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Subject: Operation and Assembly Manual for the Psyche Sampling System

1.0 Assembly Manual

The following sections will explain the processes that must be taken to successfully recreate this device and the maintenance that is required for each general subsystem. Following these assembly procedures and keeping each part in it's best shape will ensure that this system is reliable, durable, and safe during its usage on the Psyche Asteroid. A full bill of materials can be seen in Appendix A, to ensure all parts are used and accounted for. Please note, however, that some parts, like the caching system and storage carousel, were not included in the final design and assembly. Due to the COVID-19 pandemic outbreak, the team was not able to implement these designs into the physical product, and therefore do not have exact assembly steps for those parts.

1.1 Tower Main Frame

The tower main frame consists of basic Tetrix® frames and screws. These parts vary, from long slender pieces to L-brackets. The assembly of such is quite simple, and can be shortened to a few steps. Because the tower main frame consists of these types of parts, variability and changeability are consistent throughout the system.

1.1.1 Assembly

To assemble the tower main frame, you must first have these components:

- 4 x 288mm Channel 39068
- 4 x 160mm Channel 39067
- 4 x 96mm Channel 39066
- 4 x L-Bracket 39062
- 2 x 288mm Flat Bar 39070
- 2 x Motor Mount 39089
- 28 x screws
- 28 x nuts

Then, follow the proceeding steps to build the main tower frame of the sampling system:

1. Create a rectangle using two 288mm and two 160mm channels. Attach them at the furthest ends and screw them into place using two screws and nuts at each end. Complete this step twice. These will be the towers. See Figure 1.

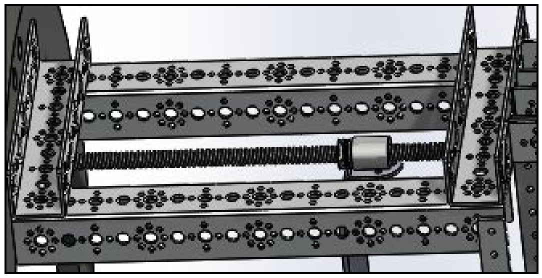

Figure 1: Rectangle Assembly

2. Attach the two 288mm bars to both the rectangular towers at the top most hole with screws and nuts. See Figure 2.

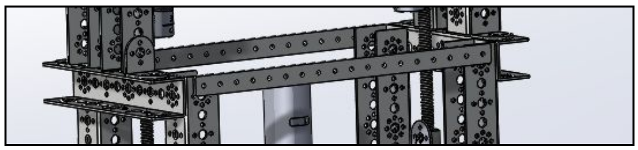

Figure 2: Bar Attachment

3. Attach the motor mount onto two 96mm channels, with each hole at each channel on the top most hole. Do this twice
4. Attach the mini tower constructed in Step 3 to the tower in the middle of the top 160mm channel using two L-Brackets and screws and nuts. Do this twice.
5. Attach the entire tower main frame to the magnetic base once constructed. See Figure 3.

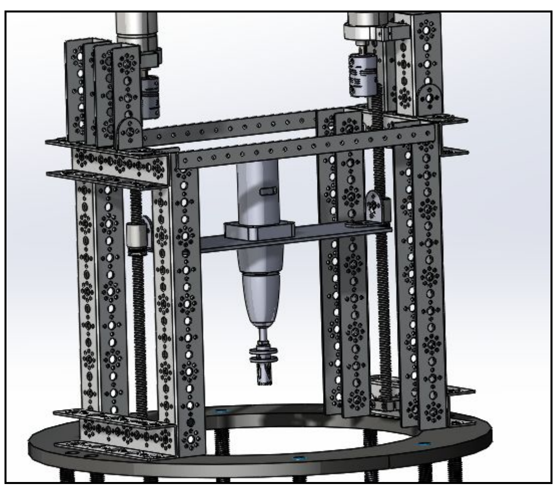

Figure 3: Tower Main Frame on top of Magnetic Base

<u>1.1.2 Maintenance Required</u>

There is not much maintenance required to keep this assembly intact. As time goes on, the user should make sure all the nuts and bolts are tightened and rigid. Avoid any rusting or wear by replacing pieces as needed.

1.2 ElectroMagnetic Base

The Magnetic Base is a fairly easy-to-assemble component, as it does not have many parts to it. The base serves as a purpose to both hold the tower mainframe and to hold the system down onto the asteroid. The actual base is to be made out of aluminum, ½ inch thick. The bolts that are attached will be used to create electromagnetic solenoids.

1.2.1 Assembly

To begin assembly, you must first have these parts:

- 1 x 17in diameter disc with a 12in hole in the middle
- 8 x ½ in Iron Bolts
- 20~30ft of 4~10AWG wire

Then, follow the following steps to assemble the electromagnetic base:

1. Attach the eight iron bolts to the tapped holes around the disc. See Figure 4.

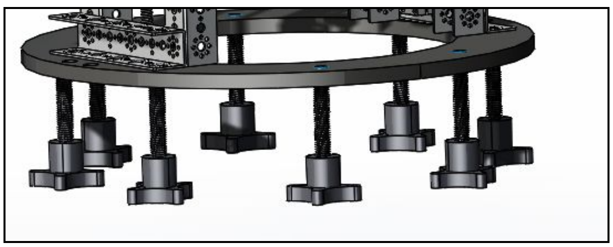

Figure 4: Iron Bolts screwed in

2. Wrap the wire around each bolt as tightly and as close as you can.
3. Run a current through the wire.

1.2.2 Maintenance Required

For this system, the only maintenance required is that the bolts need to all be level and not fall off. As well, the wire must not get loose. Avoid rusting and wear by replacing metallic parts as needed.

1.3 Drill & Linear Actuator System

The linear actuator system is primarily used to hold the drill in place and allow for vertical movements of the drill. It's assembly is fairly easy due to the fact that the majority of its parts were premade parts. Only the Drill Motor Plate that holds the drill in place was uniquely manufactured.

1.3.1 Assembly

In order to assemble the drill and actuator system, the following components are required:

- Milwaukee Drill Motor
- Drill Motor Plate
- 4 x screws

- 2 x ⅜” I.D. Ball Screw
- 2 x ⅜” O.D. Ball Screw Nut
- 2 x ⅜” I.D. Shaft End Supports
- 2 x ZipTies
- 2 x Motor Couplers
- 2 x Geared Motors
- 2 x Motor Mounts

The assembly is completed through the following steps:

1. To begin, the drill motor plate is attached to the drill motor. The clutch of the drill motor is slid through the center hole of the plate.
2. The drill motor is attached using the four screws. The plate/drill assembly is seen in Figure 5.

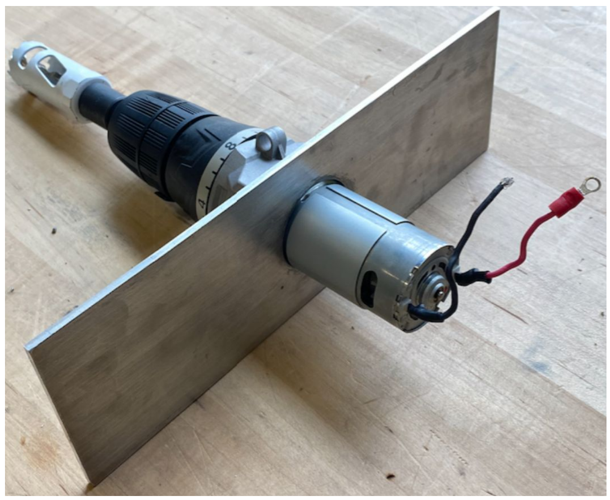

Figure 5: Assembled Drill and Plate Assembly

3. The ball screw nuts are attached to the drill plate using two zip ties. Each zip tie is placed through the supplied holes in the drill plate and are secured around the ball screw nuts.
4. Next, the ball screws are inserted through the ball screw nuts, rotating until the plate is positioned in the center of the ball screw.
5. The end stops are screwed onto the tower frame.
6. The ball screws are inserted into the end stops and are secured by tightening the set screws on the end stops.
7. The two motor mounts are attached to the tower frame.
8. The two motor couplers are attached to the geared motor shafts and the motors are inserted into the motor mounts. The mounted geared motors are shown below in Figure 6.

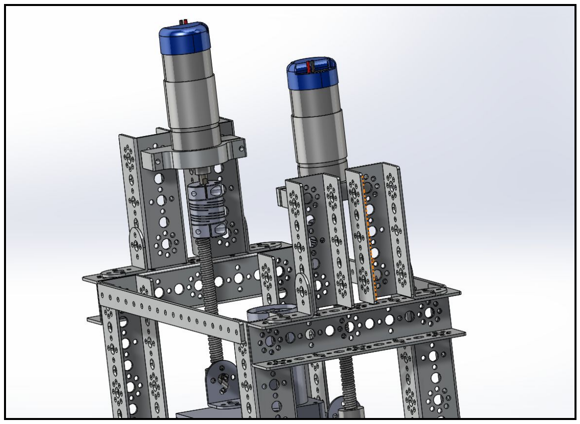

Figure 6: Installed Geared Motor Assembly

9. Finally, the motor couplers are attached to the open ends of the ball screws. This completes the Drill/Actuator assembly. The final assembly is seen in Figure 7 below.

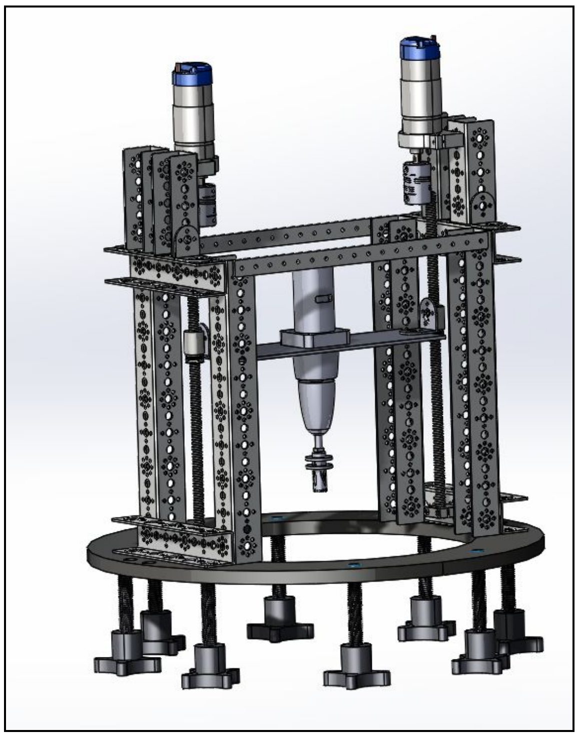

Figure 7: Finished Drill and Actuator Assembly

1.3.2 Maintenance Required

Maintenance for this assembly is minimal. The ball screws need to be greased regularly in order to maintain low resistance. The geared motors will also need to be greased in order to keep the motor from wearing out. Any other maintenance would include regularly checking the set screws and mounting screws in the assembly to maintain rigidity.

1.4 Arduino Electrical Set Up

The full sampling system will be fully powered through Arduino electrical parts and a 12V drill battery. This Arduino setup is fairly simple, as long as there is knowledge and understanding of where electrical inputs and outputs of each component must go. This section will highlight the main components that are used to power the drill, vertical linear movements, the caching systems, and the storage rotation. The full setup can be seen below, in Figure 8.

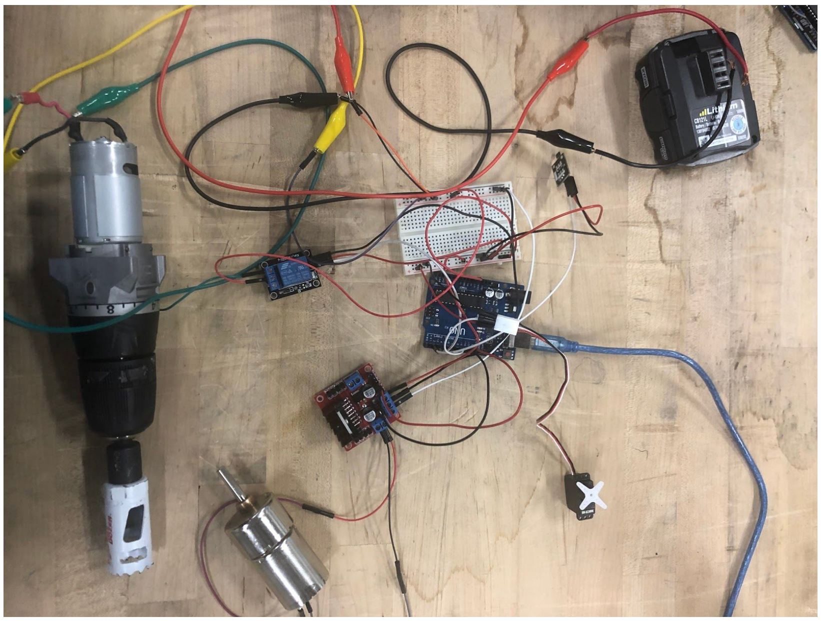

Figure 8: Arduino Electrical Setup

This will also review the required maintenance to ensure the system will be powered correctly and will stay productive while in use on the Psyche asteroid.

<u>1.4.1 Assembly</u>

First, you must have the following electrical components to create the Arduino set up:

- 2 x Torque Motors
- 1 x Drill Motor
- 2 x Servo Motors
- 1 x Dual H-Bridge Motor Driver Module
- 1 x Hall Effect Sensor
- 1 x Time-of-Flight Distance Sensor
- 1 x UNO 5V Arduino Board
- 1 x breadboard
- 1 x 12V Battery
- 1 x Relay Module

The setup also includes needing multiple alligator clips, male-male wires and male-female wires. Every component will be hooked up to the arduino board and the 12V power source through a breadboard.

Ideally, wires would be soldered together, instead of the need for a breadboard, but since the team was unable to reach this step of their assembly process, the following notes will guide through a breadboard assembly.

First, connect the UNO Arduino board to a computer via USB to power the board. Then, create a bridge connection from the Arduino board to the breadboard. This should connect the 5V and ground inputs from the Arduino board. No signal connections between the two are required. Then use the breadboard to connect the 12V positive and negative inputs. This will create a power source for all the working electrical components of the Arduino set up.

Then, incorporate the motors into the circuit. These motors include the drill motor, which will power the drill in a specified direction. A relay module will be used to connect the drill to the Arduino board and the 12V power and will be used to power the drill on/off, as well as, control the direction movements of the drill. Counterclockwise motion will remove the drill from the surface, clockwise directions will allow the drill to penetrate the surface material. The torque motors will also be powered through using a dual H-bridge motor driver. This driver will power the drills and control the rotational direction of their movements. Counterclockwise motion will pull the drill in an upward vertical movement, while clockwise movements will push the drill in a downward vertical movement. Lastly, the servo motors will be used to operate the caching system and the rotational storage carousel. These motors will be directly powered through the Arduino board, and are activated by a defined program code. Unfortunately, the team was unable to complete this assembly, so steps for this assembly are currently unavailable.

Lastly, hall effect sensors and time-of-flight distance sensors will be used to activate different parts of the program code. A hall effect sensor will track the rpm measurements of the drill motor. This sensor must be placed 1 mm away from the active drill motor. When the drill begins to slow down, the hall effect sensor will record the change of speed and cause the drill to either stop, or begin rotating in the opposite direction. It will also activate the torque motors to begin pulling the drill upward, away from the surface. The time-of-flight distance sensor should be placed above the drill, at the top of the sampling system. Once a core sample is retrieved, the torque motors will begin pulling the drill up, towards the top of the sampling system. When the drill gets within 10 mm of the distance sensor, this will begin the program code that activated the caching and storage system. It will first cause the servo motor attached to the storage carousel to move underneath the drill, and position a test tube to be right below the coring bit. The servo motor controlling the caching system will then be activated, further pushing the sampled out of the coring bit into the test tube. Once the servo motor for the caching system returns to its original position, the storage carousel will retreat back to its normal position, away from the drill area. Then, allowing the drilling procedure to occur again.

1.4.2 Maintenance Required

The only maintenance required for the electrical setup is to continually run multiple "bug" checks on the program. Be sure that the program is running as desired and ensure that all distance and sensor readings are accurate. Calibrating these sensors would be vital before sending the sampling system to the asteroid. Also, be sure to check wires for overheating and stable connection. Ensure that all wires remain in a healthy condition and that open wires are not touching or interacting with other parts. Ensure that all wires are connected safely and securely, to ensure a stable connection.

2.0 Operation Manual

This section will explain how to operate the sampling system. Fortunately, this system is fully autonomous, so once the code is imported to the Arduino's memory, the system will be able to perform on its own, without needing a manual counterpart to control it. This will further review how to operate the sampling system while it's in use on the asteroid and how to troubleshoot it from afar, if failure or error would occur to the system's operation.

2.1 Arduino Programming Operation

The goal for this project was to create a system that would be able to operate on its own and if any problems arose, the system could work around it. For the scope of this project an Arduino was used to control all the operations of the drill. Before receiving the drill, the code will be programmed onto the board and no setup is needed. Simply make sure the battery is charged and activate the ON/OFF switch. The drill will drill and collect samples automatically. Before the drill starts its operations the electromagnet will activate and will deactivate once the drilling is complete. When drilling, the system will move the drill downward into the surface and collect a core. After the core is collected it will be sampled into the caching system by raising up to allow for the storage system to engage and will drop the sample into the tubes. This process will continue until the desired amount of samples is collected.

2.2 Troubleshooting

If problems arise with the electronics be sure to unplug immediately. When troubleshooting any issues with motors or movement, first check the connections and battery. The issue is usually due to incomplete connections to the motors from the battery and the battery being dead. If the connections are not correct, re-soder and connect properly as some may have been destroyed in transportation. If the battery is dead, recharge or connect a new battery. Lastly, if the drill is not operating correctly, what is described above, the Arduino may have been connected or updated with incorrect code. For this download code provided by team and re-upload, if this does not work run the troubleshooting program to understand if there is any issue within the coding itself.

3.0 Potential Risks

After assembly and design production, the team developed a list of potential critical failures and the effects that the failure will have on the system. Each risk also has information on how to avoid each risk and mitigate and correct any mistakes that were made. It is important to take note of these potential risks and failures because if they occur while in use on the asteroid, it may become a great challenge to fix. If any of the main subsystems become inoperable, the entire system could fail. It will be vital to keep up with maintenance and hardware requirements to ensure the system operated as desired.

3.1 ElectroMagnet Stability Operation

This component's failure is that if the electromagnet does not have enough force, the entire sampling system would essentially "fly off", or disconnect, from the asteroid. This failure could be caused by an incorrect analysis of the force required by the electromagnet. This failure can be mitigated by correctly doing the analysis on the force required to hold the sampling system to the asteroid and having enough power to accompany that required electromagnetic force.

3.2 Motor of the Drill and Tightening System

This failure coincides with the tightening system, within the drill motor. Therefore, if the tightening system stalls, this component would not be able to hold the coring drill bit in place. This failure could be caused by an efficient motor that has been used with the tightening system. Whether the motor does not provide enough torque or rotates too fast, this failure can be mitigated by correctly choosing the motor that does completes the action the best.

3.3 Power Supply for the Entire System

This component is responsible for delivering the power and energy to control the entire system autonomously. If the power supply is interrupted, the drill would not operate, the torque motors would not be able to drive the drill in vertical movements, the caching system would be inoperable, and the electromagnet would power off. This failure can be mitigated by making sure the arduino codes and power supply is connected correctly and that sufficient power supply source is used.

3.4 ElectroMagnetic Coiling Wires

These specific wires are for the electromagnet and create a magnetic field when a current is passed through. This is for the stability subsystem. The failure of this component is that too much current could pass through, therefore melting the wires used to create the magnetic field, causing the sampling system to fly off. This failure can be mitigated by correctly doing the analysis of the force required to keep the sampling system on the asteroid and correctly choosing the type of wire that is sufficient.

3.5 AC/DC Converter

This part is used to help control the current passing through from the power supply to the sampling system. The failure of the part is that the sampling system would not have power, causing the system to be stagnant. This failure can be caused by having an insufficient converter to complete the job. This failure can be mitigated by researching the correct converter to use in the project.

3.6 Strength of Coring Bits

The coring bits are the drill bits that collect the samples. These coring bits could fail by inducing too much stress on the bit and either breaking the bit edges or the bit cylinder itself. The effect of the failure would be that the sampling system could not collect samples. This failure, however, can be mitigated by choosing an effective and strong coring bit to accomplish the job. The ideal coring bit would be a diamond grade drill bit, however, this was not feasible in the team’s final design due to budget restrictions.

3.7 Caching System Operation and Storage Capacity

This failure is at the lowest because it does not require attention, but it is still important. A failure of the caching system means that samples will not be able to correctly extract the sample material from the coring bits. In regards to the test tubes, they could potentially break and cause the samples to be unsecured. It is crucial for this system to safely collect that are not contaminated, therefore this failure can be mitigated by choosing reliable motors to operate the caching system and selecting strong material that will hold the samples securely.

4.0 Risk Mitigation

To mitigate these crucial failures, it is important to understand that all of these risks contribute to the efficiency and successful operation of this product. It is critical to first focus on the critical failures that coincided with the electromagnetic base. This base carries the entire sampling system, therefore it must be ensured that the base is stable and that the connections to the system body are secure before arrival to the asteroid. Next, the drill itself must be highly focused on, mostly the tightening system within the drill motor. To mitigate this risk, it is best to use an already manufactured Ryobi drill motor, instead of creating a new drill system. This ensures that the drill motor and it's tightening system would operate correctly and efficiently. The other risks can be further mitigated through the options explained in their respective descriptions.

5.0 Appendix

5.1 Appendix A: Full Bill of Materials (for Physical Product)

Bill of Materials			
Part Name	Part Quantity	Part Price	Part Description
Tetrix box	1	Provided by Dr. Trevas	Used the Tetrix box to create the tower
Drill motor	1	Used from old drill	The main that would be the main component and drills through the materials
MagBase Coiling Wire	1	Provided by Dr. Trevas	Coils around the MagBase to activate a downward directed force.
Arduino kit	1	$71.80	The Arduino kit will help in controlling all the electronic parts in the sampling system
Easy-Access Base-Mounted Shaft Support	6	$13.38	The supports keep the ends of the rods from wandering and create a more accurate motion.
External-Thread Ball Nut	2	$63.46	The balls screw nut uses ball bearings to thread onto the ball screw, reducing friction.
Mounted Linear Sleeve Bearing	2	$53.31	The linear bearing moves frictionlessly along the steel shaft .
Ball Screw	2	$44.31	The ball screw translates the rotational motion of the motor to vertical motion to raise and lower the drill assembly.
Linear Motion Shaft	2	$16.95	The linear motion shaft provides support to the drill assembly, removing the need for a second

			ball screw.
Iron Four Arm Knob	8	$11.67	These are the screws that will be attached to the base and wrapped with magnet wire.
Servo Motor	2	$31.99	The servos motors will be used to actuate the caching arm, and the sample remover.
Clamping Beam Coupling	1	$8.36	This coupler will connect the motor to the ball-screw.
Base	1	$398.74	The base will support the tower and magnetic feet.
Total		$1058.90	