about 15 lb. Therefore, the incubator should not exceed 20 lb. [1]

j. *Materials*:

I. Materials for the outside should be made of injection molded plastic or a similar lightweight plastic.

k. *Aesthetics*, *Appearance, and Finish:*

I. The design should incorporate a see-through door.

II. The temperature monitor should be able to be set to display the temperature in fahrenheit or celsius.

III. The external portions of the incubator can be "angular" if needed.

2. Production Characteristics

a. *Quantity*:

I. At this time, only one prototype is required. The client would like to be able to replicate the product in the future.

b. *Target Product Cost*:

I. The incubator must cost less than $100 per unit to produce including labor and materials.

3. Miscellaneous

a. *Standards and Specifications*

I. The incubator would ideally be able to accommodate changes in the power cord/power supply so a second mold is not needed (for example, international power cord requirements versus the standards for the US).

II. Need appropriate electronics approved for sale in the United States.

III. The FDA recommends running an incubator for 1 week prior to use with a new patient.

IV. An incubator is a class 2 device as defined by the FDA. Requirements are as such [2]:

A. Requires 510(k) application to be submitted to market.

B. Requires a set of performance standards, labeling, testing data, and "post-market surveillance".

b. *Customer*:

I. The users of this incubator would likely be private parties that feel passionately about wildlife rehabilitation.

II. These users would require a low cost and easily accessible incubator to allow for the highest impact in wildlife rehabilitation.

c. *Patient-related concerns*:

I. The device should be sterilized between uses to ensure that all animals are being safely handled and that no mixing of environments is occuring

d. *Competition*:

I. Brinsea Incubators [3] come in a variety of sizes and are often used at wildlife rehabilitation centers [4].

References

[1] "NIOSH sets 35-lb limit as the max for safe lifts," Relias Media. https://www.reliasmedia.com/articles/9596-niosh-sets-35-lb-limit-as-the-max-for-safe-lifts

[2] "Overview of Medical Device Classification and Reclassification," U.S. Food and Drug Administration. https://www.fda.gov/about-fda/cdrh-transparency/overview-medical-device-classification-and-reclassification

[3] "TLC-40 Eco Series II Parrot Brooder/Intensive Care Unit/Recovery Incubator," TLC Brooders/Intensive Care Units, https://www.brinsea.com/p-679-tlc-40-eco-series-ii-parrot-brooderintensive-care-unitrecovery-incubator.aspx (accessed Sep. 20, 2023).

[4] "The incubators," BabyWarm, https://www.babywarm.org/about-the-incubators/ (accessed Sep. 20, 2023).

B. Expenses and Purchases

The team has not yet made any purchases.