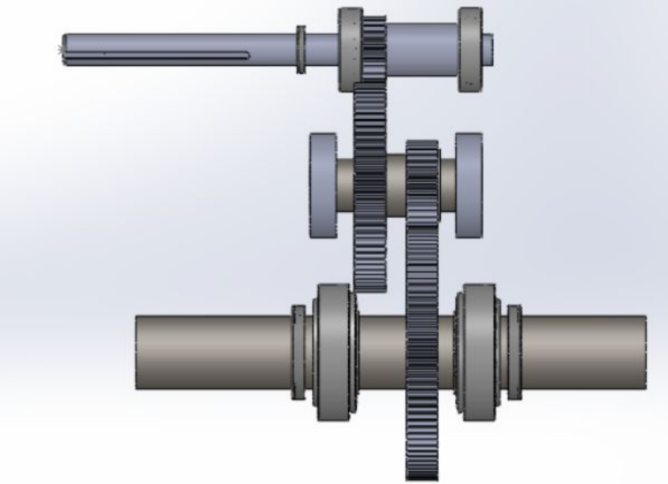
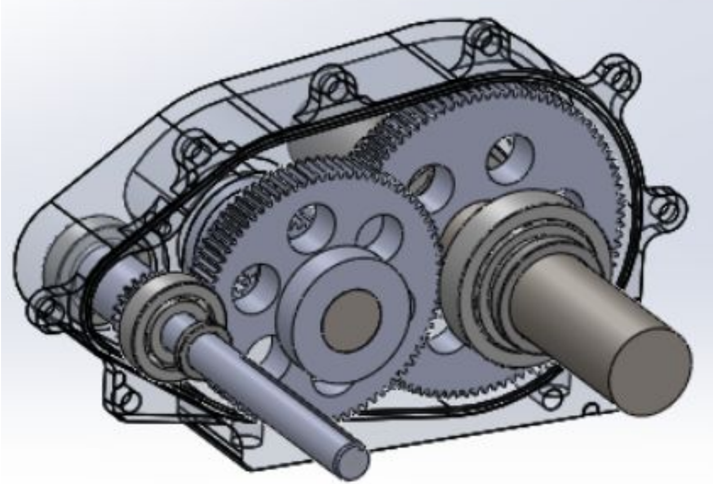
GEARBOX





Design Requirements

- Where is comp? Tucson AZ
  - Sandy, flat
- Main Goals:
  - Rock Crawl
  - Endurance Race

Gear Ratio Calculations (High)

$F_{DRIVING} = F_{DRAG} + F_{RR}$

$F_{DRIVING} = (½)*ρ*A_{frontal}*C_D*(V_{max})^2 + C_{RR}*W_{car}$

$P_{DRIVING} = (½)*ρ*A_{frontal}*C_D*(V_{max})^3 + C_{RR}*W_{car}* V_{max}$

$V_{max} = ?$

Gear Ratio Calculations(High)

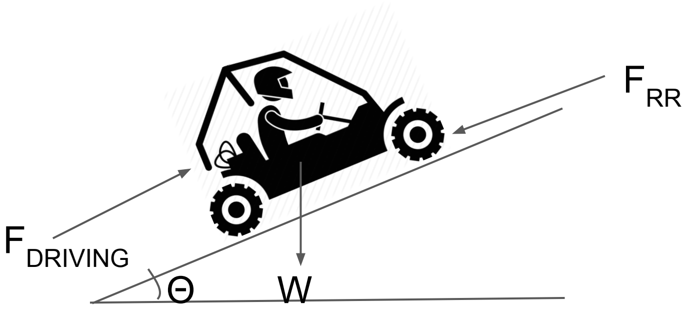
For ax^3+bx^2+cx+d = 0 (Hi-Gear)	
a	0.020172672
b	0
c	35.58
d	-3891.5624
Use an equation solver for the parameters above	
V_max(mph)	32.54

$$GR_{gearbox} = (N_{engine}*2\pi*R_{tire}*3600) / (60*5280*GR_{CVT(high)}*V_{max})$$

High Gear Ratio(Total)	6.95
CVT High Ratio	0.91
Gearbox High Ratio	7.63
(To achieve V_max)	

Constants	Values(subject to change)
Af(ft^2)	13.47
rho-air(slug/ft^3)	0.00234
Cd	1.28
Crr	0.06
P_max(lb-ft/s)	3891.5624
W_car(lbs)	593
DRIVETRAIN SPECS	
Horsepower	10
Engine Torque (lb-ft)	14
Gearbox Input Shaft Torque(lb-ft)	54.6
CVT Ratio(Low)	3.9
CVT Efficiency	0.8
Max RPM	3800
R_tire	0.83
Drivetrain efficiency	
n_belt	0.8
n_gear	0.97
n_axle	0.94
n_total	0.71

Gear Ratio Calculations (Low)



$F_{DRIVING} = F_{RR} + W*\sin(45°)$

$F_{DRIVING} = C_{RR}*W*\cos(45°) + W*\sin(45°)$

$\tau_{out} = F_{DRIVING}*R_{tire}$

$\mathbf{GR_{gearbox} = \tau_{out} / (\tau_{engine}*GR_{CVT(low)}* n_{drivetrain})}$

	degrees	radians
Slope Angle	45	0.7854
F_driving		444.47
T_out		370.39
Gearbox Low Ratio	>	9.59
(To start going forward on incline)		

Gear Ratio Summary

- 10:1 is ideal for being able to roll forward on 45° incline and still have a moderate top speed for long straights.

Gear Ratio (Gearbox)	10
Top speed (mph)	24.85
Max torque (lb - ft)	546

Gear Specs

Forward Gear	-Grade 1 Flame Hardened Steel W/Hb=400		
Gear	# of teeth	Pitch Diameter	Pitch
1	24	1.5	16
2	80	5	16
3	32	2	16
4	96	6	16
1-2 Ratio	3.333333333		
3-4 Ratio	3		
Forward Final	10		

		Gear	Pinion
		GEAR 2	**GEAR 1**
# of Teeth	N	80	24
Tooth Bending Factor of Safety	Sf	4.17	1.43
Wear Factor of Safety	Sh	4.40	1.54

		Gear	Pinion
		GEAR 4	**GEAR 3**
# of Teeth	N	96	32
Tooth Bending Factor of Safety	Sf	4.74	1.79
Wear Factor of Safety	Sh	5.08	1.96

Shaft Analysis (Calculations)

Through analysis of shear and torsional loads applied on each shaft, we were able to determine the dimensions necessary to meet our required outputs without high risk mechanical failure.

Input Shaft Loads:

Load	Force Experienced (lb)
Gear 1	-929.66
CVT	174.72
Bearing 1	167.76
Bearing 2	587.18

Output Shaft Loads:

Load	Force Experienced (lb)
Gear 4	2324.164
Bearing 5	-1067.4756
Bearing 6	-1256.68

Counter Shaft Loads:

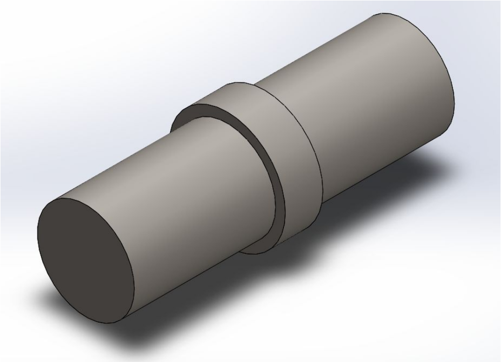
Load	Force Experienced (lb)
Gear 2	929.66
Gear 3	-2324.164
Bearing 3	116.04
Bearing 4	1278.45

Shaft Analysis (cont.)

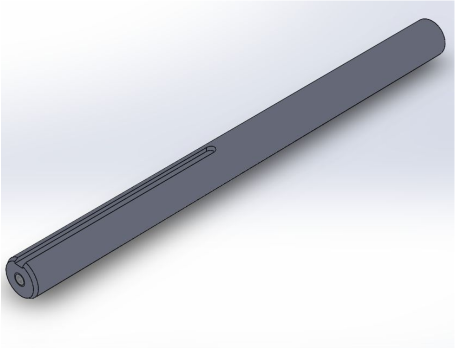
$$\sigma_{shear} = \frac{F}{A} = \frac{4V_{shear}}{\pi d^2}$$

$$\sigma_{bending} = \frac{Mr}{I} = \frac{Md}{2I}$$

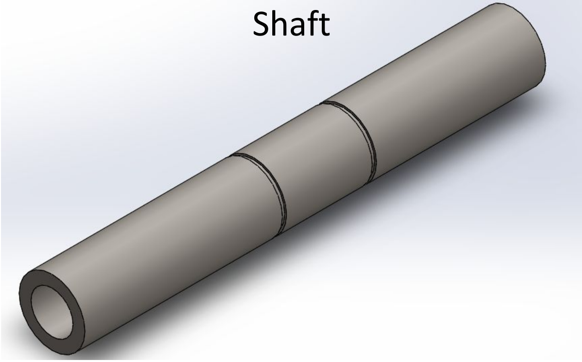
Counter Shaft



Input Shaft



Output
Shaft



Shaft Dimensions

	Input Shaft	Counter Shaft	Output Shaft
Length (in)	10.312	4.12	12.25
Min. Diameter (in)	0.75	1.25	1.75
Torsional Force (lb-in)	1352.449	4648.328	6972.49
Max Torsional Stress (Psi)	16327.03	14545.14	6625.887

*Material Chosen for all Shafts: 4140 Normalized Steel

Factor of Safety and Equivalent Stress

FOS = (Yield Strength)/(von Mises Stress)

$\sigma_1 = \sigma_{avg} + \text{sqrt}(\tau^2 + ½*(\sigma_x - \sigma_y)^2)$

$\sigma_2 = \sigma_{avg} - \text{sqrt}(\tau^2 + ½*(\sigma_x - \sigma_y)^2)$

Principal Plane Stress Equation:

$\sigma_{vm} = \text{sqrt}(\sigma_1^2 + \sigma_1 \sigma_2 + \sigma_2^2)$

(4140 Normalized Steel Tensile Strength = 95000 psi)

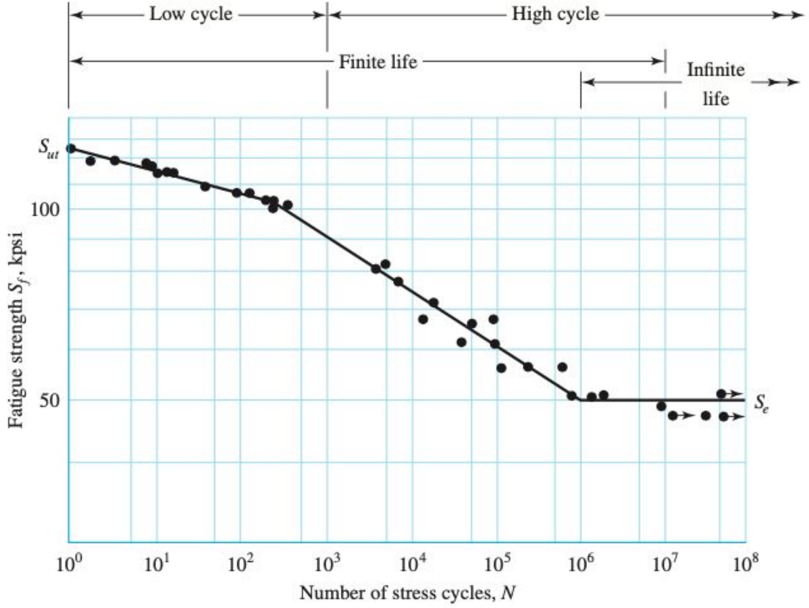
	Input	Counter	Output
Min. Factor of Safety	2.07	3.63	7.94

Shaft Life

	Input Shaft	Counter Shaft	Output Shaft
N (# of cycles)	19,421,626.19	26,885,549.84	1.84676E+19

Figure 6–10

An S-N diagram plotted from the results of completely reversed axial fatigue tests. Material: UNS G41300 steel, normalized; S_{ut} = 116 kpsi; maximum S_{ut} = 125 kpsi. *(Data from NACA Tech. Note 3866, December 1966.)*



(N > 10^7 implies infinite life for steel)

Bearings

Determine minimum Basic Load Rating of bearings based off of Desired Life.
Choose bearings given dimensions of shafts and Load Rating from Bearing spec sheet.

$$C = F*L^{1/a}$$

C: Basic Load Rating (Load which 90% of bearings from given population will survive 1,000,000 revolutions

F: Radial Load on Bearings

L: Desired Life (Millions of revolutions)

a: 3 (ball bearings) or 10/3 (Roller Bearings)

$$L = (H)(60\ min/hr)(V)$$

L: Desired Life (Millions of revolutions)

H: Desired number of hours

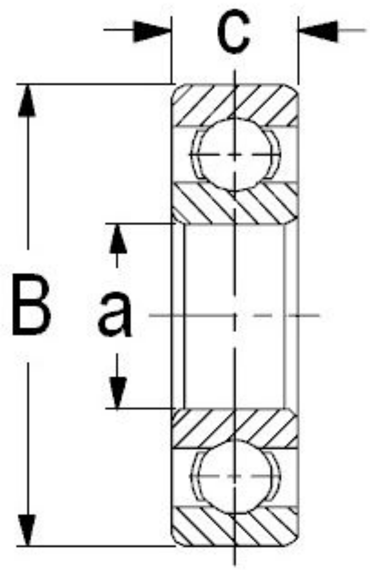
V: RPM of Bearing [Dependant on Shaft RPM]

*Shaft RPM dictated by gear reduction

Input Shaft Bearings

- Ball Bearings (minimal axial load)
- Inner Diameter: ¾ inches
- Minimum Load Capacity Rating : 1170 lbs
- Catalog Load Capacity Rating: 2950 lbs

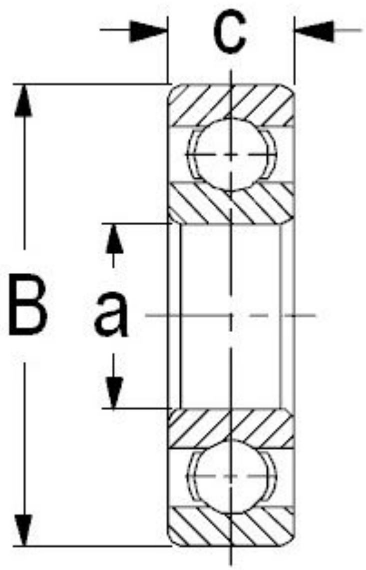
Bearing Number	Boundary dimensions(Inches)		
TBBS	a	B	C
1638	3/4	2	9/16



Countershaft Bearings

- Ball Bearings (no axial load)
- Inner Diameter: 1-¼ inches
- Minimum Load Capacity Rating : 1788 lbs
- Catalog Load Capacity Rating: 3850 lbs

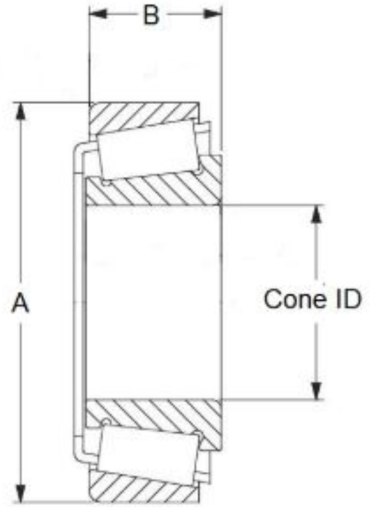
Bearing Number	Boundary dimensions(Inches)		
TBBS	a	B	C
1654	1-1/4	2-1/2	5/8



Output Shaft Bearings

- Tapered Roller Bearings [worst case scenario]
- Inner Diameter: 1-¾ inches
- Minimum Radial Load Capacity:
    - 1222 lbs radial, minimal due to axle (axial)
- Catalog Radial Load Capacity Rating:
    - 4850 lbs (radial), 2800 lbs (axial)

CONE/CUP NO	CONE I.D.	A	B
25580/25520	1-3/4"	3.26	0.937



Future Testing

- Validation of maximum speed and maximum torque