Deep Tunnel Mobilization

ECE 445 Design Document

Team 26

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1 Introduction

1.1 Problem Overview

The following problem was pitched by Professor Ann Witmer.
Late in the season, most vegetables are done for the season except some cold hardy crops. A hoop house or deep tunnels, equipped with UV resistant polyethylene plastic, can be used to extend growing periods by protecting crops from direct sunlight. If deep tunnels are moved, one deep tunnel can be used as an incubator for more crops in a given season than if it is not moved.
At the Sustainable Student Farm, there are 3 deep tunnels, each on a track twice the length of the tunnel itself. It currently takes 10-12 volunteers to move a single deep tunnel, ideally it would only take 1 or 2.
If the deep tunnels are mishandled they can be damaged. So, it will be important to ensure unnecessary stresses aren't applied to parts of the tunnel and track structures that can be comprised.
There are not any electrical outlets at the farm.

1.2 Solution Overview

We will be modifying a winch system so that it takes a switch input and ultrasonic sensor and battery voltage data, to move the tunnels to the end of the track where the winch will auto-stop before being dragged through posts at the end. Powered by a car battery, the system will be made portable so that it can pull from either side of any one of the three tunnels. It is the responsibility of the ECE team to modify the winch to stop when it reaches the end of the track, or if a load that is is higher than the tunnel on the tracks is being pulled, or if a faulty or discharged battery is being used. We will also add lights to notify the user of the state of the system that were not previously there.

1.3 Visual Aid

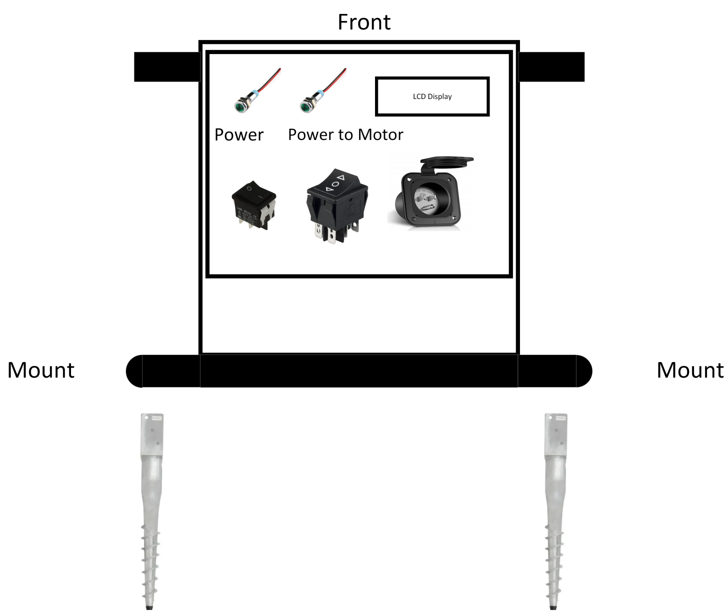

Figure 1: Visual Aid Front

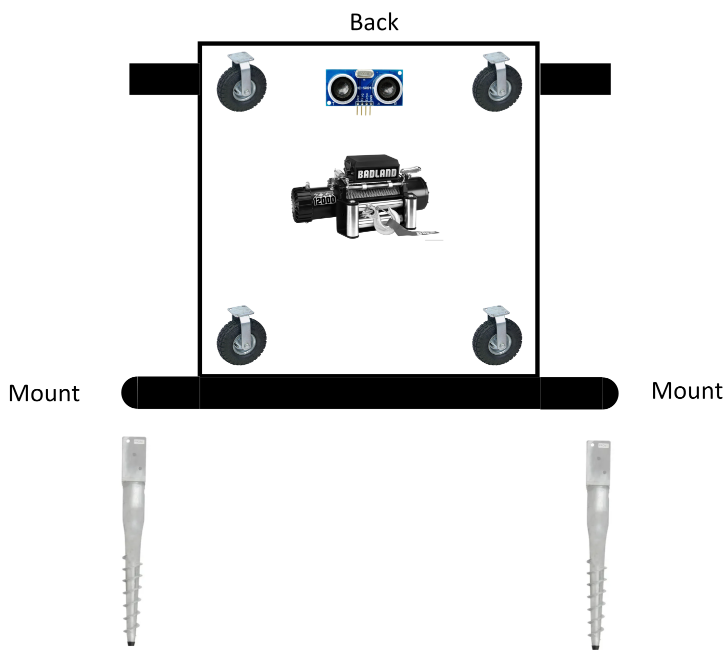

Figure 2: Visual Aid Back

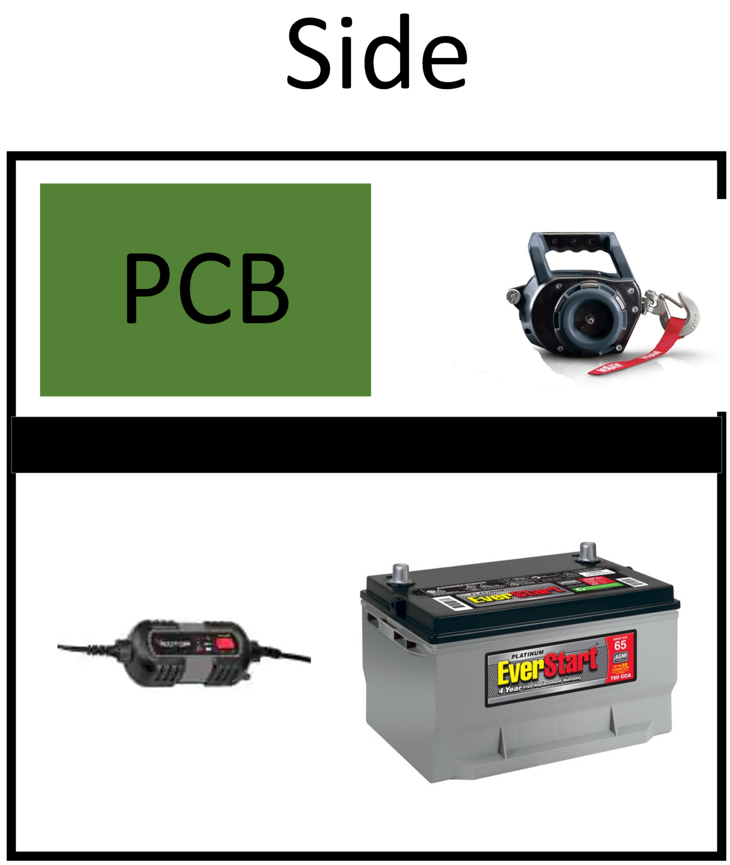

Figure 3: Visual Aid Back

1.4 High-level requirements list

- The tunnel is able to move by operating a switch. The speed of the tunnel is expected to be able to move around 10 feet per second. The tunnel should have an operating temperature between -20 degrees Celsius to 40 degrees Celsius.
- When the device is properly mounted to the ground with ground screws, the winch and assembly is secure and does not move while pulling the high tunnel. This ensures that the ultrasonic sensor can be calibrated once before the tunnel starts to move in order to stop the tunnel at the end of the field. Thus, the tunnel is able to stop with 1 foot of the end of the field.
- The control panel is able to display the relevant information to the operator like the battery State of Charge, Power indicators, motor information. The control panel should be able to pull this information from the sensors at least every 3 seconds while the system is operating.

2 Design

2.1 Block Diagram

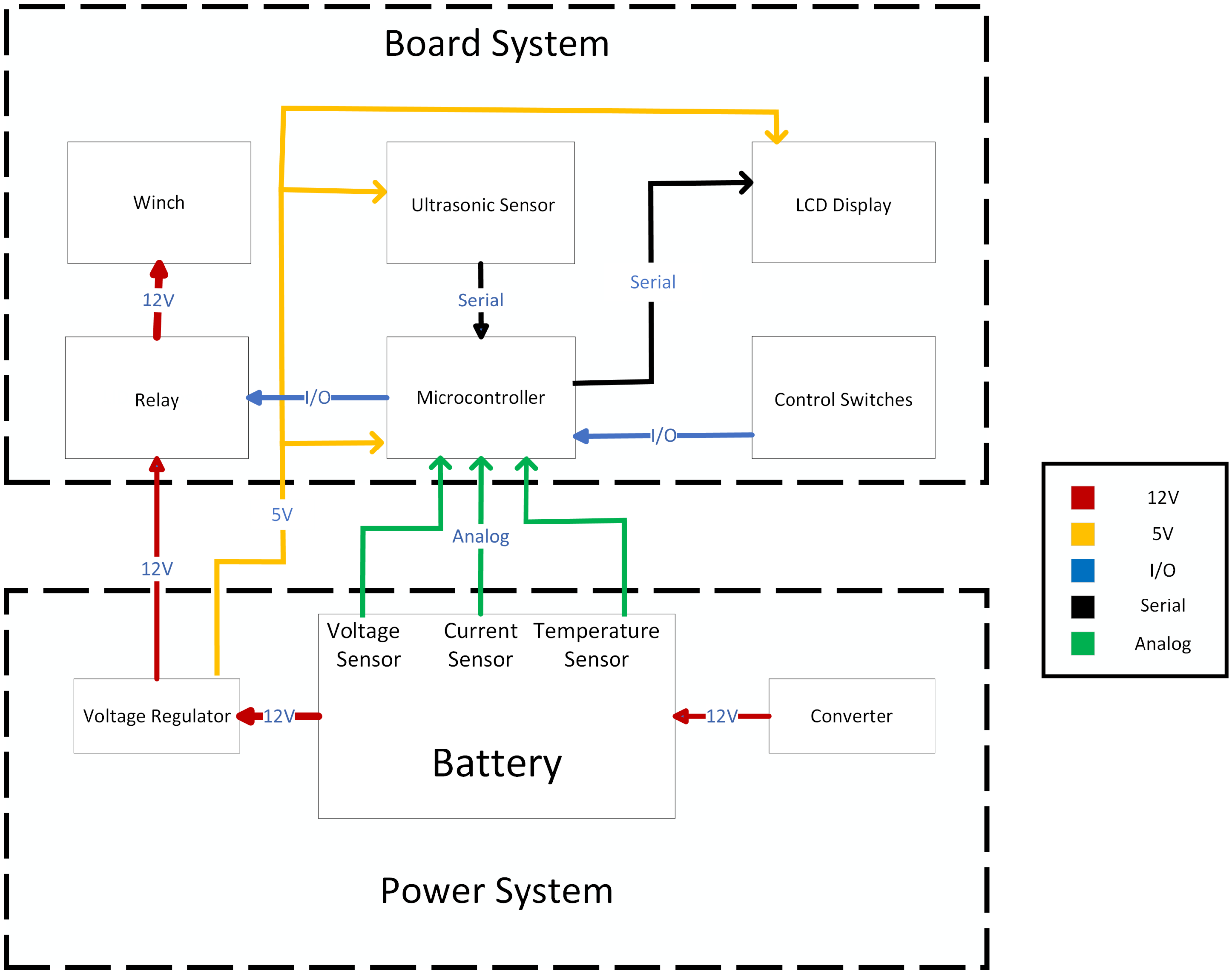

Figure 4: Block Diagram

2.2 Physical Design

The physical design of the high tunnel mover will resemble a box. The front side will have a interface panel with buttons, switches, and electrical connections that can be covered in the case of storage or moving. The back side will have an opening for the winch cable to be extended from. The will also be a cutout for the Ultrasonic sensor on the backside to sense the distance of the high tunnel when it is near the end of the field. The batteries will be located on the bottom of the box which will the structure more stability and a low center of gravity. There will also be four mounting points on each of the corners to secure the box to the ground. There will also be two handles on either side of the box to make moving the object a bit easier.

Since there is only one winch in this system. The winch will be anchored to the high tunnel through hooks on each side of the high tunnel near the rails. The ABE team will help design this mechanical system and should not affect out design.

2.3 Power System

The role of the power system is to provide power to all of the electronic components in the system. The sensors on the battery are to help ensure that the battery is able to safely charge and discharge. Any values from the sensors on the battery that are outside the expected range will be relayed to the microcontroller to display on the LCD screen. The job of the voltage regulator is to converter the 12V battery voltage to 5V for the Microcontroller and other sensors to use. In addition, the Voltage regulator also delivers 12V for the winch. The battery is charged from a converter that will maintain the battery voltage when a wall outlet is available.

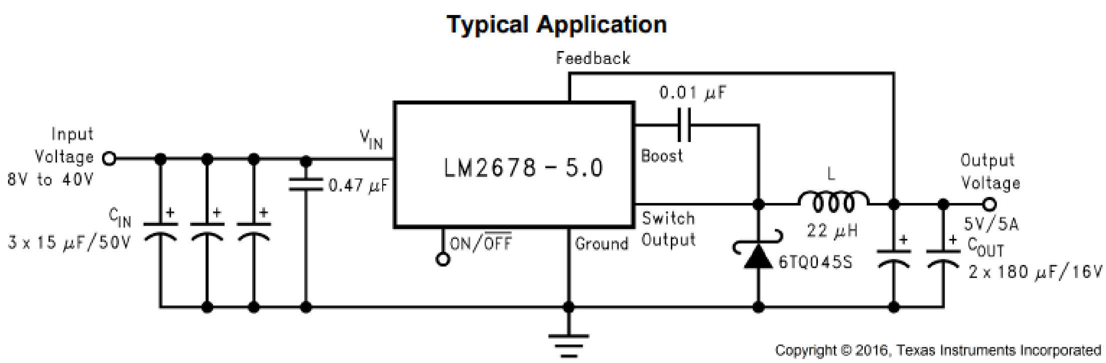

Figure 5: Typical Voltage Regulator

Table 1: Power System Verification Table

Requirements	Verification
1. The voltage regulator must be able to regulate the voltage for the winch, the microcontroller, and the sensors.	1. Connect the voltage regulator to a DC power supply and test that the output voltage of the regulator is 12±5% for the winch and 5±1% for the microcontroller and sensors. Use an Oscilloscope to probe the output voltage to ensure that the voltage ripple is within specifications.
2. The sensors connected to the battery are able to measure the over voltage, under voltage, over current, and temperature of the battery to ensure that it is working in optimal conditions situations	2. For the voltage sensor, a DC power source and digital multimeter to correlate the sensor data with the actual battery voltage. For the current sensor, a power resistor,a DC power source, and the oscilloscope current probes will be use to correlate the analog value from the current sensor to the actual current readings from the oscilloscope. For the temperature sensor, a thermocouple will be placed in hot water with a thermometer. Then the analog value from the thermocouple will be correlated with the actual temperature.

2.4 Front Panel

The front panel houses the switches and indicator LEDs for the user to operate the winch. One LED will indicate the status of battery charge. Another will indicate whether the winch is in action or not. An LCD screen will indicate the status of the system.

Table 2: Front Panel Verification Table

Requirements	Verification
1. Indicator light 1 turns on when battery is properly connected.	1. When a charged battery is attached the light is on when it is disconnected it is off.
2. Indicator light 1 blinks when battery is low	2. Attach voltage source between 11.8 and 12V to the BMS simulating a low charge car battery and the light blinks.
3. Indicator light 2 is on when the winch is turning, off when it is not, and blinks when it is not turning but the switch is not in the off position.	3. Observe the LED, winch and switch position.
4. Switch position matches motor direction and whether it is on or off.	4. Use a multi-meter to check that the voltage at the pins at where the motor would be connected changes polarity with the opposite switch position and goes low in the middle.
5. LCD panel will indicate the operation of the winch and sensors.	5. When the system is on the screen should indicate so. When the winch is moving, the screen should indicate what direction it is moving.

2.5 Control

The control system is our 3rd party device for operating the winch. The controllers that come off the shelf for winches require that you hold down the switch continuously to pull the line in or unravel it out. At the line pull speed of 9.5 feet per second, it would require you hold down the button for approximately 10 minutes if you were to move the tunnel the 96ft (plus additional time unravelling the line). The controllers are simply momentary DPDT switches that connect pins that go into the off the shelf solenoid box as shown below.

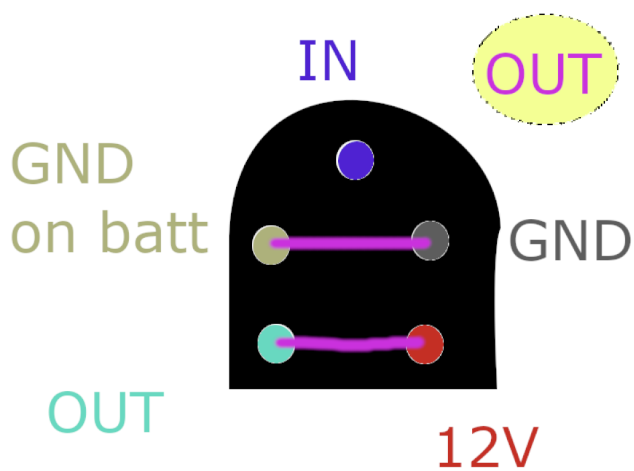

Figure 6: Pin connection in ”out” position

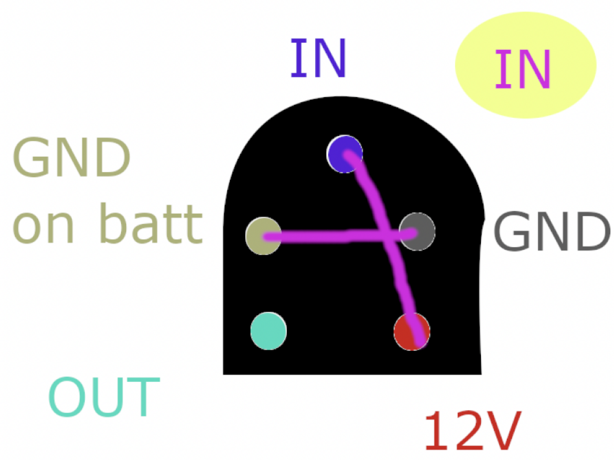

Figure 7: Pin connection for "in" position

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By replacing the momentary switch with a switch that fixes into position the user would not need to wait holding the button but additional control features will need to be implemented in order to prevent the switch from continuing to power the motor when:
a) winch winds to the end of the line
b) tunnel gets to the end of the track
c) the tunnel is obstructed
d) winch is running on a low battery.
To stop the motor, even when the pins are connected at the solenoid, a relay controlled by the micro controller will be placed in series with the battery's positive terminal.
The cases a and c can be informed from reading a voltage divided current coming from the battery. into the micro controller. Because the current drawn is dependent on the load and the amount of rope spooled, in case a, the current should not change. If obstructed (c), the current will spike to draw too high an amperage. In the case the battery is low, (d), the voltage will be low. For case b, in which the tunnel is at the end of the track, an ultrasonic sensor with Bluetooth will be used and screwed into the hole at the post leg photographed below.

Figure 8: Where the ultrasonic sensor will be placed

So that it is not lost, there will be a place to mount the Bluetooth/ultrasonic sensor module on the rolling container by the front panel.

Table 3: Control Verification Table

Requirements	Verification
1. Switching at pins works the way the diagrams show	1. Use continuity mode on DMM to see that connections in our 3rd party remote match those of the manufacturer.
2. Relay cuts power	2. Put hand on ultrasonic sensor and the winch stops.
3. Winch stops when obstructed	3. Tow a vehicle and pump breaks, winch stops.
4. Must be able to start and stop the motor	1. Testing the connection and polarity of the motor side connections with a multimeter when the control side of the solenoid is powered
5. Change of Motor Direction	2. With an oscilloscope, a DC power source, and an function generator, measure the solenoid's frequency that the solenoid can switch at from each of the three positions and at different duty cycles. Ensure that the solenoid can operate at 5% to 100% duty cycle.
6. Control of Speed and Torque output	3. After the second requirement is met, the winch will be set at different speeds with no load to test that the line rate of winch varies. Then, some resistance will be added to pull larger and larger objects. The torque can be calculated from a torque sensor.
7. Overload protection	4. A current sensor will measure the current going to the motor and ensure that it stays below the rate current for that specific line length.
8. Electrical Fault Protection	5. If the motor fails, power will be cut off to the motor.

2.6 Tolerance Analysis

Moving the tunnel requires a lot of charge. If a single charge of a car battery failed to move a tunnel across the track that would be unfortunate. So how many tunnels can a single car battery charge move?
The table below is from the chosen winch's manual.

Line Pull lb	(kg)	**Line Speed** fpm	(mpm)	**Amp Draw** (@ 12V)
0	(0)	15.5	(4.7)	101
3000	(1361)	9.5	(2.9)	173
6000	(2722)	7.4	(2.3)	244
9000	(4082)	5.7	(1.7)	311
12000	(5443)	4.4	(1.3)	359

Figure 9: From Badlands winch manual

Assuming 12 people each push 100 pounds, it will take 1200 pounds to pull the tunnel. So, we should expect on a pull the winch will draw around 150 A.
The battery holds 70AH.
Which would yield .4666 hours or 28 minutes of pulling.
At a pulling rate of 11 feet per second, 28*11 = 308ft
The tunnel needs to move 96ft
So a battery will pull a tunnel 308/96 = 3.21 lengths of the track.
Because it will also take some charge to unravel the winch, the 3 tracks will not be pulled on a single charged, but with the second battery they will.

3 Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

From the UIUC ECE average starting salary data for Electrical Engineering students, the average salary from the graduates of the academic year of 2019 to 2020 was $76,129 [2]. For our team, we each expect to contribute 10 hours per week for the rest of the semester to develop and test our prototype. In our cost calculation, we assume that the salary corresponds to a regular 40 hour work week while working 50 weeks out of the year.

Student Cost calculation:

1. $\$76,129$ / 50 weeks / 40 hours per week = $38.06
2. $\$38.06 *$ 10 hours per week $*$ 7 weeks = $2664.52 per student.
3. $\$2664.52 *$ 3 students = $7993.55

Machine Shop calculation:

This to be determined with the resources of the ABE team.

3.1.2 Parts

Table 4: Components Table

Item And Part Number	Quantity	Unit Cost	Total Cost
BadLand ZXR Winch 63770, 64045, 64046	1	$349.99	$349.99
EverStart Platinum AGM Battery, Group Size 65 (12V/750 CCA)	1	$149.84	$149.84
Ultrasonic Transceiver and Receiver UTR-1440K-TT-R	2	$12.26	$24.52
5595101007F LED SNAP-IN PANEL 5MM 3V RED 350-2133-ND	10	$1.531	$15.31
WB242D1121 SWITCH ROCKER DPST 20A 125V EG4758-ND	1	$5.57	$5.57
R5DBLKBLKHF0 SWITCH ROCKER DPDT 15A 125V EG1541-ND	1	$3.36	$3.36
HAUL-MASTER 10in Rigid Pneumatic Caster	4	$17.99	$71.96
Mayne No-Dig Ground Screw	4	$39.99	$159.96
LCD Display Adafruit 782	1	$24.95	$24.95
1.5 Amp Battery Charger, Battery Maintainer, Trickle Charger, 6V and 12V, Fully Automatic	1	$19.98	$19.98
Narva 68022 12V 200Amp 4 Pin Heavy Duty Relay	1	$90.16	$90.16
LM2678S-5.0/NOPB	1	$5.10	$5.10
KTJ500B156M55AFT00 Cap	3	$3.31	$9.93
860020373009 Würth Elektronik Cap	2	$0.15	$0.30
ADM32FSC-220M Inductor	1	$2.02	$2.02
FA16X8R1H474KNU06 Cap	1	$0.50	$0.50
M39014/01-1496 Cap	1	$1.55	$1.55
6TQ045S Schottky Diode	1	$1.23	$1.23
STM32F103C8T6 Processor	1	&7.48	&7.48

3.2 Schedule

Table 5: Schedule Table

Week	Progress	Responsibility
2/28	Finish Design Document and Design review	Youssef, Nisha, Jonathan
2/28	Power system PCB	Jonathan
2/28	Microcontroller circuit and relay PCB	Youssef and Nisha
3/7	Check connections on PCBs	Nisha
3/7	Machine shop Revisions	Youssef
3/7	Sizing of device for machine shop	Jonathan
3/7	Ordering Parts with ABE	Youssef, Nisha, Jonathan
3/21	Second round Relay PCB	Youssef
3/21	Second round Power system PCB	Jonathan
3/21	Programming Microcontroller	Nisha
3/28	Mircocontroller logic with relays	Youssef
3/28	Build Power System PCB and start testing	Jonathan
3/28	Develop Microcontroller code	Nisha
4/4	Relay testing and	Youssef
4/4	Finish Testing and both PCB testing	Jonathan
4/4	Finish front panel testing	Nisha
4/11	Full system test at farm	Youssef, Jonathan, Nisha
4/11	Build panel. Test winch without load, measure battery performance.	Youssef, Jonathan, Nisha
4/11	Mount winch to pull tunnel verify that it works correctly with ultrasonic. Record how much pulling can be done with a single battery.	Youssef, Jonathan, Nisha

4 Discussion of Ethics and Safety

Considering this project is aimed to help make sustainable agriculture easier, the implementation should maintain this sustainable ethos. A portable electric power supply, instead of a combustion generator would allow for the possibility of sustainably sourced power. Energy is only one resource involved, others are rare earth metals and other materials. A design that is modular, so that one system can be applied to each of the three deep tunnels, would not only be fiscally beneficial but ethically responsible as well.

One of the goals listed in section 7.8 of the IEEE code of ethics is, "to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies."(IEEE 7.8) The technology we are developing enables farmers to utilize the most out of their season without needing to rally or hire a large group of people to move their deep tunnels. It is important to emphasize that this convenience advances our ability as individuals to produce agriculture independently so that we are no longer dependent on unsustainable corporate food chains to feed us. People are becoming aware of the societal and environmental benefits of such a shift into local, owner run farms. As the code suggests, it is important to make sure that people are aware that with agricultural and technological advancements, running a farm has become more manageable and its yields will be plentiful, if people invest in tools like the one we are

proposing.
As far as safety is concerned, commercial electric winches operate at usually no more than 10 feet per minute. Though this pace may require some patience, it has the benefit of making the system safer to operate. Another safety concern would be in the construction and testing of the system. Despite the fact we will try to consider all variables in preventing the deep tunnel from breaking, in the case in which it does break, it is important that no one is right next to it. Before operating no one should be on or right next to the track. A good idea would be to add a buzz sound and delay before the tunnel makes its journey down the track. We will also add a switch to kill the power going to the motors as another safety feature.

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