Ro-Beast 2.0: User Manual

This is the ultimate user manual for the anechoic chamber testing platform, the Ro-Beast 2.0, designed by Group 11 in the Mechanical Engineering Section of the 2023-24 ENGG 4000 Senior Design Project cohort. See the following QR code for the full CAD model and more.

Figure 1. QR code to Full CAD assembly, Animations, and PCB Schematics

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Key Terms

EUT: Equipment under Test

Ro-Beast 2.0: the physical structure, hardware, and code of the testing platform

GUI: Graphical User Interface

Operating Limits:

Vertical Elevation:

- Range – 1.04 m to 1.93 m
- Speed – 0 to 10 mm/s
- Measurement interval – 0.1 mm to (range – current height)
- Resolution – 6 microns/step

Tilt Range:

- Range – 0° to 90°
- Resolution – 15°

Azimuthal Rotation:

- Range – 0° to 360°
- Speed – 2°/s to 30°/s
- Measurement interval – 0 to 99.9˚ (less than (range – current azimuth) to successfully measure)
- Angular step resolution - 0.0321°/step

Safety Concerns

First and foremost, there are some safety concerns with the use and operation of this device, so it is up to the User to operate at their own risk, or for future senior design groups to improve upon. In the meantime, no persons should be within 2m of the Ro-Beast 2.0 while operating the elevation mechanism.

1. **Pinch Points**
    a. There are a few main pinch points that could crush a finger. Firstly, the gap between the top plate and the support plate gets very small when at the lowest

position. Therefore, wire mesh finger guards should be installed in place. In the meantime, no persons shall be within 2m of the Ro-Beast 2.0 when the elevation is operating.

   b. Spur gears. There is an open set of spur gears which drives at fairly high RPM at the max speed and someone could get their hair caught inside or fingers.

   c. Bevel Gears. While the bevel gearset that drives the rotation mechanism is hidden from view, nothing stops the user from reaching underneath the swing bracket and touching the bevel gears when operating a rotation sweep. This is dangerous and should not be done.

2. **Lack of Load Testing:**

   a. The Ro-Beast 2.0 was finished late in the semester and therefore, full testing was not able to be carried out. While the team determined that the full applied loads of 10 kg EUT and 10 kg counterweight could be driven under the desired speeds, there WAS NOT a way to test the full load when tilted. Therefore, the user should not attempt to place EUTs greater than 1kg on the Ro-Beast 2.0 while tilted, unless they are doing so in a safe manner to determine the limits of the Ro-Beast 2.0.

3. **Dropped Objects**

   a. Since this device is quite tall at the maximum range, nobody should place foreign objects on the top plate or the EUT mount for the risk of them falling off and damaging other equipment.

Construction and Assembly Plan

The construction of the *Ro-Beast 2.0* involves many parts both electrically and mechanically. Any fabrication procedures such as welding, cutting, drilling, bending, grinding, sanding, and tapping were performed by the team in the UNB machine shop. More complicated parts that require precise fits with the lathe or CNC were fabricated by machinist Tony Guimond.

The lower supporting structure is comprised of all the parts shown in the exploded view of Figure 2, and the procedure is as follows. The 1m long support legs could be placed within the holes in the steel support feet. Use wooden spacers to keep the support feet parallel and at the desired spacing. Place the support plate on top of the support tubes. The support plate is bolted loosely to both the support tube flanges, after which the cross bracing would be placed and bolted down. M10 bolts and nuts were used to fasten all structural components to the support plate and M8 bolts, nuts and washers were used to fasten the cross bracing to the support feet.

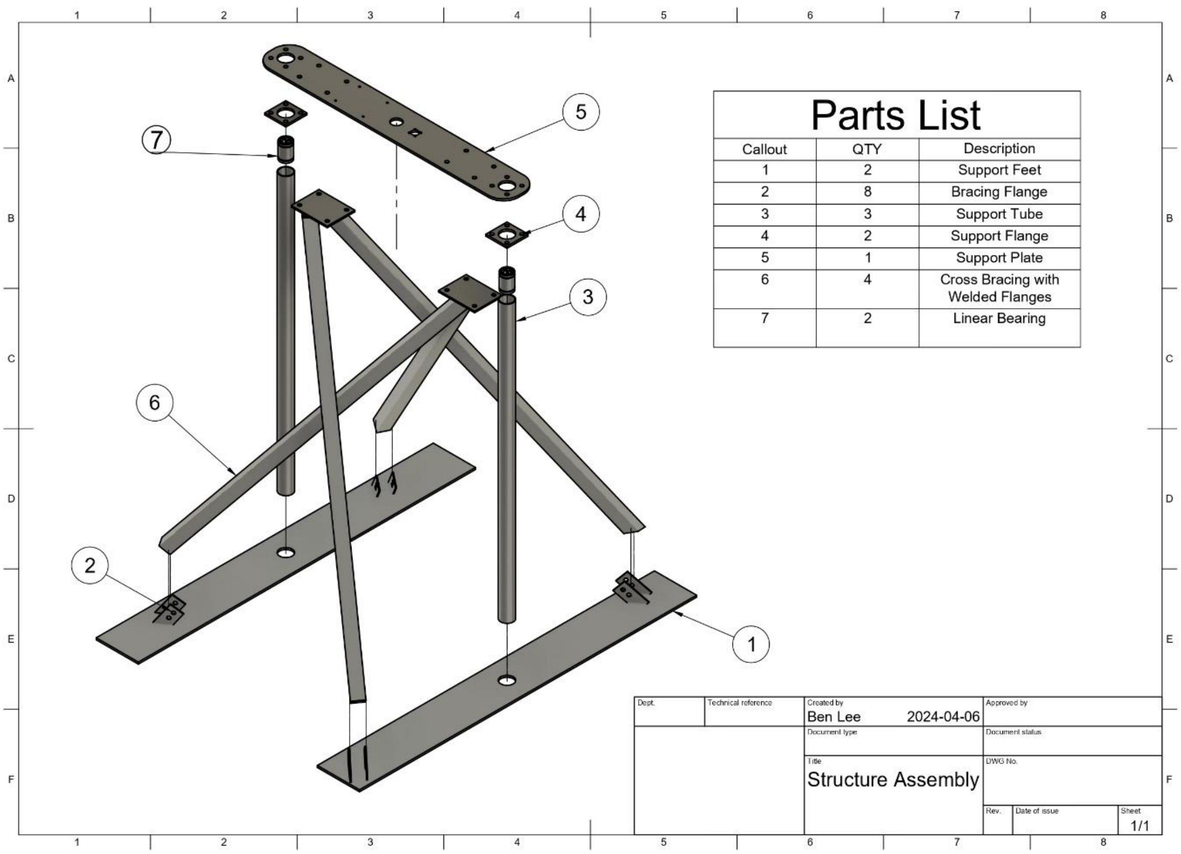


Figure 2. Bottom Structure Assembly Exploded View

After the lower structure was assembled the upper structure was fabricated and assembled as shown in Figure 3. The oil-impregnated flanged sleeve bearings were press-fit into the sides of the swing bracket, the tilt shaft had M10 threads tapped into the end, slid through the flange bearings, and the whole swing bracket was bolted to the tilt brackets with custom oversized washers. This ensured that the tilt shaft was pulled into the holes in the tilt bracket which would take the load so the bolt would not be in shear. The tilt brackets and counterweight slider were bolted to the top plate using ¾” UNC aluminum bolts and nuts. The linear rails were fastened to the top plate with standard M10 nuts and washers. The ball screw was bolted on with an M12-1 fine thread locknut after first putting a steel spacer beneath the top plate.

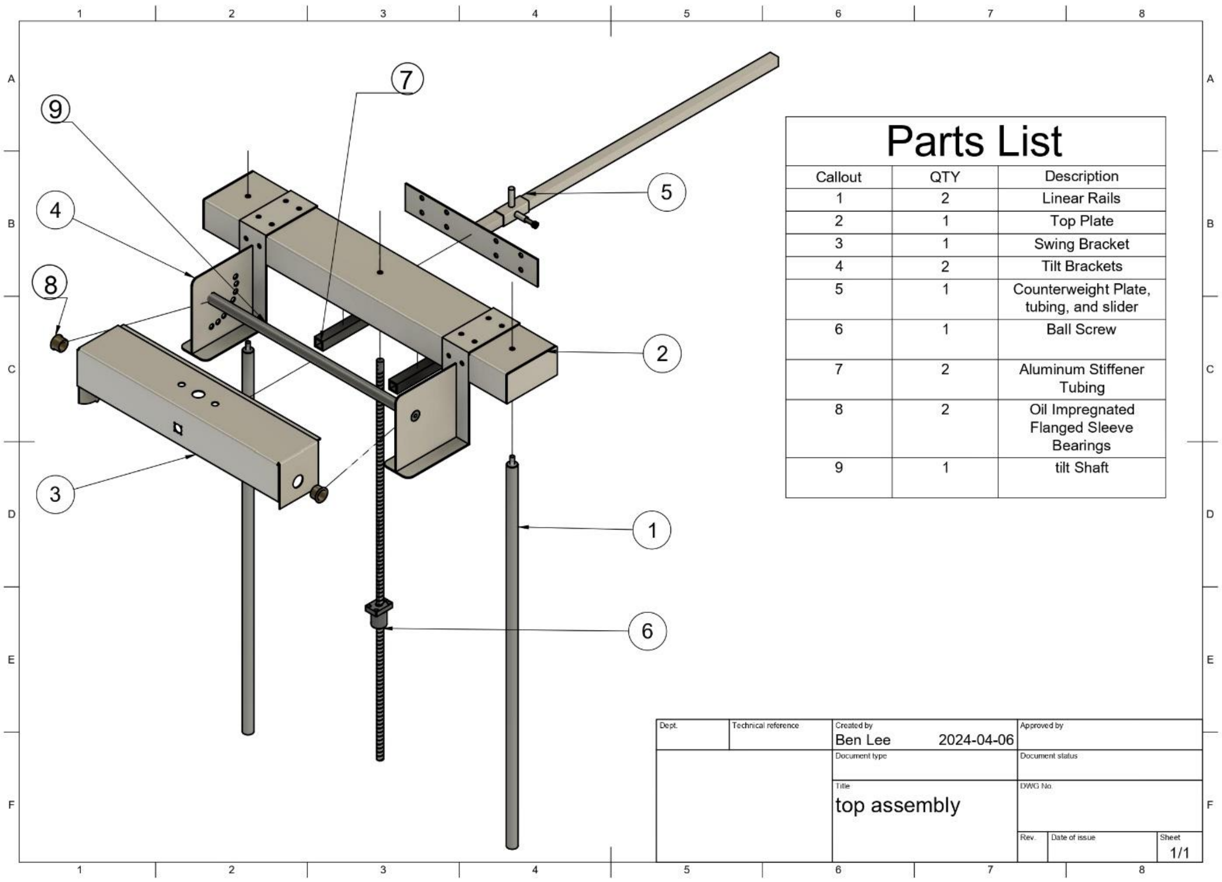


Figure 3. Top Structure Assembly Exploded View

An exploded view of the rotation mechanism assembly is shown in Figure 4. The EUT mount was cut on a bandsaw and sanded from a 1” thick 9” diameter plate from plywood. The EUT shaft adapter was machined to spec from a 3” piece of aluminum on the lathe and CNC, then screwed into the mount with wood screws. The EUT shaft was fixed into the mount and adapter with set screws. An oil-impregnated thrust washer was placed over the hole in the swing bracket and the shaft was slid in. Underneath, the flange bearing was bolted to the swing bracket and the bevel gear was fixed to the EUT shaft’s exposed end with set screws. Then the motor was bolted onto the swing bracket’s front face and secured with M2.5 screws. The pinion was attached to the shaft with a set screw and the encoder was mounted to the back of the motor. Assembling the rotation assembly was easily done when not attached to the tilt brackets and top plate, as the tilt shaft had to be removed to access the bolts for the motor.

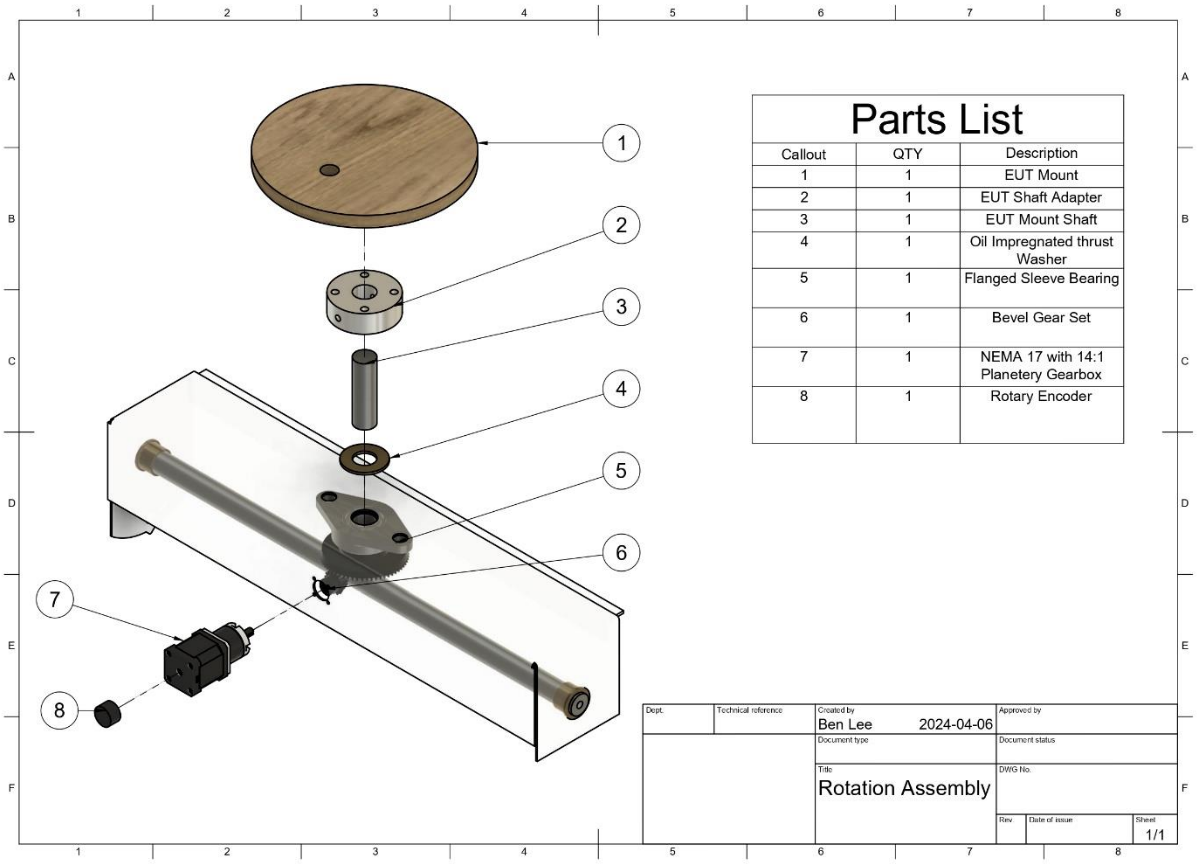


Figure 4. Rotation Assembly Exploded View

The assembly figure for how the elevation motor and ball screw are assembled is shown in Figure 5. The motor was bolted to the support plate after having a shaft keyway cut into both itself and the corresponding spur pinion. The set screw locks the pinion in place. Ensure the spur gear is bolted to the ball nut tightly. The spacer was placed over the hole in the support plate, a needle roller thrust bearing was placed on top, the spur gear was bolted on the ball screw nut, and the ball screw and nut were slid into the hole in the support plate. A 2-piece 3D printed housing was designed to hold the DC electromagnetic brake onto the back of the stepper motor since the bolt-hole pattern did not align. Before the motor is bolted on, its motor-brake 3D printed housing piece is slid over, then the DC electromagnetic brake is slid into its housing piece, and the two parts were bolted together with standard M4 screws.

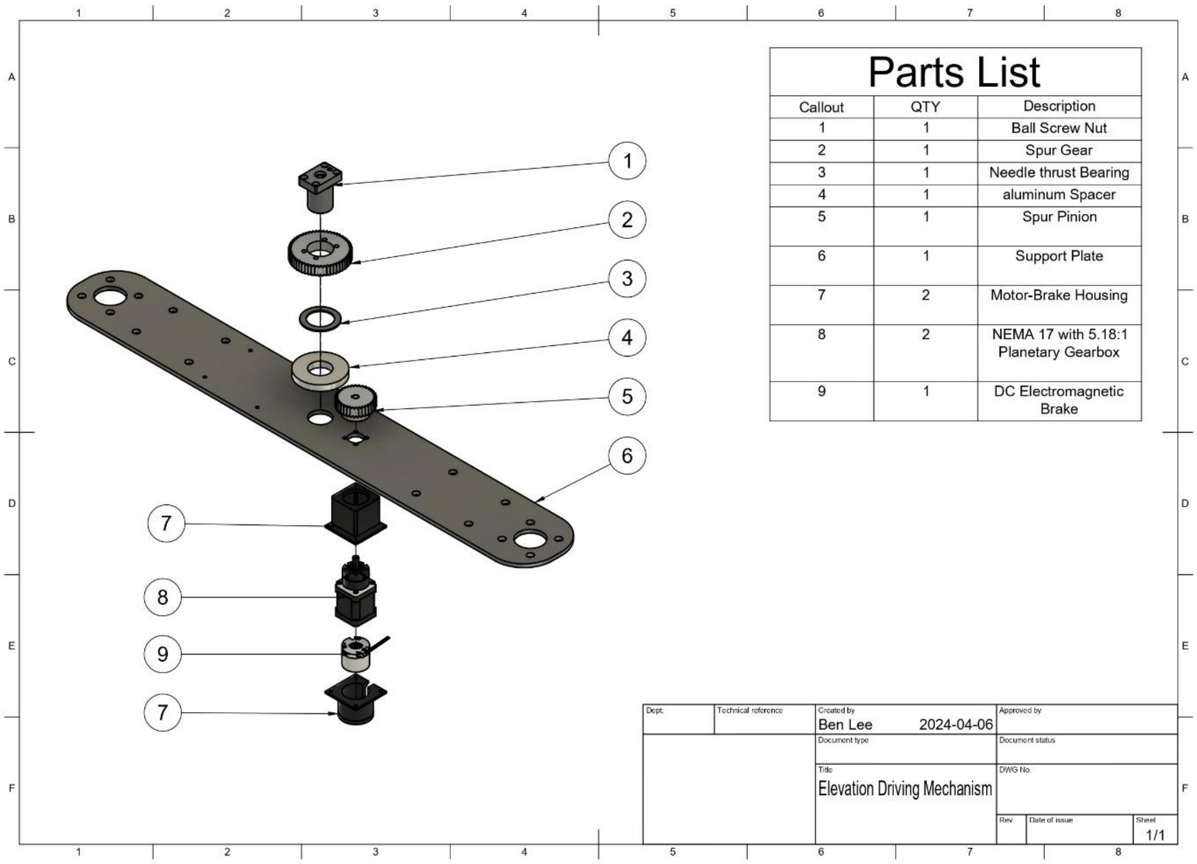


Figure 5. Elevation Driving Mechanism Assembly Exploded View

Once the structure has been completely assembled, the team placed the limit switches on the tilting, rotation, and vertical translation mechanisms with M2 screws as well as 3D-printed switch mounts. The PCB was bolted to the bottom of the support plate and wires were routed with enough slack for the full range. The 3D printed limit switch trigger must be screwed onto the bottom of the ball screw which triggers the elevation limit switch defining the maximum height position. Once the aforementioned tasks and sub-assemblies were completed, the total assembly would be put together by first placing the ball screw and linear rails in the lower support structure. Then the top structure could be lowered down onto the linear rails and bolted in place, as shown in Figure 6.

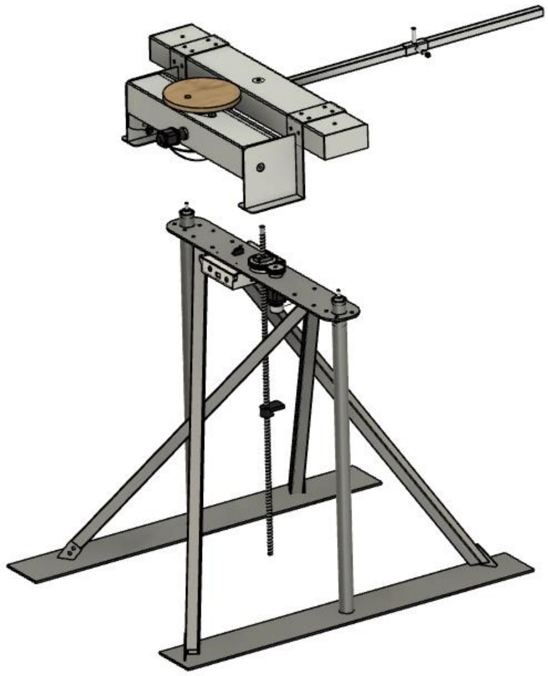


Figure 6. Full Assembly Placement View

Apparatus

Ro-Beast 2.0

The Ro-Beast 2.0 has many components, so this section will serve to familiarize the user with those features. See the figure below for a high-level view of the parts of the Ro-Beast 2.0, followed by additional views for the three main mechanisms. Refer to the

Construction and Assembly Plan exploded views for the names of each part.

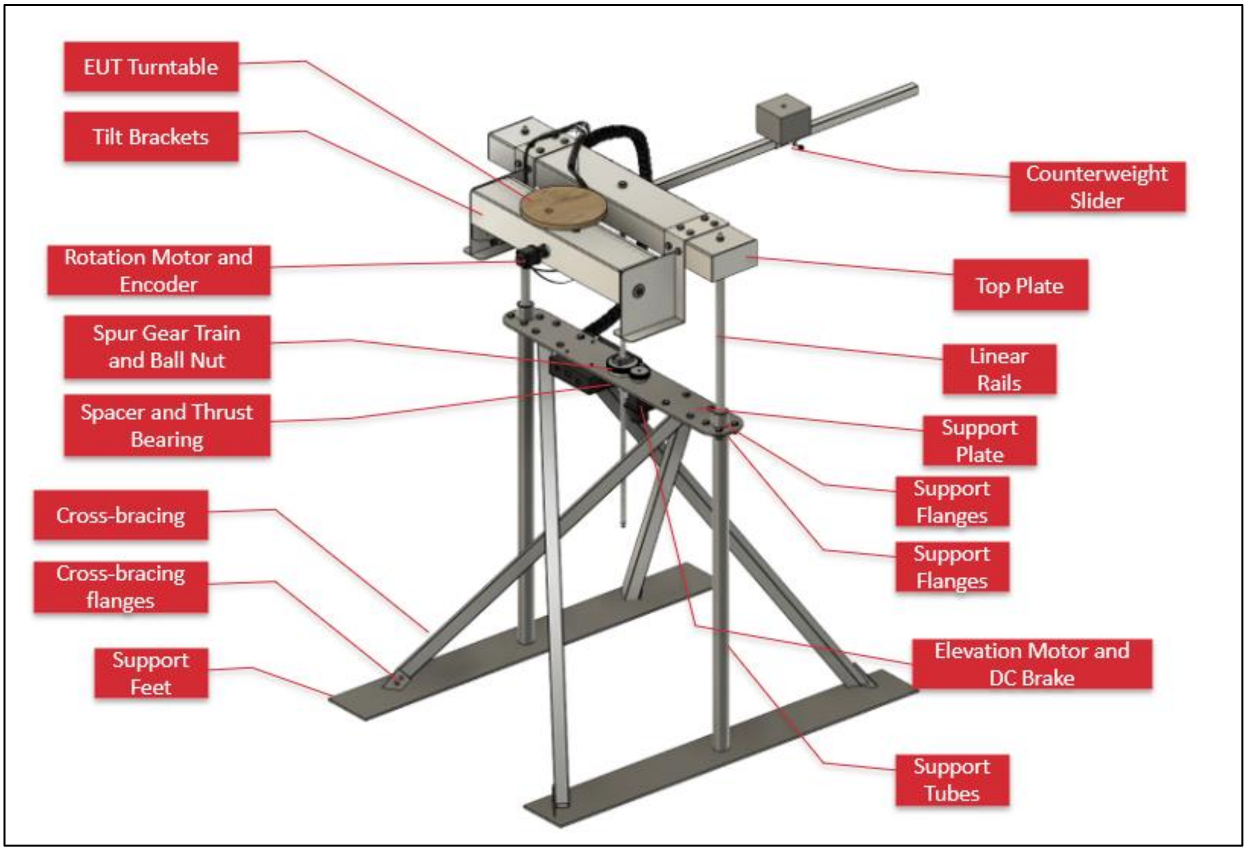


Figure 7. High-Level Diagram of the Ro-Beast 2.0

The following figures are the exploded views of the sub-assemblies: rotation assembly, elevation assembly, and the tilt mechanism. Figure 8 serves to familiarize the user with the operating mechanism for the azimuthal rotation sweep. It is driven by a NEMA 17 stepper motor with a 14:1 gearbox which drives bevel gears to rotate the EUT mount at the desired speed and positions. There is a rear-mounted encoder for positional feedback, as well as a limit switch that triggers for home position.

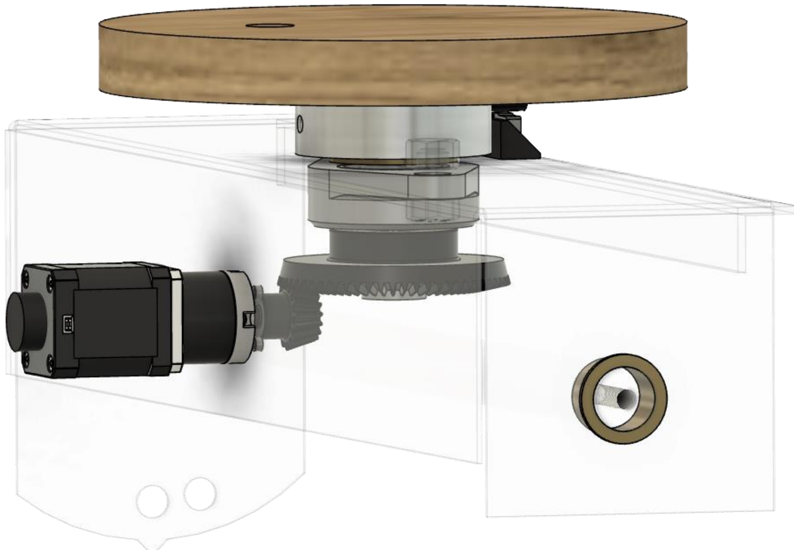


Figure 8. Rotation Mechanism

Figure 9 shows how the elevation driving mechanism is assembled. Essentially there is a NEMA17 stepper motor with a 5.18:1 gearbox that drives spur gears to rotate the nut of the ball screw which lifts the ball screw up and down. There is a DC electromagnetic Brake on the back of the NEMA17 motor to provide a locking torque when the motors are turned off. Two linear rails slide up and down in support shafts with linear bearings press fit into the support shafts to counteract moments. A limit switch on the top of the support plate and one on the bottom trigger the end range positions.

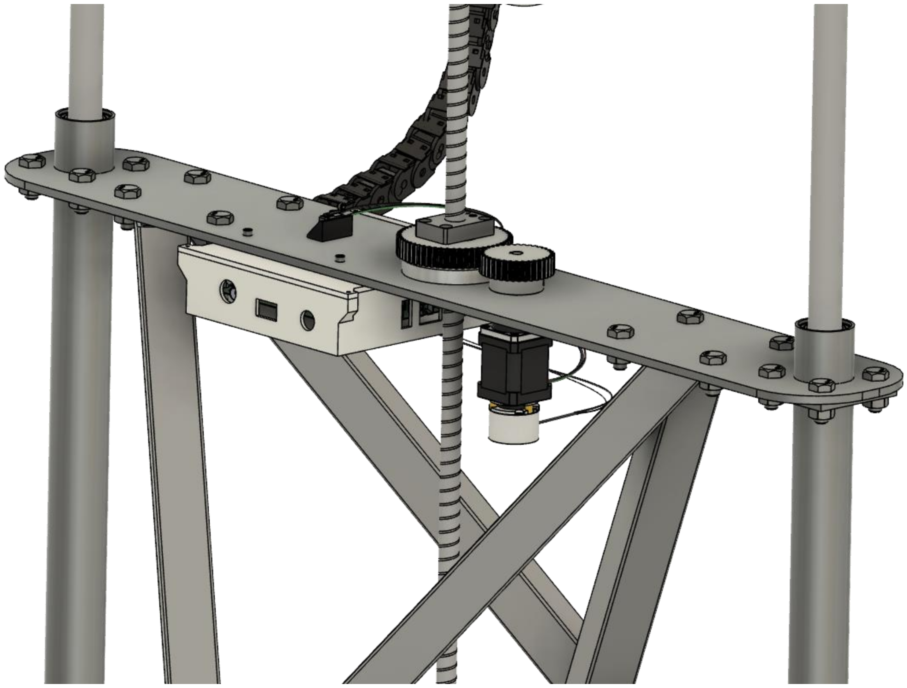


Figure 9. Elevation Mechanism

Figure 10 shows the inside of the tilt mechanism. A manual pin design is used here to offer the user 15 degrees per increment between 0° and 90°. Limit switches will trigger at each of the positions for real-time feedback. Ensure both pins are in fully by looking from the view shown below.

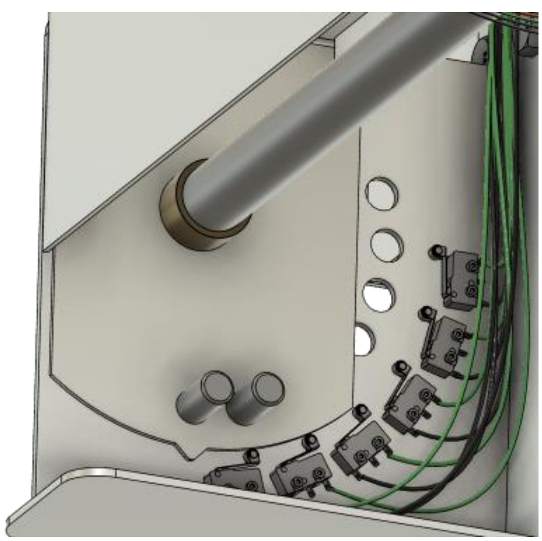


Figure 10. Tilt Mechanism

System Checklist

This section will provide a list of key items to ensure are connected and in the proper position before attempting to perform any sweep functionality, assuming the Ro-Beast 2.0 has already been constructed and assembled as per the construction section.

- Ensure all limit switches are in the correct position and align with the corresponding triggers.
- Ensure the wires from the PCB box will not get caught on any moving parts
- Ensure all peripherals are securely plugged into the PCB
- Ensure both sets of gears are meshing
- Ensure the ball screw lock nut is tight (the screw should not be able to rotate)

Quick Start Guide

How to Mount an EUT to the Ro-Beast

Currently, the team has not designed a versatile mounting method to accommodate a wide range of EUTs as it was not a focus of the scope. Currently, the EUT can just be screwed into the wooden mount.

How to Start the Ro-Beast 2.0

Requirements:

1. Constructed Ro-Beast 2.0
2. Actuators and sensors are plugged into the control board
3. USB cable connecting the host computer to the control board
4. BNC cable connecting the VNA to the control board
5. Required Python files are on the host computer

Use the DC barrel plug to power the control board. Run the Python file “Ro-Beast.py” to start the GUI. Upon startup, Ro-Beast 2.0 will home itself to 1.04 m and 0˚, indicated with limit switches.

How to Position the Ro-Beast

As outlined in Figure 11 below, two parameters must be set to position Ro-Beast 2.0: the desired height and the desired azimuth.

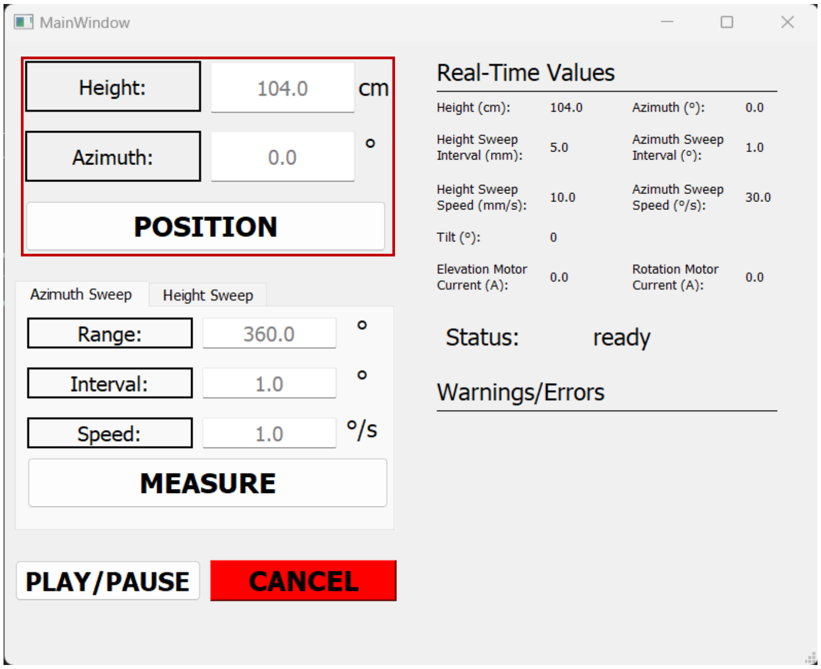


Figure 11: GUI showing the positioning section

If the height and azimuth in the text boxes differ from what is desired, enter the desired values, ensuring they are within the restrictions outlined in the Operating Limits: section. Once the values are correctly configured, press the "POSITION" button and wait for Ro-Beast 2.0 to finish moving and return to standby.

How to Take an Azimuth Sweep

As outlined in Figure 12 below, three parameters must be set to position Ro-Beast 2.0: the desired final azimuth (range), the desired interval between measurement pulses (interval), and the desired sweep speed (speed).

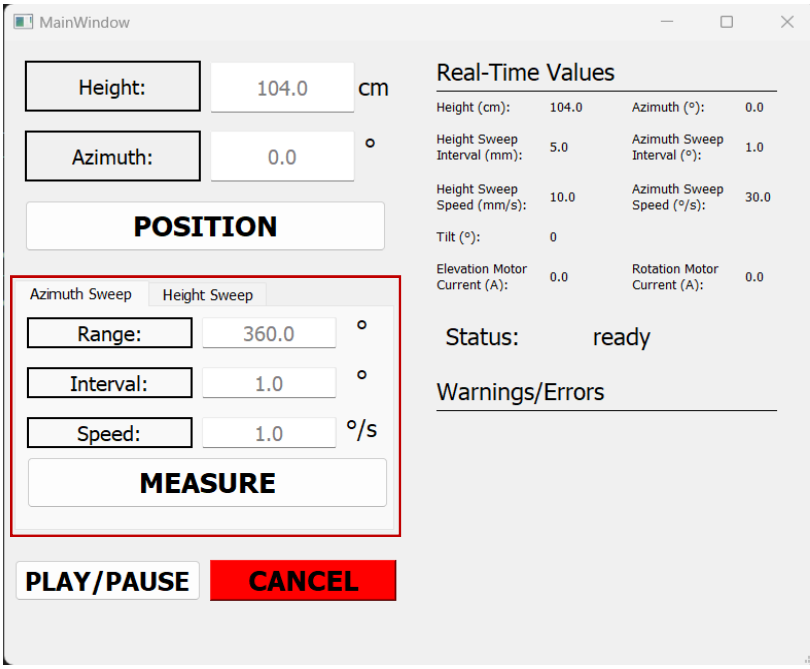


Figure 12: GUI showing Azimuth Sweep tab

If the range, interval, and speed text boxes differ from what is desired, enter the desired values, ensuring they are within the restrictions outlined in the Operating Limits: section. Note that the measurement interval must be less than the azimuthal distance the Ro-Beast 2.0 will be travelling. Once the values are correctly configured, press the "SWEEP" button. Once the sweep is completed, Ro-Beast 2.0 will re-home itself to 1.04 m and 0˚ and will then return to standby.

How to Take a Height Sweep

As outlined in Figure 13 below, three parameters must be set to position Ro-Beast 2.0: the desired final height (range), the desired interval between measurement pulses (interval), and the desired sweep speed (speed).

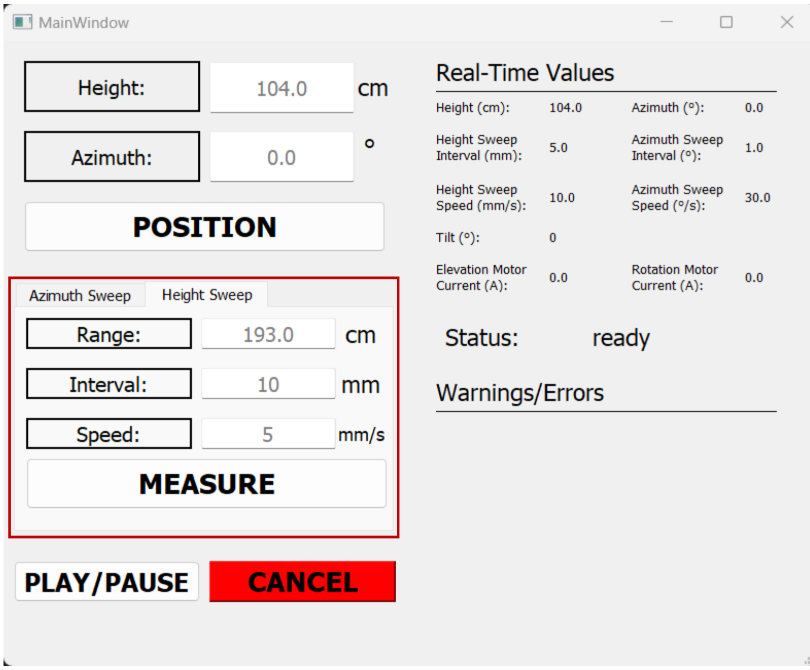
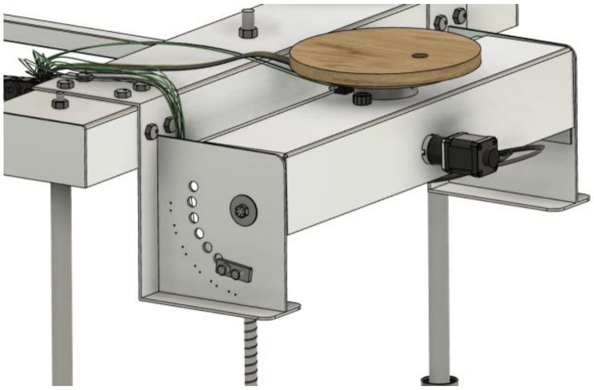


Figure 13: GUI showing Height Sweep tab

If the range, interval, and speed text boxes differ from what is desired, enter the desired values, ensuring they are within the restrictions outlined in the Operating Limits: section. Note that the measurement interval must be less than the distance Ro-Beast 2.0 will be travelling. Once the values are correctly configured, press the “SWEEP” button. Once the sweep is completed, Ro-Beast 2.0 will re-home itself to 1.04 m and 0˚ and will then return to standby.

How to Adjust Tilt

1. Hold the swing bracket
2. Remove pins from the tilt bracket
3. Rotate the swing bracket to the desired angles. Ensure the holes on the tilt bracket are aligned with the holes on the swing bracket
4. Insert pins to lock the swing bracket



How to Adjust the Counterweight

See the attached Excel worksheet for how to adjust the counterweight to prevent deflection and promote levelness. As shown in Figure 14, the user must input four variables to determine the position of the counterweight along the slider.

Counterweight Positioning Look-up						
USER INPUTS	**Value**	**units**		**Counterweight Position**		
Mass of EUT (NOT TO EXCEED 10KG)	1	kg		**Position of Counterweight with EUT**	**43.33333333**	**cm**
Tilt Position (0° default)	90	° from vertical				
EUT center of mass (NOT TO EXCEED 50cm)	5	cm		standby counterweight position without any EUT	37.77777778	cm
mass of counterweight (NOT TO EXCEED 10kg)	4.5	kg				

Figure 14. Counterweight Positioning Look-up

Variables:

1. **Mass of EUT** – this is the mass in kg and cannot exceed 10 kg
2. **Tilt Position** – this is the angular tilt position shown by the GUI in degrees

3. **EUT Center of Mass** – this is how far out the center of mass of the EUT is from the face of the EUT mount Figure 15. This parameter can be determined by placing the EUT on a slim rod and positioning it until it balances, like a see-saw.

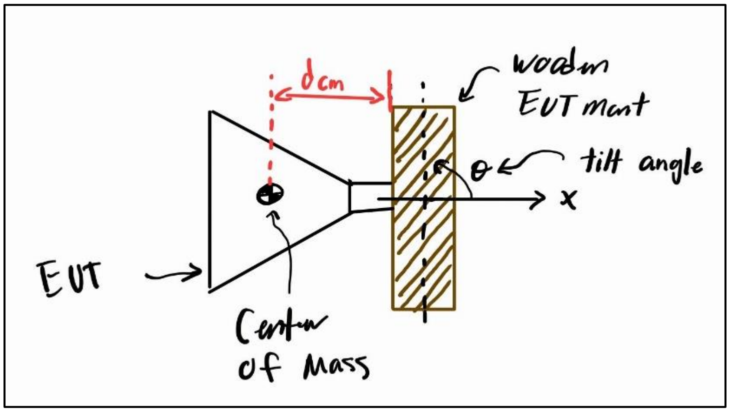


Figure 15. Visual Diagram of Center of Mass

4. **Mass of Counterweight** – the mass of the counterweight must not exceed 10kg. The counterweight should have a central hole to slide onto the counterweight slider which will prevent it from falling. Any small gym weight plate should work. Use the tightening bolt to lock the slider in place.

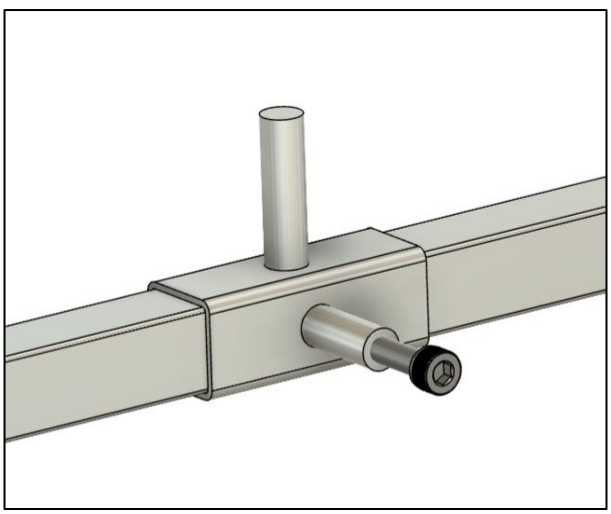


Figure 16. Counterweight Slider

Once all those values are entered, the box in green will tell you how far to position the slider along the rod, measured FROM the surface where the slider is bolted to the top plate. If the position that shows up is farther than 90 cm, something is wrong. Either the counterweight is too light, the EUT exceeds 10 kg, the position of the center of mass exceeds 50 cm, or a combination of these things. The slider cannot be positioned farther than this. Use a ruler to get it to an approximate location.

Other GUI functions

Play/pause: when this button is pressed, the system will pause in its current state and maintain all current values. Once this button is pressed again, the system will resume what it was doing.

Cancel: when this button is pressed, the system will re-home itself to 1.04 m and 0˚ and await in standby.

How to Shut off the Ro-Beast 2.0

Remove power from Ro-Beast 2.0, close the GUI, and disconnect the power cable, USB cable, and VNA cable.

Software Issues to be Resolved for Full Functionality (as of 2024-04-11)

- Currently, there is a potential UART overflow issue only allowing one command to be sent to the system. For example, once positioning or a sweep is performed, the system must be turned off and back on to perform another.
- The real-time values are not being sent to the GUI. The architecture has been built out in the software, but some bugs are hindering this functionality.
- The status is not being sent to the GUI.
- The play/pause button functionality must be created.
- More warnings and errors could be created to ensure the safety and proper operation of the system.