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**VETMED: CAT CYSTOCENTESIS TEACHING MODEL**

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FINAL REPORT

*BME 200/300*

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## **Abstract**

Urine sample collection is a common diagnostic taken by veterinarians [1]. Because of this, a quick method to obtain sterile urine is necessary. That is where cystocentesis comes in. Cystocentesis is a routine procedure used to withdraw urine by inserting a needle through the skin and into the bladder [2]. This procedure is delicate meaning it is possible to damage internal structures if the needle is inserted incorrectly. Therefore, there is a need for a helpful teaching model that allows veterinary students to practice cystocentesis. There are very few teaching models on the market. One teaching model, developed by Universidad de Buenos Aires, includes a filled water balloon placed inside a stuffed animal that students practice withdrawing a “urine sample” from. The second model, the Cystocentesis Trainer, is a clipped balloon that sits in a covered tray, and it functions similarly to the first model. Due to the lack of teaching models, most veterinary students gain practice by working on cadavers or live animals. This is helpful in some cases, but cadavers often have empty bladders which is unrealistic. To solve this problem, a teaching model will be constructed that allows students to practice this procedure in a low-risk environment. Because most veterinary students have the skills needed to withdraw liquid from the body, the final design is composed of an electrical component that notifies students whether they have correctly entered the bladder or made a mistake by hitting another organ while keeping animals safe and building students’ confidence.

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## **I. Introduction**

Veterinarians have to collect urine samples from cats and other animals on a regular basis as a common diagnostic test [1]. The process of collecting a sterile urine sample by waiting for an animal to urinate naturally can be very difficult and time-consuming. One method that is used to collect a urine sample is to have a cat urinate onto non-absorbent litter and collect the sample after; however, this method may not produce a sterile sample, which is vital to receive accurate test results [3]. It is for these reasons that cystocentesis is an important procedure for veterinarians to master. Cystocentesis is a procedure in which a syringe is inserted through the abdominal wall of an animal and into the bladder where a sterile urine sample can quickly and easily be collected [2]. Unfortunately, there are some risks that come with this procedure. Although not common, veterinary technicians can lacerate the bladder or other internal organs such as the kidneys and the superior vena cava. If this happens, ailments such as uroabdomen and hemorrhage can occur and possibly cause fatality thus proving the importance for having a way to allow veterinarians to practice this procedure in a low stress environment.

Today, there are very few products that have been designed to allow for the practice of cystocentesis. The first simulator that the team discovered is the Cystocentesis Trainer developed by SurgiReal. This product consists of a tray, a sleeve, a balloon, and a clip. The liquid filled balloon (simulating the bladder) is to be placed in the white tray (simulating the abdomen) and then clipped off. Then, the sleeve (simulating the abdominal wall) is placed over the tray [4]. For the price of \$99.99, veterinary students can set up the device as seen in Figure 1 and practice the cystocentesis procedure. The next device that was found is a low-cost, easy-to-assemble

simulator (Figure 2) that was developed at Universidad de Buenos Aires' Veterinary School [5]. In this model, a latex balloon filled with water is placed inside a stuffed animal and closed with a zipper [6]. In addition to these models, Michigan State University claims to have cat cystocentesis model on their campus, but no patent or proof can be found [7].



*Figure 1: The cystocentesis trainer completed with a balloon tray*



*Figure 2: Universidad de Buenos Aires' model that uses a zipped stuff animal and latex balloon.*

At the University of Wisconsin-Madison Veterinary School, students only have two ways to practice cystocentesis: on live animals and cadavers. As discussed earlier, if the procedure is done incorrectly on a live animal, death or other serious complications can occur. Currently, the use of a cadaver is the only method that allows students to practice this procedure in a safe

environment. However, these do not do a great job of simulating the actual procedure because the bladders are often empty. The objective of this project is to develop a teaching model for feline cystocentesis that notifies veterinary students when they have made mistakes, thus aiding in the learning of proper techniques that can be used when performing this procedure live. With the creation of a new device, students will be able to keep animals safe and secure throughout this procedure.

## **II. Background**

Cystocentesis is a routine veterinary procedure wherein which a needle is inserted into the bladder through the abdominal wall to obtain an uncontaminated urine sample [2]. There are a few reasons that this procedure may be performed. The most notable reason is to collect a sterile urine sample for urinalysis or bacterial culture [8], while a less common use of the procedure is done to relieve a severely distended bladder. The latter is typically a last resort because puncturing a distended bladder may result in a rupture leading to uroabdomen, which is the presence of urine in the peritoneal cavity [2]. Cats with feline idiopathic cystitis (bladder inflammation) or other painful bladder conditions may require analgesia administration before sample collection [9]. A sterile urine sample collected via cystocentesis can provide information on the hydration of the cat, the turbidity of their urine, their level of kidney function, the amounts of blood, pus, glucose, bilirubin, ketones, and protein in the urine, the pH of their urine, and information on casts, urinary crystals, and the bladder in general [2].

The procedure is performed with the cat held on its side, back, or standing up with the hind legs extended to provide easier access to the bladder [8], and the area is usually shaved and sterilized. First, the veterinarian will palpate and immobilize the bladder. Once the veterinarian

has successfully immobilized the bladder, they will insert a 1-inch needle, with 6- or 12-mL syringe attached, through the abdominal wall at a 45-degree angle into the bladder until it reaches the hub of the syringe. If the veterinarian cannot find the bladder, they are often told to envision an “x” between the last four nipples on the torso and insert the needle the center of the envisioned letter. Urine is then aspirated into the syringe barrel. The veterinarian releases the bladder directly after and withdraws the syringe [2].

The cystocentesis procedure takes only a few minutes to complete and is often done without sedation or anesthesia unless the cat is difficult to manage [2]. Overall, the risk associated with cystocentesis is very low, but if done incorrectly, complications can include the puncturing of internal organs, bladder lacerations, and vagal reactions such as retching, panting, hypersalivation, urination, and collapsing [2]. Fortunately, most students who perform this procedure do not run into these complications. Instead, they find themselves not puncturing any organs or puncturing the small intestine after going through the abdominal wall leading to air being drawn into the syringe.

The client for this project is Melissa Shear, a graduate student at the University of Wisconsin-Madison’s School of Veterinary Medicine, and she is advised by Dr., Jessica Pritchard. Their objective for this project is to create a realistic model with which the cystocentesis procedure can be accurately simulated. This model will be used by veterinary students, allowing them to make mistakes and learn from them in a risk-free environment. Some key elements the clients would like to see include a lifelike bladder and a notification system that lets students know they have done something wrong. All materials used in the model, especially those that are representations for the skin, bones, and organs, must have similar mechanical



properties to the respective parts on living cats. A full list of criteria and expectations for the model can be found in the Appendix. The final prototype must properly simulate the procedure [10].

### III. Preliminary Designs

Because the client wants to have a fully functioning bladder, the team has developed designs that focus heavily on how the bladder will look and function inside the developed structural design.

#### A. Bladder Designs

##### 1. Frankenbladder

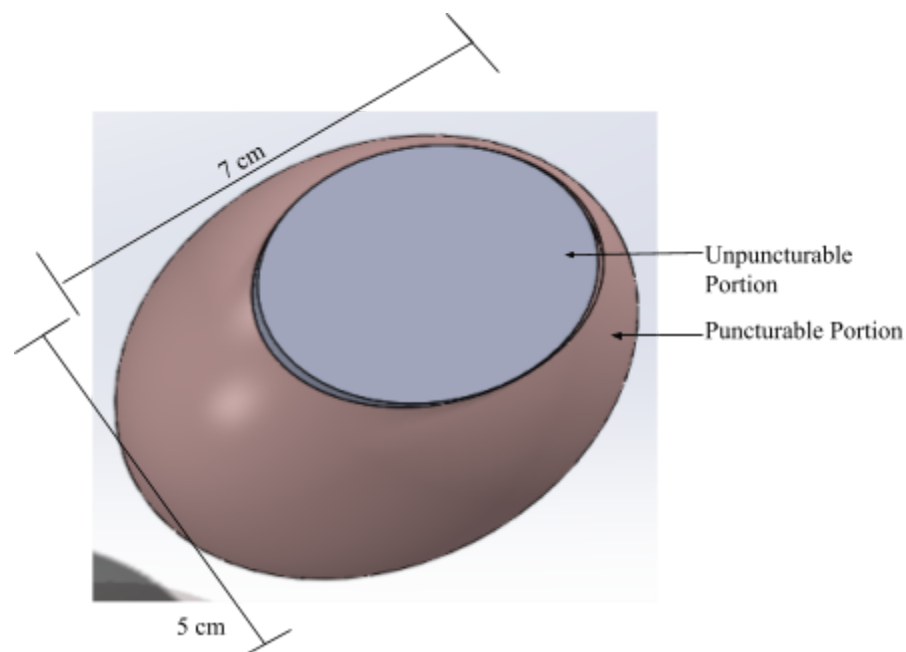
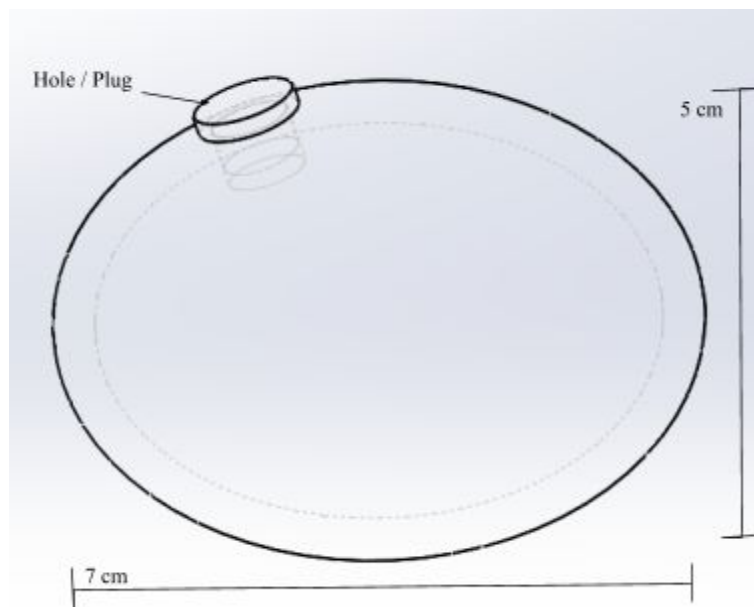


Figure 3. The Frankenbladder bladder design that incorporates both a puncturable and unpuncturable portions.

Frankenbladder, Figure 3, has a puncturable mesh portion and an unpuncturable plastic portion. The unpuncturable aspect will ensure the structural integrity of the bladder by giving the design a rigid body to prevent collapsing, rupture, and leakage. The puncturable portion has

mechanical properties similar to that of bladder tissue in a cat. This design will be 7 cm long and have approximately a 5 cm diameter at the center. One disadvantage of this design is the method of refilling since the bladder must be removed in order to replace the liquid meaning there would be a high level of expected maintenance throughout the lifetime of the device. The plastic attachment must also be stable enough to endure the shear force and displacement caused by a puncture. Additionally, the puncturable aspect would need to be replaced with a fresh portion after a certain number of uses.

## 2. No Diaper Needed

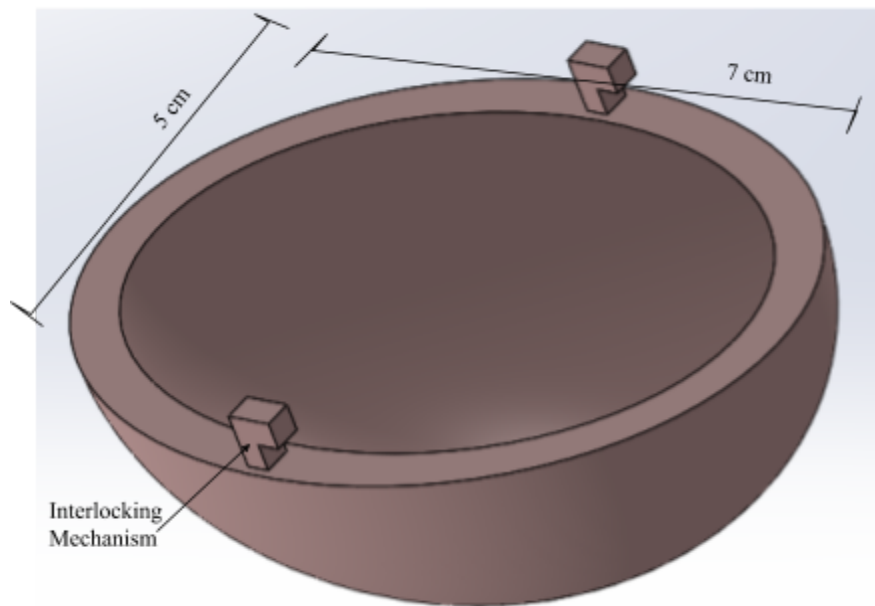


*Figure 4. The No Diaper Needed bladder design that uses sealant technology of tire companies to hold liquid after being punctured.*

The second bladder design, No Diaper Needed, as seen in Figure 4, incorporates the relatively new, self-sealant technology of car tires. This design involves consists of an inner lining of the gel-like sealant that is found in resealable tires. The sealant has the ability to fill the holes that will be made by the needles during practice of cystocentesis [11]. This will increase the usability of the design because the material will not have to be replaced as often as the

Frankenbladder. The sealant in tires is constantly adhering to the surface due to heat and the rotation of the tire [12]. There is nothing in the teaching model that will rotate the bladder meaning that the users will have to remove the bladder and rotate in a few times before each use. The dimensions of No Diaper Needed are the same as Frankenbladder which can be seen in Figure 3.

### 3. Puzzle Pee-ces



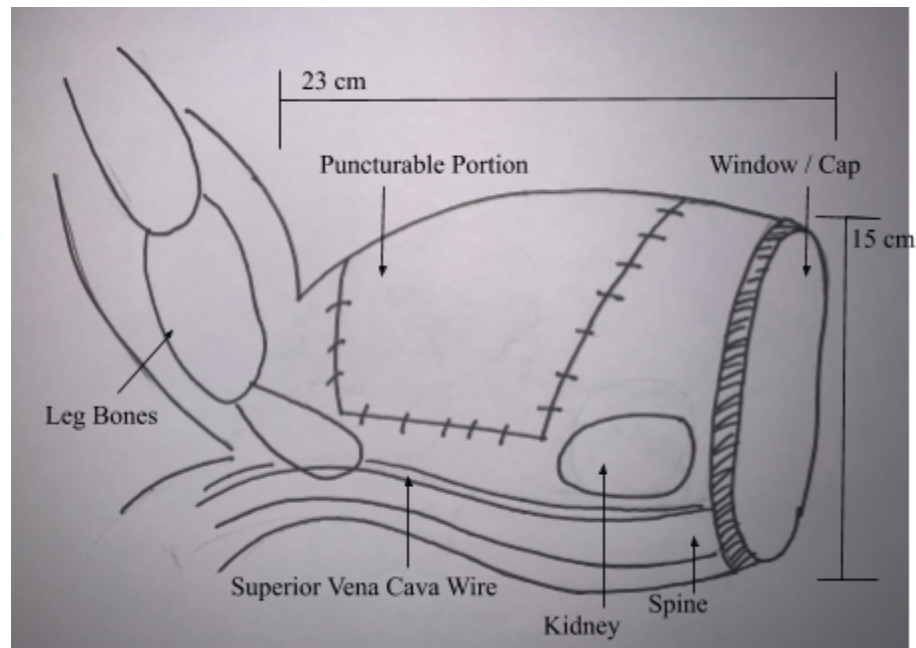
*Figure 5. Half of the Puzzle Pee-ces bladder designs that interlocks with the other half to make a full bladder that can encapsulate a water balloon.*

Puzzle Pee-ces, as seen in Figure 5, contains two interlocking halves of equal size with dimensions equivalent to the previous bladder designs. The interlocking mechanism displayed above illustrates the function rather than the final design. The material used will have similar mechanical properties to a feline bladder, but it will not hold liquid. Instead, the device will encapsulate a water balloon or a similar structure that will hold the “urine”. Because the model does not have to hold liquid, the larger list of available material will allow the properties to be more comparable to a real-life bladder. The chosen external material will determine how many

times it can be punctured before replacement is needed. One disadvantage to this design is that if the water balloon were to pop, water could leak out of the bladder structure possibly ruining the external structure and circuitry. The interior of the structural design will be easily accessible in order to allow for simple exchange of water balloons.

## B. Structural Designs

### 1. Kittens Get Stitches



*Figure 6. The Kittens Get Stitches structural design is only the lower portion of a cat and has anatomically accurate bone structure of the lower portion.*

Kittens Get Stitches is a structural design that focuses solely on the lower portion of the cat. The rightmost edge of the model is a see-through cap that will act as a window allowing observers to view the practice procedure as it's happening and as a way for users to study the internal anatomy. The interior aspects are visible from the side view in Figure 6, but only be visible from the window in the teaching model. The design is anatomically correct in terms of bone structure and will include organs such as the bladder, kidneys, and the superior vena cava.

The bladder is not depicted in the above figure because the bladder design was not determined. The main portion of the teaching model will be approximately 23 cm long and 15 cm wide. This design will encompass an electrical component that will notify the user when the kidneys or the superior vena cava, which will be made of conductive material, is hit through the completion of a circuit. The exterior of the structure will have two separate skins. One skin will be made of a puncturable material to allow access to the bladder, and the other skin will be for structural purposes.

## 2. The Vision

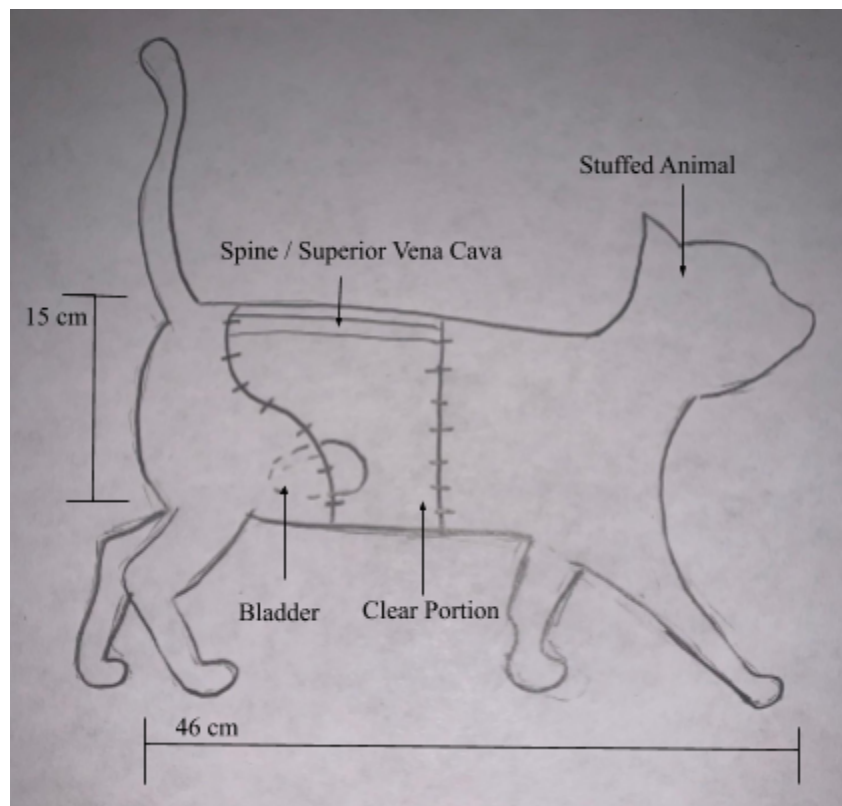
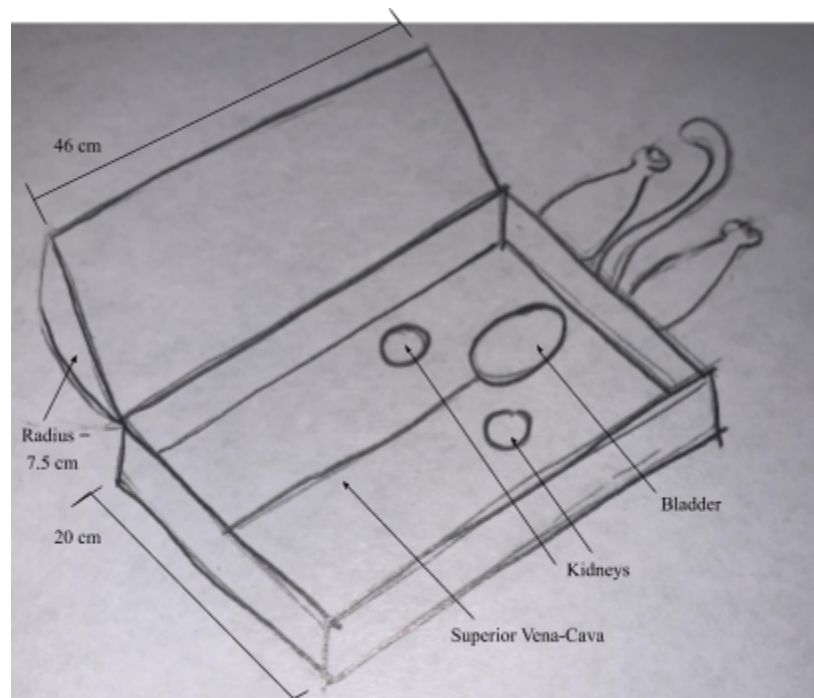


Figure 7. The Vision is a structural design that manipulates the interior of a stuffed animal.

The Vision, as seen in Figure 7, utilizes a stuffed animal for the body of the teaching model but alters the mid-portion of the exterior. This altered portion will be transparent allowing the user to view what is occurring inside the body during practice of the procedure. Because

veterinarians are not able to view the internal anatomy during cystocentesis, a penetrable cloth will be available to cover the clear portion for a more accurate model. Finding a material that is easily puncturable is a foreseeable difficulty with this design. The Vision will also include the electrical component, that was discussed earlier, to notify students when a mistake was made. This design is simple and will allow the team to focus on the bladder and replicating the mechanical properties of a cat.

### 3. The Wrap-Around



*Figure 8. The Wrap-Around puts the cat in a box with a lid that has a curve replicating the belly of a cat.*

The Wrap-Around, Figure 8, minimizes the structural design to a box with a concave top cover. This design will have fake legs and tail on the bottom for the assistant to practice the various leg positionings associated with cystocentesis. The interior of the box will include the bladder structures representing the kidneys and superior vena-cava. This design is highly geared to the retrieval of urine and the complications but disregards many of the technical aspects. The

simplicity of this design will cause it to vary from the anatomical structure of a cat. This means that it will not do the best job of simulating the environment of a live procedure. The Wrap Around is the biggest of the structural designs at 46 centimeters long, excluding the legs and tail, and 20 centimeters wide.

#### IV. Preliminary Design Evaluation

##### A. Design Matrices

##### 1. Bladder Design Matrix

Criteria (Weight)	Puzzle Pee-ces		Frankenbladder		No Diaper Needed	
Realism (25)	5	25	4	20	5	25
Ease of Use / Simplicity (20)	4	16	3	12	3	12
Easy to Store (15)	5	15	3	9	2	6
Ease of Fabrication (15)	3	9	1	3	1	3
Durability (15)	4	12	3	9	5	15
Cost (10)	4	8	4	8	2	4
Total Score (/100)	85		61		65	

Table 1: The Design Matrix for the bladder designs of the cystocentesis teaching model.

The criteria for the bladder design matrix, shown in Table 1, above was determined based on requests from the client and the ability of the team. After rating each constraint for the three designs, it was determined that Puzzle Pee-ces was the winner for the bladder designs. Puzzle Pee-ces was ranked the highest or tied for highest in every category with the exception of durability. No Diaper Needed ranked higher in durability because it has the ability to be punctured repeatedly while retaining liquid. The durability and the realism of No Diaper Needed

caused it to rank slightly higher than Frankenbladder after final calculations. The main downfall for both of the lower ranking designs was ease of fabrication. Figuring out how to connect the Frankenbladder materials will prove to be difficult and No Diaper Needed has many layers to its fabrication. The “Easy to Store” category ratings were based on how easily the liquid could be removed to maintain the structural stability of the bladder’s material. Considering Puzzle Pee-ces does not directly hold the liquid but encapsulates a water balloon, it ranked a perfect five out of five in this category.

## 2. Structural Design Matrix

Criteria (Weight)	Wrap Around		The Vision		Kittens Get Stitches	
Realism (25)	2	10	5	25	5	25
Ease of Use / Simplicity (20)	4	16	4	16	4	16
Easy to Store (15)	3	9	3	9	4	12
Ease of Fabrication (15)	4	12	1	3	3	9
Durability (15)	4	12	2	6	4	12
Cost (10)	3	6	5	10	4	8
Total Score (/100)	65		69		82	

*Table 2: The Design Matrix for the structural designs of the cystocentesis teaching model.*

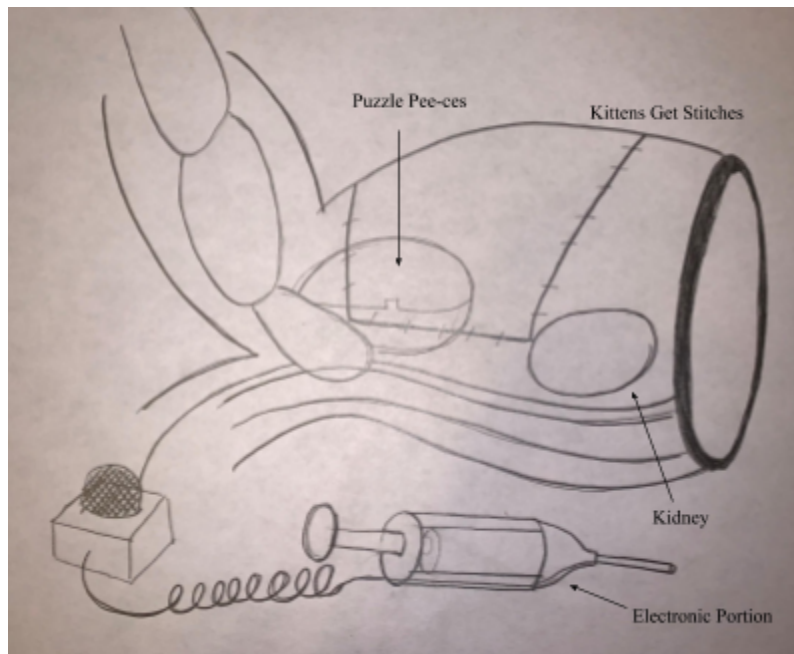
The structural design matrix, shown in Table 2, has the same criteria as the bladder design shown previously. Kittens Get Stitches was the winner of this matrix ranking in with a total of 82 points which is over 10 points higher than the second place design. Despite this large score margin, each of the three designs scored the highest in a decent number of categories. The stuffed animal aspect of the Vision caused it to rank high in both the realism and cost categories. However, because the Vision is constructed with a stuffed animal, it ranks low in durability



because the fabric will most likely wear fast. The Wrap Around scored the lowest because it did not rank highly in the majority of the criteria categories and lost a large amount of points in realism because the structure does not accurately replicate that of a cat. Kittens Get Stitches won due to the summation of high ranking in most categories. However, Kittens Get Stitches ranked low in the “Ease of Fabrication” category because the various parts require precise construction. The other two designs ranked higher in this category.

## B. Final Design

### 1. Proposed Design

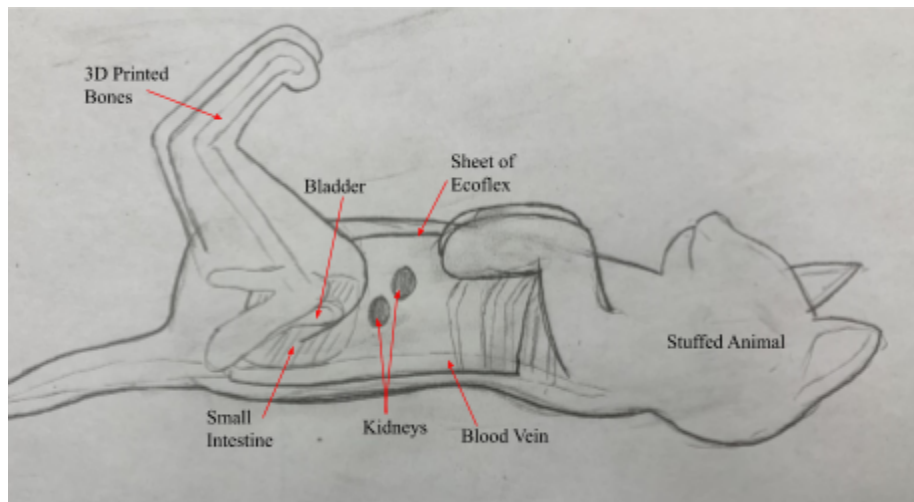


*Figure 9. The proposed final design, Frankenkitty-- a combination of Kittens Get Stitches, Puzzle Pee-cess, and an electrical portion.*

The design matrices played a key role in determining the proposed final design. After evaluating each design, the proposed final design, Frankenkitty as seen in Figure 9, is a combination of the Puzzle Pee-ces and Kittens Get Stitches designs (Figures 5 and 6, respectively) with an electrical component. The electrical component is not evaluated in the

design matrix because the simplicity of the element lead to one feasible option with an open circuit connected to the other organs that would close if the circuit was completed with the needle.

## 2. Final Design



*Figure 10: The drawing of the altered final design without the circuitry element.*

A visit to the University of Wisconsin-Madison Veterinary School allowed the team to practice the procedure and gather a deeper understanding of the potential problems associated with cystocentesis. After deliberation the proposed final design, Figure 10, was altered to better accommodate the important complications. One important piece of information that was learned during the vet school visit was that most students performing this procedure do not have difficulty aspirating urine or liquid from the bladder of a cat or cadaver during the procedure. Instead, the major difficulties lie in finding the bladder. Because of this, the team decided that it would be best to eliminate the liquid filled bladder element of the design. It was collectively determined that the project should instead focus on helping students locate and puncture the bladder. Therefore, the updated final design is completely electrical and will let students know if they have correctly or incorrectly done the procedure. All important internal organs, including

the superior vena cava, kidneys, urinary bladder, and small intestine are to be made with aluminum foil, a conductive material that will allow for the completion of the composed circuit and notification of success or mistake.

## **V. Fabrication/Development Process**

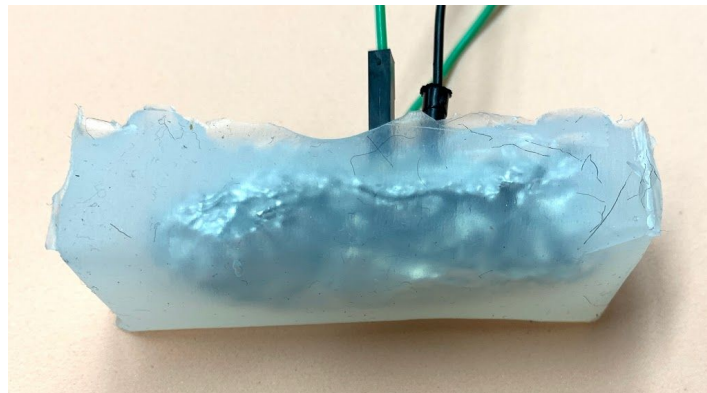
### **A. Materials**

A detailed list of the materials and fees for the prototype can be found in the Appendix on page 32. The outer structure of the cystocentesis model was replicated with a stuffed toy cat, Attatoy Regit the Plush Tiger Toy. Originally, to provide internal support, the team planned to incorporate 3D printed feline bones from a CT scan provided by the client. After unforeseen delays receiving the CT scans, the team utilized a 3D printed half-cylindrical, PLA structure with a honeycomb pattern to provide an abdominal cavity. Aluminum foil was used to replicate the internal organs because it is both conductive and malleable. In order to isolate the circuit connected to the bladder while still allowing it to be palpated, the bladder was encapsulated in Ecoflex 0030. Ecoflex Gel - Trial unit was initially used but it did not accurately represent the tissue of a cat. A sheet of Ecoflex 0030, approximately one centimeter thick, was created to rest between the 3D printed structure and the cloth of the stuffed cat to simulate the muscle tissue of the abdominal wall. The electrical component of the design incorporated a printed circuit board, a four prong LED light, wiring, an electronics box, a battery case, and batteries. All which work together to provide feedback on the procedure by completing circuits connected to the various organs when the needle comes into contact. The wiring and light did not need to be purchased because the team already owned these items.

### **B. Methods**

## 1. Internal Organ Fabrication

The bladder of the teaching model is composed of ecoflex and aluminum foil. The size of the bladder was determined by direct measurements taken by the team on the bladder of a cadaver of a dog during a visit to the University of Wisconsin Veterinary School. To begin, the aluminum foil was molded to a size of 1.5 centimeters in diameter and 5.5 centimeters long. The foil was folded in a loose manner allowing for it to be squeezed. To obtain the desired shape and size of the ecoflex capsule, a mold was constructed out of parchment paper and aluminum foil. The rectangular mold measured 2.0 centimeter by 6.0 centimeter by 2.0 centimeter. Parchment paper was added for easy removal after the ecoflex had set. Once the mold was complete, the two parts of Ecoflex 0030 were combined and poured into the mold. Following this, the aluminum foil bladder was inserted into the Ecoflex. The complete bladder was removed from the mold after the Ecoflex went through a four hour curing period and can be seen in Figure 11.



*Figure 11: The finalized bladder used in the design with the wires attached*

The sheet of ecoflex was fabricated in a manner similar to that of the bladder but on a larger scale. This ecoflex mold measured 12 centimeters by 18 centimeters by 1 centimeter. The size and shape of the remaining organs were approximated to replicate those of an average cat

based on observations and previous knowledge. These organs were repeatedly adjusted repeatedly to ensure they fit the complete structure. The diameter of the vein was about 6 millimeters, and the final dimensions of the small intestine were 7 centimeters by 7 centimeters by 4 centimeters. The teaching model's kidneys more accurately represented those found in a cat as it was discovered that a cat's kidney range from 3.0 to 4.3 centimeters in length with an ovular or bean shape.

## **2. Circuit Fabrication**

Outside of practice that was completed in Biomedical Engineering Design 201, the team collectively had limited experience with circuitry. To run the model electronically, the team sought out an expert in the field of circuits, Dr. Amit Nimunkar, to gain more knowledge on the topic and determine the best way to wire the teaching model. In this meeting, Dr. Nimunkar concurred with the initial thought to use aluminum foil for the various organs that are included in the teaching model.

For the rest of the circuit, the team's design is quite simple. The circuit diagram is shown below in Figure 12 and the circuit's main components include four AA batteries to power the circuit with six volts of electricity, a four-pin RGB LED, and two major "paths" that can be taken. The first path, which is taken when power is supplied, goes directly into a 3.3 k $\Omega$  resistor and the blue light will turn on. The other path powers a needle directly which, after making contact with an aluminum foil internal organ, powers the red light through a 220  $\Omega$  resistor. If the aforementioned needle instead contacts the bladder, the green light will be powered through another 220  $\Omega$  resistor.

The team planned to use a printable circuit board for the final prototype, but printing mistakes and time constraints prevented that from working. Instead, the team soldered wires into a pre-made board, as shown in Figure 16, and connected the parts on the underside with solder and extra wires.

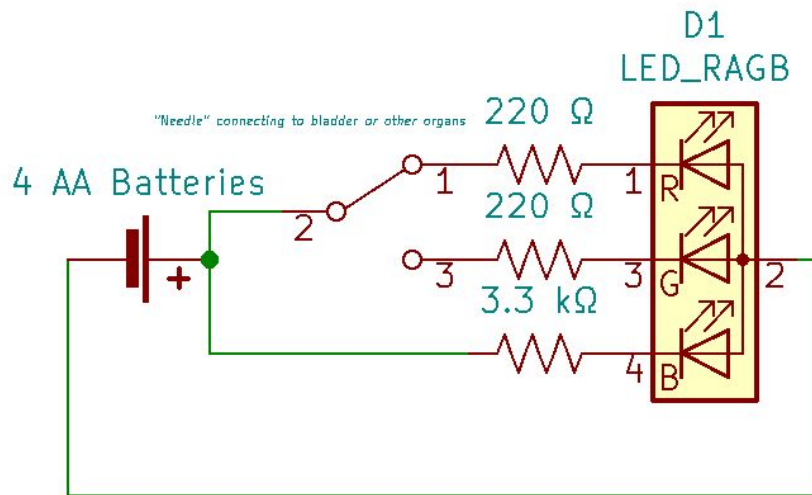
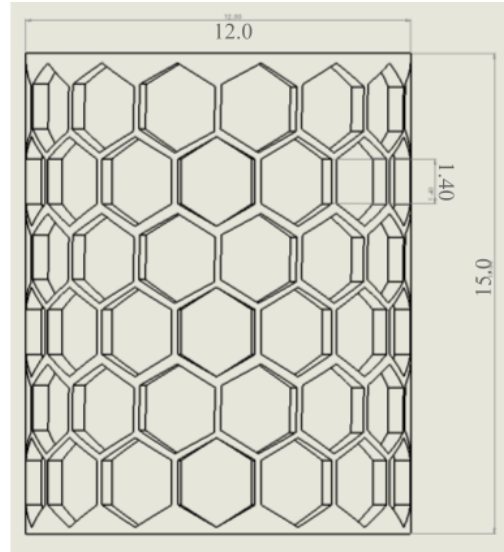


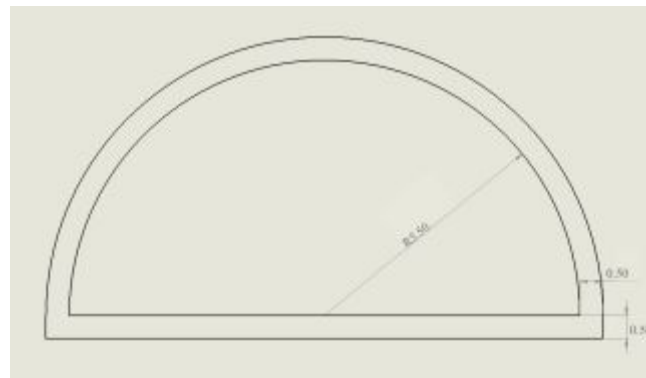
Figure 12: The final circuit diagram, showing 6V powering either the blue light through a 3.3 kΩ resistor or the red or green lights, depending on where the needle contacts, through the 220 Ω resistor.

### 3. Model Fabrication

The fabricated pieces described in the previous two sections were compiled into the structural design aspect. The structural design, which can be seen in Figures 13 and 14, is a half-cylindrical, 3D printed honeycomb made of PLA to replicate the abdominal cavity. The structure has a 6.0 centimeter radius and is half a centimeter thick, thus the total width 12.0 centimeters. The 3D-printed structure measures 15.0 centimeters in length and is 6.50 centimeters tall. Each side of the hexagons within the honeycomb structure is congruent measuring 1.40 centimeters.



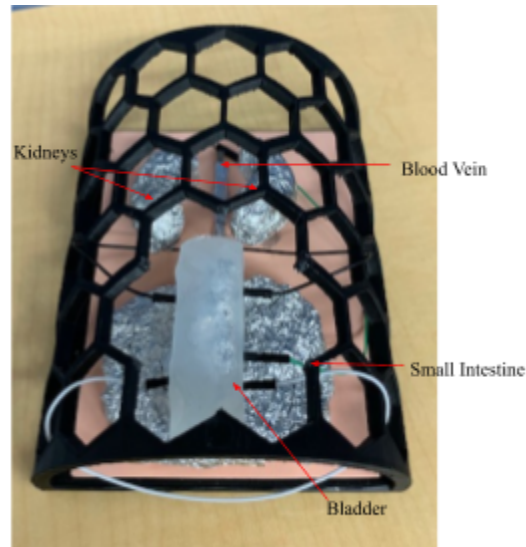
*Figure 13: The top view of the interior structural design with dimensions for the length, width, and hexagon sides in centimeters.*



*Figure 14: The side view of the interior structural design with dimensions for the length, width, and hexagon sides in centimeters.*

Before the internal structures were arranged, a foam pad was fixated to the bottom of the structure and the center hexagon in the second row from the bottom was removed. This was done to allow for easier access to the bladder and limit the possibility of students hitting one of the hexagon sides when inserting the needle. The superior vena cava was centered on the bottom of the structure. The small intestine was placed toward the bottom edge with the bladder sitting on top of it as would be the case in a live cat with a full bladder. These organs were then hot glued into place. Following this, the kidneys were hot glued onto centimeter long sticks and adhered

about 3 centimeters behind the small intestine mirroring each other about the superior vena cava. The layout of the internal structure is depicted in Figure 15.



*Figure 15: The complete internal structure of the final prototype*

Wires were attached to the individual organs and connected to the electrical aspect of the project. Then, all stuffing was removed from the stuffed animal's abdominal region and the 3D-printed structure containing the organs was placed inside. The back of the stuffed animal was closed using velcro that was sewn on each side of the original seam.

### **C. Final Prototype**

Aspects of the internal structure and organ placement of the design can be found above in the Methods section in Figures 11 to 15. The compilation of each of these aspects and more are seen below in Figures 16, 17, 18, and 19, all of which are elements of the final prototype. Figures 16 and 19 depict inside and outside of the electronics box while Figures 17 and 18 represent the structural design complete with the stuffed animal.



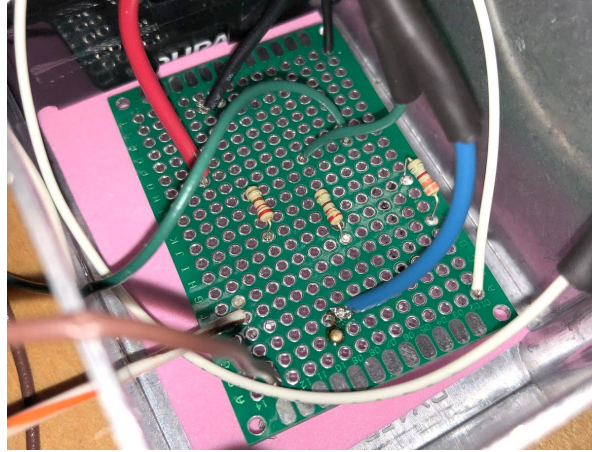


Figure 16: The finalized circuit board, soldered and wired on the underside and placed in the electronics box (Figure 19)

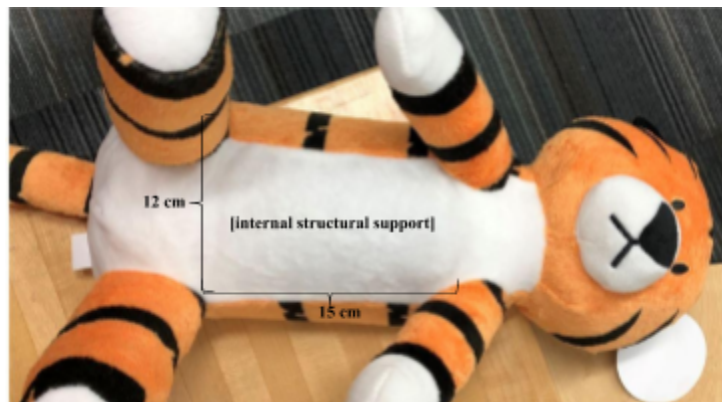


Figure 17: The prototype completed with the surrounding stuffed animal.

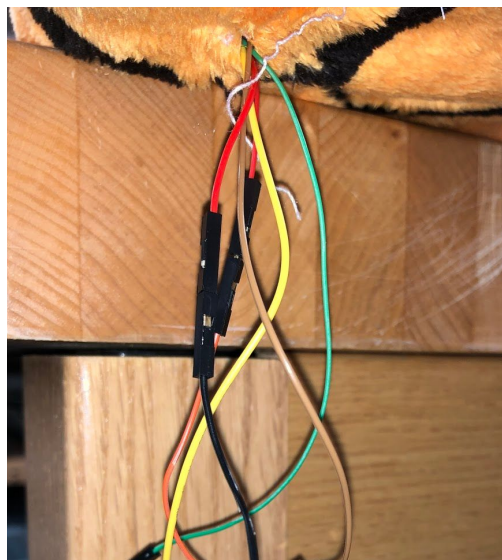


Figure 18: The entrance of the circuitry element into the stuffed animal through the back of the neck.

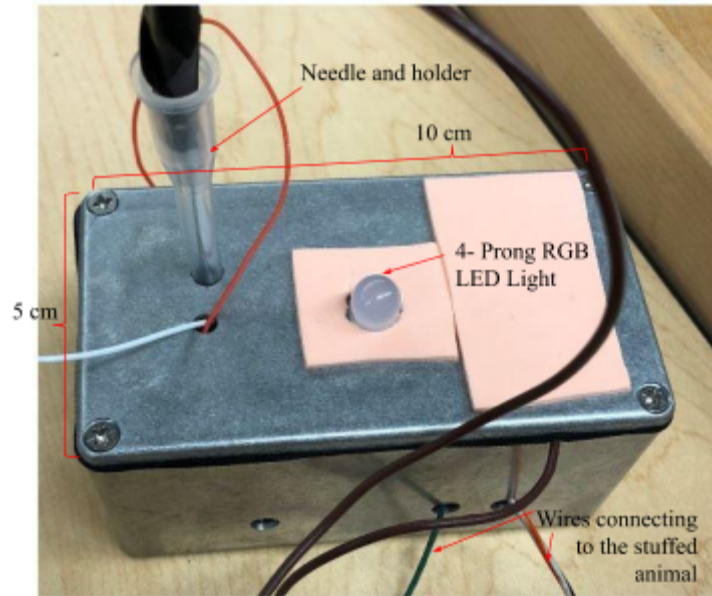


Figure 19: The outside of the electronics box that controls the circuitry element of the device.

## D. Testing

### 1. Circuitry Testing

Testing for the circuitry was relatively straightforward, but underwent several stages. The first stage was the learning stage, which consisted of determining which configuration of resistor values displayed the appropriate light color. The second stage of testing involved manipulating the power source to get an ample brightness for the light at all times. The final stage of testing included ensuring that the circuitry would not be affected by the box it is inside of.

### 2. Material Testing

The mechanical properties of ecoflex were determined using the MTS Sintech machine. The team wanted to perform compression tests to see how much pressure it would take to puncture through the ecoflex of the bladder to reach the aluminum foil and complete the circuit. Unfortunately, it was determined that with such a fine needle and limited available technology, testing on the machine would be unsafe. Therefore, tensile testing was performed on the two

forms of ecoflex-- Ecoflex 0030 and Ecoflex Gel Trial Unit. Figure 20 represent the initial setup of the tensile test for the ecoflex materials-- both had identical setups. The initial dimensions of each piece of the ecoflex and the data obtained from the tests are shown in Tables 3 and 4 of the results section of this report.



*Figure 20: The tensile test set-up for the second specimen of the ecoflex gel - trial unit-- the Ecoflex 0030 setup mimics this*

Tensile testing was utilized to determine whether ecoflex is representative of feline tissue, and if so, which type does so the best. Through initial observation of the texture and overall quality of each type of ecoflex, Ecoflex 0030 was expected to have more mechanical similarities to feline tissue. The data gained through these tests is expected to have high variation from any specific tissue because it is an approximation of many.

### **3. Complete Model Testing**

Upon completion of the prototype, the team performed mock cystocentesis procedures by inserting the needle through the exterior of the cat and aimed for the bladder as well as another organ, to test both aspects of the notification system. The team would have preferred for several experts in the field to corroborate their experiments, but due to lack of time, this did not occur.

The client, a veterinary student who has performed the procedure numerous times, was able to provide limited feedback after using the teaching model multiple times.

## VI. Results

### A. Circuitry Results

The team decided on using two 220  $\Omega$  resistors into the red and green light pins and a 3.3 k $\Omega$  resistor into the blue light pin. After the second test, the team concluded that the light should have no less than four volts of electricity should be supplied to the circuit, as the light will then be too dim, and that no more than eight volts of electricity should be supplied, as it has the potential to blow the light bulb out, which can lead to a lengthy replacement. Finally, the team secured the box closed and all light colors retain their level of brightness.

### B. Material Results

Shown in Tables 3 and 4, are the results of the tensile tests for Ecoflex Gel Trial Unit and Ecoflex 0030, respectively. The dimensions are included in these tables to allow for comparison of each test piece. The Ecoflex Gel Trial Unit stress-strain graph was not consistent because it contained many peaks and valleys with high ranges throughout the test.

*Table 3: The dimensions, young's modulus, and max strain of the Ecoflex Gel Trial Unit.*

Specimen	Thickness [mm]	Width [mm]	Length [mm]	Failure	Elastic Modulus [Pa]	Observed $\epsilon_{\text{Max}}$
1	2.19	17.17	85.00	Brittle	650.97	1.09
2	2.81	28.70	89.00	Brittle	11598	0.95
<b>Averages</b>					<b>6124.5</b>	<b>1.02</b>

*Table 4: The dimensions, young's modulus, and max strain of the Ecoflex 0030.*

<b>Specimen</b>	<b>Thickness [mm]</b>	<b>Width [mm]</b>	<b>Length [mm]</b>	<b>Failure</b>	<b>Elastic Modulus [Pa]</b>	<b>Observed <math>\epsilon_{Max}</math></b>
1	5.56	13.83	35.00	Slip	172446	2.05
2	5.53	26.87	66.00	Slip	71613	1.31
<b>Averages</b>					<b>122030</b>	<b>1.68</b>

Because the team was unable to find data on the mechanical properties of feline tissue, so all conclusions were drawn from comparison to human tissue. Previous studies have found that human skin has an ultimate tensile strength of 27200000 Pa, an elastic modulus of 98970000 Pa, and a failure strain of 25.45 [13]. The team predicts that the ultimate tensile strength and failure strain of the cat tissue are lower because of the additional hair follicles of the fur, and the elastic modulus will be higher because the skin is stiffer. It is expected that the hair follicles will act similar to discontinuities causing premature failure.

Comparison of stress could not occur because both types of ecoflex had unforeseen complications regarding the collected data. Discontinuities in the initial specimens most likely accounted for such variances, and additional tests would need to be done with more uniform pieces. Despite many attempts, the team was unable to retrieve failure data on Ecoflex 0030 as the test piece would slip out of the grips before this point could be reached. The team contributed the slippage to the thickness of the pieces and a low elastic modulus. If time allowed, additional tensile testing with thinner pieces would occur to allow for more accurate data. The stress-strain curve with the slippage can be found on page 35 of the Appendix.

The comparison of the elastic modulus determines if the stiffness of the ecoflex is reflective of the stiffness of the composite of tissue it is supposed to represent. The average

elastic modulus of Ecoflex 0030 is similar to the expected value of 125000 Pa [14] implying that the data is accurate prior to the slippage. The variation of the elastic modulus for the Ecoflex Gel Trial Unit is presumably due to the stress variations due to non-uniform manufacturing. Overall, the exact elastic modulus of the composite is unknown, but it is important to take into account that the elastic modulus of the muscle of human is 12000 Pa [15] as it plays a major part in the composite. Thus the overall elastic modulus is more similar to the experimental data than it first appeared. The data obtained implies that the Ecoflex 0030 better represents the desired stiffness of tissue, but additional testing of the Gel Trial Unit with uniform manufacturing is needed to confirm this conclusion.

The slippage of the Ecoflex 0030 affected the observed max strain, it but indicated that a large deformation can occur within the elastic region. Again, with the addition of muscles and other tissue, the max strain of the complete combination of tissue that the ecoflex is representing is expected to be lower than that of the skin alone. Because the application in the project has small deformation, the conclusion can be drawn that the ecoflex will not change shape during the lifespan of the teaching model. On the other hand, the Ecoflex Gel Trial Unit did fail. Although the discontinuities in manufacturing could have caused premature failure, the 1.02 observed max strain is approximately 40% lower than the 1.68 of the ecoflex 0030.

Despite the errors of both testing experiments, the team believes that the Ecoflex 0030 best represents the tissue of a cat. Additionally, the sticky texture of the Gel Trial Unit is not conducive for the overall procedure as it adds a resistance that is not seen in normal tissue.

### **C. Complete Model Results**

The team came to a consensus that the model accurately replicated the feel of the procedure that was performed on the canine cadaver in the vet school. The layers of Ecoflex similarly represented the resistance of canine tissue, and the buoyancy of the Ecoflex sheet surrounding the bladder did a good job representing the difference in the feel of the soft intestine and bladder. The notification system relayed the correct feedback each time the needle came in contact with the bladder, and it returned a yellow light when the needle was correctly inserted into the bladder but was inserted too far and entered the small intestine. The team did not expect this to happen when building the circuit, but it provides another form of valuable feedback to students.

The client tested the device following the team's testing period. In one of the tests performed by the client, she palpated for the bladder and then punctured the needle through the abdominal wall into the bladder, and in her other test she inserted the needle in where she expected the kidney to be. She did this to confirm that the placement of the organs was anatomically correct. The client agreed that the model did an accurate job representing the feel of cystocentesis. Overall, the constructed model met the criteria of the Project Design Specifications (PDS) and the client.

## **VII. Conclusions**

Cystocentesis is a simple and important procedure that can go wrong quickly if not done correctly. For this reason, the ultimate goal of this project was to develop a teaching model that will allow students in UW-Madison's School of Veterinary Medicine to practice performing feline cystocentesis in a low stress environment. Through this practice, students will gain the skills needed to properly perform the procedure. The chances of lacerating organs surrounding

the bladder which could lead to potential fatality and withdrawing nothing but air due to not puncturing anything will be drastically reduced when working on live patients.

The overall fabricated design met the criteria specified in the product design specifications, Appendix C. Tensile testing concluded that the Ecoflex 0030 mimicked the mechanical properties of the composition of tissue to a satisfactory degree. The Ecoflex provided the necessary resistance to the insertion of the needle and the variation of the bladder from the surrounding organs. Furthermore, the circuitry element provided consistent feedback by changes in the color of an LED light. The overall design met the expectations of the client, a professional in the veterinary field, in terms of mimicking the anatomy of a cat and the feel of the procedure.

The final fabricated design accurately replicated the basic aspects of cystocentesis of a cat. However, the model is not perfect and many adjustments can be made so that it better represents cystocentesis. To begin with professionals in the veterinary field should be surveyed on the device. Although, the client was able to provide minimum feedback, the additional and more constructive feedback gathered from a survey and more individuals will give the team more discrete adjustments to employ. Outside of the feedback, the most important change that the team would like to make to the teaching model is the addition of 3D printed bones for structural purposes. The original plan was to 3D print bones from CT scans in the MakerSpace. Unfortunately, the veterinary staff that were assigned to send the documents over were unable to find documents that the team needed in a timely manner thus not allowing for enough time to get the bones printed and added to the final prototype. The addition of this element would have allowed for a more realistic feline structure and the ability to manipulate the position of the cat so cystocentesis could be performed in different positions.



Another addition that the team wants to make in the future involves making different sized bladders that can be switched in and out. During the trip to the Veterinary School, the client informed the group that sometimes the bladder is not full when it is necessary for students to withdraw urine from live animals and the amount of urine in the bladder changes its position in the abdominal cavity. In the future the addition of various size bladder would allow veterinary students to practice in different circumstances that they might experience throughout their careers.

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## IX. Appendix

### A. Materials

Table A1 includes all the expenses of the semester including materials and fees. Objects such as the ecoflex gel- trial unit and the LED lights are not included as the team had them from prior projects and did not purchase them this semester.

*Table A1: The complete list of materials bought and fees needed to complete the project.*

Item	Description	Supplier / Link	Quant.	Date	Price	Total
Aluminum Foil	roll of reynolds wrap used to replicate the organs	Kwik Trip	1	11/1/19	5.48	5.48
Plush Cat	stuffed animal used to replicate the frame of a cat	<a href="#">Attatoy</a>	1	11/14/19	23.99	23.99
Battery Case	five battery cases	<a href="#">Amazon</a>	1	11/14/19	9.99	9.99
Ecoflex 00-30	gel that solidifies into a soft silicone rubber over time	<a href="#">Amazon</a>	2	11/14/19	36.99	73.98
Electronics Box	metal box used for electronics	<a href="#">Amazon</a>	1	11/14/19	6.54	6.54
PCB Boards	for makerspace circuit board	<a href="#">Amazon</a>	1	11/17/19	9.25	9.25
Shop Fee	fee to use makerspace equipment	UW Makerspace	1	11/22/19	50	50
PLA	3D printed structure material	<a href="#">UW Makerspace</a>	2	11/23/19 12/3/19	17.48 11.40	128.88
Batteries	Duracell AA4 for powering model	UW Badger Market	1	12/2/19	6.46	6.46
					<b>Total Price:</b>	<b>\$314.57</b>

### B. Results-- Material Testing

Figure A1 is the stress-strain curve of the first specimen of ecoflex. From the data the ultimate strain and young's modulus was derived. It is important to note that the specimen never failed but rather slipped from the grips in increments labeled as slippage.

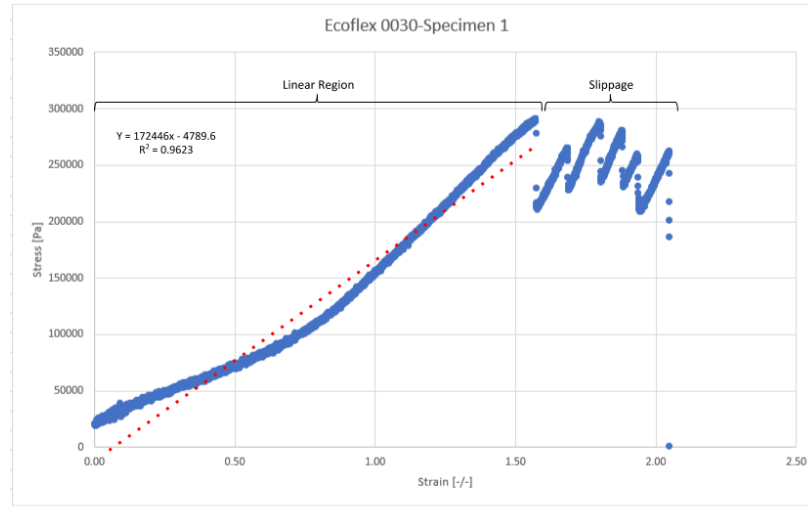


Figure A1: The stress-strain curve of the first specimen of ecoflex 0030.

### C. Product Design Specifications

**Function:** Sterile urine is vital in diagnosing a variety of diseases in animals. Cystocentesis is a common procedure that is used to access sterile urine from cats due to the difficulties associated with catching their urine. This procedure involves great risk, as the needle being inserted into the bladder must be accurately placed to avoid puncturing organs around the bladder that can cause fatality, such as the kidney and caudal aorta. At the University of Wisconsin-Madison Veterinary School, there is currently no way for students to practice this procedure except on live animals, which if done incorrectly can cause death, or on cadavers, which do not do a great job of simulating an actual procedure because the bladders are often empty. The goal of this project is to develop a teaching model for veterinary students to practice this procedure, and be notified when they have made mistakes, thus aiding in the learning of proper techniques that can be used when performing this procedure on live animals.

**Client requirements:**

- Budget of \$500
  - Most of which is expected to be spent on circuitry and creating realistic anatomical structures
- Develop a realistic urinary tract
  - Includes the bladder and kidneys
  - Keep general anatomical shape and location
- Simulate the cystocentesis procedure
  - Compatible to a cat lying on its side or back
  - Able to palpate the abdomen to feel for the bladder during the procedure
- Resemble at least the lower portion an eight pound cat
  - Prefer cloth skin and plastic bone/support structures
    - Options include a stuffed animal as the outer structure
  - Capable of opening model to identify structures and replace parts

### **Design requirements:**

#### **1. Physical and Operational Characteristics**

- a. *Performance Requirements:* Cystocentesis is a very delicate procedure that many veterinary students do not feel confident in performing. Research has shown that veterinary students have strongly preferred to be employed at practices that provide them with mentors and have a lot of supervision because they do not feel they have the proper skills or abilities to complete procedures [P1]. However, veterinary students that have had hands-on practice with these procedures have reported feeling more confident in their line of work. Therefore, the main purpose of this model is to allow students to practice the

cystocentesis procedure and learn how to improve their techniques when mistakes are made. The constructed model will have an artificial bladder, made with material that is palpable and contains a good conductor so students can complete a circuit that will provide feedback when the model needle makes contact with the bladder. During cystocentesis procedures, it is possible for other organs and veins to get lacerated causing uroabdomen and hemorrhage among other things. Because of this, the final model will be constructed to notify students, with a sound similar to the game Operation, when they have hit something they should not have during the procedure.

- b. *Safety*: In order to use this teaching model, users will need to handle a syringe and needle. The FDA regulations for sharps are as followed used sharps should immediately be placed in a FDA cleared sharps disposal container [P2]. The model should minimize the likelihood of contact of the sharp with the operator's hand. If struck by a sharp, the FDA approved procedure is to wash the area with water and soap/disinfectant. Seek medical attention immediately afterward [P2].
- c. *Accuracy and Reliability*: The testing model should accurately depict the urinary system of a cat. The urinary system within the model should be anatomically correct in regards to shape, size and location. Additionally, the bladder must be able to reliably create a closed circuit when contact is made by a model needle that is wired to the circuit. The circuitry should be reliable for 500 demonstrations.
- d. *Life in Service*: The device will be used as a teaching model for many students, and as such it must be able to withstand multiple uses. The model skin must be able to withstand

multiple punctures from a syringe. As a goal, this device should be in service for 500 demonstrations.

- e. *Shelf Life*: The testing model should be stored in a cool, dry environment and should last a minimum of seven years in such an environment. The alkaline batteries that are going to be used to power the electrical portion of the device have a shelf-life of five to ten years [P4].
- f. *Operating Environment*: The cystocentesis teaching model will be used by students and instructors in the Veterinary School at the University of Wisconsin-Madison. The goal of the model is to assist students in gaining experience and practice performing the cystocentesis procedure to prevent them from making fatal mistakes when performing the procedure on a live specimen. When not in use, the teaching model will be stored on a shelf in a room temperature environment. This means that the model may be exposed to dust and/or dirt when left unused for a while. While the device is being stored, it should not undergo any shock loading because nothing would be placed on top of it to prevent damage..
- g. *Ergonomics*: As the device will be modeling the cystocentesis, the operator should use as much force as they would during the actual procedure. The bladder of the device should be able to withstand five newtons of force, as the full bladder of a cat undergoes around 1700 Pa of pressure [P3].
- h. *Size*: For the purpose of the device, the size and shape should mimic that of an eight pound cat. A healthy cat of this weight would average about 46 centimeters in head and body length (excluding the tail) [P5]. Considering that only the lower half of the cat is

needed to teach cystocentesis, the design will most likely measure 23 centimeters plus the length of the tail. With these size restraints, the device will be easily portable for maintenance or general use. The bladder of the cat should be around 7 cm long and have a diameter of 5 centimeters in the center, these values were approximated from the volume and size of a human bladder [P6]

- i. *Weight:* The device is supposed to mimic the structure of an adult cat, which can range in weight from 2.27 kilograms to 9.07 kilograms [P5]. For the teaching model, the team is trying to replicate the average adult cat at 3.63 kilograms [P7]. The weight of the model will differ from this due to the electronic portion as well as the possible elimination of the upper torso and head. The device should be anywhere from 2.27 to 4.54 kilograms so it can be easily transported and semi-replicate the feel of a live-subject.
- j. *Materials:* The device can encompass any material except those that may release harmful chemicals or shatter when punctured. The materials used should replicate the biomechanical properties of the tissue of a cat. The frame and bone structure will most likely be constructed of plastic.
- k. *Aesthetics, Appearance, and Finish:* From looking at the few cystocentesis simulation models that have been made around the world and discussing with the client, the final cat model should be the average size of an adult cat which is no more than 3.63 kilograms. A stuffed animal can be used for the skin of the model; however, if there is time following testing periods, the client would like to see a silicon based skin made for the model, along with an exterior wall that can be opened so students can study the anatomy. The major organs and veins that need to be present within the model include the vena cava, the



kidneys, and the urinary bladder. In addition to these, skeletal structures such as the pelvis and spine will need to be 3-D printed and placed inside the model.

## 2. Production Characteristics

- a. *Quantity*: The veterinary school needs one teaching model-- the model would consist of a bladder that connects to a circuit, a structural component, an electrical component to notify when the bladder is struck vs. when other structures are struck, and other important body tissues.
- b. *Target Product Cost*: The budget for the creation of the cystocentesis teaching model is 500 dollars. Previous models used by the veterinary school are made up of a stuffed animal and a water balloon [P8]. As the design aims to more accurately reflect the possible dangers of the cystocentesis procedure, the 500 dollar budget is appropriate. The majority of this budget will most likely go toward purchasing and developing structures that will represent internal anatomy accurately while providing feedback to the user vis-à-vis an electronic component.

## 3. Miscellaneous

- a. *Standards and Specifications*: There are no specific international or national standard approvals needed for a veterinary teaching model.
- b. *Customer*: The main customer of this device is veterinary hospitals and schools; therefore, the model should reliably replicate the anatomy and physiology of a cat

bladder. The external portion of the device should be realistic but this is of less importance than the bladder itself. The model should notify the operator when a mistake is made such as nicking the aorta or kidneys as well as when the procedure is completed correctly.

- c. *Patient-Related Concerns:* Due to the nature of the project, there is no “patient”. There is a concern related to the operator. It is possible for an accidental needle stick, but that chance will be minimized as much as possible. There are no concerns about patient data or sterilization.
- d. *Competition:* There are no official competitors on the market. However, other universities, such as Michigan State University and Universidad Buenos Aires, have developed models to help students in the veterinary school gain practice on the cystocentesis procedure. Although difficult to find further information, it is known that Michigan State has created a urinary bladder simulation model to allow students to practice withdrawing sterile urine through a needle [P9]. Universidad Buenos Aires developed a low cost cystocentesis model using a stuffed animal, latex balls, a baby diaper, a latex probe, a rubber clamp, and artificial urine. This model was tested by 19 faculty members and 90 students with 90% and 89% of individuals reporting that the model was very good, respectively [P10].

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