To: Dr. David Trevas

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Subject: ER's and TR's Revamp Memo

This memo is to highlight the current customer and engineering requirements that the team is focusing on to date. This includes all components of a remotely operated, small scale, electrically powered excavator specialized for residential irrigation. The design has not been changed from the last semester, yet the scheduling has had changes. Due to the COVID-19 pandemic, the team has not received purchasing instructions which results in a scheduling setback.

1 Customer Requirements (CRs) (Davis)

Customer requirements for the project have remained largely unchanged since the preliminary report last semester. The only exception has been the initial requirement of the excavator possessing ground penetrating radar to detect pvc piping, wires, and metal pipes in digging areas. This requirement was the least prioritized by the client and was completely dismissed due to the inability to create or purchase a radar system that would be within the client's budget. All other customer requirements for the excavator remain, including remote operation, 6-hour workday, electrically powered, durable, safe, reliable, and can dig a 1-foot by 6-inch trench. Table 1 provides a list of the customer requirements, their prioritized weightings, and justifications.

Customer Requirements	Weight	Justification
Remote Operation	4	Remote operation is crucial to complete success of the project. The client will accept a wired control variation, but remote operation exponentially expands future operation possibilities.
Full Workday	3	Although it would be a luxury for the excavator to work 8 consecutive hours, it is not imperative, and 3-6 hours will be accepted.
Electrically Operated	5	A fully electric power supply has been designated as a "must have" feature by the client.
1'x6" Trench	5	The main goal of operation.
Ground Penetrating Radar (No Longer a Requirement)	1	While this feature would be amazing to have for cable, pipe, and pvc detection, it is very expensive from every angle.
Durability	4	The excavator and all components must be durable enough to survive hundreds of hours of work, but it is not imperative to engineer the excavator for an infinite lifespan.
Safety and Reliability	5	Safety and Reliability are not included in Figure 1 because these are of the highest priority and have a strong relation to every engineering requirement.

Table 1: Customer Requirements [1]

2.2 Engineering Requirements (ERs)

Engineering Requirements	Justification
Body/Base Design	The body design will be a key point of interest with respect to the durability and reliability of the excavator. A robust body design will prevent the excavator being stuck and protect other main components and systems.
Arm & Bucket Kinematics and Design	An optimized arm and bucket design are imperative for meeting the main objective of digging an irrigation trench. Over engineering these components may add unnecessary costs, while the opposite may produce failures during unusual circumstances.
Arduino: Electronic Control Unit (ECU)	Arduino and the ECU will be the main bridge between the remote operator and all controls on the excavator. It is essential that the ECU is completely reliable with all functions, which include wheel motion, arm motion, and bucket motion. Tying in functionality to control all motor systems and hydraulics.
Electric Power Supply	The electric power supply achieves the goal of creating a fully electric excavator, but its role is critical. These batteries are the sole contributor to all operations of the excavator.
Motion Control Systems	Motion control relates to the hydraulic systems of the excavator. While the ECU is the median between the operator and the excavator, the motion control system is the median between the ECU and all hydraulic operations of the bucket and arm.

Table 2: Engineering Requirements [1]

2 Engineering Requirements (ERs)

The Engineering requirements for our project are listed in the table above. These requirements are the project standards that will satisfy our customer requirements which are creating a garden sized excavator, capable of digging a 1 foot deep by 6-inch-wide irrigation trench, remotely operated, and its power supply must be electric. In the following we explain in more detail these Engineering Requirements.

2.1 ER #1: Excavator Kinematics (Oscar)

2.1.1 ER #1: Bucket and Arm Digging Forces Target = 8 KN

The teams target digging force was calculated through initial calculations based on current micro excavator designs on the market. Our team chose this value in consideration to the forces that these available excavators were producing. To stay within the scope of our project we settled on a lower value than what the market excavators were producing. This value is 8KN and will ensure sufficient force for any use within the scope of the excavator.

2.1.2 ER #1: Digging Forces Tolerance = +/- .5 KN

The tolerance selected for this project will be +/- .5 KN. Our team was able to calculate a rough estimate of the minimum digging force that we will need based on our initial design kinematics. Then our team used this minimum digging force and calculated our target forces. Through this process our team chose the tolerance target value of +/- .5 KN to ensure that in the worst-case scenario we will still have sufficient digging force.

2.2 ER #2: Power Supply (Ryan)

2.2.1 ER #2: Duration of Operation - Target = 6 Full Hours

The team's target for operational use is for a 6-hour workday between charges. The team chose a 6-hour day due to the practical uses of the design. A small-scale excavator with a 1' by 6" bucket would be ideal for irrigation trenches or digs in areas that are difficult to reach, such as residential backyards. The design is powered by 4 12-Volt marine batteries, which provide ample power for a 6-hour period.

2.2.2 ER #2: [Descriptive Title] - Tolerance = +/- 45 minutes

By using product specifications, the team has concluded that 4 batteries will power the design within a 45-minute tolerance of the 6-hour goal. The batteries chosen are lead acid 12-Volt, which means that they can produce 20 amps of current for 6.25 hours, and 10 amps of current for 12.5 hours. Because the team has not been given purchasing instructions regarding parts and materials at this time, there has not been any testing to verify power consumption. Although the expected tolerance is 45 minutes, the true tolerance cannot be calculated at this time due to lack of testing abilities.

2.3 ER #3 (changed from Summer): 90-degree arm rotation

2.2.3 ER #3: Arm motion allowing easy dumping

The first excavator arm that was designed was fixed to the base and does not allow rotational movement for easily dumping dirt. The engineering change will allow the excavator to stay planted and rotate 90 degree to dump the dirt instead of having to move back and turn the entire excavator for each load of dirt removed from the digging location. The 90-degree motion of the arm will save a substantial amount of time and will also preserve the battery capacity due to the fact the only the arm will be moving compared to the whole excavator moving.

2.2.4 ER #3: Bearing and motor for 90-degree arm system

Installing a bearing on the bottom of the arm where it connects to the base of the excavator with a motor system that allows 90-degree movement of the arm. This addition will add cost to the project but we believe that extra cost is worth the time savings and ease of usage when digging.

3 Testing Procedures (TPs)

In this section, testing procedures are discussed that will ensure each main system of the excavator will reliably work and that the engineering requirements are met. Testing categories include the hydraulic system, ECU, swivel motors, Bluetooth, and wheel motors.

3.1 Testing Procedure 1: Hydraulic Systems (Zhiyu)

3.1.1 Testing Procedure 1: Objective

The main purpose of testing the hydraulic system of the remote excavator is to ensure that the power of the hydraulic system is normal and can achieve the purpose of controlling the excavator's motion. First, to test the hydraulic pump of the hydraulic system, it is required that the hydraulic pump can work and can provide pressure to the fluid. Secondly, it is necessary to test the entire hydraulic circuit. It is required that the fluid can be pressurized by the hydraulic pump, and the fluid can be controlled by the hydraulic valve and hydraulic manifold. The fluid can circulate in the hydraulic system. What is really going on is the testing of hydraulic pumps. The hydraulic pump is the power source of the hydraulic system to ensure that electrical energy can be successfully converted into mechanical energy.

3.1.2 Testing Procedure 1: Resources Required

Hydraulic system test requires a complete hydraulic system and power supply. The hydraulic pump test is the basis of the hydraulic system test. It only needs to turn on the power of the hydraulic pump and quickly turn it off to observe whether the hydraulic pump is working. The test of the hydraulic circuit requires a complete hydraulic system. The hydraulic system is fed with fluid and connected to the power source. The movement of cylinders is adjusted by three control valves. If the cylinders can be adjusted by the control valve, it means that the hydraulic circuit can operate normally. The components of the hydraulic system have been purchased, and the team needs to assemble the hydraulic system circuit. Power needs to be provided by a battery system.

3.1.3 Testing Procedure 1: Schedule

Due to the impact of COV-19, the team cannot provide an exact test time in the near future, but the team hopes that the test can be completed in September. Testing requires the team to have a certain knowledge of mechanical fluid mechanics and hydraulic systems. In addition, the team needs to complete the assembly of the hydraulic system.

3.2 Testing Procedure 2: Motor, Bluetooth, Wheels (ECU) (Davis)

3.2.1 Testing Procedure 2: Objective

Testing procedures regarding the electronic control unit, and its subset systems being the Bluetooth module, wheel motors, and swivel motor, will ensure operability and compatibility with the power supply. The tests will first be conducted with the wheel motors and swivel motors being tested separately, while Bluetooth operability will be included in both tests. Conducted testing will display that all wheel motors can power forward and reverse, as well as function independently to turn. The swivel motor will be simply tested with forward and reverse functionality, and its main goal will be to position the arm of the excavator, although its conception is still in the design phase. Overall, these tests will determine the fulfillment of the concepts to create an electrically powered excavator that is remotely operated.

3.2.2 Testing Procedure 2: Resources Required

The resources needed to conduct these tests include a micro controller, Bluetooth module, Android device, and at least four DC electric motors. Including the desired power inverter within these tests ensure compatibility between all electrical subsystems and the power supply. While the team currently possess the necessary micro controller and testing software, purchasing instructions are still needed to acquire the motors, inverter, and batteries. Once these parts are acquired, testing can be done at the garage of any team member's residence.

3.2.3 Testing Procedure 2: Schedule

Scheduled testing has been the most impacted by the COV-19 pandemic, as the team ideally desired to be testing these systems at the beginning of September. The main impediment to testing at the time is a lack of understanding provided to the team regarding available budget and purchasing abilities. Currently, the microcontroller, Bluetooth module, and many parts of the hydraulic control system have been purchased at the team's own expense, while the hydraulic pump and rams have been provided by NAU.

References

[1] Excavator Team, “Final Proposal”, NAU Department of Mechanical Engineering, August, 2020