EAR TAG THERMOMETER FOR LIVESTOCK

Design Review

An ear tag that contains a thermometer to monitor herd health.

Connie Fan, Yue Wang, Michael Goldstein
ECE398PSC
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Ear tag thermometer for livestock

SECTION 1: INTRODUCTION

Statement of Purpose

Herd health management is insufficient as it costs the cattle industry over 2 billion dollars in losses annually. As of this year, there are about 92.0 million heads of cattle in the United States, an increase of 3% from 89.1 million heads in 2015. Of these cows, digestive and respiratory illness, mastitis, and other diseases kill approximately 1.5 million of them. Medicating herds presents myriad problems ranging from high operation costs, loss of organic status, animal death, overmedication, to antibiotic resistance. Since easily noticeable symptoms are not expressed until after the contagious period, illnesses are often spread quickly in herds and as of such, thereby exacerbating the problem of cattle medication further. It is difficult to isolate specific sick animals so medicine is often distributed through food to medicate large swaths of the herd. Due to this, herds are often overmedicated. Scientists have linked overmedication to antibiotic resistance in bacteria in humans and cattle alike—leading to a host of other problems for posterity.

In addition to health concerns, some farmers incur extra costs once they are forced to use antibiotics on cattle. According to the Division of Agriculture and Natural Resources at the University of California “there are no effective organically approved medicines for treating [certain illnesses] in cattle...if an organically certified cow or calf gets [ill] it is usually treated with a non-organically approved medication, removed, or...sold as conventionally raised beef” which leads to substantial losses for organic cattle farmers.

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The concerns raised in this section pertain only to cattle, once expanded to include other livestock such as pigs and sheep, the losses and damages are even greater.

Objectives

Overview
- Accurately take the temperature of an animal
- Stays securely fastened to animals and require minimal maintenance
  - No battery replacement needed for duration of host animal’s life
  - Reusable (if animal is slaughtered or retired)
  - Not costlier than normal ear tag installation
- Send timed updates to a central database
  - Accompanying software will show alerts for animals that may be sick
  - Accompanying software will store data to show trends
- Maintains functionality of normal tag
  - Shows animal identification
  - Barcode ties animal to lineage, health, and other records
- Humane and doesn’t harm the animal or interfere with certifications (e.g.: organic)

Goals
We want to construct a modified cattle ear tag that has a built in thermometer with a transmitter so that a farmer can monitor the individual temperatures within the herd. The device should be humane, robust, be easily installed, have the same functionality as a normal cattle tag, and affordable.

Consideration of Alternatives
Currently, there aren’t many alternatives to our proposed solution. According to the Princeton Veterinary Hospital, “farm animals are [good at hiding their illnesses], it can be difficult to see early signs …by the time you notice some of these signs, their sickness may have already been going on for some time.” Farmers and veterinarians can individually take the temperature of livestock and selectively medicate or just medicate the entire herd (as it the current practice) if several animals are ill.

Benefits
By knowing the temperatures of an animal, farmers can more accurate catch the warning signs of illness (such as respiratory infections, which kill 1,055,000 cows a year) and isolate sick animals thereby presenting rampant spread of disease. Additionally, knowing exactly which animals are ill and preventing the spread of disease lets veterinarians selectively medicate livestock—this keeps medication and vet bills low and allows the maximum number of animals to keep certifications. The augmented tag has the same information and

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5 Princeton Veterinary Hospital. “5 signs your farm animals may be sick.” Princeton Veterinary Hospital. 2015. Web. 11 Nov. 2016.

features as a normal tag, is reusable in the case of livestock harvest or retirement and does not require battery changes for the duration of the average livestock's lifespan.

**SECTION 2: DESIGN**

**Block Diagram**

![Block Diagram](image)

**Figure 1: Block Diagram**

**Block Descriptions**

**Thermistor**
Input: Power from Control Unit  
Output: Power to Control Unit  
This is just a thermistor designed to measure the temperature of the livestock. The resistor takes in power from the control unit and then outputs that power to the control unit again. Because the resistance varies with temperature we can measure the incoming current and voltage to calculate the temperature of the livestock.

**Control Unit**
Inputs: Signal from Clock, Power from Battery, Power from Thermistor  
Outputs: Data to Analog to Digital Converter, Power to Thermistor, Power to Analog to Digital Converter, Power to RF Transmitter
The control logic is all done in hardware. We have several counters attached to the clock to keep track of how much time has elapsed, and when it counts up to an hour it will reset itself and provide power to the thermistor, converter and transmitter. It will then keep providing power for around 1 second so that the readings from the thermistor has enough time to pass through the analog to digital converter and then transmitted by the RF transmitter.

**Analog to Digital Converter**
Inputs: Data from Control Unit, Power from Control Unit
Output: Data to RF Transmitter
This block is in charge of transforming the analog current readings it receives from the control unit into a digital signal that it passes to the RF transmitter.

**Table 1: Analog to Digital Converter Pin Layout**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-8</td>
<td>Takes in analog data</td>
<td>Current Reader</td>
</tr>
<tr>
<td>9</td>
<td>Grounds digital circuit</td>
<td>Ground</td>
</tr>
<tr>
<td>10</td>
<td>Controls chip on/off</td>
<td>Control Unit</td>
</tr>
<tr>
<td>11</td>
<td>Optional digital input</td>
<td>Not Used</td>
</tr>
<tr>
<td>12</td>
<td>Digital output</td>
<td>RF Transmitter</td>
</tr>
<tr>
<td>13</td>
<td>Clock</td>
<td>Clock</td>
</tr>
<tr>
<td>14</td>
<td>Grounds analog circuit</td>
<td>Ground</td>
</tr>
<tr>
<td>15</td>
<td>Reference voltage</td>
<td>Battery</td>
</tr>
<tr>
<td>16</td>
<td>Supply voltage</td>
<td>Battery</td>
</tr>
</tbody>
</table>

**RF Transmitter**
Inputs: Data from Analog to Digital Converter, Power from Control Unit
Output: Wireless Data to RF Receiver
This block takes the digital signal from the analog to digital converter and transmits it wirelessly to the RF receiver at 315 MHz. Our receiver only accepts ASK, so we will be using the ASK input of the transmitter.

![RF Transmitter Schematic](figure3.png)

Figure 3: RF Transmitter Schematic

![RF Transmitter Suggested Circuit](figure4.png)

Figure 4: RF Transmitter Suggested Circuit


<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ASK Data Input</td>
<td>Analog to Digital Converter</td>
</tr>
<tr>
<td>2</td>
<td>Reference Oscillator Input</td>
<td>Frequency Reference</td>
</tr>
<tr>
<td>3</td>
<td>Reference Oscillator Output</td>
<td>Frequency Reference</td>
</tr>
<tr>
<td></td>
<td>Ground</td>
<td>Ground</td>
</tr>
<tr>
<td>----</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Toggle for FSK Mode</td>
<td>Not Used</td>
</tr>
<tr>
<td>6</td>
<td>FSK Data Input</td>
<td>Battery</td>
</tr>
<tr>
<td>7</td>
<td>Chip Enable</td>
<td>Control Unit</td>
</tr>
<tr>
<td>8</td>
<td>Output Ground</td>
<td>Ground</td>
</tr>
<tr>
<td>9</td>
<td>Output</td>
<td>Antenna</td>
</tr>
<tr>
<td>10</td>
<td>Power Supply</td>
<td>Battery</td>
</tr>
</tbody>
</table>

**Battery**
Outputs: Power to Control Unit, Power to Clock
This is the battery that provides power for the ear transmitter. It provides power to the control unit as well as the clock.

**Clock**
Input: Power from Battery
Output: Data to Control Unit
This is the crystal acting as a clock for the ear transmitter. It allows the control unit to calculate how much time has passed in order to properly time when to transmit the data.

**Surge Protector**
Input: Power from Wall Plug
Output: Power to Raspberry Pi
This is the surge protector for the receiver unit. Since the power is being drawn from a wall plug, if there happens to be a current surge this will protect the rest of the receiver unit from being damaged.

**Raspberry Pi**
Input: Power from Surge Protector
Output: Power to RF Receiver
This is the calculating component of the receiver unit. It takes the current readings from the RF receiver and calculates the temperature that would cause those current readings. It can then store the data in its memory and later pass the data on through the built in USB adapter. Since the receiver unit is plugged into a wall, this is always on and ready to receive new data.

**RF Receiver**
Input: Wireless Data from RF Transmitter, Power from Raspberry Pi
Output: Data to Raspberry Pi
The RF receiver is always on and ready to receive new data from any of the ear transmitter’s RF transmitters at 315 MHz in ASK. Any data it receives will be sent to the raspberry pi unit for processing.
Software State Machines & Descriptions

State Machine – Thread 1 (processing received temperature notifications)
**ST_IDLE**
Does nothing until a temperature notification is received

**ST_RECEIVED**
Processes the temperature notification and adds it to the database of temperatures.

State Machine – Thread 2 (server upload control)

![State Machine Diagram](image)

**ST_IDLE**
Keeps a timer and after one hour, transitions to **ST_TRANSMIT**.

**ST_TRANSMIT**
Sends all new temperatures to the server via the internet.

**ST_WAIT_4_ACK**
Waits for an “ack” from the server. If none is received within 10 seconds the retransmit # is incremented and the state transitions to **ST_TRANSMIT**, unless the retransmit # is greater than 3 in which case it transitions to **ST_ERROR**.

**ST_ERROR**
Blinks a red LED.
### Requirements—Tag

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
</table>
| 1. Battery Life of 2 years  
  a. Battery must have capacity of at least \( 17500 \times x \text{ mAh} \) where \( x \) is the current the device draws on average, in mA  
  b. The unit must draw no more than \( \frac{175000}{y} \text{ mA} \) where \( y \) is the capacity of the battery in mAh | Using a minimization scheme, select parts such that both requirements are met according to the datasheet.  
  1.a: Simply select an appropriate part, check the datasheet to ensure the tolerance of the capacity still does not cause the requirement to fail.  
  1.b: Run the device for 1 day with an ammeter attached to the battery. The average current must be no more than \( \frac{175000}{y} \text{ mA} \) where \( y \) is the capacity of the battery in mAh. |
| 2. Thermal resistor must have a tolerance of no greater than 1% | Select a part that has a tolerance of no greater than 1%. Using a hot plate, heat a glass of water to 40 degrees Celsius. Place the thermistor in the glass of water. Ensure the measurement is exactly 40 degrees \( \pm 0.4 \) degrees. |
| 3. Must provide temperature updates to receiver at least once per hour | Setup the tag unit and the receiver. Leave both running for 24 hours. At the end of the trial, check the logs of the receiver and ensure that for every hour in the 24-hour period, it received at least one update. |
| 4. Thermistor must be able to operate in the range 30-50 degrees Celsius | Check the datasheet of the selected part and ensure its operable range is at least that wide. |
| 5. Must have a mass of no more than 150 grams. | Select parts such that the total sum of their weights is no greater than 150 grams (especially important for heavier parts like the battery). After the prototype is constructed, measure its mass on a triple beam balance. If the measured mass plus the tolerance of the balance exceeds 150 grams, the verification fails. |
| 6. The device must be humane and comfortable for the animal | Consult a veterinarian on the design and have it approved. Test the prototype on some animals and have a veterinarian confirm it is causing |
The device must continue to operate if it gets wet (water resistant)  

Drop the device in a glass of water at a depth of no more than 0.5m. It must continue to operate normally and transmit temperatures.

8. Must transmit to a receiver at least 50 meters away.  

Setup the device with a receiver that is 50m away. Perform the verification for requirement 3.

9. The device must operate in temperatures as low as 32 degrees Fahrenheit  

Put a tag in a freezer. Lower the temperature to 32 degrees Fahrenheit. It must continue to operate normally and transmit temperatures.

10. The device must operate in temperatures as great as 90 degrees Fahrenheit  

Put a tag in the oven. Raise the temperature to 90 degrees Fahrenheit. It must continue to operate normally and transmit temperatures.

**Requirements— Receiver**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Must be able to receive transmission from the same frequency the tag operates on</td>
<td>Setup a tag. Ensure the receiver is receiving data from the transmitter of the tag.</td>
</tr>
<tr>
<td>2. Must be able to interact with “slave” or “master” receivers for large operations that require more than one receiver</td>
<td>Place 2 receivers 100m apart -- one master and one slave. Ensure the master is able to report the temperature for the entire herd, including those reported to the slave.</td>
</tr>
<tr>
<td>3. Must present the temperatures in a user-friendly way</td>
<td>Survey users of the prototype and ensure they report that they are able to access the information they need with minimal help</td>
</tr>
<tr>
<td>4. Must be able to report when an animal is running a fever</td>
<td>Place a tag in a glass of water heater to a temperature in the fever range for that type of animal. The receiver must report that the animal is running a fever.</td>
</tr>
</tbody>
</table>
Calculations

Power Consumption

We are only doing the calculations for the ear transmitter set since the receiver unit is plugged into a wall socket and power is not a problem.

For operation, we will initiate a signal broadcast once every five minutes, and the broadcast will last for around one second. During the downtime, only the control unit and clock should be operating.

First, we will calculate the power draw for the always on control unit and clock. The crystal oscillator appears to act as a resistor of about 35k ohms, and the counters need around 1.5mA of current. The comparator unit is of negligible power draw since their effective resistance is much greater than 30 ohms.

For the clock, with a supply voltage of 3.5V current can be calculated as:

\[ I = \frac{V}{R} = \frac{3.5V}{35000\Omega} = 0.1mA \]

So, the always on portion takes up around 1.6mA of current.

Now we calculate the power draw for the units that only turn on for 1 second every 5 minutes. The thermistor has a resistance of about 10k ohms, the current reader needs about 10mA of current, the analog to digital converter needs 2uA of current, and the RF transmitter needs around 6.9 mA of current.

For the thermistor, we calculate how much current it needs:

\[ I = \frac{V}{R} = \frac{3.5V}{10000\Omega} = 350uA \]

So, the units will need around 7.25mA of current for 1 second every five minutes.

In total, for an hourly rate, the device will need:

\[ 1.6 + 7.25 \times \frac{5min}{60min} \times \frac{1s}{60s} = 1.61mAh \]

This means that if we want to operate it for 2 years on a single battery, the battery would need:

\[ 1.61 \text{mAh} \times \frac{24 \text{ hours}}{1 \text{ day}} \times \frac{730 \text{ days}}{2 \text{ years}} = 28207 \text{mAh} \]

Ear Tag Strength and Force of Installation

Canadian Cattle Identification Program (CCIA) recommends that tags recommend between 70 to 100 pounds of force to correctly insert in cattle ears and requires force of no more than
120 lbs. Any force over 75 lbs. can potentially tear the tag out of an adult steer’s ear.\textsuperscript{7} Tag installations that follow guidelines tend to take about 70 lbs.

An ear tag by itself weights about 0.03 lbs. The combined weight of the ear device including the tag is about 0.05 lbs. (rounded up to account for deviations in weight and less chance of underestimation.)

Let’s assume the best case installation where all guidelines are followed.

\[
\text{Force Conversion Constant (normal tag)} = \frac{70 \text{ lbs}}{0.03 \text{ lbs}} = 2333.33
\]

The weight of the tag effects how much force it applies to the surrounding tissue during installation and recovery. If our modified tag asserts more than 120 lbs. we will consider our augmented ear tag inhumane.

\[
2333.33 \times 0.05 \text{ lbs} = 116.67 \text{ lbs of force asserted}
\]

This amount of force asserted during installation and recovery, 116.67 lbs. is within our permitted range therefore the tag would not impede the livestock animal’s health or the installation of the tag with conventional tools. It is humane and within the permissible range as set by the CCIA.

\textbf{SECTION 4: TOLERANCE ANALYSIS}

The requirements we choose for tolerance analysis are the operating temperature requirements. Our requirements state that the device must be operable between 32\textsuperscript{8} and 90 degrees Fahrenheit.\textsuperscript{8} The requirement for temperature was chosen in accordance to the temperatures where livestock can survive outdoors. Our logic is that if our device can operate in a range of temperatures that spans the entire range of extreme temperatures that livestock can live in, then it should be able to handle any range of temperatures it is likely to encounter during its use.

\textsuperscript{7} Glen, Barb. ”Warm tags for better retention.” The Western Producer. 24 Jan, 2014. Web. 20 Nov. 2016.


SECTION 5: COST AND SCHEDULE

Cost Analysis

**Labor**

<table>
<thead>
<tr>
<th>Name</th>
<th>Hourly Rate</th>
<th>Total Estimated Invested Hours</th>
<th>Total Labor Funds Needed (Hourly Rate<em>2.5</em>Total Hours Invested)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connie Fan</td>
<td>$30.00</td>
<td>100</td>
<td>$7500</td>
</tr>
<tr>
<td>Michael Goldstein</td>
<td>$30.00</td>
<td>100</td>
<td>$7500</td>
</tr>
<tr>
<td>Yue Wang</td>
<td>$30.00</td>
<td>100</td>
<td>$7500</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td><strong>$22500</strong></td>
</tr>
</tbody>
</table>

**Parts and Prices**

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Price</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal Oscillator</td>
<td>$0.15</td>
<td>Mouser</td>
</tr>
<tr>
<td>RF Transmitter</td>
<td>$0.56</td>
<td>Digikey</td>
</tr>
<tr>
<td>Ear Tag w/ Barcode</td>
<td>$0.94</td>
<td>QC Supply</td>
</tr>
<tr>
<td>10K Thermistor</td>
<td>$0.75</td>
<td>SparkFun</td>
</tr>
<tr>
<td>Battery, MercFree, Silvox386, 3V</td>
<td>$1.15</td>
<td>Supplies Guys</td>
</tr>
<tr>
<td>4x10 Bit Converters</td>
<td>$2.04</td>
<td>Mouser</td>
</tr>
<tr>
<td>Analog to Digital Converter</td>
<td>$2.10</td>
<td>Allidelec</td>
</tr>
<tr>
<td>Current Monitor</td>
<td>$1.02</td>
<td>Mouser</td>
</tr>
<tr>
<td><strong>Receiver</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raspberry Pi 3</td>
<td>$39.95</td>
<td>Adafruit</td>
</tr>
<tr>
<td>RF Receiver 315MHz</td>
<td>$4.95</td>
<td>Adafruit</td>
</tr>
<tr>
<td>USB Wall Charger</td>
<td>$2.49</td>
<td>FireFold</td>
</tr>
</tbody>
</table>

**Total Cost:**

<table>
<thead>
<tr>
<th>Cost</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8.71</td>
<td>Ear transmitter tag (one per animal)</td>
</tr>
<tr>
<td>$47.39</td>
<td>Beacon/Receiver (one per herd)</td>
</tr>
<tr>
<td>$22500</td>
<td>R&amp;D Labor</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$22555.89</strong></td>
</tr>
</tbody>
</table>
## Suggested Schedule

<table>
<thead>
<tr>
<th>Deadline</th>
<th>Task Description</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/29</td>
<td>Project Proposal Part 1 &amp; 4</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>9/29</td>
<td>Project Proposal Part 3</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>9/29</td>
<td>Project Proposal Part 2</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>10/6</td>
<td>Draft Mockups</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>10/6</td>
<td>Draft Parts List</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>10/6</td>
<td>Make revisions for proposal</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>10/13</td>
<td>Design Review</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>10/13</td>
<td>Finalize Parts List</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>10/13</td>
<td>Deliver Draft Schematics</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>10/20</td>
<td>User Study/Feedback</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>10/20</td>
<td>Order Parts</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>10/20</td>
<td>Deliver finalized schematics</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>10/27</td>
<td>Set up Raspberry Pi</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>10/27</td>
<td>Construct software interface—store temperatures</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>10/27</td>
<td>Breadboard Assembly</td>
<td></td>
</tr>
<tr>
<td>10/27</td>
<td>RF Receiver/Transmitter Setup</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>11/3</td>
<td>Construct software interface—alerts for high/low temps</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>11/3</td>
<td>Thermistor Setup on Board</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>11/3</td>
<td>Verify Thermistor transmitting to receiver</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>11/10</td>
<td>Part 1 of Final Paper</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>11/10</td>
<td>Verify thermistor board runs on battery power</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>11/10</td>
<td>Automatically register barcode on ear tag to entry in database</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>11/17</td>
<td>Integrate thermistor board + components and ear tag</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>Date</td>
<td>Task Description</td>
<td>Person</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>11/17</td>
<td>Construct second ear tag transmitter for testing purposing</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>11/17</td>
<td>Part 2 of final paper</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>11/24</td>
<td>Verify functionality, provide sample readings</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>11/24</td>
<td>Temperature/weather/environmental conditions stress testing</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>11/24</td>
<td>(Reach goal) Provide temporary installation on an animal at the vet school on campus</td>
<td>Yue Wang</td>
</tr>
<tr>
<td>11/27</td>
<td>Gather readings from livestock with installation</td>
<td>Connie Fan</td>
</tr>
<tr>
<td>11/27</td>
<td>Verify reusable condition after removal from test subject</td>
<td>Michael Goldstein</td>
</tr>
<tr>
<td>12/1</td>
<td>Prepare Demo &amp; Finalize Final Paper</td>
<td>Connie Fan</td>
</tr>
<tr>
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<td>User feedback</td>
<td>Michael Goldstein</td>
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<td>Finalize Presentation</td>
<td>Yue Wang</td>
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SECTION 6: ETHICAL CONSIDERATIONS

Relevant IEEE Ethics Guide Provisions:

[1] to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

[3] to be honest and realistic in stating claims or estimates based on available data;

[5] to improve the understanding of technology; its appropriate application, and potential consequences;

[6] to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

[7] to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

[8] to treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;

[9] to avoid injuring others, their property, reputation, or employment by false or malicious action;

[10] to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

Safety Guidelines:
Though no actual construction occurred, we adhered to strict guidelines. We had all values double checked, verified that all vendors sourced their materials legally, that all planned construction and machine shop work was to be done by certified professionals. On top of this, we repeatedly accepted criticism and implemented changes. All group members contributed equally and were not subject to any form of discrimination including but not limited to on the basis of sex, orientation, age, national orientation, or religion.
SECTION 7: REFERENCES

Bibliography


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