TEAM LOST
Black Box

Milestone 2

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Overview

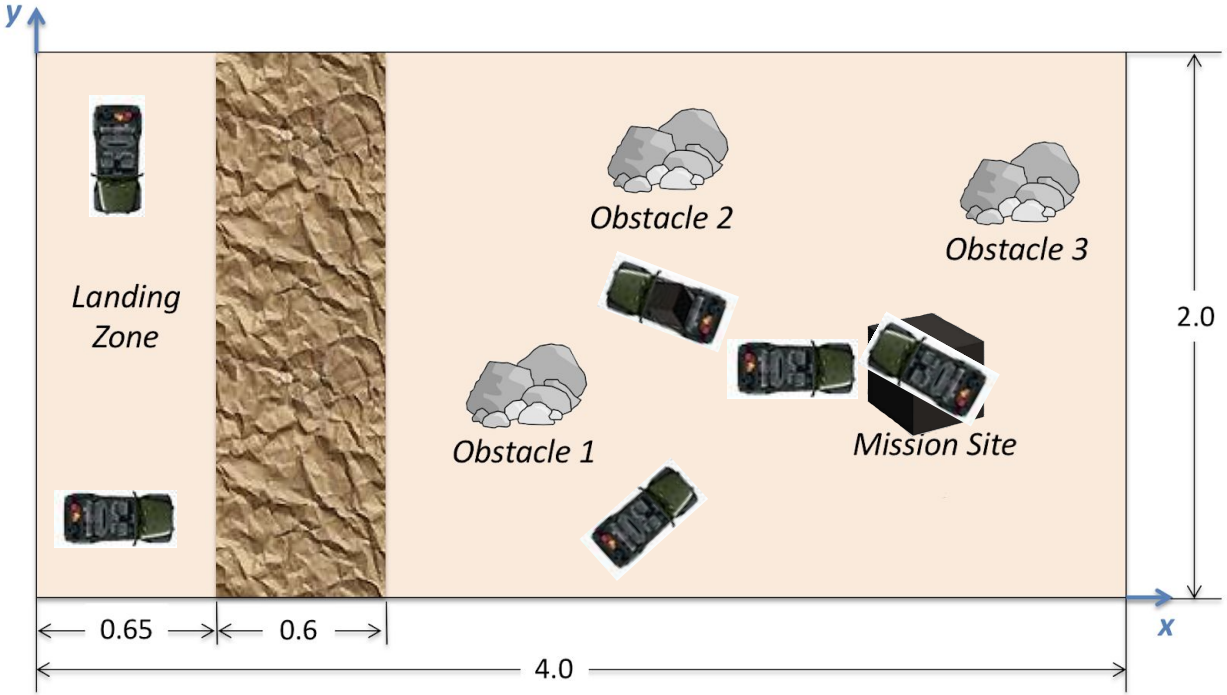
- Introduction
- Structure and CAD
- Design and Calculations
  - Subsystems:
    - Motor and Propulsion
    - Power and Circuitry
    - Sensors (Ultrasound, Infrared)
- Control Algorithm
- Bill of Materials and Mass Chart
- Gantt
- Construction and Testing Plan
- Anticipated Problems

Mission Objectives

- Navigate to within 250 mm of the black box locator beacon
- Measure and transmit the coordinates of the black box

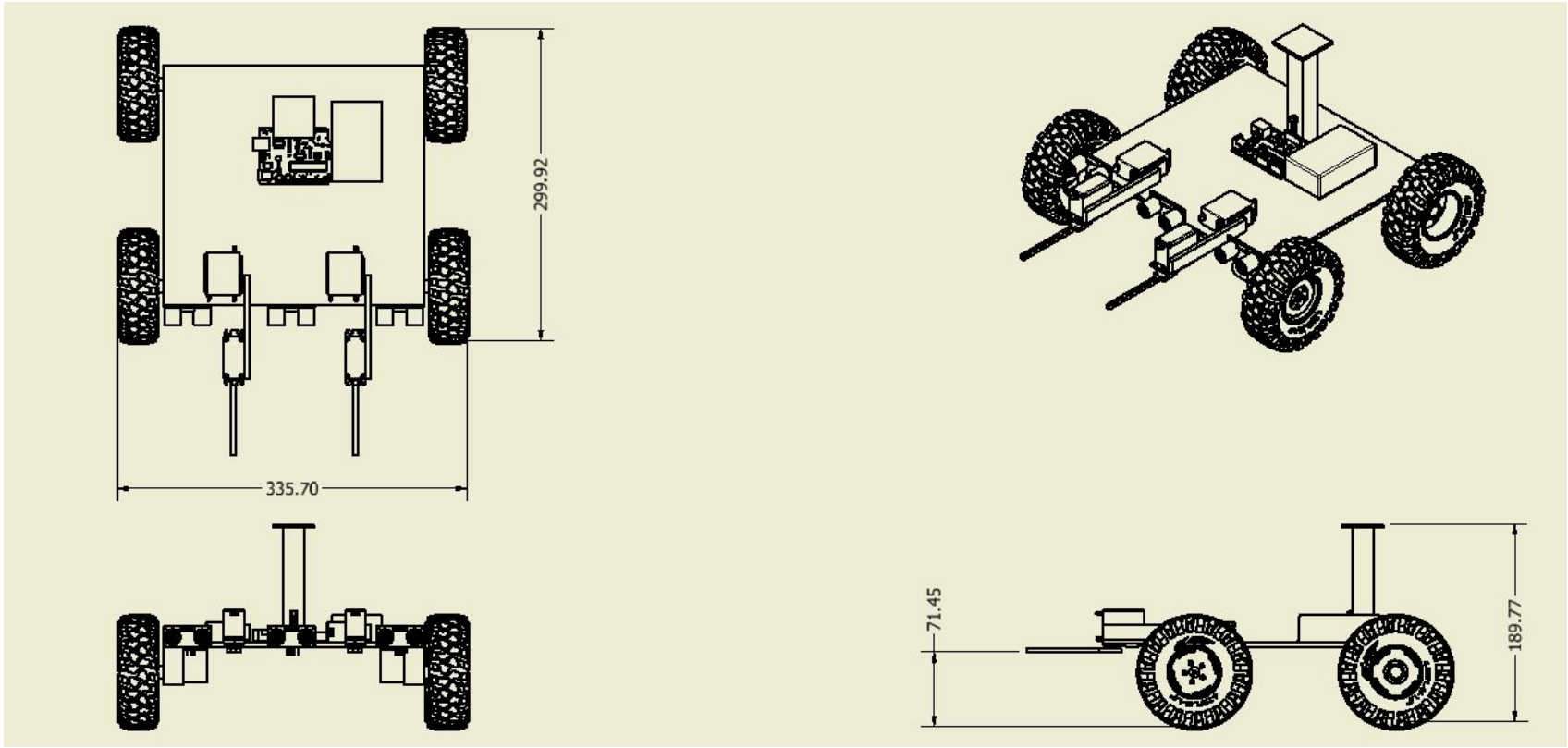
<u>Advanced Objectives</u>

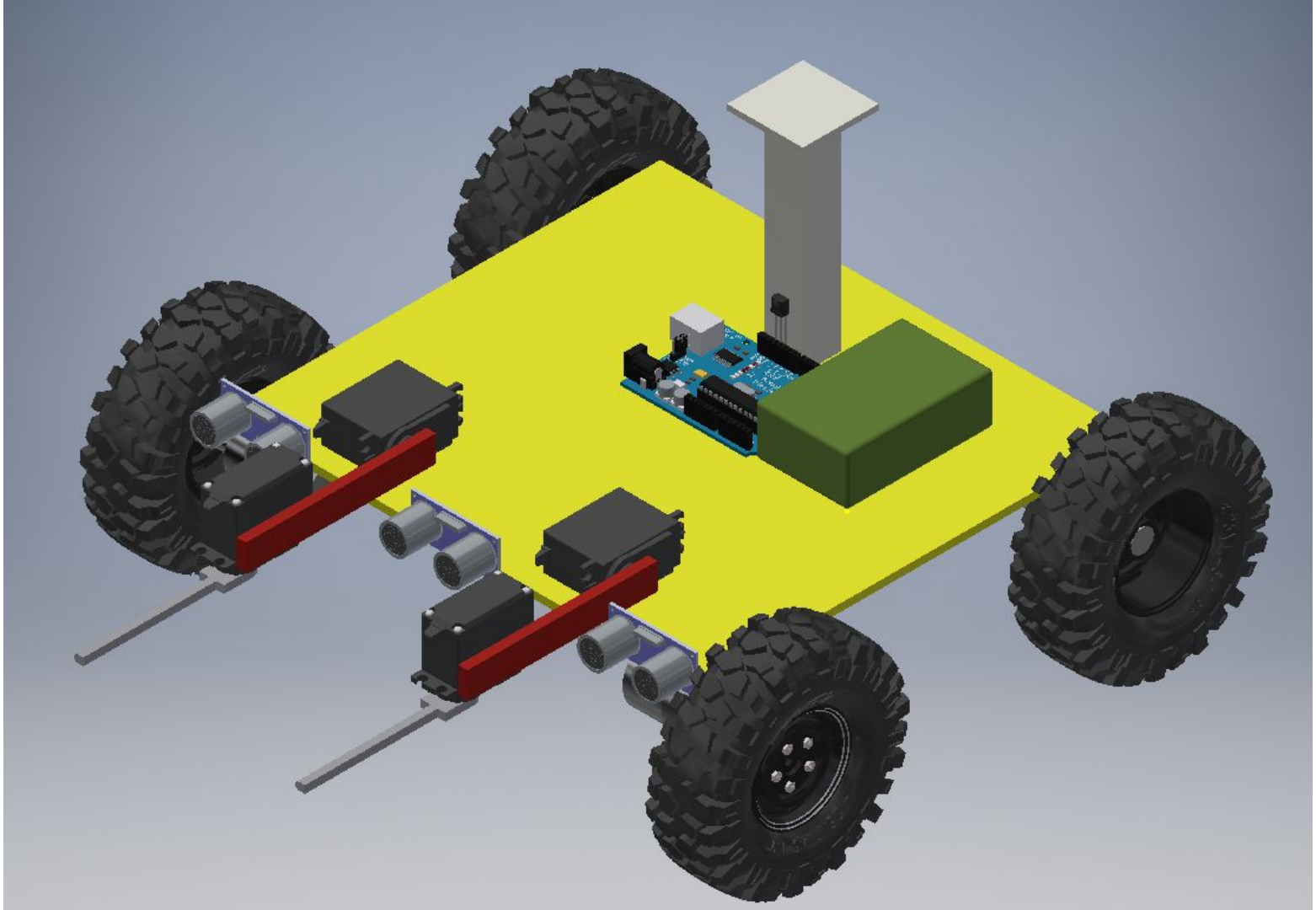
- Acquire the black box by lifting it entirely off of the sand
- Deliver the black box to the landing zone



Product Specifications

Dimensions





Calculations at 0 Degrees

F_N = normal force
F_g = Force of gravity = (2.50)(9.81) = 24.5 N
C_{RR} = coefficient of rolling resistance
F_{RR} = force of rolling resistance
F_{sf} = force of static friction
TE = tractive effort
τ = torque
ω = angular velocity
r = radius of the wheels = 5.00 cm
w = width of the wheels = 3.60 cm
d = diameter of the wheels = 10.0 cm
μ = Coefficient of static friction = 0.700
h_{cg} = height of CoG (arbitrary) = 0.130 m
L_{cg} = length from CG to wheel = 0.100m
L_w = length from wheel to wheel = 0.200 m

$$F_N = \frac{F_g}{4} = \frac{2.50(9.81)}{4}$$
$$= 6.13\ N\ on\ each\ wheel$$

$$C_{RR} = \left[3.33\ x\ \left(\frac{6.13}{3.60(10.0)^2}\right)\right]^{1/3} = .384$$

$$F_{RR} = C_{RR} \cdot F_N = (.384)(6.13) = 2.35\ N$$

$$F_{sf} = \mu \cdot F_N = (0.700)(6.13) = 4.29\ N$$

$$F_{RR} < TE < F_{sf} \rightarrow \boxed{2.35\ N < TE < 4.29\ N}$$

Calculations at 35 Degrees

- $F_{Nr} = \frac{mg(L_{cg}\cos(35)+h_{cg}\sin(35))}{L_w} = \frac{24.5(0.100\cos(35)+0.130\sin(35))}{0.200}\ x\ \left(\frac{1\ F_{Nr}}{2\ wheels}\right) = 8.53\ N\ per\ rear\ wheel$
- $F_{Nf} = \frac{mg((L_w-L_{cg})\cos(35)-h_{cg}\sin(35))}{L_w} = \frac{24.5((0.200-0.100)\cos(35)-0.130\sin(35))}{0.200}\ x\ \left(\frac{1\ F_{Nf}}{2\ wheels}\right) = 1.50\ N\ per\ front\ wheel$
- $C_{RRr} = \left[3.33\ x\ \left(\frac{8.53}{3.60(10.0)^2}\right)\right]^{1/3} = 0.429$
- $C_{RRf} = \left[3.33\ x\ \left(\frac{1.50}{3.60(10.0)^2}\right)\right]^{1/3} = 0.241$
- $F_{RRr} = C_{RR} \cdot F_N = (0.429)(8.53) = 3.66\ N$
- $F_{sfr} = \mu \cdot F_N = (0.700)(8.53) = 5.97\ N$

$F_{RR} < TE < F_{sf} \rightarrow$ $3.66\ N < TE < 5.97\ N$

Calculations

@0	$2.35\ N < TE < 4.29\ N$
@35	$3.66\ N < TE < 5.97\ N$
Combined	$3.66\ N < TE < 4.29\ N$

Desired Torque:

$TE\ x\ r = \tau = 3.73(5\ cm)$

$= 18.6\ N \cdot cm$

TORQUE

- $d = \frac{1}{2}at^2 \rightarrow 15.0\ m = \frac{1}{2}(180.s\ x\ 180.s)a \rightarrow a = 0.001\frac{m}{s^2}$
- $F_{N\ total} = 4(6.13) = 24.5\ N$
- $C_{RR}L = \left[3.33\ x\ \left(\frac{24.5}{3.60(10.0)^2}\right)\right]^{1/3} \cdot 24.5 = 14.9\ N$
- $TE - C_{RR}L = ma \rightarrow TE = 2.50(0.167) + 14.9 = 15.3N\ x\ \left(\frac{1}{4\ wheels}\right) = 3.73\ N\ TE\ for\ each\ wheel$

Selecting a Motor

Torque (desired) = 18.6 $N{\cdot}cm$

= 1.90 $kg{\cdot}cm$

Chosen Motor:

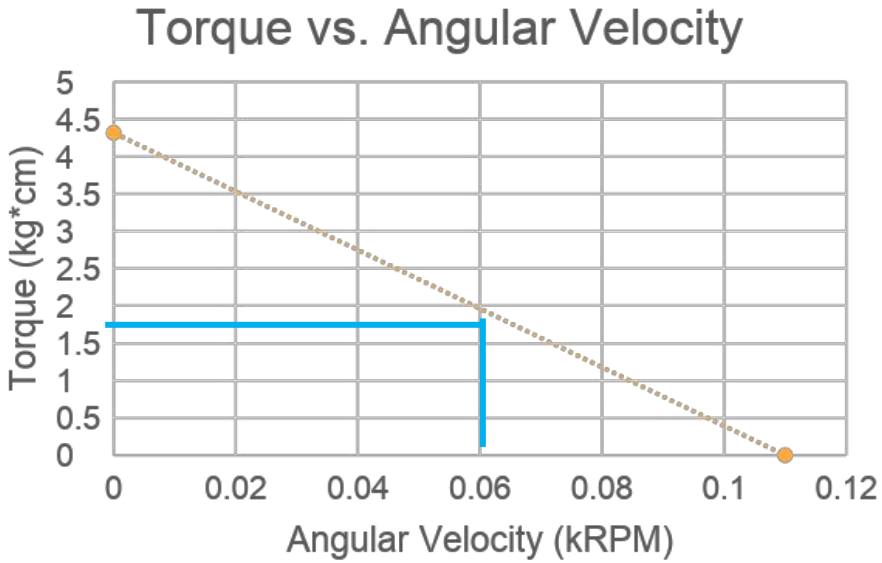
No-load speed: 0.110 kRPM

Stall torque: 4.32 kg$\cdot cm$

No-load current: 0.100 Amps

Stall current: 1.10 Amps

Linear equation:



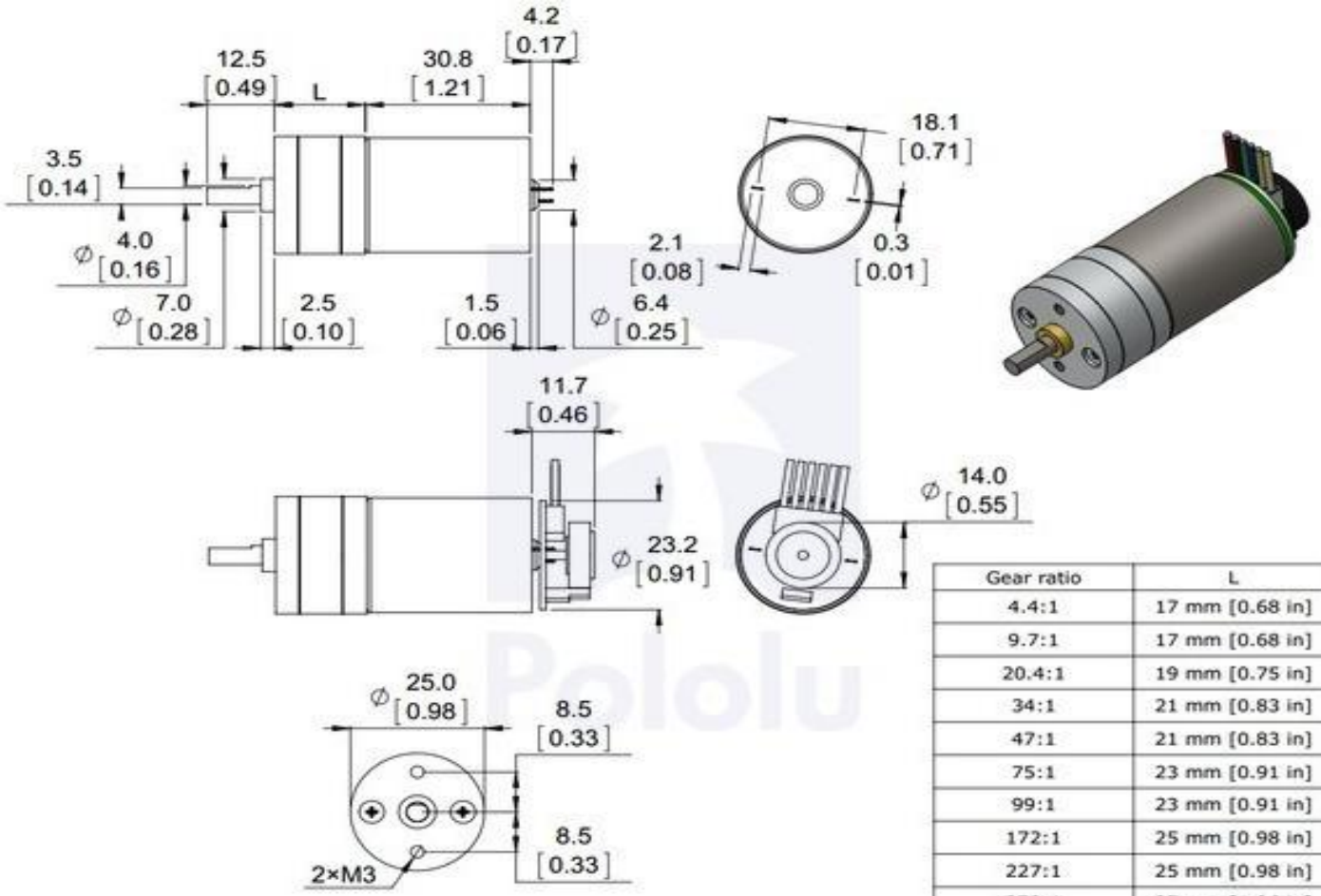
$$\tau = (-39.3)\omega + 4.32$$

$$18.6\ N \cdot cm \rightarrow 1.90\ kg \cdot cm$$

$$1.90\ kg \cdot cm = (-39.3)\omega + 4.32$$

$$\omega = 0.0616\ kRPM = 61.6\ RPM = 6.45\ \frac{rad}{s}$$

Selected Motor

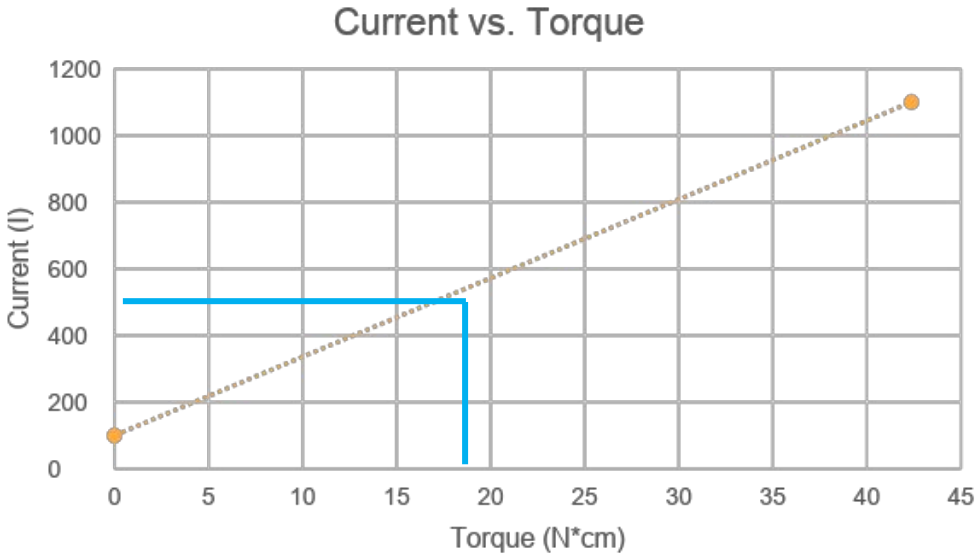


Gear ratio	L
4.4:1	17 mm [0.68 in]
9.7:1	17 mm [0.68 in]
20.4:1	19 mm [0.75 in]
34:1	21 mm [0.83 in]
47:1	21 mm [0.83 in]
75:1	23 mm [0.91 in]
99:1	23 mm [0.91 in]
172:1	25 mm [0.98 in]
227:1	25 mm [0.98 in]
378:1	27 mm [1.06 in]
499:1	27 mm [1.06 in]

Selected Battery Calculations

- $I = 23.6\tau + 100.$
- $I = 23.6(18.6) + 100. = 539\ mA$
- Current draw = 539 mA
  for each wheel

Selected Battery:
12V Ni-MH 2800mAh Battery Pack



Circuit Design of Propulsion System

Mission Specific Sensing

- Sensing Boulders
- Sensing on site

Circuit Schematic of All Sensors

Mission Specific Actuators

- PICKING UP MECHANISM
- And give circuit schematic

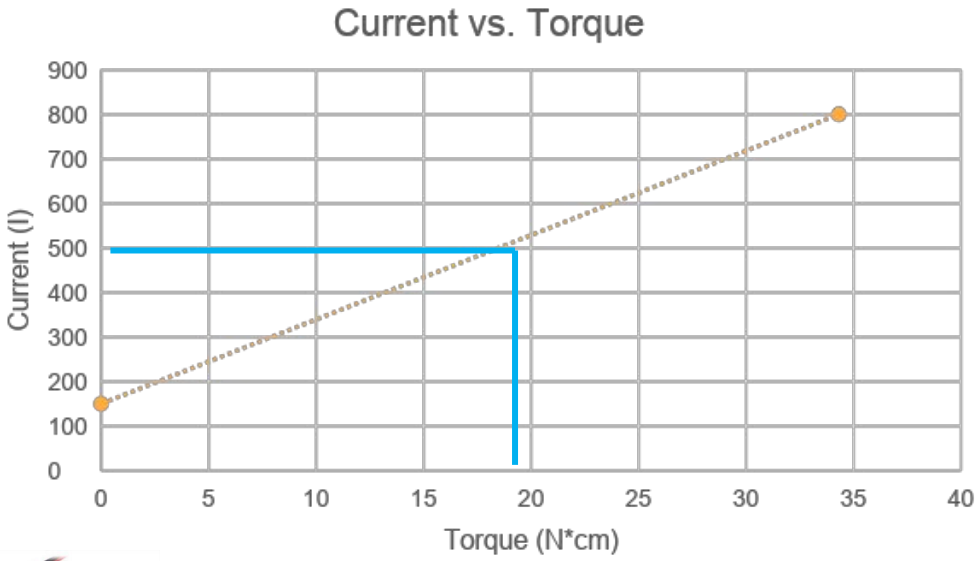
Desired Torque Calculation at 45 degrees

- $2\tau = 2(F_s r) + F_b(r + .06)$
- $2\tau = 2(.014 * 9.8)(.065) + (.3017 * 9.8)(.125)$
- 2τ = .02548 + .03958
- τ = .1975 N*m
- Desired τ = 19.75 N*cm

τ = Desired Torque
F_s = Force of Servo
F_b = Force of Black Box
r = Distance between Servo 1 and 2

Selected Battery Calculations

- $I = 18.938\tau + 150.$
- $I = 18.938(19.75) + 150 = 524\ mA$
- I = 524 mA per servo
- Total Power Draw: 2.1A



Selected Battery:
6V NiMH
2200 mAh
Continuous Discharge 2.2A

Navigation

Stages

- Leaving LZ
- Boulder avoidance
- Travel to destination
- On site actions (which should include re-positioning)
- Returning home to LZ

Control Algorithm

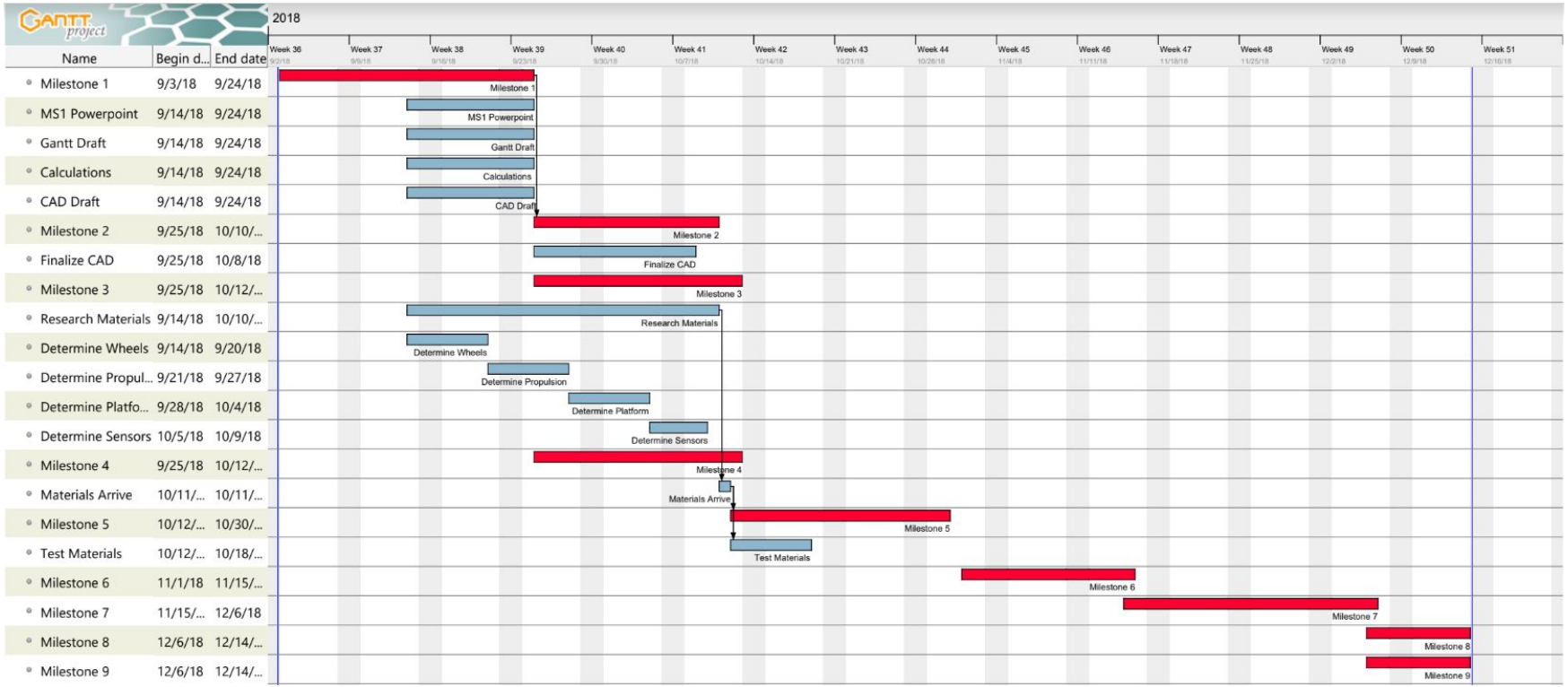
Expected Bill of Materials

Material	Cost (USD)	
APC220	$	26.44
Wheels	$	24.43
Infrared Sensor	$	7.49
Romeo Microcontroller	$	29.98
Ultrasonic Distance Sensor	$	5.38
Fiberglass Base	$	5.00
Control System	$	34.95
Battery	$	29.95
Forklift Motor (4x)	$	45.96
Forklift Arms (2x)	$	5.00
Motors	$	21.95
Total:	$	236.53

Expected Mass Chart

Items	Quantity	Estimated Mass(kg)	Source
APC220	1	0.03	Web
Wheels	4	0.8	Web
Infrared Sensor	1	0.005	Web
Romeo Microcontroller	1	0.06	Web
Ultrasonic Distance Sensor	3	0.009	Web
Base	1	0.366	Actual
Control System	1	0.15	Estimated
Battery	1	0.251	Web
Forklift Motor	4	0.18824084	Web
Forklift Arms	2	0.05	Estimated
Motors	4	0.4831	Web
Total		2.39234084	

Gantt Chart


2018
Week 36
Week 37
Week 38
Week 39
Week 40
Week 41
Week 42
Week 43
Week 44
Week 45
Week 46
Week 47
Week 48
Week 49
Week 50
Week 51
Name
Begin d...
End date
Milestone 1 9/3/18 9/24/18
MS1 Powerpoint 9/14/18 9/24/18
Gantt Draft 9/14/18 9/24/18
Calculations 9/14/18 9/24/18
CAD Draft 9/14/18 9/24/18
Milestone 2 9/25/18 10/10/...
Finalize CAD 9/25/18 10/8/18
Milestone 3 9/25/18 10/12/...
Research Materials 9/14/18 10/10/...
Determine Wheels 9/14/18 9/20/18
Determine Propul... 9/21/18 9/27/18
Determine Platfo... 9/28/18 10/4/18
Determine Sensors 10/5/18 10/9/18
Milestone 4 9/25/18 10/12/...
Materials Arrive 10/11/... 10/11/...
Milestone 5 10/12/... 10/30/...
Test Materials 10/12/... 10/18/...
Milestone 6 11/1/18 11/15/...
Milestone 7 11/15/... 12/6/18
Milestone 8 12/6/18 12/14/...
Milestone 9 12/6/18 12/14/...

Anticipated Problems + Solutions

- Parts breaking
  - Buy new materials when needed
- Disagreement
  - Majority rules, resolve problems in a mature fashion
- If lifting the black box lead to the OSV tilting from the weight
  - Add more counterweights to the back of the OSV
- If forklift arms can’t correctly orient themselves around the black box
  - Write code to allow the OSV to have a greater scope of navigation

QUESTIONS?