Final Design Review

SEED Team 14
Track Assisted Cart
Team TAC

The University of Vermont

The Team

Project Manager
Edward Ling, Mechanical Engineering

Manufacturing Engineer and Safety Coordinator
Wilson Ezequelle, Mechanical Engineering

Financial Manager
Sam Andris, Electrical Engineering

Logistics Manager
Paul Lowe, Electrical Engineering

Test Engineer
Zack He, Mechanical Engineering

Our Client

built by Newport

bringing beautiful, intricate designs to life

Owner, President, and CEO: Dave Laforce

Director of Operations: Paul Gariepy

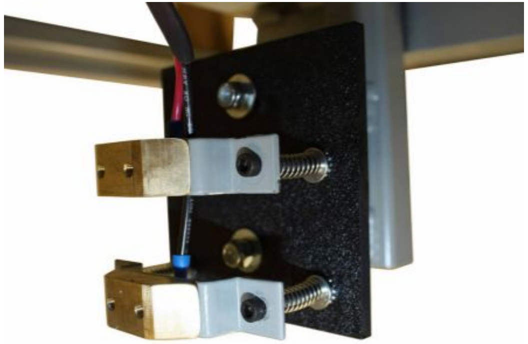
Problem Statement

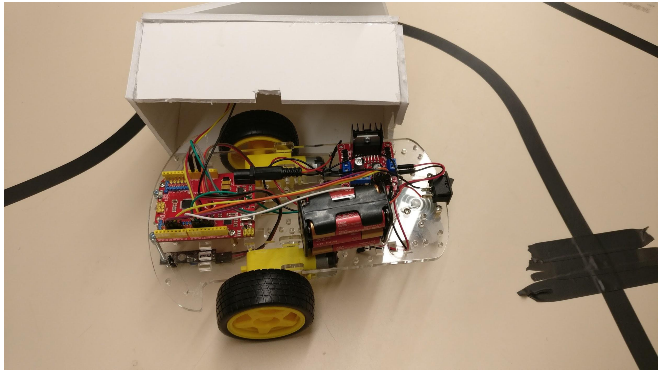
Built by Newport struggles with production flow and efficiency within their manufacturing finishing line. Currently, Built by Newport moves their products by hand around the finishing assembly area for various treatments.

- Hand pushed carts are disruptive to production flow, and inefficient
- A guided, motorized cart is desired to streamline production flow
- Allow employees more time to focus on product quality
- Existing designs are too expensive, include excessive functionality

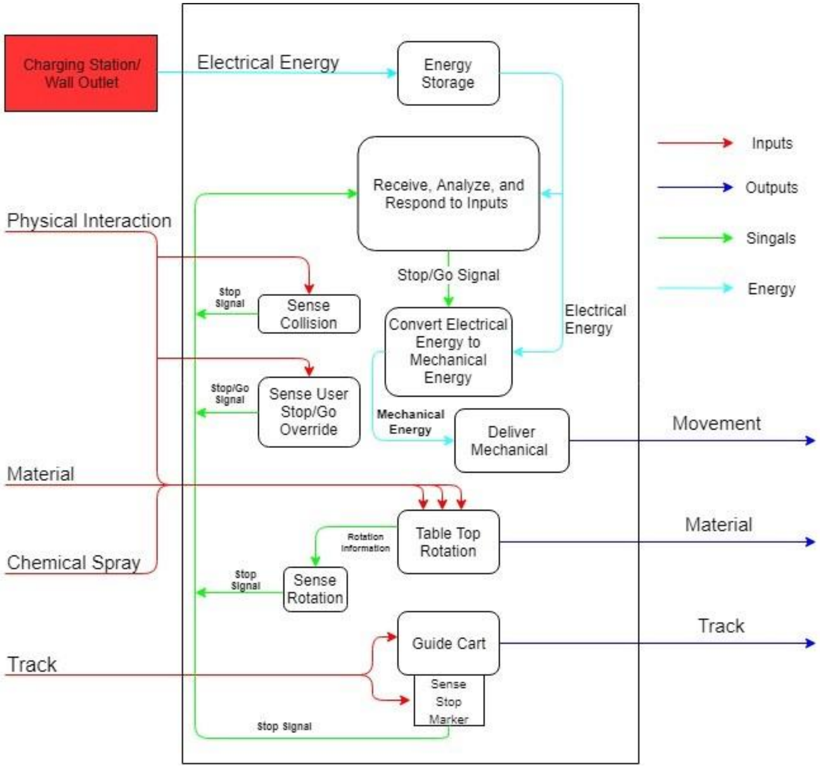
Design Options

- Rotational mechanism
  - Lazy Susan vs Stud and Rollers
- Line following vs track following
- Frame geometry
  - On-going, frequently changed
- Battery charging
  - Station vs in-cart charging





Working Design Concept: Functionality



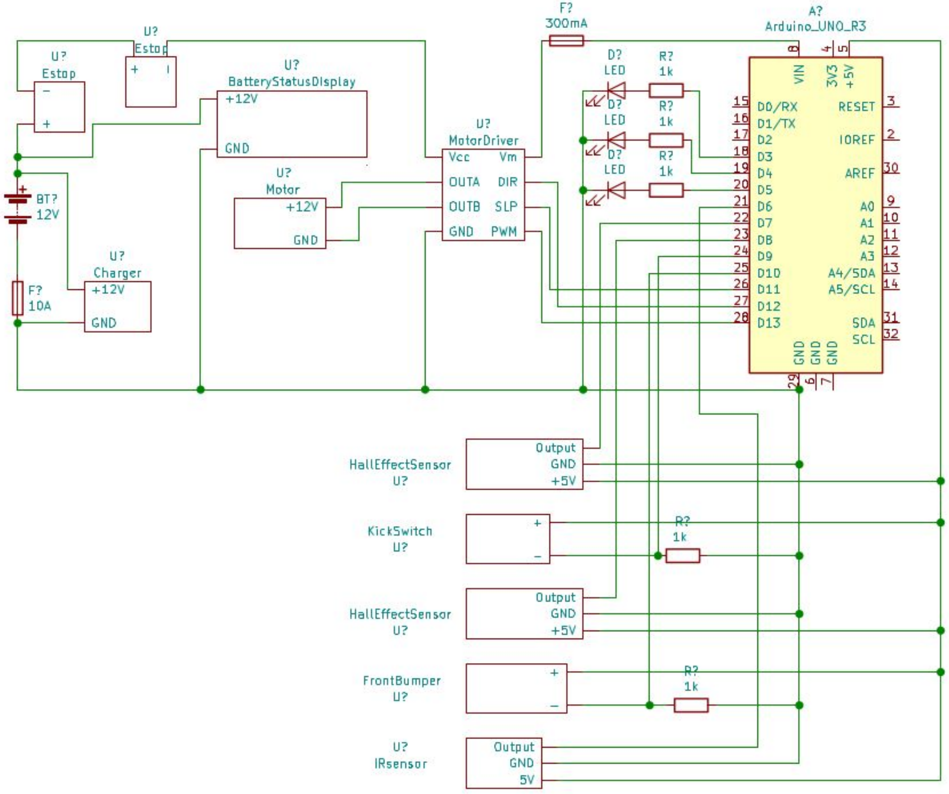
Main Functionality and Flow of Material and Energy

- Electrical energy is transmitted from charging station to battery to power electric motor
- Physical inputs detected by sensors
  - Emergency stop bumper
  - Table top rotation
  - On/off switch
  - Stop signal in track
- Material is loaded to and unloaded from table top
- Factory workers interact with material by spraying treatments

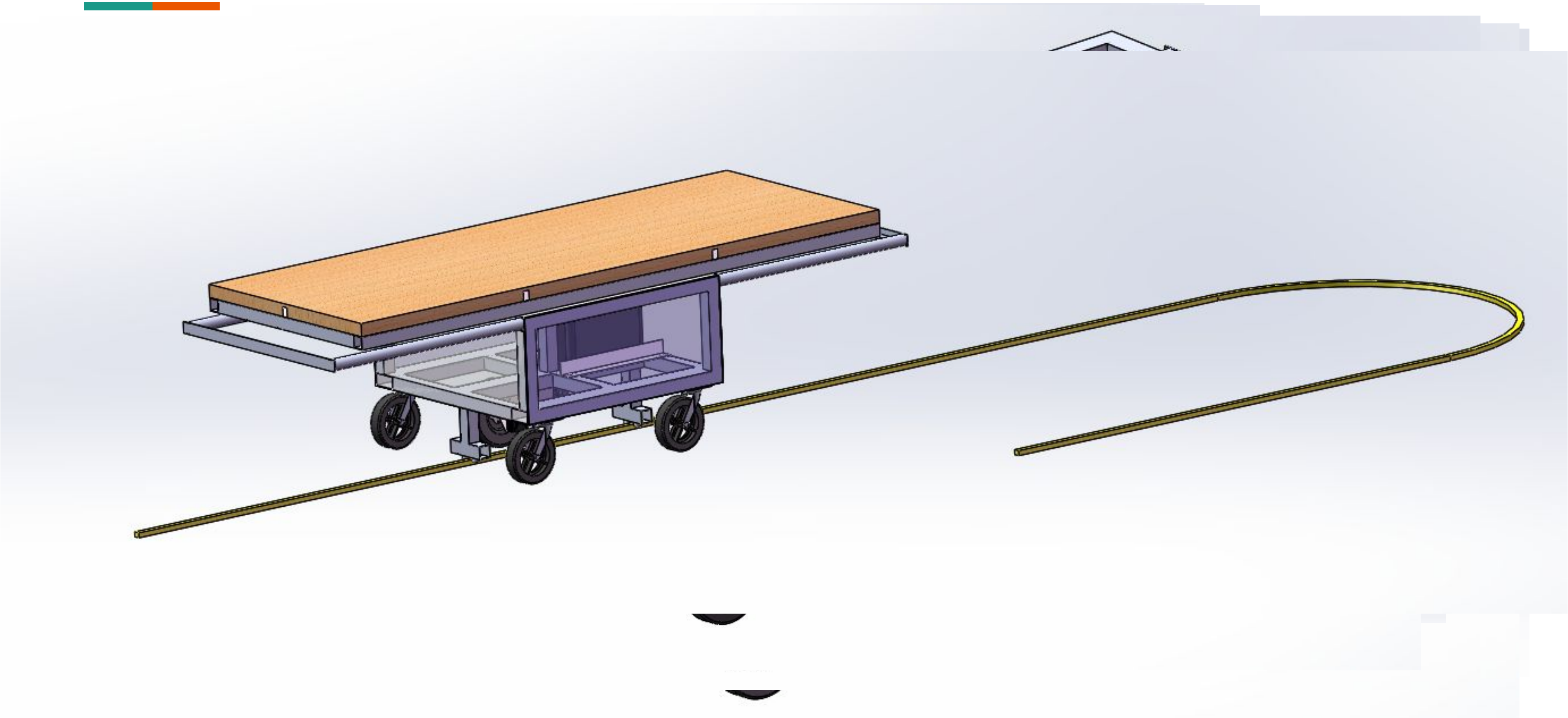
Working Design Concepts: Electrical Schematics

Circuit Schematic:

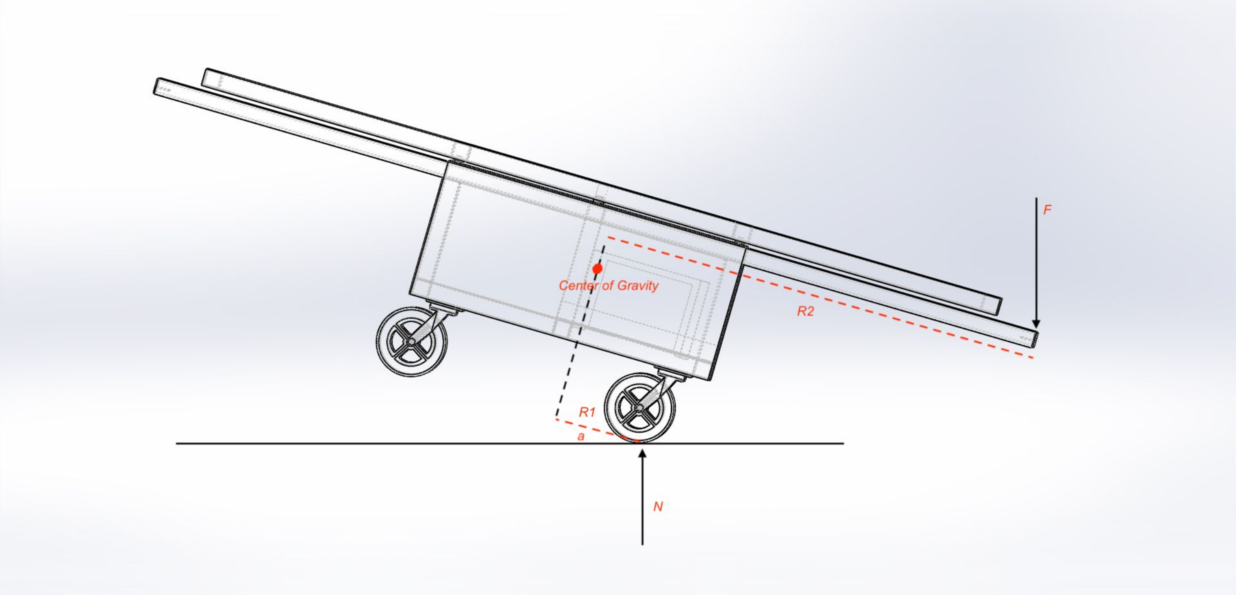
- 12 VDC Lead Acid Battery
- Reverse Voltage Protection
- 2200 μF Coupling Capacitor
- 10A Main Fuse
- 300mA Microelectronic Fuse
- Inrush Current: 2.5 A
- Steady State Current: 1.08 A



Working Design Concepts: Mechanical Design



Analysis: Tipping



$$x = \frac{\sum x_i}{m_i}$$

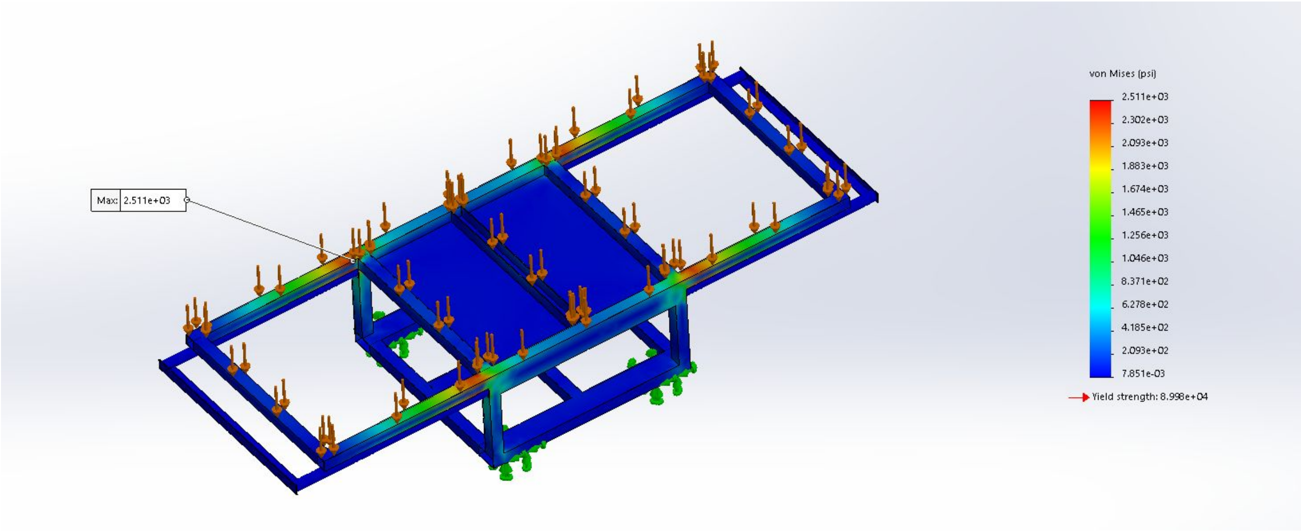
$$y = \frac{\sum y_i}{m_i}$$

$$= 16.21in$$

$$\sum M_o = 0 \Rightarrow NR_1cos(a) - FR_2cos(a) = 0$$

$$\Rightarrow F = \frac{NR_1}{R_2} = \frac{169.65*24.18}{52.15} = 78.66lbs$$

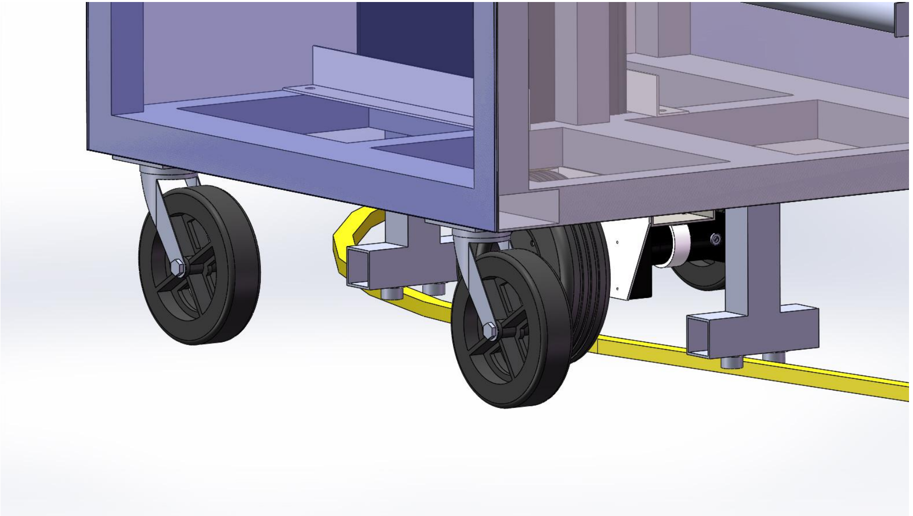
Analysis: Loaded Structure



$$\text{Safety Factor} = \frac{\sigma_y}{\sigma_{max}} = \frac{89980}{2511} = 35.83$$

Analysis: Turn Radius

- Theoretical turn radius done in Solid Works is 27 inches
  - Not that realistic
- Safe assumption of at least 5 ft
- During testing, the track was too stiff and sharp angles made by cutting the track prevented the cart from achieving 3 and 4 foot turn radii



Degree of Table Misalignment Verification

4/18/19 - Pass

Angle = arctan(displacement/15 inches) * 180/pi

The average for each direction is lower than the threshold of 3 degrees

		Clockwise		Counter-Clockwise	
Trial	**A**	**Displacement**	**Angle**	**Displacement**	**Angle**
1	15	0.5625	2.148	0.5625	2.148
2	15	0.5625	2.148	0.5625	2.148
3	15	0.625	2.386	0.5	1.909
4	15	0.5625	2.148	0.5625	2.148
5	15	0.625	2.386	0.5625	2.148
Average			2.243		2.09

Operational Velocity

4/17/19 - Pass

Average was 19.61 ft/min which lies within the threshold of 18-22 ft/min

Trial #	Distance (ft)	Time (s)	Speed (ft/min)
1	4	12.4	19.35
2	4	12.2	19.67
3	4	12.3	19.51
4	4	12.2	19.67
5	4	12.1	19.83
Average	4	12.24	19.61

Engineering Specifications

Engineering Specifications							Verification	Results	
ID	**Relative Weight**	**Specification**	**Target**	**Units**	**PASS Threshold**	**Notes**	**Verification Method**	**Measured Results**	**Results (Pass/Fail/Not Tested)**
10	5	Force required to engage stop bar	4	lbs	3.5-4.5 lbs	Force needed to trigger front bumper sensor	Measurement	Average: 4.22	Pass
20	12	Torque required to disengage rotational soft-lock	N/A	ft·lb	N/A	Force required to free table top from locked position	Measurement		Not Tested
30	14	Carrying capacity	250	lbs	Greater than 230	Maximum load that can be carried without severly limiting perfomance of the cart	Measurement		Pass
40	10	Operational velocity on a level surface	20	ft/m	18-22	Normal operating speed of the cart	Measurement	~20	Pass
50	11	Table misalignment detection	3	deg	Less than 4	Cart must stop if table becomes X degrees out of misalignment	Measurement	2.3	Pass
60	11	Runtime	300	minutes	Greater than 270	Runtime will decrease with the increase of payload.	Analysis	828	Pass
70	6	Turn radius of track	3	ft	Less than 4	The minimum turn radius	Measurement		Fail
80	10	Motor Torque	30	in·lb	Greater than 25		Measurement	Average: 37	Pass
90	7	Stopping distance	2	inches	Less than 4	The distance cart stops completely after passing the magnet or triggered by operator	Measurement	0.8	Pass
100	14	Time to stop after derailing	2	seconds	Less than 3	Time for cart to come to a complete stop after derailing	Measurement	Average: 1	Pass
Total	**100%**							**Relative Pass %**	**82%**

Schedule

Final Design Phase:

- Final Cart Modifications - Week of 4/22
  - Re-wire
  - Install final PCB
  - New mounting solution for the table misalignment sensor
- Video 4/25
  - Outline, Filming, Editing
- Design Night - 4/26
- Final Design Report and Documentation - 5/1
  - Instructional Video

Resource Allocation: FDR

Total Hours to Date: 708

Predicted: 220 hours

Actual: 157

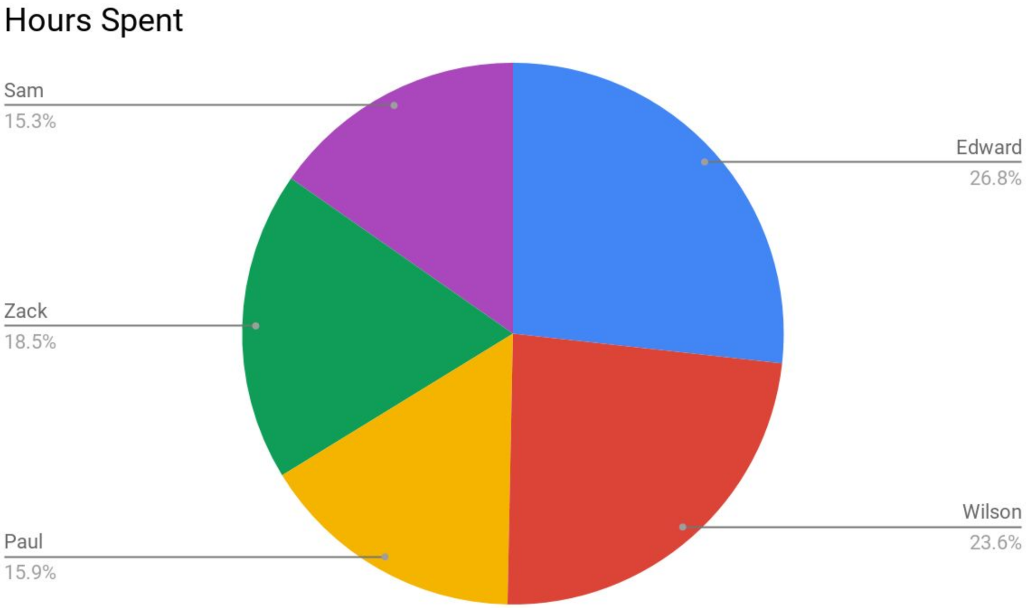
Sam: 24

Edward: 42

Wilson: 37

Paul: 25

Zack: 29



Budget

Original budget: $2,000

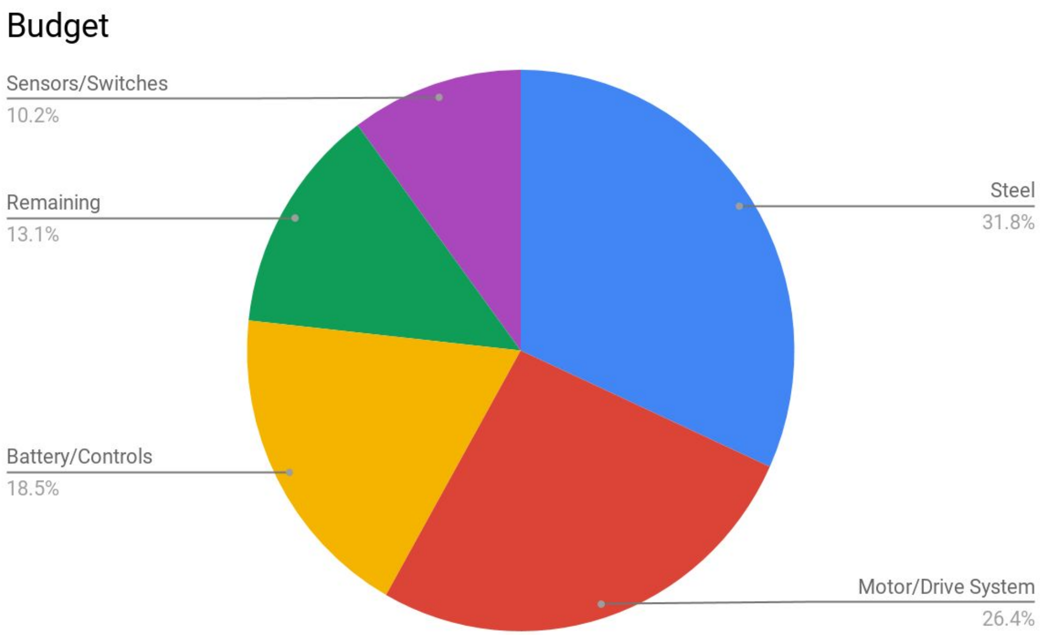
Total budget: $2,250

Total amount spent: $2,096

Predicted: $1,240

Average Cart Cost $1,735

- Steel: $635
- Motor and drive system: $527
- Sensors and switches: $203
- Battery and controls: $370



Bill of Materials

- Total amount spent: $2,096
- Predicted Total Cost: $1,240

- Actual cost of the cart: $1735
- Not accounted for: Cost of labor
  - Floyd quoted ~$800 to weld the frame
  - Materials bought by client will not be tax exempt
  - Bought some items in bulk

Lessons Learned

- Make certain of orders and allow for lead time
- Finalize design before manufacturing
- Double check calculations
- Do it right the first time
  - For example: cable management. If it were done properly the first time we wouldn’t have to re-wire the electronics
- Make sure parts will fit
  - Sometimes difficult to visualize a part ordered online
  - Create a real or CAD model to correctly size materials
- Off-the-shelf parts cannot always be relied on
  - Decide that the part cannot be purchased and discuss other possibilities

Open Issues

- Soft Lock Mechanism
  - The table frame is relatively stiff so it will not move when the cart drives, however and exact mechanical solution is desired
- Turn Radius Testing
- Table misalignment sensor reliability
  - Fix mounting
  - Add another magnet
- Tire Deflation
  - Purchase new drive wheel
  - Notify client to monitor tire pressure
- Shorten drive shaft
- Re-wiring for correct wire length