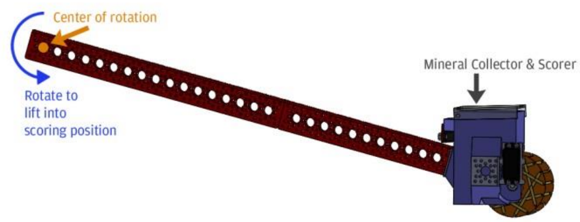
Session Date: **19 Dec 2018**

Calculations prepared by: Coach Randy

Determining torque requirement for motor that will lift arm with mineral collector & scorer on the end.

Our plan is to have an assembly that can collect minerals mounted at the end of channels. We will raise this collector into scoring position. How much torque is required for the motor that will power this lift motion?



We will use the standard formula for calculating torque. F = force; in this instance gravity will be pulling on our assembly, so the force is equal to the weight of the assembly (including the two channels). r = the radius; here it would be distance between the center of gravity for our assembly and the center of rotation.

T = r * F

T = Torque

r = radius

F = force, weight of assembly

Notice that the torque requirement changes as the assembly is raised, and the angle of the force (gravity) changes. At any position, the torque can be calculated using a more complex formula for torque: **T =r * F * sin(θ).** However, we are interested in the maximum torque required, which is when the assembly is parallel with the ground. Because of this, we can use the simpler formula above.

First, we must find the total weight for our assembly to represent F in our equation. So, we add the weight of all the individual components in the assembly. The weight for most of the items is readily available on the supplier's website, but for some, we had to estimate. Also, we want to lift this while it is holding two minerals, and the gold minerals are heavier, so we have included 2 gold in our parts list below. We want our final torque requirement to be in oz-in, so all weights are converted to ounces.

Item	**Qty**	**Wgt**	**Total Wgt (oz)**
3D Printed parts	1	220g	7.76
HSB 485 Servo	1	1.59oz	1.59
Short Angle Bracket 585506	1	0.30oz	0.30
7 Hole Plate 585724	1	0.85oz	0.85
Clamping Hubs 545619	2		
Servo Plate 575124	1	0.35oz	0.35
Pinion Gear 0.25" 16T 615242	1		
Pinion Gear Servo Mount 32T 615290	1		
Rev Color Sensors	2		
8" long 0.25" D-shaft	1		
Minerals – Gold	2		
TOTAL			62.00oz
			F = 62.00

We need to find r. Here we can estimate that the center of gravity will be close to the point where the collector is attached to the channels, and we can use the length of the channels as r.	**r = 22.5**
Now we can calculate the total torque requirement to raise this assembly by substituting of values for F and r into our formula for torque.	**T = r * F** **T = 22.5 in * 62 oz** **T = 1,395 oz-in**
Based upon the "time to raise" calculations and looking at available parts, we believe we will have a gear ratio of 5.25:1 between the motor and assembly. Therefore, our torque requirement for the motor (Tm) will be equal to T divided by our gear ratio (GR).	**Tm = T / GR** *Tm = Required Motor Torque* *GR = Gear Ratio* **Tm = 1,395 / 5.25** **Tm = 265.7 oz-in**
We are using NeveRest 40 Gear Motors, and these are rated with a Stall Torque (Ts) of 350 oz-in. This is higher than our torque requirement, so we can use that motor for this assembly.	**Tm < Ts ?** *Ts = Stall Torque* **265.7 < 350** ✓

Determining maximum assembly weight	
We would like to know how heavy our assembly can be and still be lifted by a NeveRest40 motor. We can take our original formula and solve for F. F becomes F_{max}, we are looking for the maximum weight. T becomes T_{eff}: this is the effective torque at the point of rotation, after the motor is acted upon by our gears.	**T = F * r** **F = T / r** $F_{max} = T_{eff} / r$ F_{max} = *Max weight for assembly* T_{eff} = *Effective Torque*
The Torque from our motor will be multiplied by our gear ratio to arrive at our effective torque.	$T_{eff} = Ts * GR$ $T_{eff} = 350 * 5.25$ $T_{eff} = 1{,}837.5$ **oz-in**
Our radius r remains the same, so now we can calculate the total maximum weight we can lift.	$F_{max} = T_{eff} / r$ $F_{max} = 1{,}837.5 / 22.5$ $F_{max} = 81.67$ **oz**