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) -Food Scale -Weights (for Z motor)	-3+ People
EXP2 – Movement Test	**CR2** – 3D Movement **CR3** – Precise and Accurate Movement **ER1** – Range of Motion **ER3** – Speed **ER5** – Sensing and Control Accuracy	-Motion capture cameras located in Raz labs along with associated software -Tape measure -Marking Stickers	-Raz Labs
EXP3 – Endurance Test	**CR5** – Long Battery Life **ER6** – 30 Minutes of use	-Completed Robot -Camera with long enough battery life to video entire run time	-Table at least 4ft x 4ft in size
EXP4 – Setup Test	**CR7** – User Friendly **ER8** – Setup Time	-Completed robot -Stopwatch	-Table at least 4ft x 4ft in size
EXP5 – Size Test	**ER2** - Size	-Assembled bottom half of robot -Tape Measure	

Table 2: Back View and Internal View of Finalized Design

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 weighted top plate

Video 1: Vertical Force Testing

Video 2: XY Force Testing

Movement Test

- Test Summary
  - Will test the velocity at which the robot moves as well as how accurate and repeatable the movements are (CR2,3, ER1,3,5)
  - Utilizes: Motion capture cameras and tracking stickers
  - Isolated Variables: Velocity and position
  - Calculated Variables: Revolutions to millimeters (In code)
- 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.
- Expected Results
  - For the velocity in the XY direction the motors are currently limited to 1 m/s but have the capability to move at almost 3 m/s. The Z direction is the same but has a maximum of slightly more than 2 m/s based on theoretical RPM calculated from KV and voltage of battery.
  - For the position, the motor encoders are accurate to within two degrees of rotation so for a 10 mm diameter shaft the movements of the robots should be accurate to within 0.0175 mm.

Video 3: Vertical Velocity Test

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
- Expected 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

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
- Expected Results
  - We anticipate that one of us will be able to setup the robot in less than one minute

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

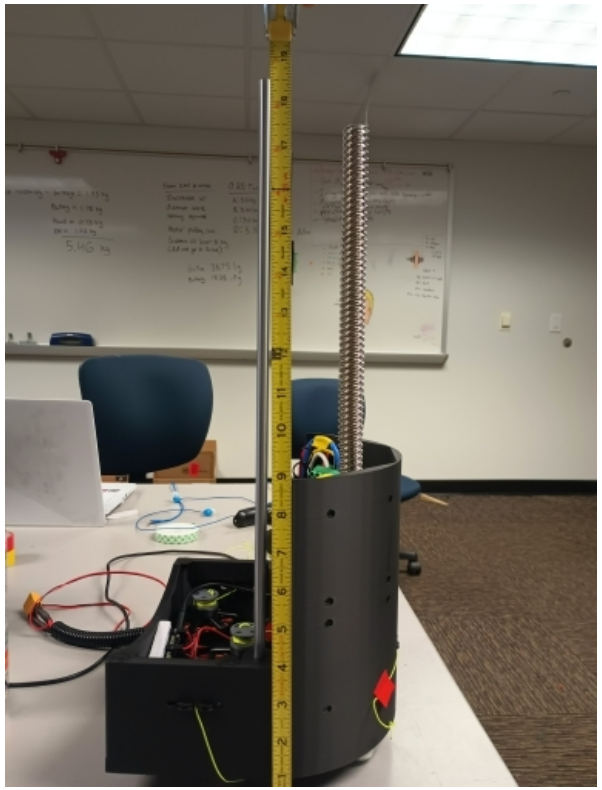

Figure 2: Height Measurement

Specification Sheet - CR

Requirement	CR Met	Client Acceptable
CR1- Affordable	No	Yes
CR2- 3D Movement	Yes	Yes
CR3- Precise and Accurate	Not Tested Yet	Not Tested Yet
CR4- Relatively Compact	Yes	Yes
CR5- Long Battery Life	Not Tested Yet	Not Tested Yet
CR6- Aesthetically Pleasing	Yes	Yes
CR7- User Friendly	Yes	Yes

Table 3: Customer Requirement Evaluation

Specification Sheet - ER

Requirement	Target	Tolerance	Read Value	ER Met	Client Acceptable
ER1- Range of Motion	2'x1'x1'	±0.5mm	N/A	Not Tested Yet	Not Tested Yet
ER2- Size	8"x8"x8" (Original)	N/A	8"x8"x19"	No	Yes
ER3- Speed	1m/s	N/A	N/A	Not Tested Yet	Not Tested Yet
ER4- Force	10N	±0.1N	29.4N (Minimum for horizontal motors at 0.25 turns/s). 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	Not Tested Yet	Not Tested Yet
ER6- Battery Life	30 minutes	N/A	N/A	Not Tested Yet	Not Tested Yet
ER7- Production Cost	$1,000 (Maximum)	N/A	$2,350.10	No	Yes
ER8- Set-up Time	1 minute	N/A	N/A	Not Tested Yet	Not Tested Yet

Table 4: 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 5: QFD


Thank you!
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Questions?

None

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