# Flying Squirrel

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# Design Requirements

| Customer Requirements | Engineering Requirements |
|---|---|
| **CR1**- Affordable | **ER1**- Range of Motion (2'x1'x1' envelope) |
| **CR2**- 3D Movement | **ER2**- Size (8"x8" overhead area limit) |
| **CR3**- Precise and Accurate | **ER3**- Speed (1m/s in any direction) |
| **CR4**- Relatively Compact for Storage | **ER4**- Force (Produce 10N in any direction) |
| **CR5**- Long Battery Life | **ER5**- Sensing and Control Accuracy (<0.1mm and 0.1N sensing, <0.5mm and 1N control) |
| **CR6**- Aesthetically Pleasing | **ER6**- Battery Life (30 minutes of use) |
| **CR7**- User Friendly | **ER7**- Production Cost (<$1000, later removed) |
| | **ER8**- Set-up Time (1 minute) |

Table 1: Customer and Engineering Requirements

# Top Level Testing Summary

| Experiment | Relevant DRs | Testing Equipment Needed | Other Resources |
|---|---|---|---|
| **EXP1** – Force Output Test | **ER4** – Force | -Luggage Scale (for XY motors)<br>-Food Scale<br>-Weights (for Z motor) | -3+ People |
| **EXP2** – Movement Test | **CR2** – 3D Movement<br>**CR3** – Precise and Accurate Movement<br>**ER1** – Range of Motion<br>**ER3** – Speed<br>**ER5** – Sensing and Control Accuracy | -Motion capture cameras located in Raz labs along with associated software<br>-Tape measure<br>-Marking Stickers | -Raz Labs |
| **EXP3** – Endurance Test | **CR5** – Long Battery Life<br>**ER6** – 30 Minutes of use | -Completed Robot<br>-Camera with long enough battery life to video entire run time | -Table at least 4ft x 4ft in size<br>-Weights |
| **EXP4** – Setup Test | **CR7** – User Friendly<br>**ER8** – Setup Time | -Completed robot<br>-Stopwatch | -Table at least 4ft x 4ft in size |
| **EXP5** – Size Test | **ER2** – Size<br>**CR4** – Relatively Compact for Storage | -Assembled bottom half of robot<br>-Tape Measure | |
| **EXP6 –** Budget Test | **CR1** – Affordability<br>**ER7** - Production Cost (<$1000, later removed) | -BOM | |
| **EXP7** – Aesthetic Test | **CR6**- Aesthetically Pleasing | -Client<br>-Completed Flying Squirrel Prototype | |

Table 2: Top Level Testing Summary

# Force Output Test

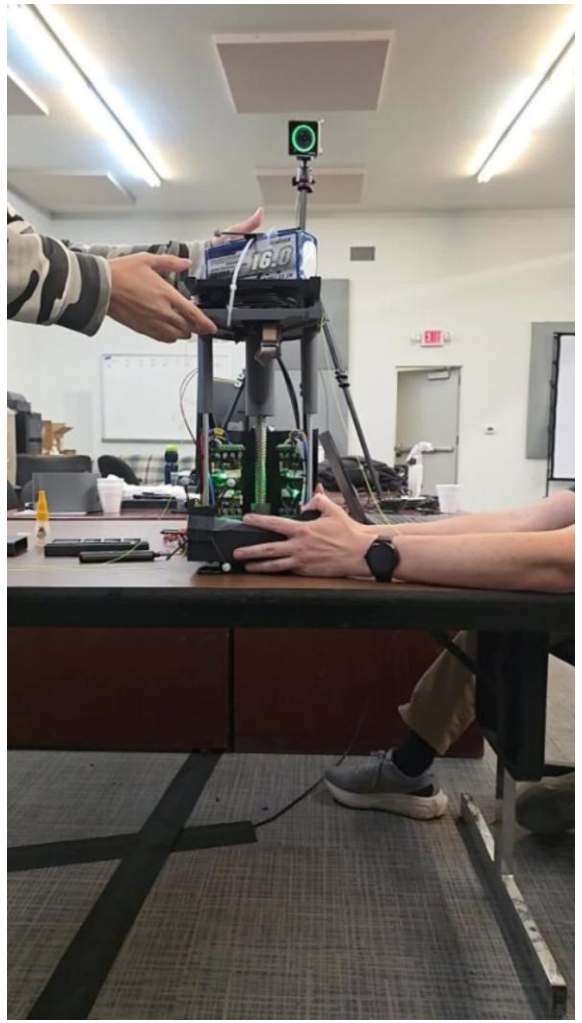
- Test Summary
  - Will test force produced by the robot (ER4)
  - Utilizes: luggage scale, food scale, weights
  - Isolated Variables: Force and Mass
  - Calculated Variables: Force = mass * acceleration
- Procedure
  - For xy motors, one team member must pull on the cable with the luggage scale while another holds the robot in place (with the motor pulling towards the robot), until the motor stalls
  - Mass value is read from the scale and multiplied by gravitational acceleration to obtain force value
  - For the z motor, weights are stacked on the stripped-down top plate to simulate the weight of the top components plus ten Newtons
  - Motor is run to see if vertical motion occurs
- Results
  - The minimum stalling force for one of the horizontal motors is approximately 29 Newtons
  - The vertical motor is able to lift the fully assembled top plate with an extra 10N of force applied, which is approximately 54N in total

Video 1: Vertical Force Testing

Video 2: XY Force Testing

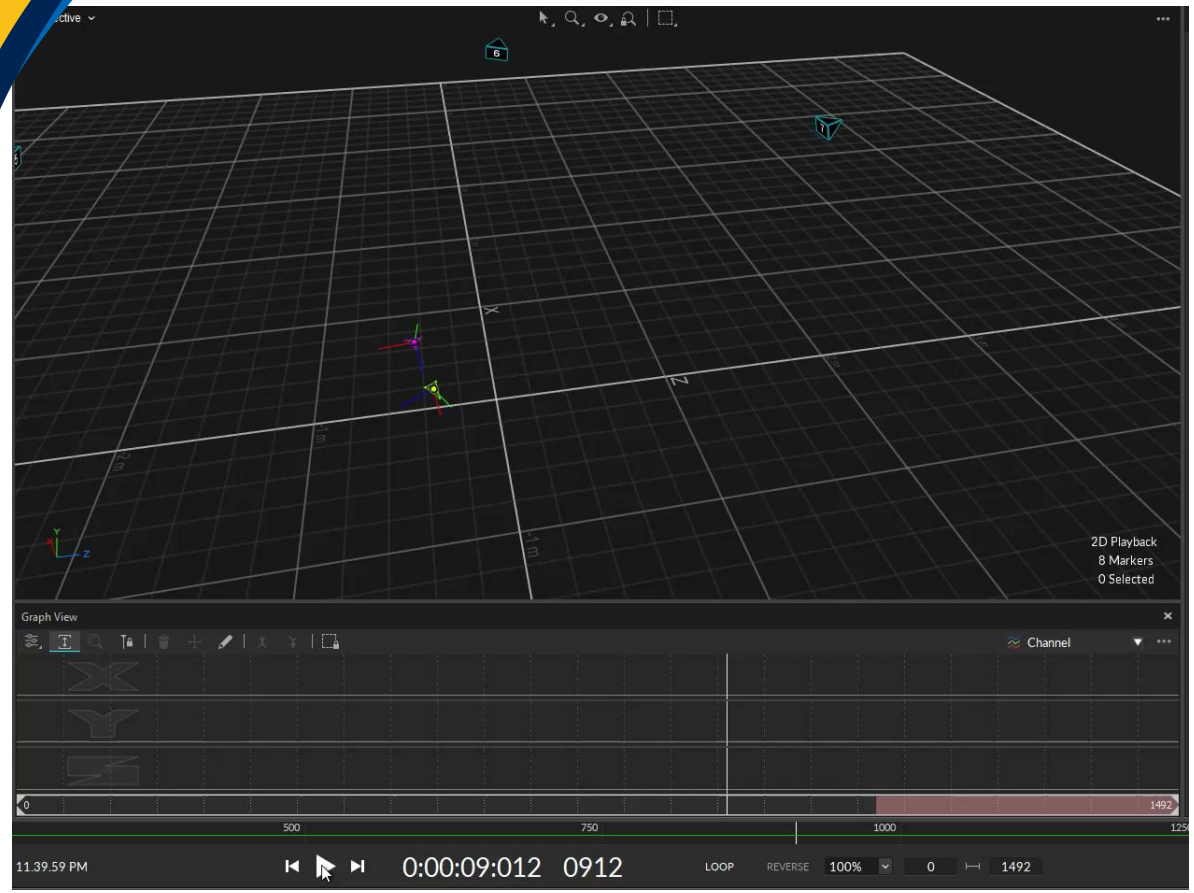
# Movement Test

- Test Summary
  - Tested the velocity at which the robot moves as well as how accurate and repeatable the movements are (CR2,CR3, ER1,ER3,ER5)
  - Utilizes: Motion capture cameras and tracking dots
  - Isolated Variables: Position and time
  - Calculated Variables: Revolutions to millimeters (In code), velocity from change in position divided by change in time
- Procedure
  - Place tracking dots on robot so cameras can track its movement
  - Place motion capture cameras surrounding the test area of the robot
  - Setup robot
  - Run robot and motion capture software then analyze the movements to see if the velocity and position are within specification.
- Results
  - The robot, when tested, was able to move about 1 m/s vertically and 2 m/s horizontally
  - Velocity measured using motion capture cameras with an accuracy of less than 1mm/s

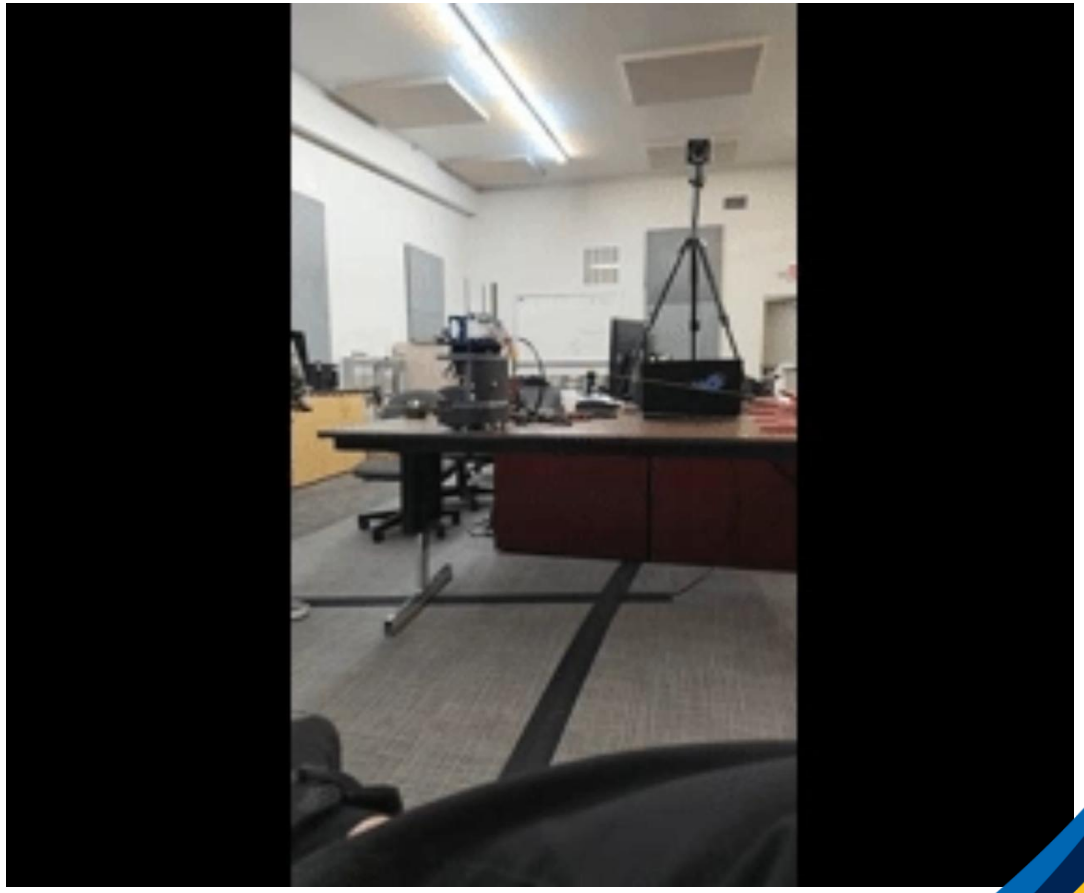


Video 3: Vertical Velocity Test

# Movement Test




Video 4: Horizontal Velocity Test MOCAP



Video 5: Horizontal Velocity Test MOCAP
Slow motion



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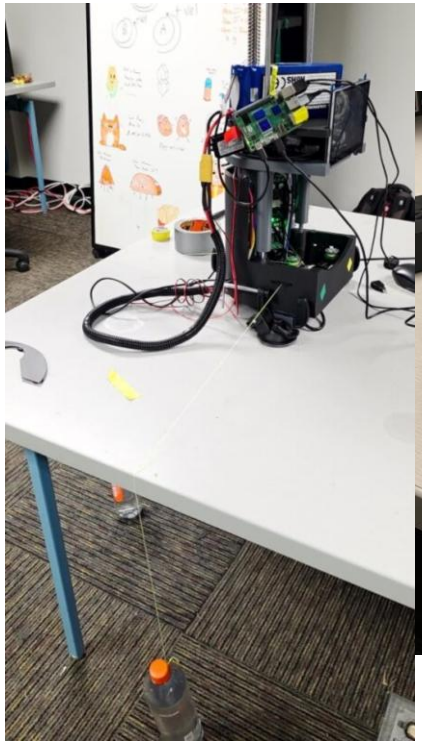
# Endurance Test

- Test Summary
  - The robot's battery life while in use will be determined by this test (CR5, ER6)
  - Utilizes: complete Flying Squirrel, video camera
  - Isolated Variables: Battery Life
  - Calculated Variable: None
- Procedure
  - We plan to run a procedure that will involve all four motors and simulate extended use by a patient
  - While the robot is continuously running, it will be monitored by either team members or the video camera
  - We will monitor the time to see if it can run for 30 minutes
- Results
  - After force testing which required the motors to exert more work than the robot will see during actual use the battery depleted less than 1%, giving us a run time of significantly greater than 30 minutes
  - Following the actual test, examining battery revealed that it had depleted about 15%
  - From full charge, the Flying Squirrel should be useable for around 2 hours 10 minutes before it reaches half charge
  - The battery will not reach dangerous state of charge due to depletion below 20%



Video 6: Endurance Test Procedure


Figure 1: Battery



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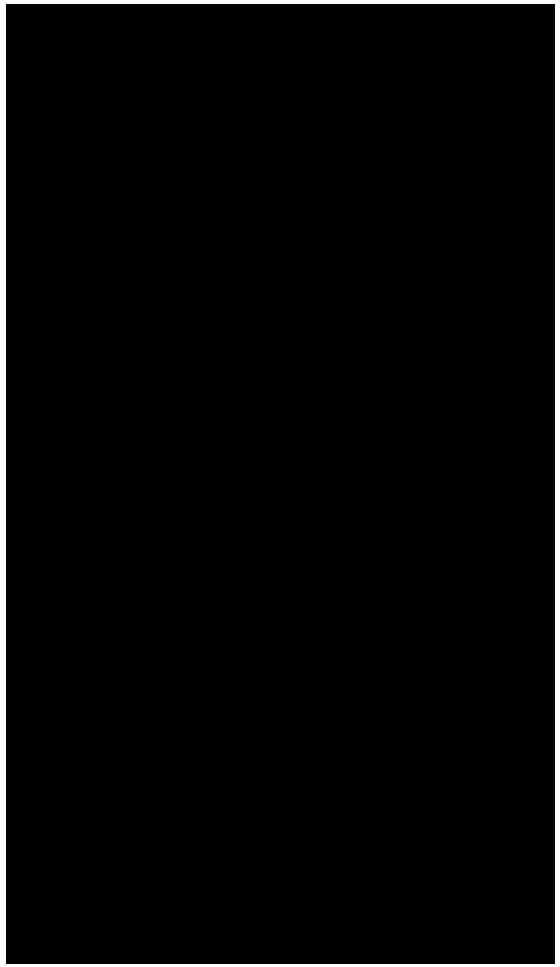
# Setup Test

- Test Summary
  - This test will evaluate how long it takes to set up the robot from its most inactive state (CR7, ER8)
  - Utilizes: compete Flying Squirrel, stopwatch
  - Isolated Variables: Setup Time
  - Calculated Variables: None
- Procedure
  - The robot will be reduced to its stowed position, with power off, cables retracted, and anchors detached from any work surface
  - One team member must carry the Flying Squirrel to a proper work surface, pull out and attach the anchors, then power it on while another team member monitors the time elapsed
- Results
  - Setting the Flying Squirrel up from its stowed configuration took approximately 43 seconds



Video 7: Setting Up the Flying Squirrel

# Size Test

- Test Summary
  - This test will evaluate the size of the robot (CR4, ER2)
  - Utilizes: tape measure
  - Isolated Variables: Length, Width, Height
  - Calculated Variables: None
- Procedure
  - One team member will simply measure the length and width of the Flying Squirrel's base, then measure the height from the work surface to the tallest point (The support rods)
- Results
  - The length and width of the robot are both within the 8 inch limit
  - The lead screw and the support rods exceed 8 inches at 19 inches, but our client has long since retired the height limit

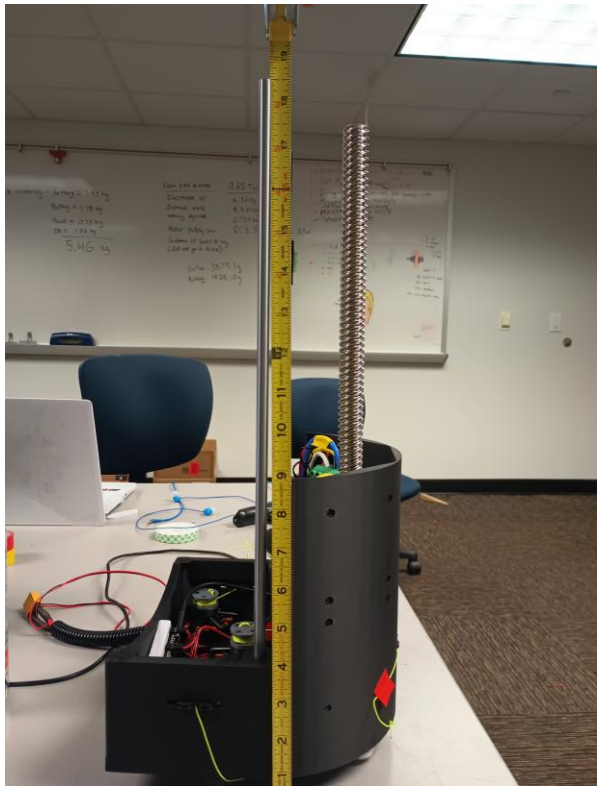


Figure 8: Height Measurement

# Aesthetic Test

- Test Summary
  - This test will evaluate the size of the robot (CR6)
  - Utilizes: Client
  - Isolated Variables: Client Approval
  - Calculated Variables: None
- Procedure
  - Observed by client
- Results
  - Client approved

Figure 9: Happy Reza

# Budget Test

- Test Summary
  - This test will evaluate the cost of robot (CR1, ER7)
  - Utilizes: BOM
  - Isolated Variables: Price
  - Calculated Variables: None
- Procedure
  - Total cost of BOM
- Results
  - Total budget spent: $2357.09
  - Total budget remaining: $1392.91

| | Bill Of Materials | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Raw Materials, Parts or Components | ($) Unit Cost | make/buy | Primary vendor | Manufacturer | lead time | Part Status | QTY | ($) Total cost |
| 1 | 3 Axis force sensor | 320.57 | buy | zhimin | zhimin | Arrived | on hand | 1 | 320.57 |
| 2 | ODrive S1 | 59.00 | buy | Odriverrobotics | Odriverrobotics | 2 week | on hand | 4 | 236 |
| 3 | 16384 CPR Absolute RS485 Encoder with Cable for ODrive Pro or S1 | 149 | buy | Odriverrobotics | Odriverrobotics | 2 week | on hand | 4 | 596 |
| 4 | Heat Spreader Plate | 12 | buy | Odriverrobotics | Odriverrobotics | 3 week | on hand | 3 | 36 |
| 5 | Harness Build Kit | 9 | buy | Odriverrobotics | Odriverrobotics | 4 week | on hand | 4 | 36 |
| 6 | Dual Shaft Motor - D5312s 330KV | 59.00 | buy | Odriverrobotics | Odriverrobotics | 2 week | on hand | 4 | 236 |
| 7 | PLA (3Kg) | 49.71 | buy | Amazon | creality | 2 days | on hand | 1 | 49.71 |
| 8 | drylin® lead screw, dryspin® high helix thread, right-hand thread, 1.4301 (304) stainless steel | 64.8 | buy | Roton | Roton | 1.5 weeks | on hand | 1 | 64.8 |
| 9 | dryspin® lead screw nut, high helix thread, RSR | 48.02 | buy | Roton | Roton | 2months | on hand | 1 | 48.02 |
| 10 | 2x OVONIC 3S Lipo Battery 15000 mAh 130C 11.1V LIPO battery with EC5 plug for 1/8 RC truck | 138.38 | buy | ovonic | ovonic | 1 week | on hand | 1 | 138.38 |
| 11 | Raspberry Pi 5 8GB | 80 | buy | electromaker | raspberrypi | Arrived | on hand | 1 | 80 |
| 12 | Arduino UNO R4 | 27.5 | buy | Amazon | ELEGOO | Arrived | on hand | 1 | 27.5 |
| 13 | Strap | 8.99 | buy | industrialsafety | industrialsafety | 1 week | on hand | 1 | 8.99 |
| 14 | 6.5x3 touch LED screen | 0 | buy | waveshare | waveshare | 2 weeks | on hand | 1 | 0 |
| 15 | Ball bearings | 8.99 | buy | harborfreight | harborfreight | 3 days | on hand | 1 | 8.99 |
| 16 | DC power supply | 33.94 | buy | Amazon | Nice-Power | 3days | on hand | 1 | 33.94 |
| 17 | Suction cup | 12 | buy | Amazon | Airhead | 3 days | on hand | 3 | 36 |
| 18 | Fishing line | 10.98 | buy | Amazon | eyond Braid Braide | 3 days | on hand | 1 | 10.98 |
| 19 | C-Clamp | 5 | buy | Home depot | Amerella | 3 days | on hand | 3 | 15 |
| 20 | screws | 18.98 | buy | Home depot | Amerella | 3 days | on hand | 1 | 18.98 |
| 21 | linear ball bearings | 5.83 | buy | misumi | misumi | 1 week | on hand | 1 | 5.83 |
| 22 | Amplifier Load cell | 6.99 | buy | Amazon | amazon | 3 days | on hand | 1 | 6.99 |
| 23 | Uxcell 10mm OD 8mm Inner Dia 400mm Length 6063 Aluminum Tube | 6.22 | buy | harfington | harfington | 1 week | on hand | 2 | 12.44 |
| 24 | Dc power steper | 6.99 | buy | Amazon | Amazon | 2 week | on hand | 1 | 6.99 |
| 25 | terminal block distribution | 12.99 | buy | Amazon | OOMO | 3 days | on hand | 1 | 12.99 |
| 26 | Breadboard | 9.99 | buy | Amazon | amazon | Arrived | on hand | 1 | 9.99 |
| | | | | | | | | Total= | 2357.09 |
| | | | | | | | | remai | 1392.91 |

Table 3. BOM

# Specification Sheet - CR

| Requirement | CR Met | Client Acceptable |
|---|---|---|
| CR1- Affordable | No | Yes |
| CR2- 3D Movement | Yes | Yes |
| CR3- Precise and Accurate | No | No |
| CR4- Relatively Compact | Yes | Yes |
| CR5- Long Battery Life | Yes | Yes |
| CR6- Aesthetically Pleasing | Yes | Yes |
| CR7- User Friendly | Yes | Yes |

Table 4: Customer Requirement Evaluation

# Specification Sheet - ER

| Requirement | Target | Tolerance | Read Value | ER Met | Client Acceptable |
|---|---|---|---|---|---|
| ER1- Range of Motion | 2'x1'x1' | ±0.5mm | Larger tables accept length of cable needed. Smaller tables limit range | Yes | Yes |
| ER2- Size | 8"x8"x8" (Original) | N/A | 8"x8"x19" | No | Yes |
| ER3- Speed | 1m/s | N/A | 1m/s vertical motion. 2m/s horizonal motion | Yes | Yes |
| ER4- Force | 10N | ±0.1N | 29.4N (Minimum for horizontal motors at 0.25 turns/s).<br>56N (Minimum for vertical motor) | Yes | Yes |
| ER5- Sensing and Control Accuracy | 0.1mm, 0.1N (sensing), 0.5mm, 1N (control) | N/A (Tolerance Requirement) | N/A | No | No |
| ER6- Battery Life | 30 minutes | N/A | Completed 30-minute run-time test with 15% charge | Yes | Yes |
| ER7- Production Cost | $1,000 (Maximum) | N/A | $2,350.10 | No | Yes |
| ER8- Set-up Time | 1 minute | N/A | Set up complete in 43.87 seconds | Yes | Yes |

Table 5: Engineering Requirement Evaluation

# Quality Function Deployment

| | | TR Correlations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Production Cost | | 9 | | | | | | |
| Speed | | 1 | 9 | | | | | |
| Force | | 1 | 3 | 9 | | | | |
| Control and Detection | | 3 | 3 | 3 | 9 | | | |
| Device Size | | 1 | 3 | 1 | 1 | 9 | | |
| | | | | | | | | |
| | | **Technical Requirements** | | | | | | |
| **Customer Needs** | **Customer Weights (1-5)** | Production Cost | Speed | Force | Control and Detection* | Device Size* | N/A | N/A |
| Affordability | 5 | 9 | | | 3 | 3 | | |
| 3rd Dimension Movement | 4 | 3 | 1 | 1 | | 1 | | |
| Precision and Accuracy | 3 | 3 | 9 | 9 | 9 | | | |
| Size | 4 | 3 | 1 | | | 9 | | |
| Cosmetics | 1 | 1 | | | | 1 | | |
| User Friendliness | 5 | 3 | | | | 9 | | |
| **Technical Requirement Units** | | Dollars ($) | Meters per Second (m/s) | Newtons (N) | Millimeters (mm) | Inches (in) | | |
| **Technical Requirement Targets** | | 2000 | 1 | 10 | 0.1 | 8x8x19 | | |
| **Absolute Technical Importance** | | 31 | 42 | 35 | 93 | 100 | | |
| **Relative Technical Importance** | | 5 | 3 | 4 | 2 | 1 | | |

Table 6: QFD


Thank you!
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# Questions?

None



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