Final Design Report
Portable Ultrasound Case

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Abstract

We were given the task of designing a case that could hold the MyLabONE ultrasound device as well connect to a Digital Radiographer also in the case. This unit also needed to be self-powered for a 6 hour period. We first measured all components and weighed them to better design an ideal sized case to hold all components safely. We researched batteries, types of foams, methods for safe traveling, and connectivity for the Digital Radiographer. After deciding on a dimensioned case which is a production size we then created or obtained CAD drawings for all components including the case, foam, metal cover, and hinges. During this time we remained in close contact with our sponsor as well as make several trips to meet with our sponsor and the case manufacturer. We decided that all metal materials needed to be stainless steel for easy sterilization and to help prevent bacteria growth due to its rust/scratch resistance. The foam chosen is a closed cell type which is water-proof and easiest to clean. It also acts as a dampener and will protect the contents inside the case. The case material is made from an industrial strength plastic which is very durable and lost lasting. It also has a life time warranty. A doctor with his Ph.D. in Electronics has figured out how to make the MyLabONE and the Digital Radiographer recognize each other. We have finalized our designs and built and tested a prototype case for the MyLabONE system. The prototype has been approved by Esaote, and will likely be subject to more design iterations by Dr. Waldsmith and staff following this project. As of June 2, 2011, Team Eye Spy has concluded this design project.
Chapter 1 - Introduction

1.1 Introduction:

Technology in all areas is moving at a rapid rate toward the smallest and sleekest designs physically possible. In the medical world, important medical instruments, which were once confined to hospitals and vet clinics due to their large sizes, are no exception. This movement in technology has struck a chord in the large animal veterinary field, as it allows for the necessary equipment to be brought to the patient, rather than the other way around. For our senior project, we will be working with Vetel Diagnostics to create a portable case in which vets could bring the new, smaller ultrasound devices out into the field. Our team, Eye-Spy, consists of two mechanical engineering students, Katie Hoose and Tobe Johnson, and we will be working under advisor Sarah Harding of the Mechanical Engineering department at California Polytechnic State University in San Luis Obispo, CA. Our overall goal is to design and build a case for the MyLabONE ultrasound device. As an additional goal, we will also attempt to integrate the MyLabONE device into the current Digital Radiography (DR) technology that Vetel Diagnostics has previously designed. As it stands, Vetel Diagnostics and future veterinary users are stakeholders in our project.

1.2 Background:

Vetel Diagnostics has been pioneering the idea of creating rugged, durable cases designed both to augment the existing technology and to allow the devices to be easily accessible in every environment. In this particular case, Esaote has created a smaller ultrasound device; however it has several drawbacks that do not allow it to be successfully used outside the hospital.

There are several companies out there that can be found via Google.com search who have cases for the ultrasound devices they currently use. However, we have yet to find a company that has developed a case quite as rugged as Vetel has proposed or that has integrated power, or a case that integrates their ultrasound device with the digital radiographer. We plan to carefully view and understand how other cases are being designed. From there we can find any potential flaws and improve on them with our own design.

Esaote’s MyLabONE has a high resolution 12 inch touch screen, as well as a base operating system of windows XP. It has the ability to be used as a handheld device, or it may be placed in a small stand, or a rolling cart. Although it is not confined to a cart, and it has two batteries to allow it to be hand held, it is still a fragile device that would not stand up well to being taken outdoors. Beyond that, it clearly is necessary to charge those batteries fairly often, something that is simply not always possible in the field.

Figure 1. Esaote MyLabONE Ultrasound Device
Digital radiographers (DR) have been used since 1992 for medical purposes. They have allowed doctors, vets, scientists and more to better understand what their patient has going on. This has allowed for a better diagnosis and quicker feedback and thus better overall outcomes for their patients. This device also helps cut costs and pollution by limiting the use of x-ray film.

Vetel Diagnostics has pioneered the idea of creating a portable DR system. They are currently selling these products to groups like IMMS (Institute for Marine Mammal Studies) and equine veterinary clinics, and their technology was first to the scenes after the Haiti earthquake. As the DR systems require a computer in order to function, it is an easy step to the idea of using the MyLabONE and its XP operating system as the computer.

1.3 Objectives:

Our overall goal for this project is to design and build a case to house the MyLabONE ultrasound device for Vetel Diagnostics. Additionally, we are hoping to be able to integrate the MyLabONE into the current Digital Radiography case designed by Vetel Diagnostics. If it succeeds, the ultrasound device will also serve as the necessary computer for the DR system.

From our meetings with Dr. Waldsmith, our sponsor, we have decided on the following list of needs and expectations:

- The case must be durable. It must be able to withstand the everyday wear and tear, as well as be able to protect the valuable devices from long drops, hooves, etc.
- Ease of use is extremely important. The ultrasound devices should be easily removable from the case, the batteries should be easily charged or replaced, and the ultrasound probes should be easily accessible and easily exchanged. The user should have a fully functioning ultrasound system as soon as the case is opened.
- A fully functioning ultrasound case needs to be able to sit flat on the ground. There should be no danger of the case flipping itself over beneath its own weight.
- Both systems are lacking in the keyboard and mouse department. An easily accessible, yet small version of both of these will be integrated into the case to provide for easier use.
- Additionally, the MyLabONE will be integrated into Vetel's existing Digital Radiography system. It will be able to be used both as an ultrasound system, as well as the operating system behind the digital radiography.
Our specifications can be seen in our Quality Function Deployment (QFD) analysis chart in Appendix A. The QFD chart is a tool that allows us to easily visualize the way all of the requirements and specifications interact with each other. For example, the ‘roof’ part of the QFD, the triangle up top, shows us how each specification affects the others. If they are strongly related, we know that if one fails, the other will as well. Inversely, if they are negatively related, we know that failing one specification may actually help another. This helps us to keep track of how well we are succeeding with our design. Below the ‘roof’ is where the design requirements and specifications connect. This allows us to make sure that we have all of the proper specifications in terms of the requirements. If we do not have specifications corresponding to a requirement, it is clear that we are missing important specifications. A tabular representation of our design specifications is shown in Table 1.

Table 1. Technical Specifications for Case Design

<table>
<thead>
<tr>
<th>Spec #</th>
<th>Parameter Description</th>
<th>Requirement or Target</th>
<th>Tolerance</th>
<th>Risk</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight</td>
<td>Under 30 lbs</td>
<td>MAX</td>
<td>L</td>
<td>T,S,I</td>
</tr>
<tr>
<td>2</td>
<td>Size</td>
<td>Max combined 45 in</td>
<td>MAX</td>
<td>L</td>
<td>S, I</td>
</tr>
<tr>
<td>3</td>
<td>Stability</td>
<td>Sits flat on the ground when open, does not flip backwards.</td>
<td>EXACT</td>
<td>L</td>
<td>T, I, S</td>
</tr>
<tr>
<td>4</td>
<td>Durability</td>
<td>Able to survive 1 m drop on concrete, pass the ‘dog test’, and survive tests by local vets</td>
<td>NA</td>
<td>L</td>
<td>T, I, S</td>
</tr>
<tr>
<td>5</td>
<td>Power</td>
<td>Self-powered - Battery life = At least 6 hours, external power hook up</td>
<td>± 1 hr</td>
<td>M</td>
<td>T</td>
</tr>
<tr>
<td>6</td>
<td>Easy to Use</td>
<td>Easy access/connection to various ports, MyLabONE set at ideal viewing angle</td>
<td>NA</td>
<td>L</td>
<td>T, I</td>
</tr>
<tr>
<td>7</td>
<td>Easy to Set up</td>
<td>Easy access to accessories stored in case i.e. probes, keyboard, mouse</td>
<td>NA</td>
<td>L</td>
<td>T, I</td>
</tr>
<tr>
<td>8</td>
<td>Safety</td>
<td>Meets all US and international requirements for product safety</td>
<td>EXACT</td>
<td>L</td>
<td>A, S</td>
</tr>
<tr>
<td>9</td>
<td>Combo Set Up</td>
<td>Integrate MyLabONE with current Digital Radiography technology.</td>
<td>NA</td>
<td>H</td>
<td>T, A</td>
</tr>
</tbody>
</table>
There are three levels of risk, High, Medium, and Low for these goals. High risk corresponds to how difficult it is going to be to complete that specification. We have chosen the integration of the MyLabONE into the DR system to be our most difficult task. The DR system is known for being difficult when it comes to networking, and it is thus far unknown whether the two will be compatible. The compliance column represents how we are going to decide if our specification has been met. There are four possibilities: analysis (A), testing (T), inspection (I), and comparing to similar designs (S).

Chapter 2 – Design Development

2.1 Method of Approach:

To efficiently accomplish the goals we have defined, it is important to continuously keep in touch with the client. Keeping Vetel involved every step of the way will ensure that we will not stray from what they require. After our first meet and greet with Dr. Waldsmith, we had to start solving the problem by defining the project requirements as per our client’s wishes. Once the requirements had been established and agreed upon, we wrote out a set of technical specifications that met with the requirements. These specifications will later be used to verify that our design has met with our goals. During this time, we were also researching. We began to gather information we will need in order to begin the design process, as well as information on Vetel and its ideas.

2.1a Idea Generation

Our next step was to begin the brainstorming process, using techniques such as a ‘morphological attributes’ list and ‘scatter’. From there we were able to narrow our ideas down to a list that best satisfies our requirements and specifications, as well as look the most aesthetically pleasing.

Our initial idea generation session used morphological attributes lists in order to generate ideas on how to design several important components of the larger design. The components we chose to focus on were the placement of the ultrasound device within the case, the type of material best suited for the insides of the case, the best type of battery, and the type of compartment doors.

2.2 Structured Solution Process

It quickly became clear as we went through the list of important components that a couple of them did not require a long list of different options. The list of possible batteries consisted solely of sealed lead acid and any kind of rechargeable battery pack. The possible solutions to the other components are as follows.
2.2a  Types of Material

We decided on a list of three different types of materials we could use in the case. First was the type of foam that comes perforated in cubes. This type of foam allows the builder to simply pull out the cubes he or she does not want, in order to create any type of shape desired. This foam would allow for an easy setup, however the visual appeal of it is very low. Next was simply a single piece of foam. Instead of pulling out pieces as before, the holes would have to be cut out of the foam. Again, this is not very visually appealing. Finally, using a single piece of foam, in order to hold components like the probe and the gels, and covering it in a piece of 1/8 inch thick colored plastic. This would allow for a sleek, professional look, and still protect the case components.

Table 2: Design Matrix for Packing Material

<table>
<thead>
<tr>
<th>Packing Mat'l</th>
<th>Ease of Setup</th>
<th>Safety of parts</th>
<th>Visually Appealing</th>
<th>Holding ability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt.</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Foam squares</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>53</td>
</tr>
<tr>
<td>Plastic Top + One Piece Foam Under</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>71</td>
</tr>
<tr>
<td>One piece foam</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>59</td>
</tr>
</tbody>
</table>

As you can see from Table 2, we have weighed the three choices against each other. The most important design consideration is the visual appeal, and the least important consideration is the ease of the setup. With these weights, we have found the best choice to be the plastic cover with foam beneath.

2.2b  Compartment Doors

Upon deciding the type of packing material, it became clear that we needed to decide upon a way to access the everyday use items easily, and still maintain the sleek and professional look. These items would be held in the foam base, and the plastic above it would need to be able to open.

The sliding door design, Figure 1, requires that one piece of plastic slides beneath the other in order to reveal the compartment underneath. It is a simple and easily produced solution; however it will cause the plastic to be at different heights in some parts of the case. This will detract from the overall look. This solution also requires that we have twice the amount of space needed for a compartment, so that the sliding piece will have the room to move aside.
In order to compensate for the space issue on the sliding doors, we also designed a sliding door that can roll up, Figure 2. The top of the door will be a seamless piece of plastic; however the bottom will have slits cut in it. This will allow the door to bend and roll. We can then have a sliding door that does not take up much space. However, this design will require more work to create than the others.

To best use space, we designed a door with hinges, Figure 3. The door would be able to be lifted up to reveal the compartment beneath. The hinges detract from the seamlessness of the look we are aiming for; however it is the easiest door.

Our final possibility is the flip door, Figure 4. This door pivots on hidden brackets to open vertically. The door can be opened either by pressing on the backside of the door, or in this case the left side or it may be lifted by the small handle. This will keep the seamless look, and it will add to the visual appeal of the case functionality.

### Table 3: Design Matrix for Compartment Doors

<table>
<thead>
<tr>
<th>Hideaway Doors</th>
<th>Visual Appeal</th>
<th>Ease of Setup</th>
<th>Ease of Use</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt.</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Hinge in Back</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Roll Away</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>Sliding</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>48</td>
</tr>
<tr>
<td>Flip</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>53</td>
</tr>
</tbody>
</table>

Table 3 shows that the visual appeal of the compartment doors are more important that the ease of use and the ease of setup. From these three considerations, we found that the flip doors are the best choice for this case.

#### 2.2c Ultrasound Placement

The decision on where to place the ultrasound systems in the case did not require several different versions. The nature of this piece of the puzzle allows us to simply study the components and the shape of the case itself to discern where the problem areas might occur, and where the user gets the best functionality out of the product.
In the case of the MyLabONE system, it is clear that it needs to be placed centrally in the length of the case, and towards the back of the width. Beyond the visual appeal of this placement, this allows for the weight in the case to be more evenly distributed, as the MyLabONE system is a fairly heavy piece of equipment. Placing the system to either side would make it awkward to carry around and placing it further forward in the case would make the case more likely to tip when set upright.

We are currently assuming that the weight of the MyLabONE, coupled with the weight of the extra components discussed later will compensate for the case’s tendency to flip when opened. If this assumption proves false, we will move the MyLabONE forward in the case until the weight distribution is correct.

2.3 Concept Designs

Our design for the MyLabONE ultrasound device is shown in Figure 5. Since this device is essentially a touch screen computer with ultrasound capabilities, we have incorporated a Digital Radiographer into the design. Essentially, we have chosen to take Vetel’s DR system and replace the original computer with the MyLabONE and its XP operating system.

![Figure 7. Configuration of MyLabONE Case](image)
As you can see from the diagram, the MyLabONE is placed centrally in the case, with the necessary components for using it placed around it. In order to protect the system from damage, and yet still maintain a sleek, professional look, we have chosen to use a piece 1/8 in thick plastic set on top of a single piece foam to hold everything in place. The ultrasound system is placed in the case at the optimum viewing angle required for the MyLabONE, and it is sunk about 2 inches deep. We plan on placing the system so that the top of the plastic will just meet with the bottom of the MyLabONE screen. The edge of this plastic piece will be covered in a type of smooth, weather resistant material in order to protect the MyLabONE from damage while the user slides the system in and out. Toward the rear of the case, the battery pack portion of the system will be able to be pressed into a pair of clips. These clips will be attached to the bottom of the case, and will prevent the system from sliding.

The Digital Radiographer will be kept in the top of the case, as it is in Vetel’s current case, and a piece of foam will be strapped over it for protection when it is not in use.

The idea behind this design is that when the case is closed, the top of the MyLabONE will be fit snugly against the foam in the lid, providing an even more secure hold against possible traumas. Beneath the MyLabONE will be a layer of closed cell foam about a ½ inch thick.

On either side of the MyLabONE are the storage spaces for the necessary system components. These include the power supply, the gel and cleaning solution, a probe, and batteries. The extra battery space we have included will be used by the rechargeable Li-Ion battery pack discussed later. These components will be placed in the underlying foam base in order to achieve as little movement of the components as possible, as well as to provide protection for the fragile probes. In order to make the gels and probes easily accessible, the plastic above those compartments will be hinged, Figure 6.

As you can see from the figure above, the hinges for these doors will allow for the door to flip up. The user may press down on the hinge side or lift the handle in order to cause it to pivot and reveal the compartment underneath. The door above the probe compartment will have a thin layer of foam covering the bottom of it, so as to better protect the probe.
Chapter 3 – Final Designs

3.1 Original Final Design

Our original design for the final case design included the use of pneumatic cylinders to lift the MyLabONE system up to a user friendly level. During the manufacturing portion, it became clear that the cylinders chosen would be unable to function properly without access to continuous compressed air. Due to this, we redesigned the easel portion of the design to eliminate the cylinders.
3.2 Final Design

The digital radiographer and its respective components will be placed and mounted in a similar fashion to past Vetel cases. The best location is in the top of the lid which will provide ample space for the MyLabONE and its components in the base of the case. The lid will be composed of a “sandwich” of components, consisting of two plastic sheets held apart by rubber and metal columns. The area between the two sheets will hold the necessary DR wiring, including...
the DR power supply and motherboard, the USB hub power supply, an Ethernet hub, and the various wiring for the DR ports.

B. Protective Metal Sheet

The aluminum cover shown will provide a stable and safe surface for the components of the MyLabONE and the closed cell foam underneath. The metal will be powder coated, and thus be rust free as well as scratch resilient. Powder coated aluminum was chosen for its light weight, and its scratch resistant surface. In the medical field it is crucial to have sanitized instruments. Although plastic and aluminum are lighter then steel they can easily be scratched. Any scratches, crevices, or tears can become a hot spot for bacteria to grow and eventually spread. Even with proper cleaning practices this bacteria may still be present. Bacteria can kill the patient. This cover can also be taken out and easily cleaned greatly reducing the chance of bacteria growing on the surface. The metal sheet has three small holes in it that allow for the battery switches, as well as the wires that will travel from the top of the case to the bottom. Specs for aluminum can be seen in Appendix B.4.

C. Probe and Battery Compartment

In order to allow the user to carry important equipment, we have designed two storage compartments. The delicate probe will be stored in this larger compartment, with the cases battery pack placed at the bottom. A layer of foam will protect the probe from the batteries.

C1. Battery Pack and Charger

One of the ultimate goals of the case is to have it be completely self-powered. While it is a ways from being able to power the DR portion of it as well, we have designed the case to provide extra charge for the MyLabONE system. The battery pack will
consist of 8 3.7V, 10 Ah lithium polymer cells. The cells will be set up so that 4 in series are in parallel with another 4 cells in series. This will create a 14.8V, 20 Ah pack, which should be sufficient to provide extra power to the MyLabONE. The analysis of this battery pack can be found in Appendix C. Due to the amount of amp hours this battery pack has, we need to use a specialized charger. The charger is variable and can handle more than one type of battery. Both the pack and the charger will be stored in the large accessories compartment. The battery pack will be stored in the bottom part of the compartment, while the charger will be stored towards the top. This will allow the charger to be accessed and visible to the user.

C2. Probe Location

The probe for the ultrasound system will be stored above a layer of foam that covers the battery pack in the large accessory compartment. The compartment will be fully covered in foam in order to protect the delicate probe.

C3. Inverter Location

In order to power the MyLabONE through a battery pack, the systems power supply requires a 120V input. The output of the battery is 12V, therefore there is a need to change the batteries output. As the output of a cigarette lighter in cars outputs approximately the same voltage, we chose to use an automotive power inverter. This allows us to hook the battery up to the inverter and plug the power supply for the MyLabONE into the other side. Because of space, we have chosen to place the inverter in the lid of the case, along with the DR components. This will cause extra wires to move back and forth between the case sides, but the case will have a better visual appeal without a large inverter in plain sight.
C4. Power Supply Location

The power supply for the MyLabONE will also be placed in the bottom of the large accessories compartment. This will allow it to be easily accessible should the user wish to take the MyLabONE out and use it without the case.

D. Inner Foam

Closed cell foam is fairly dense foam that is waterproof, strong, and resilient. It is ideally suited for products requiring shock absorption. This padding is a great way to diminish effects of vibration and dampening. The foam is designed to surround and protect the important and fragile components, as well as keep them in place during transit.

E. Outer Casing

Princeton Case West has been manufacturing cases for Vetel Diagnostics for several years now and we will continue to use their cases. The case is made from a strong and durable plastic that will help protect its contents. The case dimensions will be 28”x19”x10”.

F. Accessories Compartment

The flip-open compartments were chosen for their ability to be visibly appealing as well as very efficient in space saving. This design places the latch as close to the inside wall of the case as possible when opened and also provides a smooth flat surface in line with the top surface inside the case. It is important to have enough space in the case to carry all of the necessary components. This reduces the number of items to be carried in travel and in turn can reduce travel costs.
G. MyLabONE Easel

Paired with the platform and slider will be an easel that holds the MyLabONE safely in place. The user will be able to detach the system from the case and slide it up out of the easel. The surface of the easel will be covered in closed cell foam, in order to protect the system from damage. At the bottom of the easel is a hole to allow the user to connect the power, as well as to allow the system to vent. Due to the weight of the MyLabONE system, the easel will be made of stainless steel. This will allow for the easel to have the strength to resist bending beneath the weight of the system, and will also resist scratching. The steel will also be powder coated to add to the visual appeal of the case.

The same closed cell foam used to line the case will be used to line the easel. This will provide protection for the MyLabONE against the metal of the easel. The user is able to wedge the bottom of the system into the foam cut out, and still retain access to the ports.

H. MyLabONE Base Platform

Although the friction hinges could be attached directly to the bottom of the case, in order to give the entire easel system more rigidity, we have chosen to attach a stainless steel T plate to the case bottom. The friction hinges are attached to this plate. The stainless steel does not allow for excessive bending when the friction hinges are being used, which is ideal. The case plastic is more likely to deform and possible break under the pressure of the friction hinges.
I. MyLabONE Slider

A slider will be used to raise the scanner (MyLabONE) just above the foam once the case is opened for accessibility. The scanner can be rotated from 0°-270° for the optimum viewing angle at any height. This is made possible by use of stainless steel friction hinges.

3.3 Prototype

During the manufacturing process, the build ran into several design considerations that were previously unmentioned. This caused the case design to be restarted several times. As the deadline grew closer, we were unable to completely redesign the case for the last problem, and this has caused our prototype to differ slightly from our design.

In essence, this prototype is a proof of concept, and allows the sponsor to prove to Esaote that this case does hold all of the necessary components for both an accessible ultrasound and a DR system. After this project is finished, the sponsor will be creating more cases based on our final design.

Out prototype design uses a case that is 22x19x10 inches, which is the maximum depth Princeton Case West is able to make the case. This height allows to MyLabONE to be pressed into the case when it is closed, and therefore secured during transit. This case is the same size as the case used for Vetel’s Empower Wireless Portable case, which allowed us to acquire it for cheaper than special ordering an uncommon size.
This size, although able to accommodate the majority of the components, was unable to allow the user to plug devices into the system. The most important piece of this proof of concept case, however, is the easel. Space for various accessories can be designed in during the next design iterations, a process that Vetel is continuously performing for all of their cases, but this our main goal for this case was to successfully prove that our answer for holding the ultrasound system was valid.

As you can see in Figure 22, the majority of the space in the prototype is taken up by the MyLabONE and its need for some port room. It is because of this that we have added an additional 6 inches to our design. This will allow the area for the probe, seen on the right side of the case, to be enclosed in a compartment for better visual appeal. In addition, that extra six inches will allow for the 8 lithium polymer batteries and their charger to be placed in the case. For this prototype, space dictated that we not include the battery pack that would cause the case to be self powered.

Although we were unable to include the battery pack, we were able to build it. The cells were set up so that 4 in series are in parallel with another 4 cells in series. This 14.8V, 20 Ah pack, which should be sufficient to provide extra power to the MyLabONE, however we were unable to test its capabilities once the pack was removed from the prototype.
On the right side of the prototype is the space for the probe and the MyLabONE power supply. This power supply sits under the probe foam, and is connected to the outlet in the top of the case. It is secured to the case with Velcro, and so is easy to remove and use outside of the case.

The probe is stored in this prototype while still connected to the MyLabONE system. The probe head is placed into of a cavity to provide the best protection for it during transit, and the cord is wound up and secured through Velcro straps.
The most important part of the prototype is the easel. This piece allows the user to place the system at any angle, and with the addition of the slider, allows for it to be placed at any height as well. A sequence of the system being angled and raised is shown below.

Figure 30. MyLabONE Angling and Raising Sequence
Being able to raise or lower the system as well as angle it to precisely the right angle for any situation gives this case a huge advantage. A user of any size in any lighting situation will be able to move the screen to its optimum viewing placement with a simple push or spin of a knob.

As mentioned before, the easel travels up and down using a 3/8 inch bolt, a guide covered in a layer of rubber, and a star knob. This combination of parts allows the user to easily loosen the easel from its position and raise or lower it as they require. The layer of rubber reduces the noise level and increases the ease with which the knob can be tightened to hold the system. Despite the weight of the MyLabONE and easel, the knob needs only be lightly hand tightened to hold its load in place.
The second half of the case is devoted to the DR system. In order for the system to function, there are several electronic pieces that need to be included in the case. Similar to an old Vetel case design, we chose to make a sandwich of these electronics between two sheets of metal/plastic. Because we had to use what was available to us at the Vetel offices, the bottom sheet was made of lightweight plastic, while the top was made of thick aluminum. This metal sheet added several pounds to the overall weight, and could easily be replaced with another plastic sheet when the sponsor begins manufacturing this design. The two sheets were held apart by four metal columns bookended by thick rubber feet. These feet help absorb shocks and allow the electronics to be protected from mishandling.

Figure 37 shows the DR power supply and the circuit board required for the system to function. In addition to these two components, there are two plugs for the panel and the emitter, as well as a female power plug for the emitter to plug into. An Ethernet port and a USB hub, not included in Figure 36, are also placed on the top of the plate. A male power plug is used to power all of the components inside of the sandwich. These inner components are shown and discussed on the next page.
Underneath the top plate are all of the components to run the DR system, and to connect it to the MyLabONE. The DR power supply, the USB power supply, the MyLabONE power supply, and the female power plug are all hooked up the power hub, with the male power plug (which is plugged into a wall during use) hooked up to the other side of the hub. Power is distributed to all components in this fashion. The DR power supply, both DR plugs, and an Ethernet cable is connected to the circuit board. That Ethernet cable, along with one from the USB to Ethernet box, and on from the Ethernet port on the top of the plate are connected into the Ethernet hub.

All of these components are attached to either plate using industrial strength Velcro, and the wires are restrained with zip ties. The two plates are connected together using several screws. The bottom plate is attached to the case by four screws. These case screws were tightened so that the case remained water tight.
Once the sandwich is completed and connected to the case, a layer of foam is placed over the top. The foam cutout for the DR panel is placed to the side of the port area, and the foam cover is placed over top. For shipping, an extra piece of foam is placed over the port area. The finished product is shown.

Figure 39. DR Panel Storage and Port Access
Once the case was finished, we set up the DR portion to test if the electronics were functioning. All of the cables were hooked up, with one of the most important cables attached to the side of the case to ease the strain felt by the port. The emitter was powered by the case, and an ethernet cable connected to a laptop.

Figure 40. Case Set Up For Testing
In this case, a laptop was used in place of the MyLabONE due to the operating system that is currently being used on the ultrasound system. The DR software requires Microsoft XP Pro, which the MyLabONE does not currently have. However, the sponsor has met with Esaote and spoken about updating the MyLabONE OS. As Esaote was pleased with the design of the case, particularly the easel, they were inclined to update the ultrasound system for Vetel Diagnostics. In the future, the laptop will be replaced with the MyLabONE.

The DR system was tested several times on Tobe Johnson, and worked successfully every time.
As a proof of concept, this prototype has worked perfectly. The next design iteration will take the main components of this prototype and integrate them into a larger case, with more room for more components, and more design appeal.

3.4 Cost

Manufacturing for the designed parts including the machining and cutting of the case, stainless steel sheet and foam material will be free as we are doing all the work. The prototype cost $680.00 ± $40. The cost breakdown is as follows:

- Aluminum Metal Sheet - $30
- Case - $150
- Friction Hinge (2) - $120
- Platform, Slider, Easel for MyLabONE (Stainless Steel) - $100
- Batteries (8) - $160
- Charger - $80
- Switch (2) - $10
- 12V inverter - $30
- Additional Circuitry - $30

3.5 Material and Component Selection

The foam we chose is the closed cell variety which yields a high dampening ratio. As vibrations are eminent, oscillation will be present. The high dampening coefficient greatly reduces the vibrations which can be proven by the decay factor; \( e^{-\xi t} \) which is present with all oscillating functions. The larger the dampening coefficient, the faster the exponential decay to a steady state value, i.e. no oscillation.

Industrial strength plastic will be used to manufacture the case at Princeton Case West. This case can be seen in Appendix C. This material is very durable, rugged, and has high yield strength. Plastic deformation will not be a concern for our project as the hinges on the case will fail before the case experiences critical failure.
Chapter 4 – Manufacturing and Testing

4.1 Manufacturing

Our case was formed from a flat piece of plastic and a large press. Once the case is pressed the extra material is trimmed off. A metal rib is placed around the edge of the case, its opposite is placed on the other half of the case, and then the two halves of the case are placed on top of each other. This forms a temporary seal. Next, hinges were placed on the back side of the case and riveted in on both pieces of the case. The two case sections were now permanently attached. A handle and two locking latches were then placed on the front of the case in a similar manner. This finished the assembly/production of our case.

The top cover, originally made from SS304, was cut to size using a large foot operated shear. Once sheared, we ground the edges back to form a radius to match the inside of the case. The cutout for the MyLabONE and the hinged door were done with an angle grinder and a cutting wheel, as seen in Figure 44. This method required a lot of patience and a steady hand. SS304 is a very tough material. Later on in the project we realized the case needed to be remade to account for new parts. In doing so the top cover needed to be remade. The second time around we emailed a Solidworks file to a local machine shop and had them cut tout the shape as desired out of AL6061. This material is considerably cheaper and easier to work on. To maintain the scratch resistant qualities of the SS304 we had the aluminum top cover and hinged door powder coated. The top cover is held up by small v-shaped aluminum pieces, shelves that are riveted into the case. The top cover is screwed into those shelves to prevent it from coming out of the case.
Our easel was made from the same SS304 material as mentioned above. We used a combination of the shear, angle grinder, and a dremel tool to cut all the pieces to size as well as deburr it. Another student on campus, who is also a shop tech, helped us weld the easel pieces together with a stainless steel rod, as seen in Figure 45.

![Figure 44. Easel Being Welded](image)

A 3/8-16 bolt was then welded onto the backside of the easel. This would be used to assist the easel to move vertically to accommodate for the user of our system. After the easel was assembled, we made the easel slider from sheared aluminum pieces. Once those were tig welded together in the shape of a T, similar to the easel, we cut out a large vertical slot that the easel bolt could travel along. Once the easel is positioned at the desired height, it could be synched into place with a 3/8-16 star knob, attached on the backside. An easel base was then made out of SS304 which we bolted into the bottom of the case. The easel slider was then attached via 2 friction hinges to the base and could now pivot up from the bottom of the case when in use. This full apparatus can be seen in Figure 43.

![Figure 45. Easel Set Up](image)
The closed cell foam was originally cut by hand with a bread knife. The results were “acceptable” but more or less disastrous. We went back to the case manufacturer, Princeton Case West, in Santa Maria and the owner, Jim, was kind enough to help us with any foam we needed. He used a large ban saw and a sanding wheel to cut the foam pieces to the exact sizes needed. Hot glue was used to attach the foam pieces together.

4.1a Manufacturing Suggestions

Originally, we believed that post project, the sponsor would be able to use aluminum to replace the stainless steel we used in the easel. However, after the slider was manufactured out of 1/8 inch aluminum plate, we were easily able to see the amount of deformation it sees under the weight of the MyLabONE and easel. In particular, when the system is placed as high up as possible, the slider tends to bend and wobble. Because of this, we suggest continuing to use steel, either stainless or powder coated. Due to the cost of the MyLabONE, we believe the extra strength is much more important than price to manufacture.

4.2 Testing

We had a couple design requirements to meet. One of them was a drop test from a distance of 1 meter straight down onto a hard surface. The case and its components would be dropped from the hanging position, mimicking a person dropping the case while carrying it. We later determined that the drop test would be too risky with the MyLabONE and the Canon Digital Radiographer inside. Instead, the sponsor travelled 4,500 miles by plane with the case and all the electronic equipment inside. Fortunately, there was no damage to the case or its contents. This long journey was substituted for the drop test.

The other main test was the “dog test”. This test was to verify that the case had a tight seal and would be water proof. This is a very important design criterion to meet because of the value of the contents inside. To test this water tight seal we poured water out of a bucket with a constant flow rate. The water was poured over the screws, Figure 47, that are exposed to the outside as well as the metal seal from the two halves of the case. No water leaked into the case when pouring the water over the screws, which was our main concern. There was indication that the water had leaked into the case when pouring water over the metal.
This does draw concern, but not too much. Our reasoning for the lack of concern is that during the middle of build our sponsor made aware that we needed to add additional parts to our case which we did not have room for. We had to transfer the lid (had an extra inch in depth) from another case and mount it onto the bottom of our current case. Although the two case halves have the same length and width dimensions, no two cases have the same seal. This is because the seal is formed when the two pieces of the case are pressed together. When we introduced a different top portion to our bottom portion the seal was already going to be off. We tried to get the best possible seal by attaching two compression latches which would help synch the two pieces together. Unfortunately, this did not solve the problem but we are confident that when another case is made it will have the proper seal needed to keep the water out. A small thin rubber lining can be added if needed in the future.

The stability design criterion was omitted due to the late sponsor requested changes in the design. The top portion of the case had a considerable amount of weight added to it. It was enough to make it difficult to prevent the case from flipping over. Now, we decided that it is best for the top lid to be opened all the way, shown in Figure 48. This eliminates the need for stability in the case.

The DVPR form for the various tests can be found in Appendix E.

4.3 Management Plan

Team Eye-Spy has a very limited number of teammates. Because communication is a very big part of success for most things in life we have decided to give a very fair 50/50 split for roles to take during this project. To make communication less complicated between us and our sponsor, we both agreed that Katie will be in charge of emailing the sponsor. However, both teammates are responsible for monitoring the emails. This helps prevent a time lapse in any emails to or from the sponsor. Both team members are responsible for gathering data needed to successfully meet and exceed the requirements given to us by our sponsor for the project. Documentation and design progress is also equally shared. We meet three times per week to continue working on the project, as well as exchange any information we couldn’t relay over the phone or by email. Tobe is in charge of the prototype fabrications. Both team members will compile their manufacturing considerations, but this will be led by Tobe. For testing, both team members will meet with the sponsor to do on-site testing. Real world use will yield better real world results. Configuration of each component in the case will
be determined by both team members. Sealing devices/material will be designed/chosen by both team members as well.

Below is a time table of the dates for project advancement to completion.

**Time table:**

- Project Proposal – October 19, 2010
- Conceptual Design Review with Sponsor – December 12, 2010
- Design Report – February 1, 2011
- Status meeting with Sponsor – February 1, 2011
- Project Update Memo – March 8, 2011
- Design Expo – June 2, 2011
- Final Report – June 4, 2011

A more comprehensive time table can be found in the Gantt Chart in Appendix B. This Gantt Chart shows each step involved in the entire project process and it’s corresponding estimated time.

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**Chapter 5 – Conclusion**

We have concluded the design, build, test project for our portable ultrasound case. Although the final prototype does not include all of the components we have designed it for, it has still successfully proved our concept is functional. The largest hurdle was keeping up with the new design requirements that were unforeseen as the project progressed. With proper communication and good team work/ethics we were able to conquer these hurdles and exceed expectations within our given time frame. As we were told by our Sponsor, Dr. Waldsmith at Vetel Diagnostics, Esoate representatives were very pleased with our design which in itself was a huge success. The easel was dubbed “the missing link” for the MyLabOne case project. With our easel design the cases’ value and functionality out in the field has greatly improved from past designs and will gain interest from many professionals in the field of medical treatment. Team Eye-Spy would like to thank Dr. Waldsmith, Jim at Princeton Case West, our project advisor Sarah Harding, California State Polytechnic San Luis Obispo and its staff, for all the hard work and continual support, help, and guidance received throughout the project.
5.1 References

K.M.T - www.kmt-aktuell.de

Vetel Diagnostics - www.veteldiagnostics.com

Esaote - www.esaoteusa.com
Larger is Better
Nominal is Best
Smaller is Better

- Strong Positive Correlation
- Positive Correlation
- Negative Correlation
- Strong Negative Correlation

Customer Description:
1 = Dr. Waldsmith
2 = Vets and Assistants
3 = Zonare

Customer Requirements (Whats)

1. Light weight
2. Durable
3. Stable
1. Ease of setup
1. Self Powered
1. Combine Mylab1 and Digital Radiography
2. Physical size
2. Ease of use
1. Extra storage

Specifications (Hows)

Appendix A: QFD Chart
Appendix C: Analysis

C.1 Battery Life

(Considering only the approximated MyLabONE wattage)

\[ P = 25 \text{W} \]

\[ P = VI \]

\[ I = \frac{25 \text{ W}}{14.4 \text{ V}} \]

Therefore, the current being pulled from the battery by the system is:

\[ I = 1.736 \text{A} \]

Battery Life for a 20Ah system = \(\frac{20 \text{ Ah}}{I} = \frac{20 \text{ Ah}}{1.736 \text{A}}\)

Battery Life = 11.52 Hours
Appendix D: Vendors and Pricing

**Vendors, Products, Pricing and Information**

**Ebay.com**

Batteryworld.123 – 3.7 V 10Ah Lithium Polymer Battery $22.95

**All-Battery.com**

*Tenergy Vantage B6s Advanced Balancing Charger + Power Supply*

Supports multiple types of battery packs with one single charger

- NiMH/NiCD 1~15 cells (1.2v to 18v)
- Li-PO/Lithium Ion 1~6 series (3.7v to 22.2v)
- Li-Fe 1~6 series
- Sealed Lead Acid (SLA)

**Charger Specifications:**

1. Handle NiMH, NICD, Li-Po, Li-ion, Li-Fe, SLA Batteries
2. Build-in Balance
3. Temperature Sensor
4. DC 11V~15V, which can be directly connect to Automobile Battery. The working electric current is less than 5A when it is charged in full load. The current of the fuse is 10A which could prevent short circuit. You can use [Wall Plug AC-DC12V/5A Switching Power](#) as an power source.
### Specification

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#### Individual cell connection diagram (pin-assignment of 8-pin)
Model Brand
   Cobra
Model
   CPI 480
Spec Type
   Power Inverter
Dimensions & Weight
   6.45” x 4.17” x 2.59” / 2 lbs.
### Ultra-Strength Silicone Rubber

**Part Number:** 5781T49

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<td><strong>Notes</strong></td>
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Diamond Metal Tech
Precision Sheet Metal Fabrication

Full Spectrum Powder Coating
Local Powder Coating Company

Easel Machine Shop Suggestions

Gentry Welding & Fabrication
* (805) 544-4130
3547 S Higuera St, #H, San Luis Obispo, CA 93401

Phoenix Fabrication
2830 Mcmillan Ave # 4, San Luis Obispo, CA 93401-4701
(805) 543-2230

Abraham Steel Fabrication Inc
2741 Mcmillan Ave # B, San Luis Obispo, CA 93401-6796
(805) 544-8610
"Million Mile Warranty"
YOU BREAK IT... WE REPLACE IT, FOR FREE, FOR LIFE!

MR SERIES
TRANSPORT CONTAINERS
WITH RETRACTABLE HANDLES
AND WHEELS

FEATURES INCLUDE:

- Case shells are molded of durable, impact resistant high density polyethylene.
- Convenient retractable pull-handle.
- Quiet, durable roller-blade style wheels.
- Molded-in protective bumpers protect hardware.
- Heavy-duty twist latch system.
- Comfortable, spring loaded side handles.

Now available in 14 stock sizes.

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## Mechanical Properties

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</tr>
<tr>
<td>Tensile Yield Strength</td>
<td>276 MPa</td>
<td>40000 psi</td>
<td>AA, Typical</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>12 %</td>
<td>12 %</td>
<td>AA, Typical, 1/16 in. (1.6 mm) Thickness</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>12 %</td>
<td>12 %</td>
<td>AA, Typical, 1/2 in. (12.7 mm) Diameter</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>68.9 GPa</td>
<td>10000 ksi</td>
<td>AA, Typical, Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.</td>
</tr>
<tr>
<td>Notched Tensile Strength</td>
<td>324 MPa</td>
<td>47000 psi</td>
<td>2.5 cm width x 0.18 cm thick side-notched specimen, KI = 17</td>
</tr>
<tr>
<td>Ultimate Bearing Strength</td>
<td>607 MPa</td>
<td>88000 psi</td>
<td>Edge distance/pin diameter = 2.0</td>
</tr>
<tr>
<td>Bearing Yield Strength</td>
<td>386 MPa</td>
<td>56000 psi</td>
<td>Edge distance/pin diameter = 2.0</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
<td>0.33</td>
<td>0.33</td>
<td>Estimated from trends in similar Al alloys.</td>
</tr>
<tr>
<td>Fatigue Strength</td>
<td>96.5 MPa</td>
<td>14000 psi</td>
<td>AA; 600,000,000 cycles completely reversed stress; RR Moore machine/specimen</td>
</tr>
<tr>
<td>Fracture Toughness</td>
<td>23 MPa-m²</td>
<td>26.4 ksi-in²</td>
<td>Kic; TL orientation</td>
</tr>
<tr>
<td>Machinability</td>
<td>60 %</td>
<td>60 %</td>
<td>6-100 Scale of Aluminum Alloys</td>
</tr>
<tr>
<td>Shear Modulus</td>
<td>26 GPa</td>
<td>3770 ksi</td>
<td>Estimated from similar Al alloys</td>
</tr>
<tr>
<td>Shear Strength</td>
<td>207 MPa</td>
<td>30000 psi</td>
<td>AA, Typical</td>
</tr>
</tbody>
</table>

## Electrical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Metric</th>
<th>English</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Resistivity</td>
<td>3.99e-006 ohm-cm</td>
<td>3.99e-006 ohm-cm</td>
<td>AA, Typical at 68°F</td>
</tr>
<tr>
<td>Item No</td>
<td>Test Description</td>
<td>Acceptance Criteria</td>
<td>Test Stage</td>
</tr>
<tr>
<td>--------</td>
<td>------------------</td>
<td>---------------------</td>
<td>------------</td>
</tr>
<tr>
<td>1</td>
<td>Weight; Case with all Components</td>
<td>&lt; 30 lbs</td>
<td>Poor</td>
</tr>
<tr>
<td>2</td>
<td>Total Dimensions of Case</td>
<td>&lt; 45 inches MAX</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>Stability; Open Case, Force of 15 lbs applied at top of lid, parallel to ground, in direction of visible screen</td>
<td>Case doesn’t flip over</td>
<td>Acceptable</td>
</tr>
<tr>
<td>4</td>
<td>Durability; Suspend 1 m drop onto concrete</td>
<td>Internal Electronic parts still work and case remains sealed</td>
<td>Good</td>
</tr>
<tr>
<td>5</td>
<td>Leak Test; Pour 16 oz water over seal</td>
<td>No visible leaks after 15 minutes</td>
<td>Good</td>
</tr>
<tr>
<td>6</td>
<td>Power; At full power, operate without failure or shutdown</td>
<td>Operational time of 6 hours ± 1 hour</td>
<td>N/A</td>
</tr>
<tr>
<td>7</td>
<td>Ease of use; Time how long to connect/disconnect cables to ultrasound systems</td>
<td>&lt;1 minute to connect/disconnect cables to ultrasound systems</td>
<td>Good</td>
</tr>
<tr>
<td>8</td>
<td>Setup; Time how long to attach accessories</td>
<td>&lt;1 minute to connect/disconnect cables to ultrasound systems</td>
<td>Good</td>
</tr>
</tbody>
</table>

**Component/Assembly**
- Ultrasound case
- Vetel Diagnostics
- MyLabOne

**Sponsor:**
- Tobe/Katie
- Russ

**Report Engineer:**
- Tobe/Katie

**PROJECT:**
- Ultrasound case

**Appendix E: DVPR**

<table>
<thead>
<tr>
<th>Item</th>
<th>Test Description</th>
<th>Acceptance Criteria</th>
<th>Test Stage</th>
<th>Test Result</th>
<th>Responsibility</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight; Case with all Components</td>
<td>&lt; 30 lbs</td>
<td>Poor</td>
<td>Tobe</td>
<td>Poor</td>
<td>Failure okayed by sponsor</td>
</tr>
<tr>
<td>2</td>
<td>Total Dimensions of Case</td>
<td>&lt; 45 inches MAX</td>
<td>Poor</td>
<td>Tobe</td>
<td>Poor</td>
<td>Failure okayed by sponsor</td>
</tr>
<tr>
<td>3</td>
<td>Stability; Open Case, Force of 15 lbs applied at top of lid, parallel to ground, in direction of visible screen</td>
<td>Case doesn’t flip over</td>
<td>Acceptable</td>
<td>Katie</td>
<td>Tobe</td>
<td>Prototype top is not constrained at 90 degrees, due to the weight of the DR components.</td>
</tr>
<tr>
<td>4</td>
<td>Durability; Suspend 1 m drop onto concrete</td>
<td>Internal Electronic parts still work and case remains sealed</td>
<td>Good</td>
<td>Katie</td>
<td>Tobe</td>
<td>Test is not applicable</td>
</tr>
<tr>
<td>5</td>
<td>Leak Test; Pour 16 oz water over seal</td>
<td>No visible leaks after 15 minutes</td>
<td>Good</td>
<td>Katie</td>
<td>Tobe</td>
<td>Tightened screws do not leak; Batteries were taken out for testing.</td>
</tr>
<tr>
<td>6</td>
<td>Power; At full power, operate without failure or shutdown</td>
<td>Operational time of 6 hours ± 1 hour</td>
<td>N/A</td>
<td>Katie</td>
<td>Tobe</td>
<td>&lt;10 seconds to access/attach any given accessory</td>
</tr>
<tr>
<td>7</td>
<td>Ease of use; Time how long to connect/disconnect cables to ultrasound systems</td>
<td>&lt;1 minute to connect/disconnect cables to ultrasound systems</td>
<td>Good</td>
<td>Katie</td>
<td>Tobe</td>
<td>Vetel successfully made the two systems talk - all that is needed is XP Professional on the MyLabONE</td>
</tr>
<tr>
<td>8</td>
<td>Setup; Time how long to attach accessories</td>
<td>&lt;1 minute to connect/disconnect cables to ultrasound systems</td>
<td>Good</td>
<td>Katie</td>
<td>Tobe</td>
<td>Vetel successfully made the two systems talk - all that is needed is XP Professional on the MyLabONE</td>
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</table>