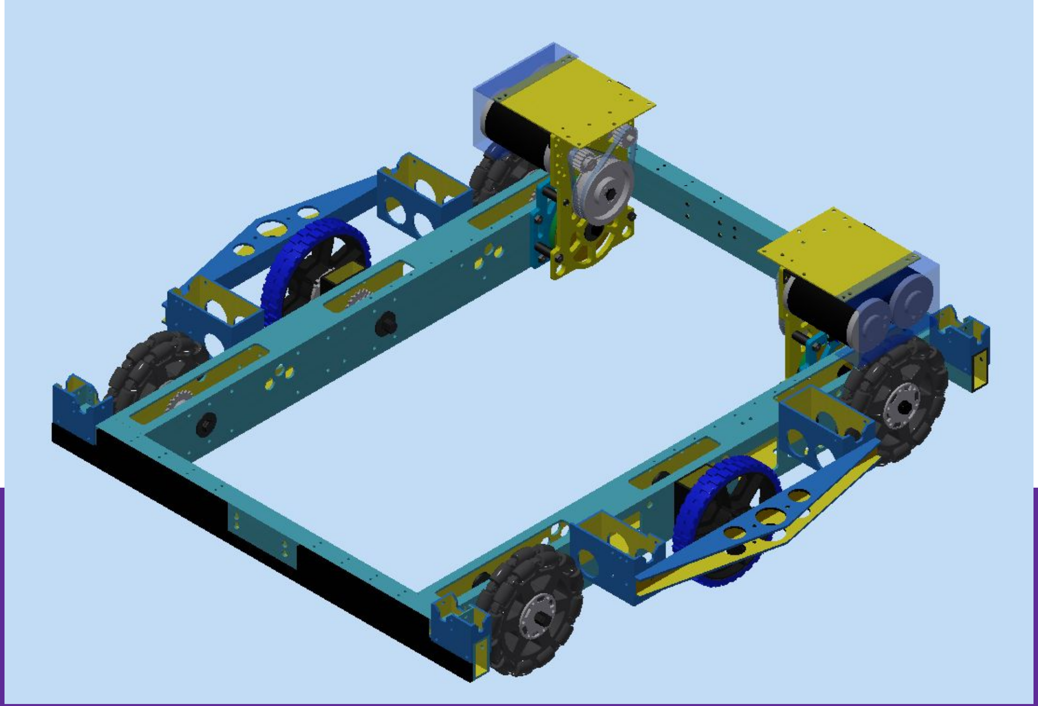
Drivetrain(ing)



Skills to Know/Learn

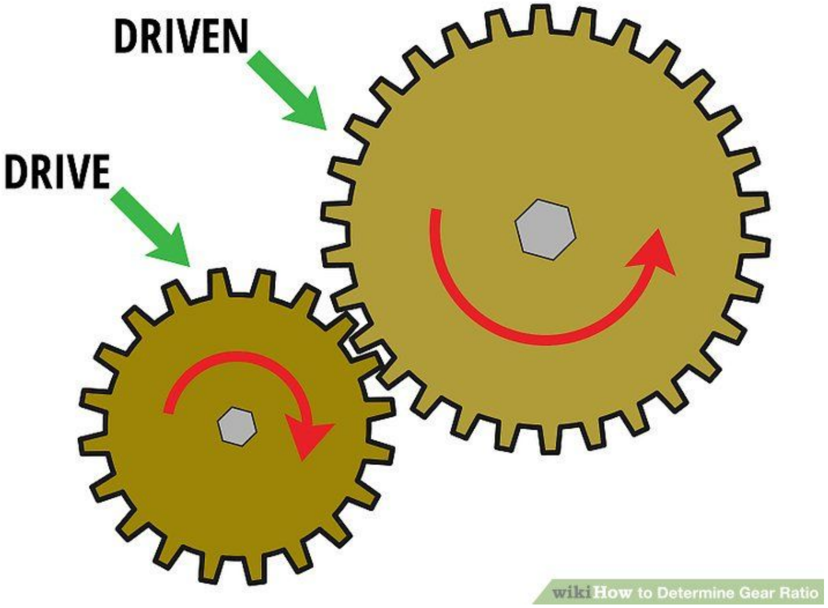
- SVN Repository
- 846 CAM tool library setup
- CAM
- Machinist Drawings
- CAD Design
- CAD Template how to correctly setup

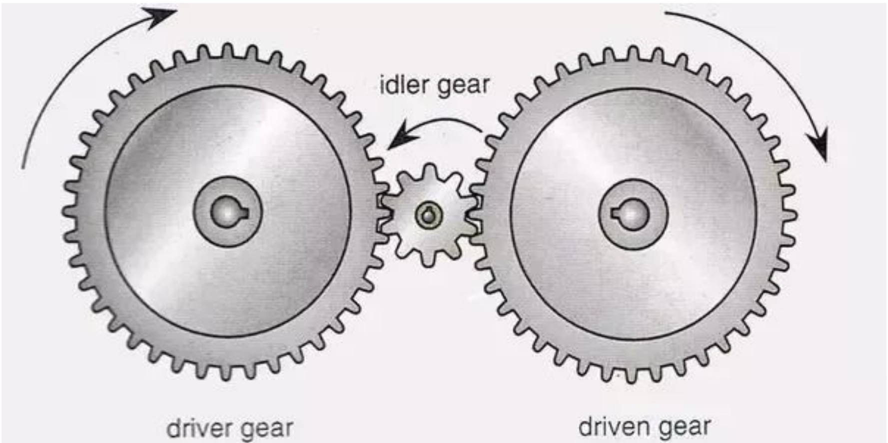
How Gears Work

Terms:

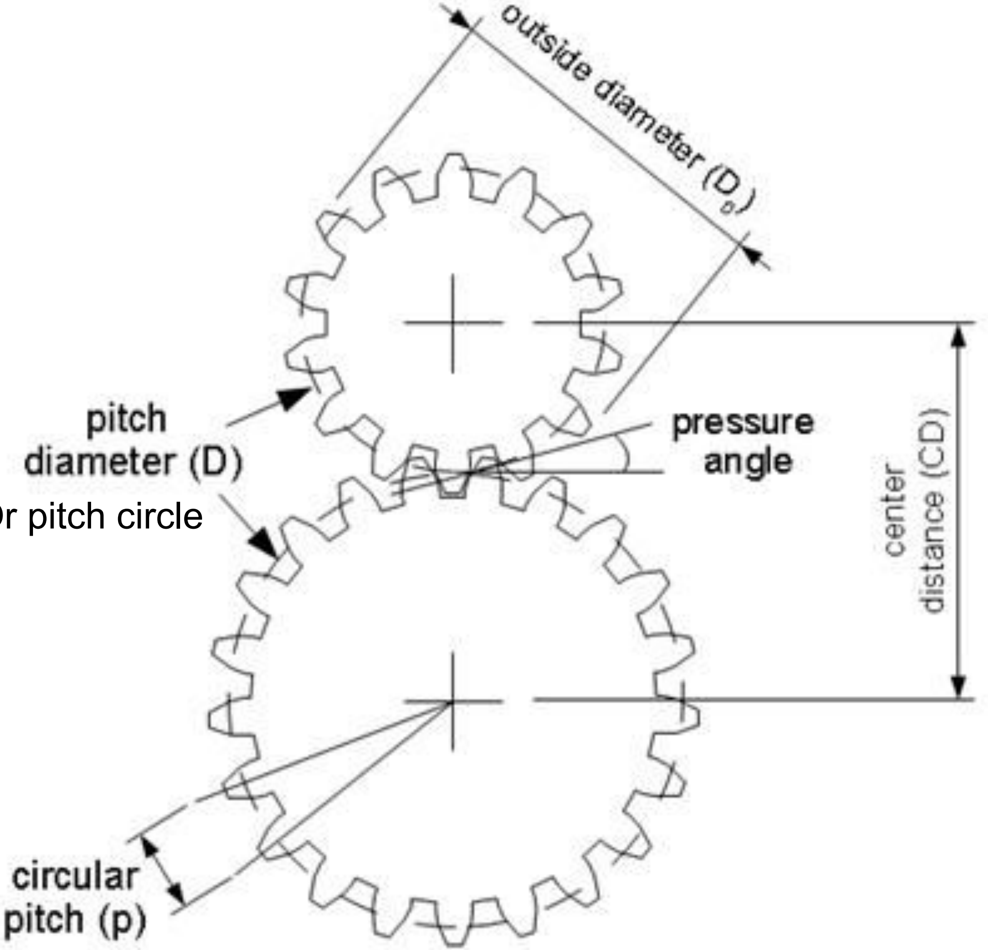
Pinion gear - small gear directly on output of motor

Idlers - gears in between input and output "a **gear** placed between a driving and a driven **gear** to transfer motion without change of direction or **gear** ratio"

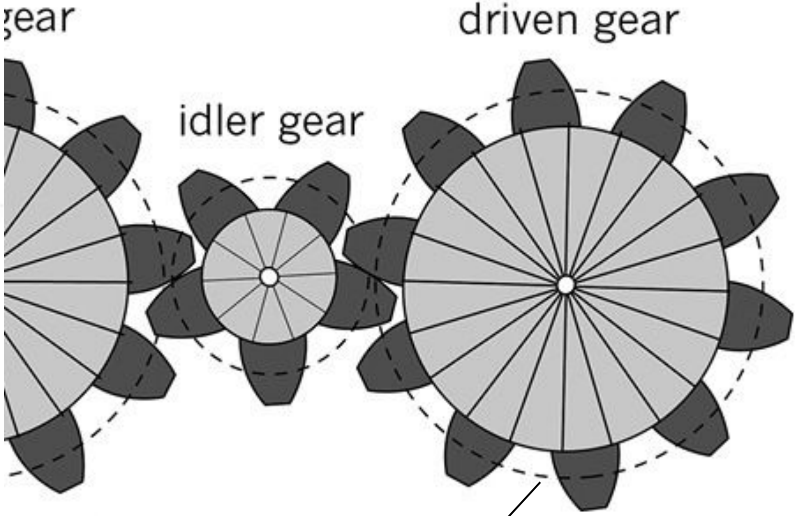




Pitch Circles are tangent



Or pitch circle



Diametral Pitch - the number of teeth per inch of pitch diameter (pitch circle)

20 DP, 1/2" Hex Bore Gears (47 Choices)

VEXpro offers an assortment of gear types, chosen to provide the greatest versatility of gearing options to users. Our sizes were specifically chosen to provide a wide spread of ratio options useful for robot designers. Larger size VEXpro gears are available so designers can accomplish their entire reduction in a single stage!

All VEXpro gears are 20 DP with 14.5 degree pressure angle, and have the same overall width -- this means it is easy to interchange VEXpro gears in your design to change a ratio without modifying the overall system; true versatility.

- 1/2" hex bores for use on hex shafts
- Made from 7075-T6 aluminum with a teflon infused ceramic coating
- Overall width 0.500"

Note: Hex bore and / or Versakey patterns are not indexed to each other, or keyed to gear teeth.

In stock

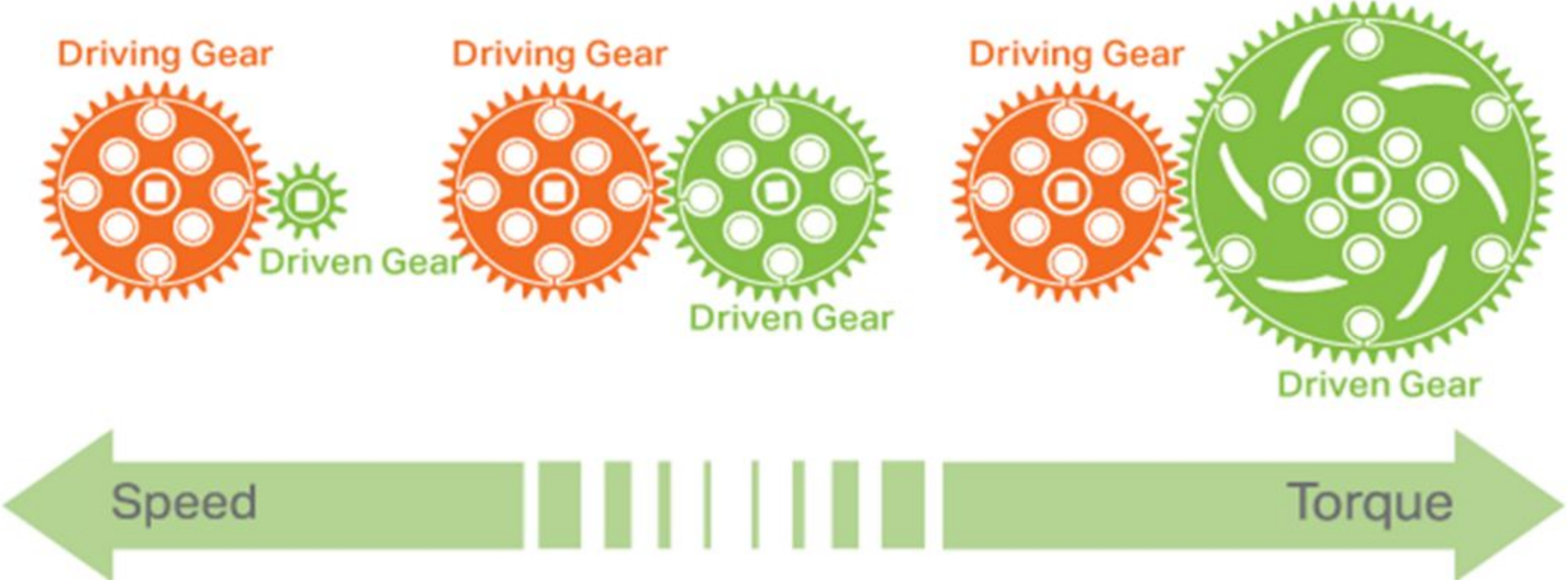
More Views

What is easier to push?

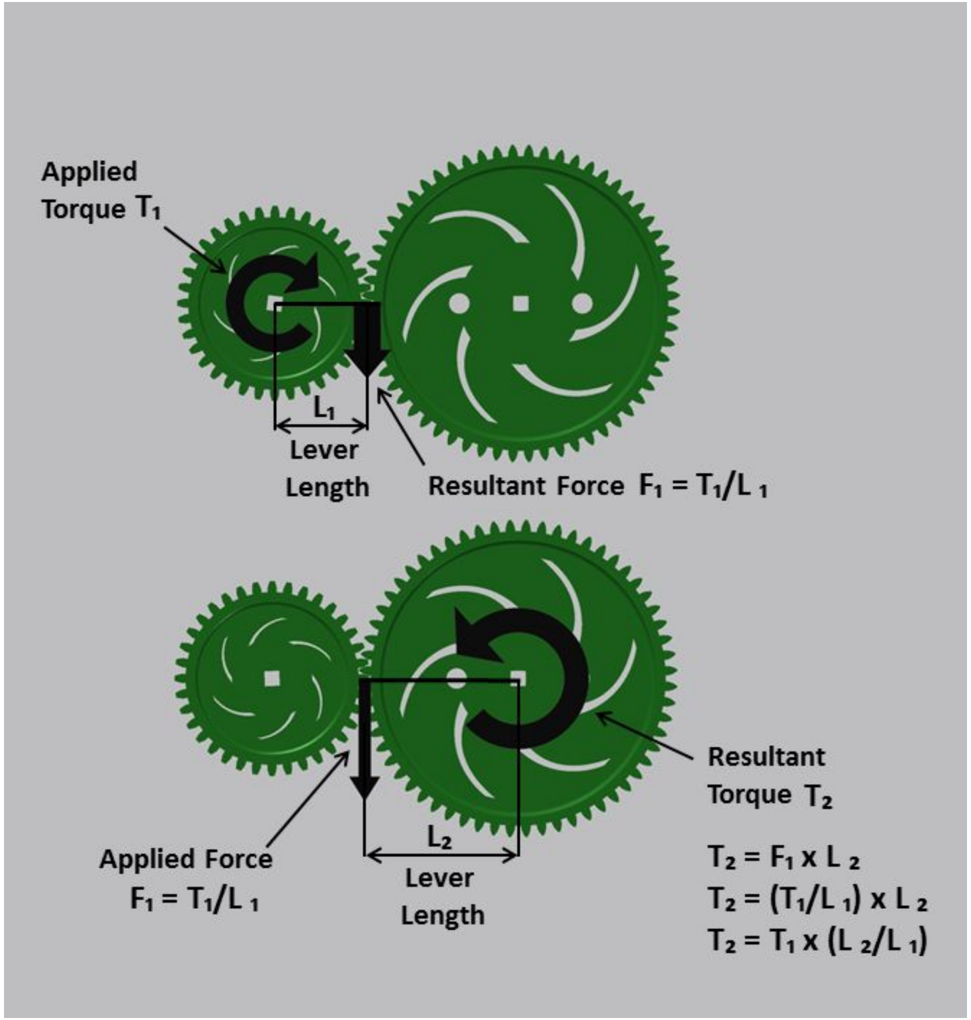
Small gear driving big gear?

Or

Big gear driving small gear?



Driving Gear
Driven Gear
Driving Gear
Driven Gear
Driving Gear
Driven Gear
Speed
Torque

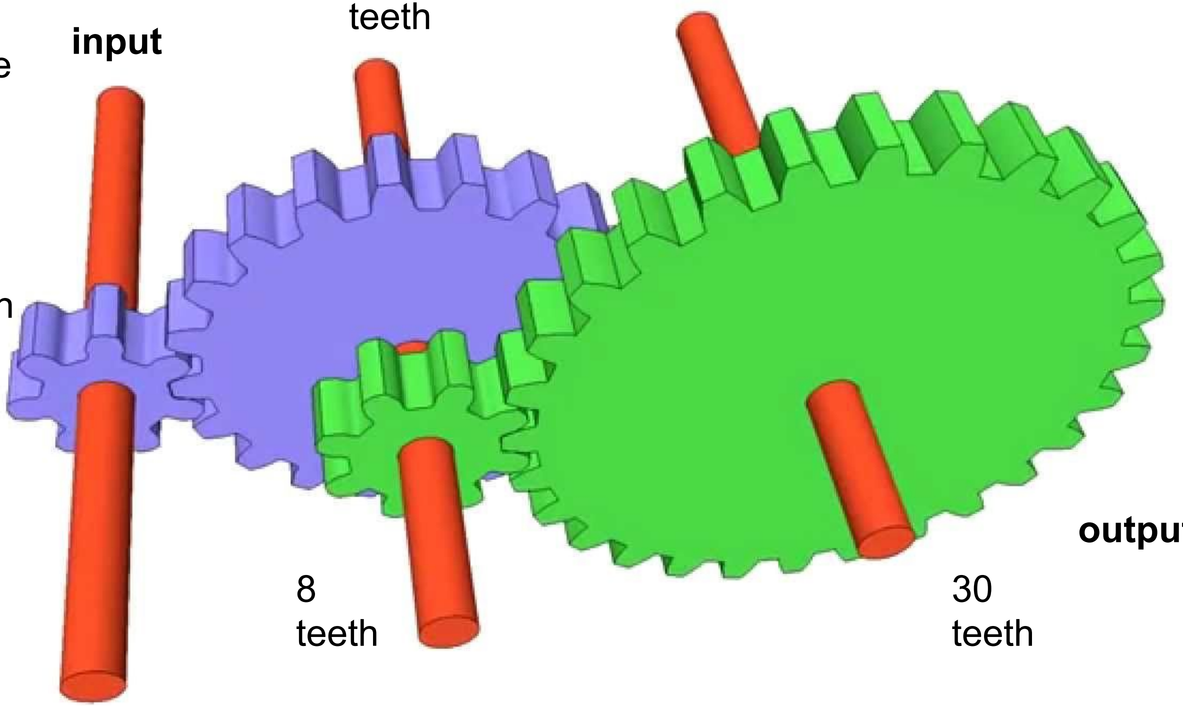


Applied Torque T1
L1
Lever Length
Resultant Force F1 = T1/L 1
Resultant Torque T2
L2
Applied Force F1 = T1/L 1
Lever Length
T2 = F1 x L 2
T2 = (T1/L 1) x L 2
T2 = T1 x (L 2/L 1)

What is the gear ratio?

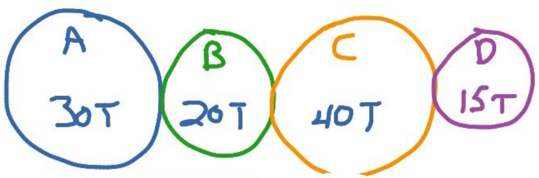
Driven over driver

Used to calculate speed and acceleration



Simple Gear Ratio Math

GEAR RATIOS



$GR(A \text{ to } B) = 2/3$

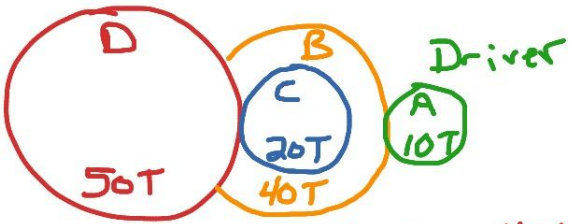
$GR(B \text{ to } C) = 2$

$GR(C \text{ to } D) = \frac{3}{8}$

$$GR_{TOTAL} = \frac{2}{3} \cdot 2 \cdot \frac{3}{8} = \frac{4}{8} = \frac{1}{2}$$

$$GR(A \text{ to } D) = \frac{n_{out}}{n_{in}} = \frac{15t}{30t} = \frac{1}{2}$$

Compound GEAR RATIOS



$$GR(A \text{ to } B) = \frac{n_{out}}{n_{in}} = \frac{40t}{10t} = 4$$

$$GR(C \text{ to } D) = \frac{n_{out}}{n_{in}} = \frac{50t}{20t} = \frac{5}{2}$$

$$\text{Find GR of train} = \overset{2}{\cancel{4}} \cdot \frac{5}{\underset{1}{\cancel{2}}} = \frac{10}{1}$$

Output	Input
GEAR A	GEAR B
60 teeth	30 teeth
120 rpm	?

Output	Input
GEAR A	GEAR B
60 teeth	30 teeth
120 rpm	?

$$\frac{60}{30} = 2$$

$$= 120 \times 2 = 240 \text{ revs/min}$$

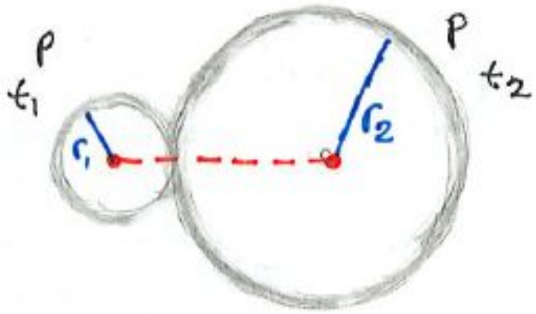
Gear Ratio Calculation Problem

Gear Distance

Given: diametrical pitch p

number of teeth t_1, t_2

Find: center distance



gear terms: diametrial pitch (DP) is number of teeth per inch of diameter, pressure angle (a) is angle between line of contact and common tangent

Gear Ratio Calculations

Gear Distance

Given: diametrical pitch p

number of teeth t_1, t_2

Find: center distance

1) total distance $= r_1 + r_2$
2) pitch diameter $= t/p$

$d_1 = t_1/p, \quad d_2 = t_2/p$

$r_1 = d_1/2 = t_1/2p$

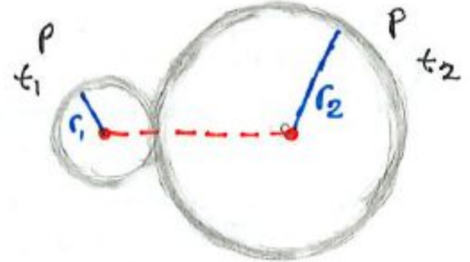
$r_2 = d_2/2 = t_2/2p$

3) simplify:

distance $= t_1/2p + t_2/2p$

$= \frac{t_1 + t_2}{2p}$

final formula: center distance $= \frac{t_1 + t_2}{2p}$



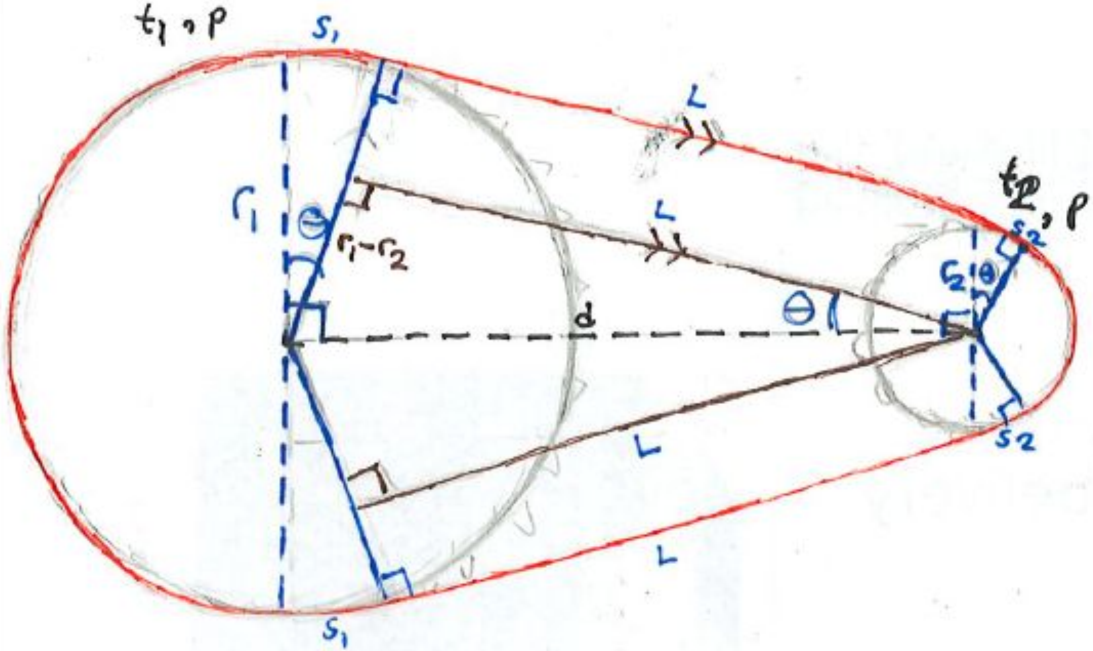
Notes about Gears:

gearboxes: often can have multiple reductions; you can keep gear distance the same if the sum of the teeth stays the same

gear terms: diametral pitch (DP) is number of teeth per inch of diameter, pressure angle (a) is angle between line of contact and common tangent

gears should have tangent pitch diameters if you want them to work!

tesseract INITIATIVE



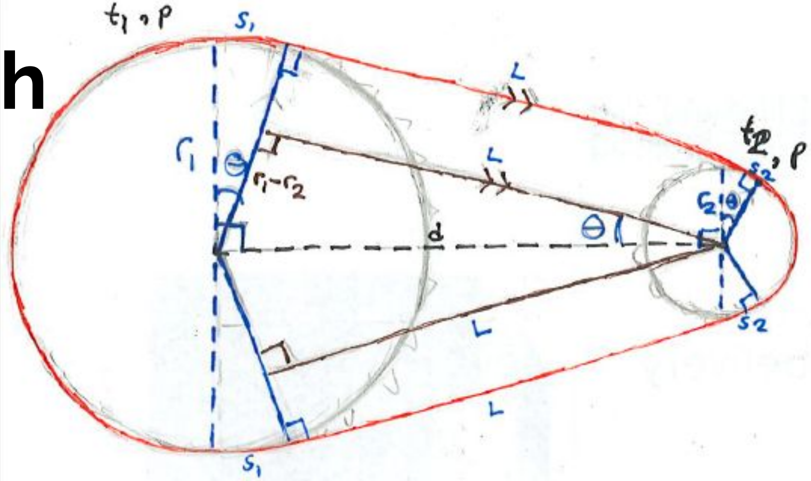
Chain Length

Given: center distance d
teeth t_1, t_2
pitch p

Find: total chain length

Chain Length

Credit: Tamara K.



Chain Length

Given: center distance d

teeth t_1, t_2

DP pitch p

Find: total ~~teeth~~ chain length

1) total length $= 2L + 2s_1 - 2s_2 + \pi r_1 + \pi r_2$
2) find L (draw construction line)

   $L^2 + (r_1 - r_2)^2 = d^2$; $L = \sqrt{d^2 - (r_1 - r_2)^2}$
3) find s_1 and s_2

   $s = r\theta \rightarrow s_1 = r_1\theta$, $s_2 = r_2\theta$

   find $\theta \rightarrow r_1 - r_2 = d\sin\theta$, $\sin\theta = \frac{r_1 - r_2}{d}$

   find $r \rightarrow$ circumference of sprocket $= tp$

   $C_1 = t_1 p$, $r_1 = t_1 p/\pi$, $C_2 = t_2 p$, $r_2 = t_2 p/\pi$
4) plug into formula

   $2L + 2\theta r_1 - 2\theta r_2 + \pi r_1 + \pi r_2$

   $2L + 2\theta(r_1 - r_2) + \pi(r_1 + r_2)$

   $2L + 2\theta\left(\frac{t_1 p}{\pi} - \frac{t_2 p}{\pi}\right) + \pi\left(\frac{t_1 p}{\pi} + \frac{t_2 p}{\pi}\right)$

   $2L + \frac{2\theta p}{\pi}(t_1 - t_2) + p(t_1 + t_2)$

   $\hookrightarrow L = \sqrt{d^2 - (t_1 p/\pi - t_2 p/\pi)^2} = \sqrt{d^2 - [p^2/\pi^2 (t_1 - t_2)^2]}$

Final formula: total length $= 2L + \frac{2\theta p}{\pi}(t_1 - t_2) + p(t_1 + t_2)$

where $L = \sqrt{d^2 - (r_1 - r_2)^2}$, $\theta = \arcsin\left(\frac{r_1 - r_2}{d}\right)$

$r_1 = t_1 p/\pi$, $r_2 = t_2 p/\pi$

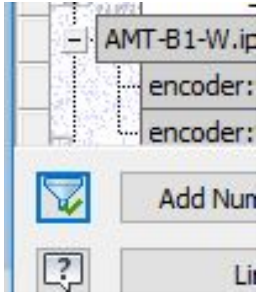
Notes about Chain and Belt:

- chain – comes mainly in #25 and #35 (.25" and .375" pitch), used with sprockets; alter length by adding/removing links
- belt – comes mainly in 5 mm HTD, used with pulleys; sold in set lengths, base spacing off belt calculations
- tensioning – belt can handle slight misalignment but chain can handle slight slack; both may need tensioning system (e.g. extra sprocket, additional holes to move pulley)

Belt Var (Belt Length)	CC	Belt Length		Percent Change	Belt Var (CC)
0.00	2.623	305.00	mm	0.00%	
0.56	2.635	305.56	mm	0.18%	0.012
1.13	2.647	306.12	mm	0.37%	0.024
-0.53	2.612	304.47	mm	-0.17%	-0.011

Navigating Parameters

Filter button helps organize what you really want to see. Usually “re-named” works well to show you all your renamed parameters



Parameters

Parameter Name	Consumed by	Unit/Type	Equation	Nominal Value	Tol.	Model Value	Key	Export P	Comment
Model Parameters									
Belt:StraightLength	geometry	in	(belt:length - ArcLength:2 - ArcLength:1) / 2 ul	2.674767		2.674767	☑	☐	
topmounting:cc	standoffs and mou...	in	4.366 in	4.366062		4.366062	☐	☐	
Reference Parameters									
ArcLength:1	Belt:StraightLength	in	4.037 in	4.037268		4.037268	☑	☐	
ArcLength:2	Belt:StraightLength	in	1.440 in	1.439969		1.439969	☑	☐	
bottommounting:cc	d180	in	3.954 in	3.953559		3.953559	☐	☐	
CentertoCenter		in	2.740 in	2.740204		2.740204	☐	☐	
standoffs:cc	d189	in	4.583 in	4.582576		4.582576	☐	☐	
User Parameters									
wheel:dia	d11	in	6.0 in	6.000000		6.000000	☐	☑	
CIM_diam	d1	in	2.52 in	2.520000		2.520000	☐	☑	
DP	d10, d9, d8, d7, d6	ul/in	20 ul/in	20.000000		20.000000	☐	☑	
belt:CIMpulley	d0	in	(belt:CIMpulley:teeth * belt:pitch) / PI	1.065210		1.065210	☐	☑	16T
belt:outputPulley	d3	in	(belt:outputPulley:teeth * belt:pitch) / PI	2.255739		2.255739	☐	☑	30T
motor:cc	d2	in	2.6 in	2.600000		2.600000	☐	☑	
belt:pitch	belt:outputPulley, ...	mm	5 mm	5.000000		5.000000	☐	☑	
wheel:smallGear	wheel:bigGear, d9,...	ul	18 ul	18.000000		18.000000	☐	☑	
wheel:bigGear	d8, d7	ul	wheel:sumTeeth - wheel:smallGear	74.000000		74.000000	☐	☑	
wheel:sumTeeth	wheel:bigGear, d10	ul	92 ul	92.000000		92.000000	☐	☑	
bottom:mounting:cc		in	4.3 in	4.300000		4.300000	☐	☑	
belt:teeth	belt:length	ul	55 ul	55.000000		55.000000	☐	☐	
belt:length	Belt:StraightLength	in	belt:teeth * belt:pitch	10.826772		10.826772	☐	☐	
belt:CIMpulley:teeth	belt:CIMpulley	ul	17 ul	17.000000		17.000000	☐	☐	
belt:outputPulley:teeth	belt:outputPulley	ul	36 ul	36.000000		36.000000	☐	☐	
encoderhole	d145	in	0.626 in	0.626000		0.626000	☐	☐	
distance_to_standoff		in	3.315 in	3.315000		3.315000	☐	☐	
AMT-B1-W.ipt									
encoder:wings	d59	in	1.819 in	1.818898		1.818898	☐	☐	
encoder:wing:mountHole	d150	in	0.113 in	0.112992		0.112992	☐	☐	

Add Numeric | Update | Purge Unused

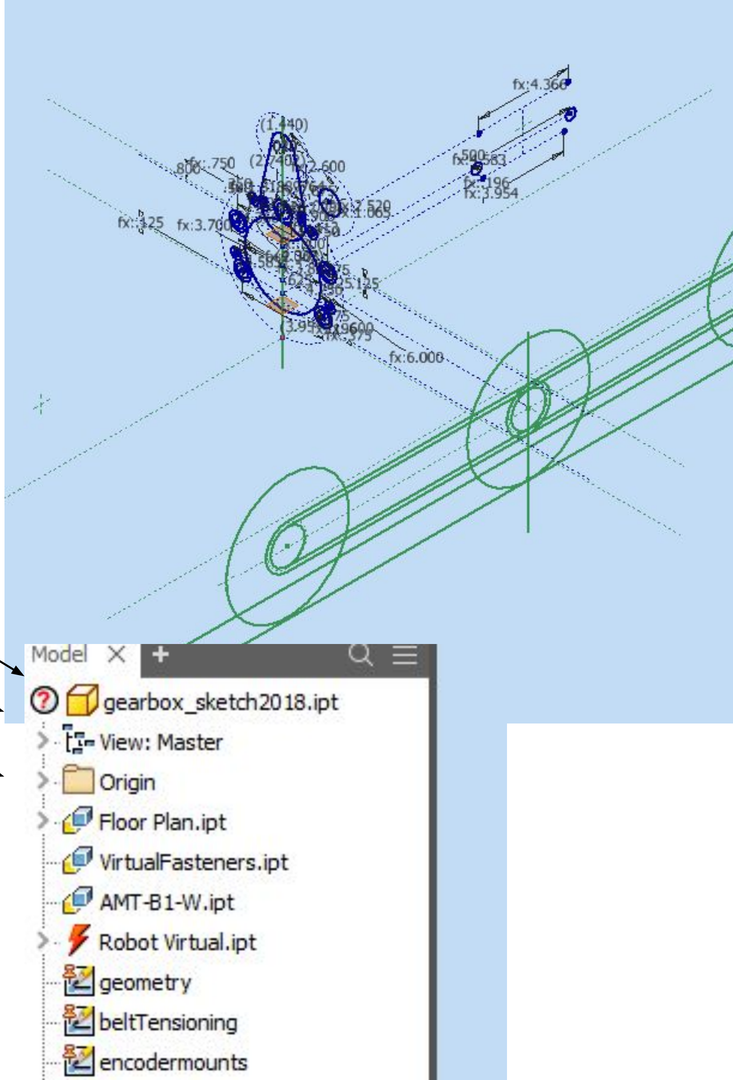
Link | ☑ Immediate Update

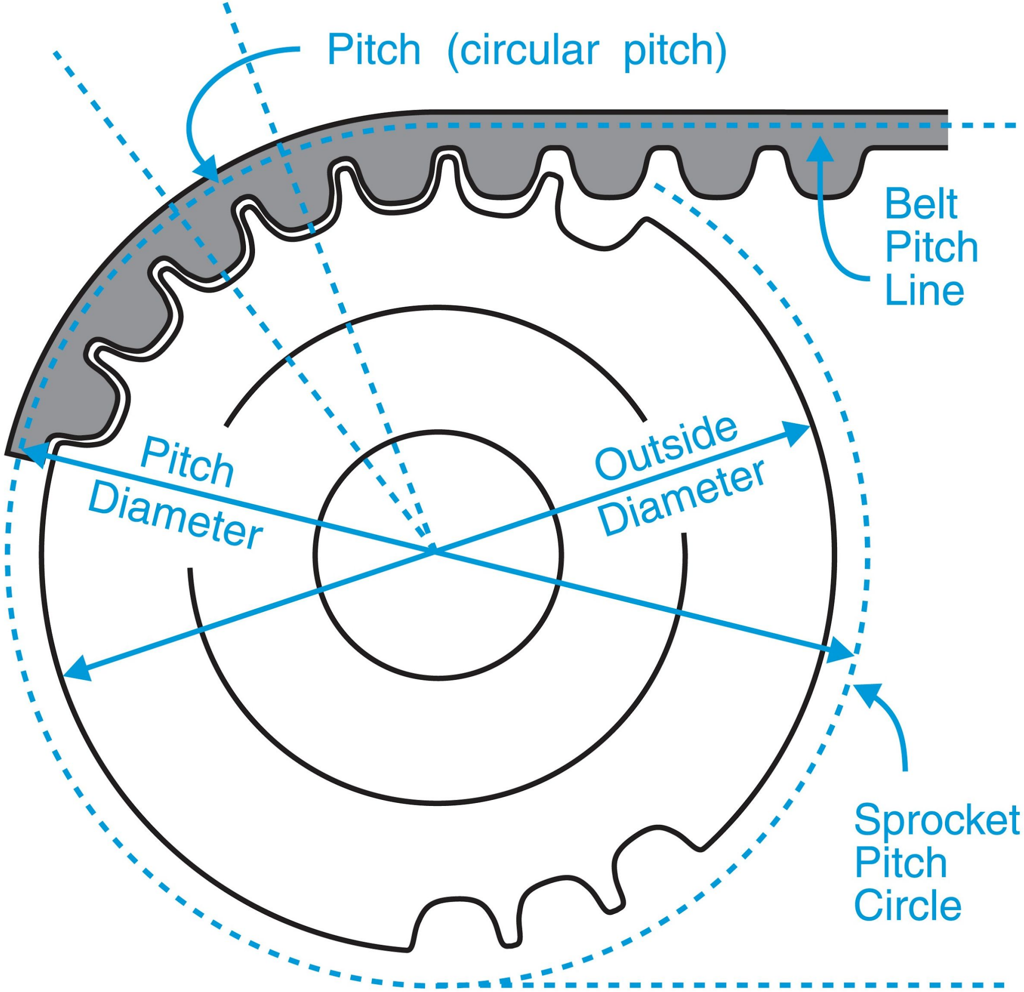
Reset Tolerance

<< Less | Done

CAD tips

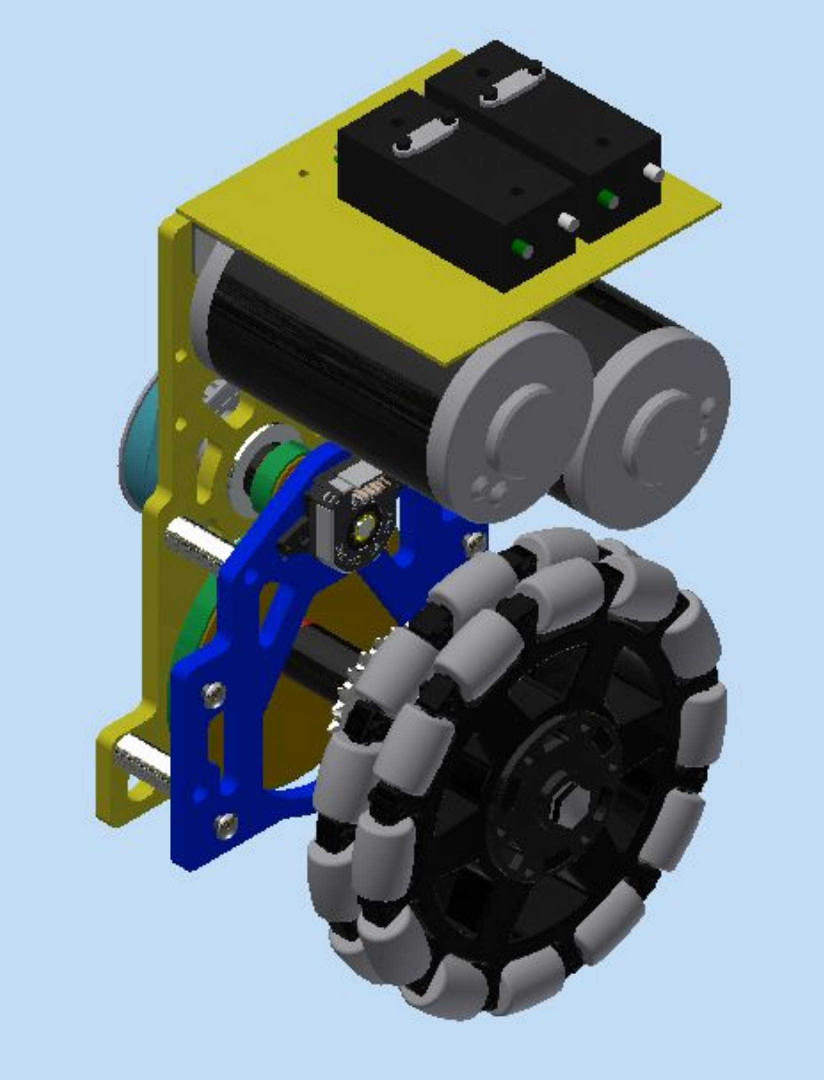
- Start with geometry sketch
- Derive sketch into new file for plates
- Derive in the frame sketch too
- Derive in fasteners (to get the exact diameters of our common fasteners)
- Derive in robot virtual to position the gearbox
- Assemble in another assembly file
- Make everything as parameterized as possible in case of changes!
- Use parameterized gear premade solid bodies that can update with changes to gear tooth number

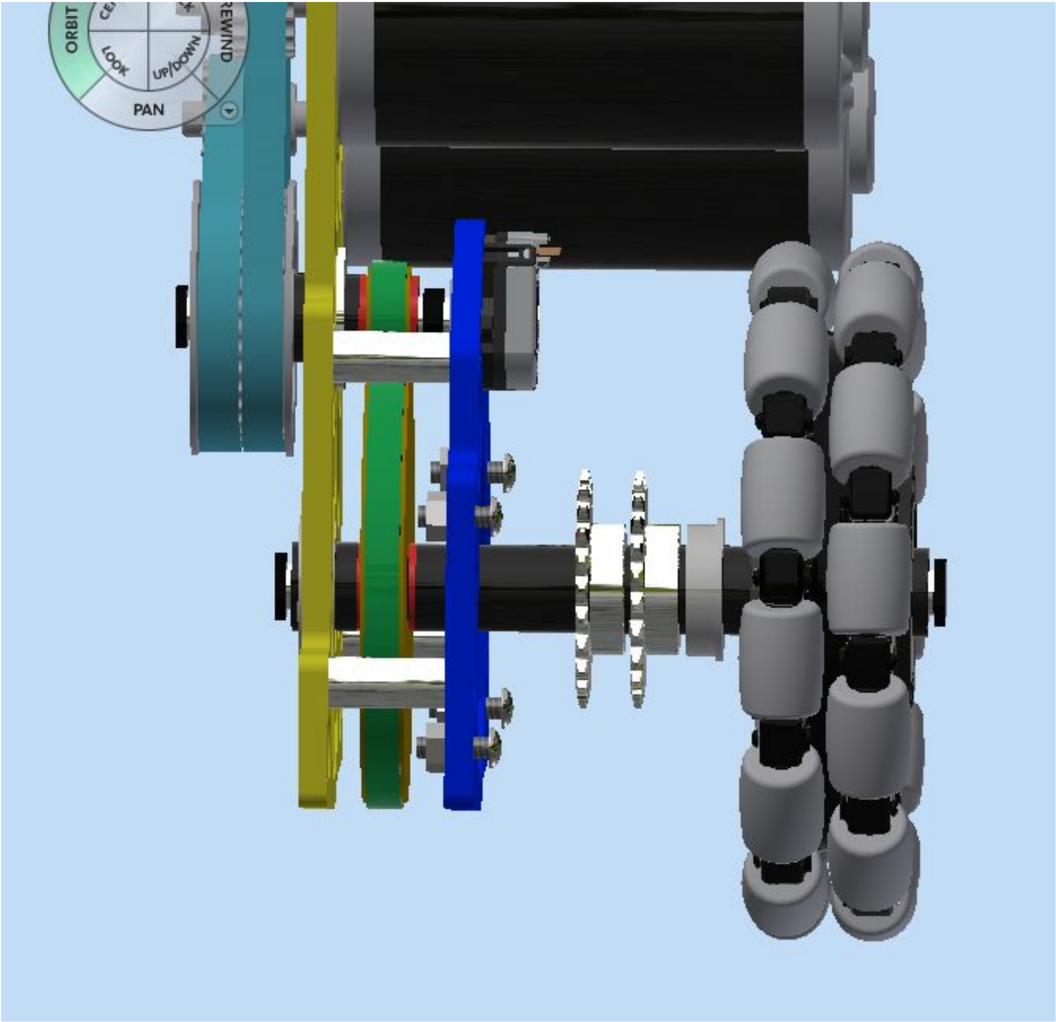


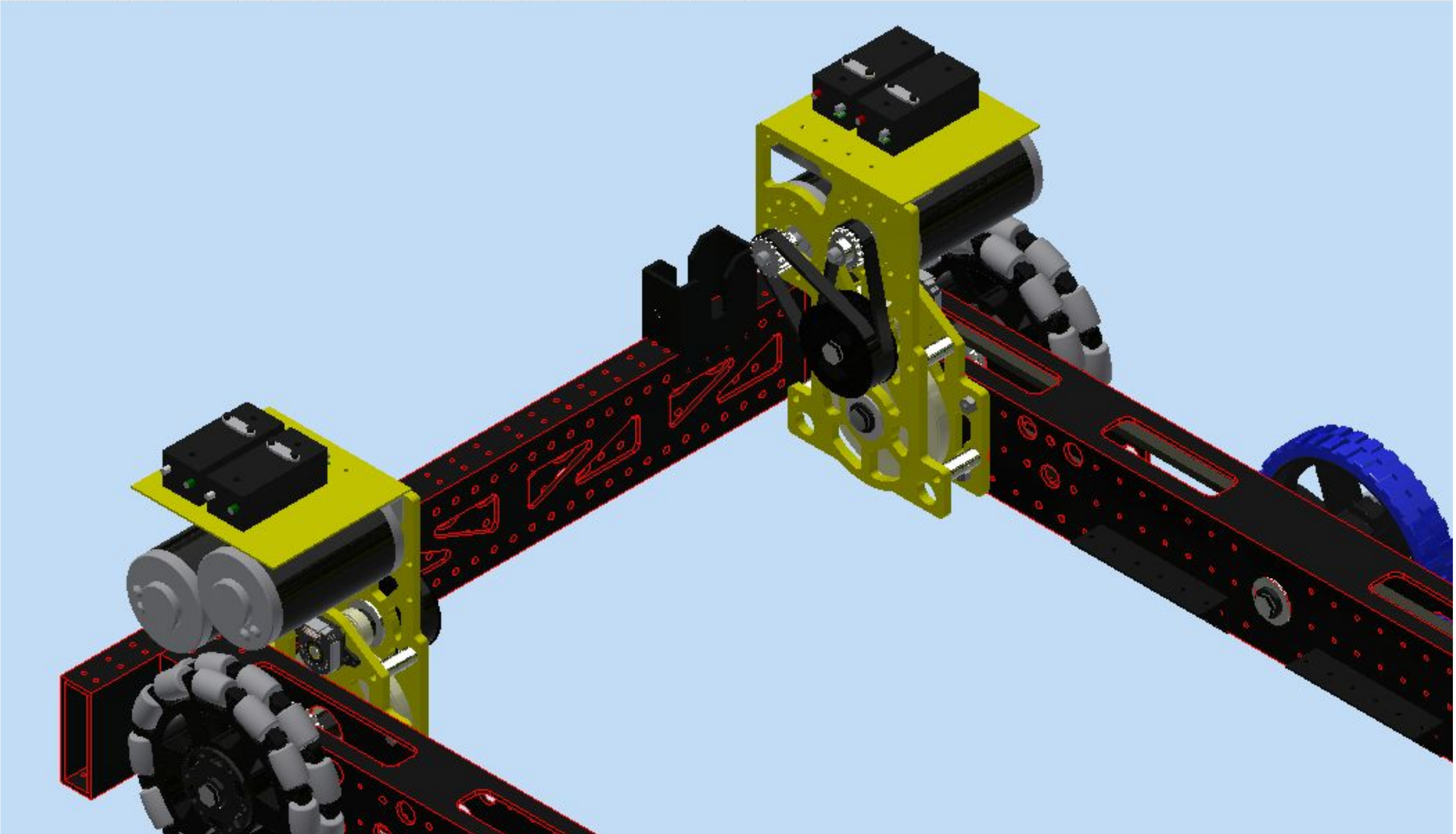


Belt pitch line and sprocket pitch circle match/are tangent for it to mesh

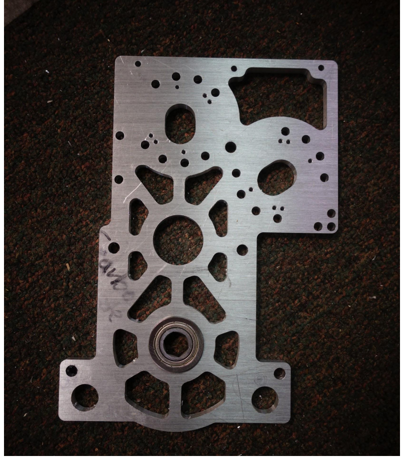
Pitch Diameter (P.D.) = (Pitch x Number of teeth) / PI




ORBIT
LOOK
UP/DOWN
PAN
REWIND



Features of a Good Gearbox



- Holes for zip ties to fit through and help route wires.
- A secure place for above for speed controllers if space allows
- Belt tensioning options (at least 4 sets of holes)
- Mirror ability! (so any plate can fit on left or right) so drill all holes through
- Easily accessible encoder (make sure you account for where software connect the wire to it)
- Ability to access holes with nut driver (so account for side of nut driver head)
- Light weight using ribs
- Extra set of encoder holes in case taping

  goes wrong

More on belt tensioning

Numbers chosen based on percent increases

We put one looser than calculated optimal and two tighter than optimal

Tightest is marked with a small double hole drill,

Optimal marked with a single hole

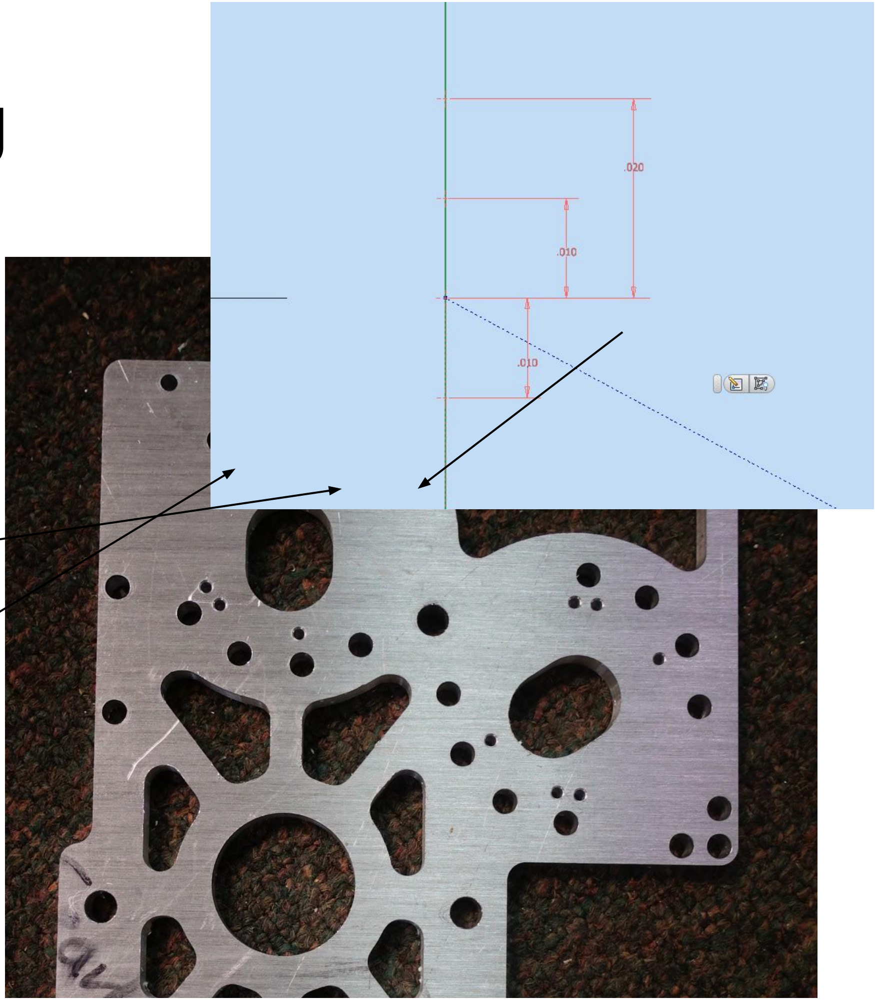


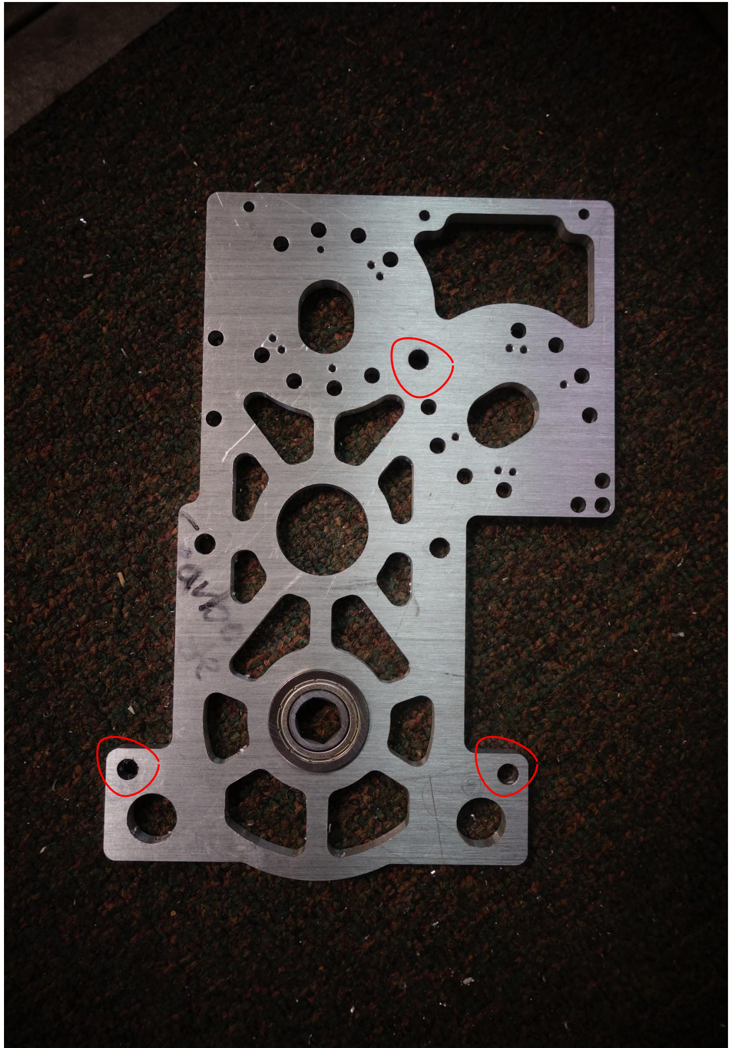
Plate Machining

Fixture plate machining:

Mount stock onto big block called a fixture plate so it is able to cut the outside contour of the plates

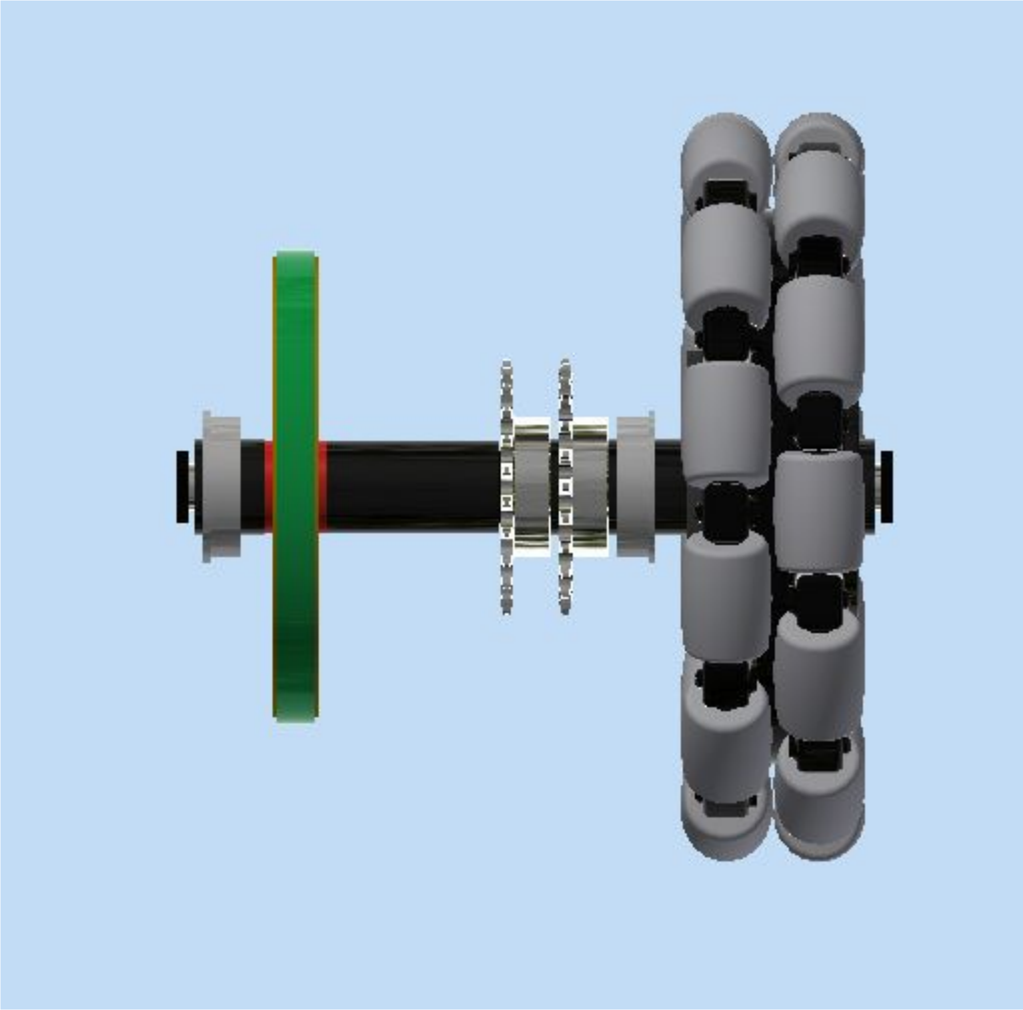
Do pairs at a time to be faster (stack two plates of quarter inch)

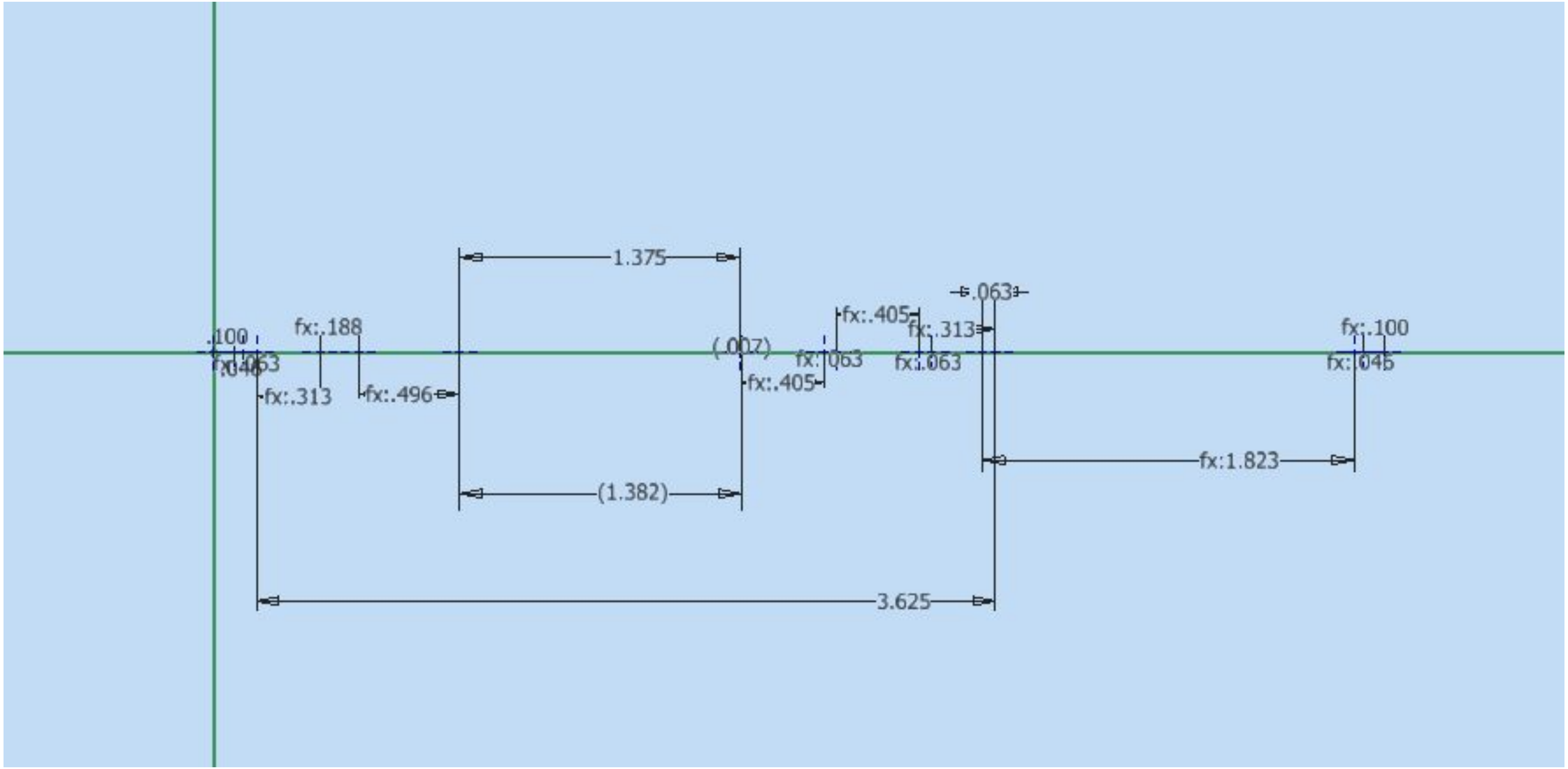
When you set up the CAM, have to add holes where it is held down to the fixture by special bolts

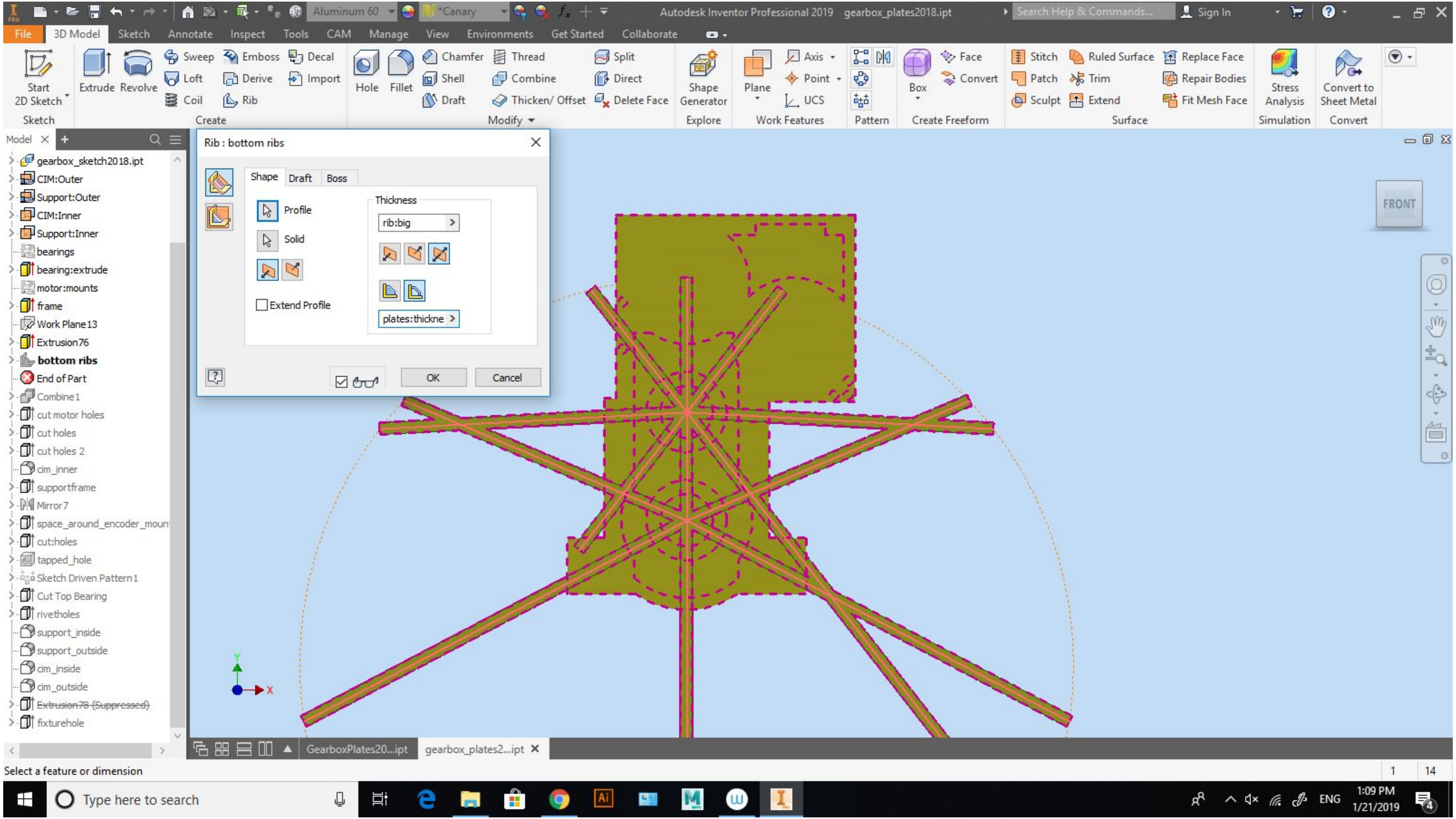


Hex shafts

- Make sure it's assemble-able!!!
- Use a number line with parameters




1.375
.063
fx:.405
fx:.313
fx:.188
.100
fx:.100
(.007)
fx:.063
fx:.063
fx:.063
fx:.045
.046
fx:.313
fx:.496
fx:.405
fx:1.823
(1.382)
3.625



Autodesk Inventor Professional 2019 gearbox_plates2018.ipt
File
3D Model
Sketch
Annotate
Inspect
Tools
CAM
Manage
View
Environments
Get Started
Collaborate
Rib : bottom ribs
Shape
Draft
Boss
Profile
Solid
Extend Profile
Thickness
rib:big
plates:thickne
OK
Cancel
gearbox_sketch2018.ipt
CIM:Outer
Support:Outer
CIM:Inner
Support:Inner
bearings
bearing:extrude
motor:mounts
frame
Work Plane13
Extrusion76
bottom ribs
End of Part
Combine1
cut motor holes
cut holes
cut holes 2
cim_inner
supportframe
Mirror7
space_around_encoder_moun
cut:holes
tapped_hole
Sketch Driven Pattern1
Cut Top Bearing
rivetholes
support_inside
support_outside
cim_inside
cim_outside
Extrusion78 (Suppressed)
fixturehole
FRONT
GearboxPlates20...ipt
gearbox_plates2...ipt
Select a feature or dimension
1:09 PM
1/21/2019

Motor Stuff

Efficiency = Pout/Pin

$P = T\omega$

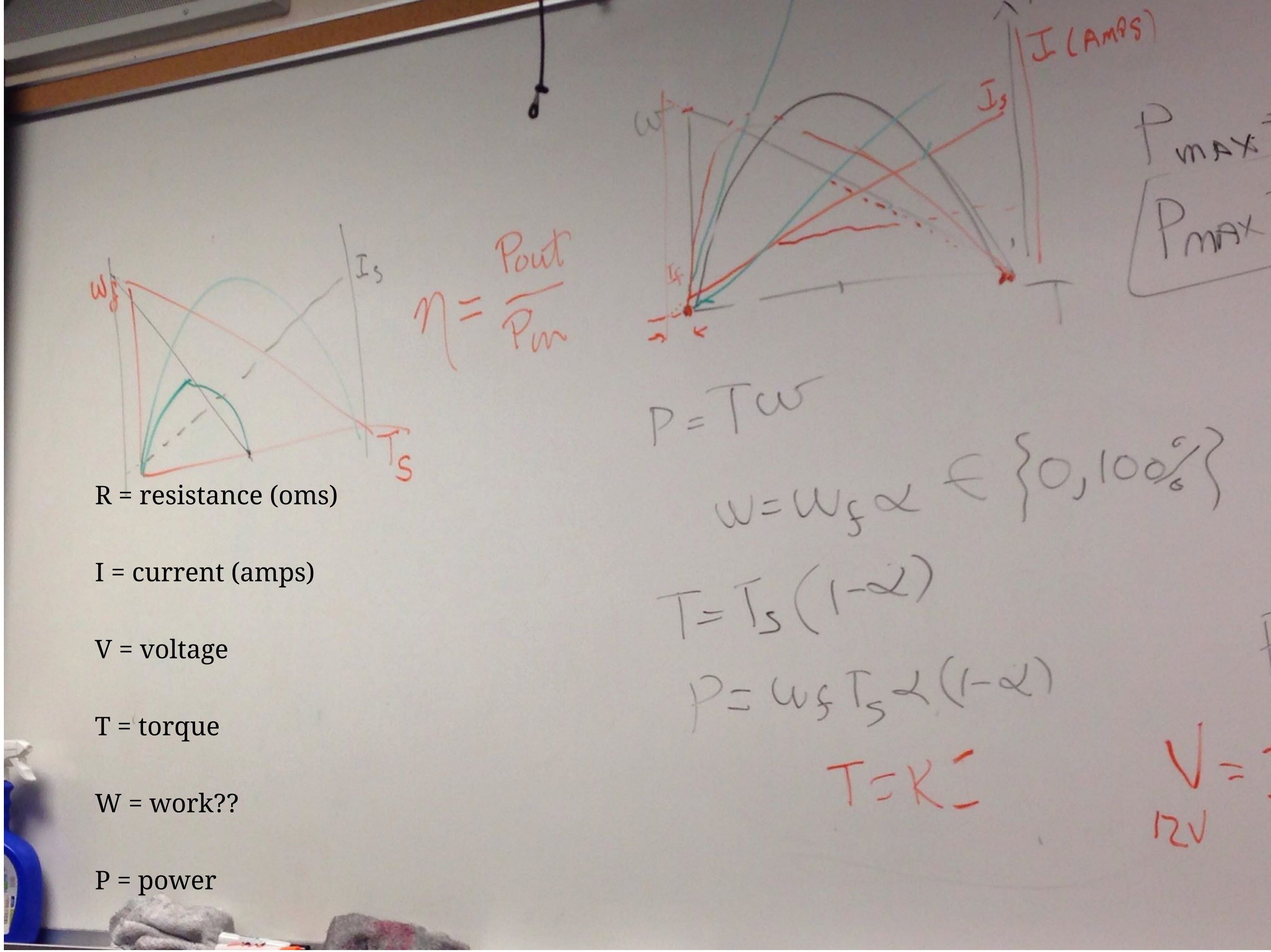
$\omega = \omega_f \alpha \in (0,100\%)$

$T=KI$

$T=T_s(1-\alpha)$

$P=\omega_f T_s \alpha(1-\alpha)$

$V=IR$



R = resistance (oms)

I = current (amps)

V = voltage

T = torque

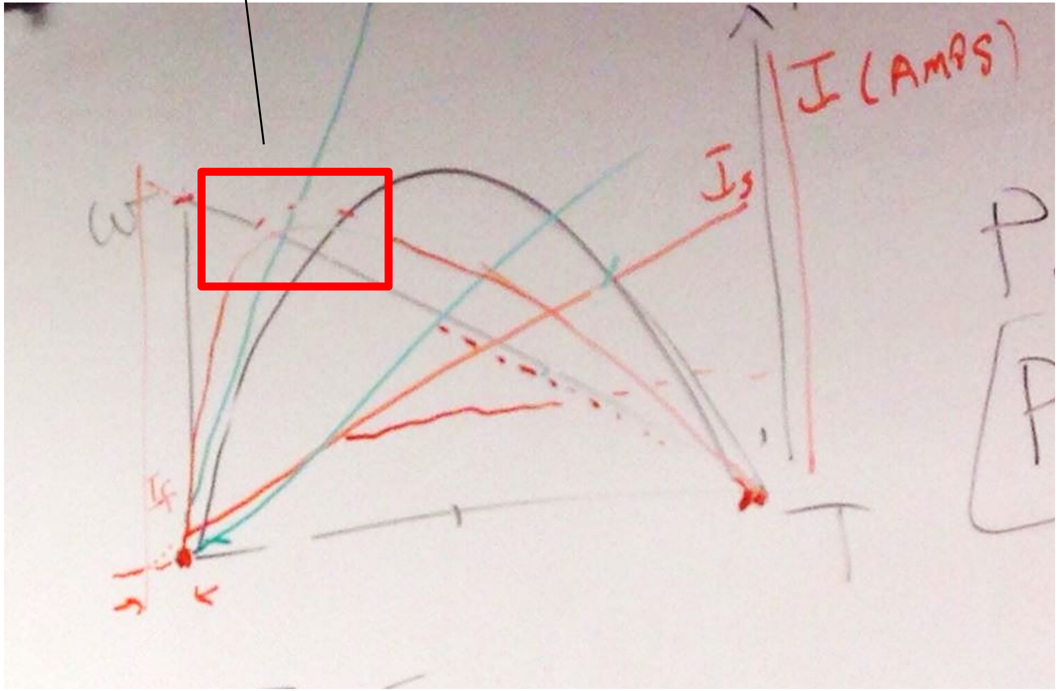
W = work??

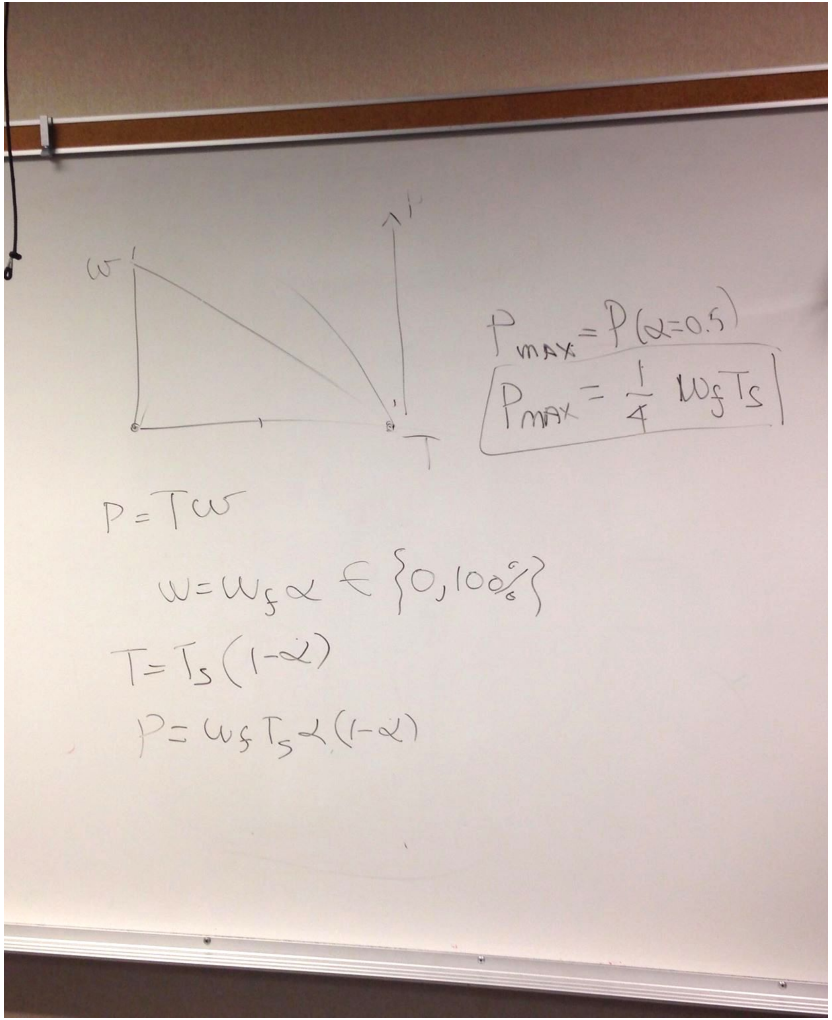
P = power

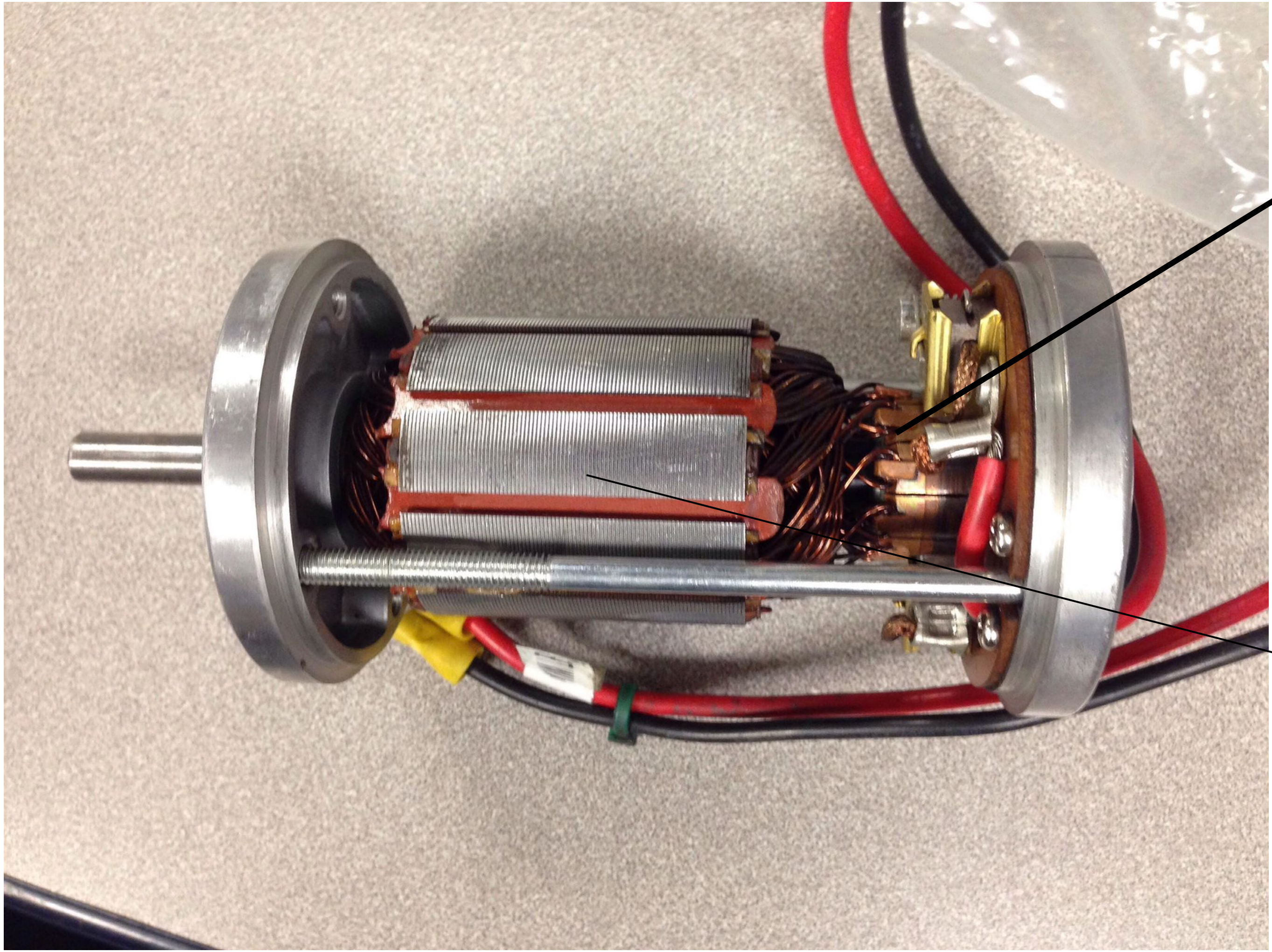
$P_{max} = P(\alpha=0.5)$

$P_{max} = \frac{1}{4} \omega_f T_s$

Optimal place, that's why we run motor @ <75%
b/c efficiency is horrible higher and it overheats






Comutator (switches direction of current)
N/S Magnets

Features of a Good Frame

Make sure everything is integrated properly and nothing overlaps (this is the only thing holding everything together)

Easy access to wheels and chains (easier to switch wheels during comp)

Strategic placement of lightening holes

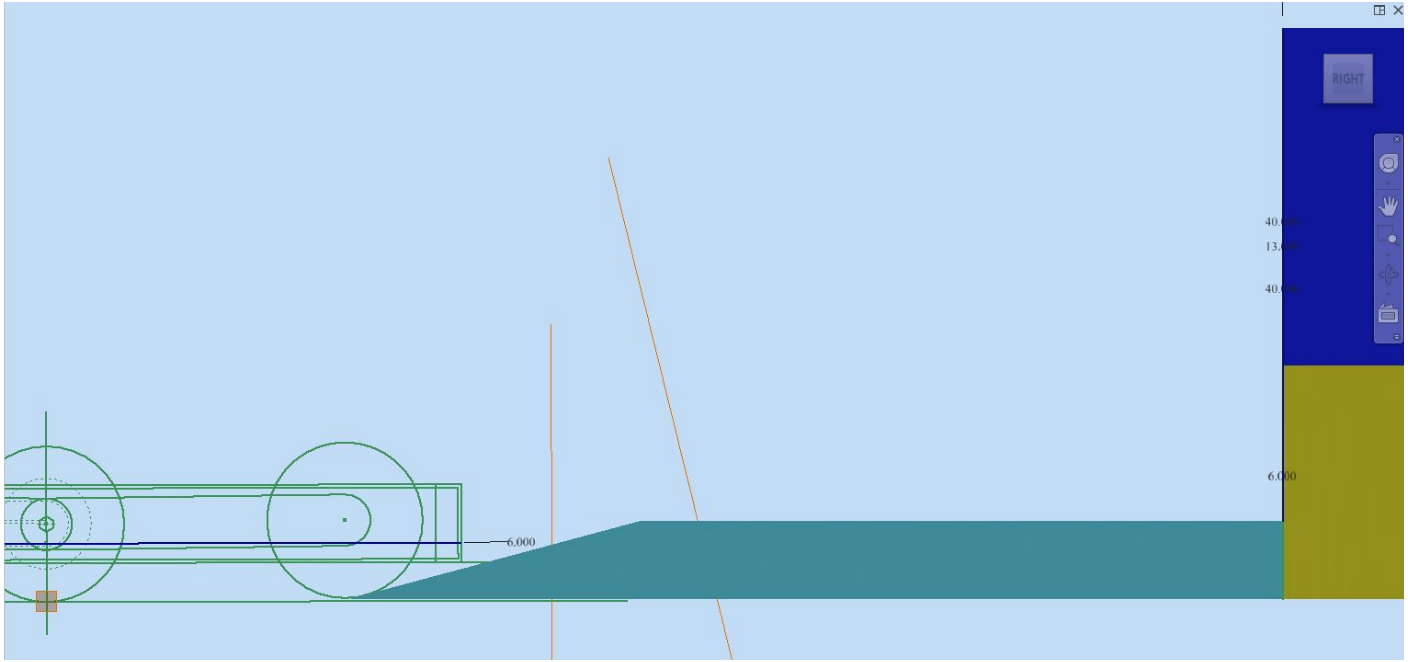
Able to go over wire protectors as well as climb over obstacles on the field (EX. Platform)

Sturdy, does not need a lot of maintenance over the season

Sprocket selection + chain length+type of wheels

Testing

Use geometry early on to test, so you don’t have to redo your work



Frame machining

Frame is typically made out of a very long metal tube (typically ~20 inches

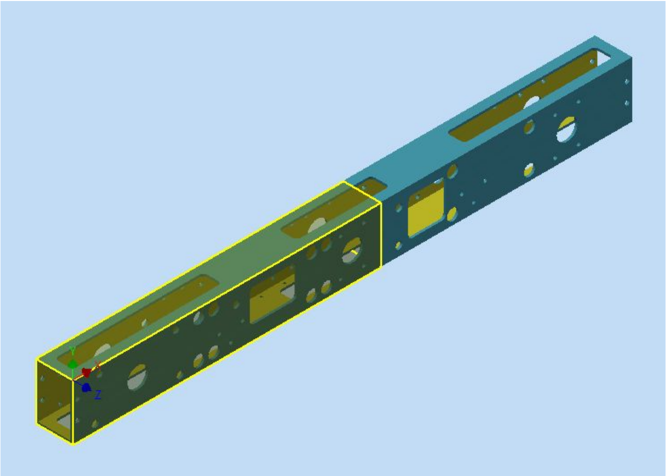
Machine only has a range of 16 inches, so we use a method called stepping

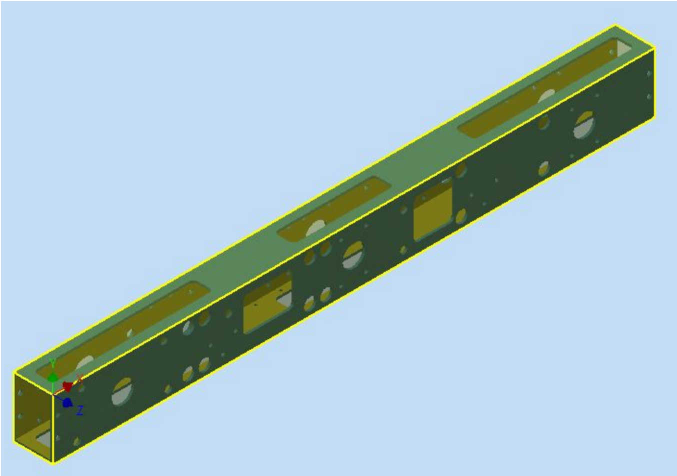
We only machine half of the tube first and move the tube “up” to machine the other half. We used a feature (such as a lighting hole or a bearing hole) that we machined in the first half of the machining to center the second half

Reference points are important, somethings can be machined from the end and therefore do not need stepping, while others (like bearing holes) are critical and need to be very precise

We also use stepping for lift bars

Stepping





Endstops

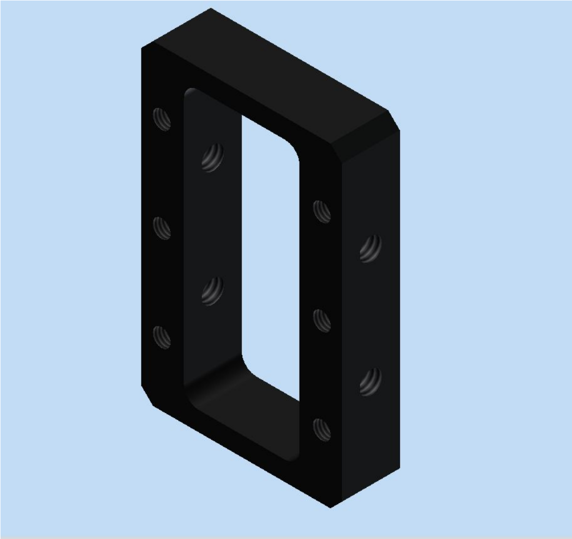
Used to connect the frame together

Custom made depending on the inside dimensions of the frame

Make sure the holes do not collide with each other

Lightening

Distance from tube (oops, mistake from last year)



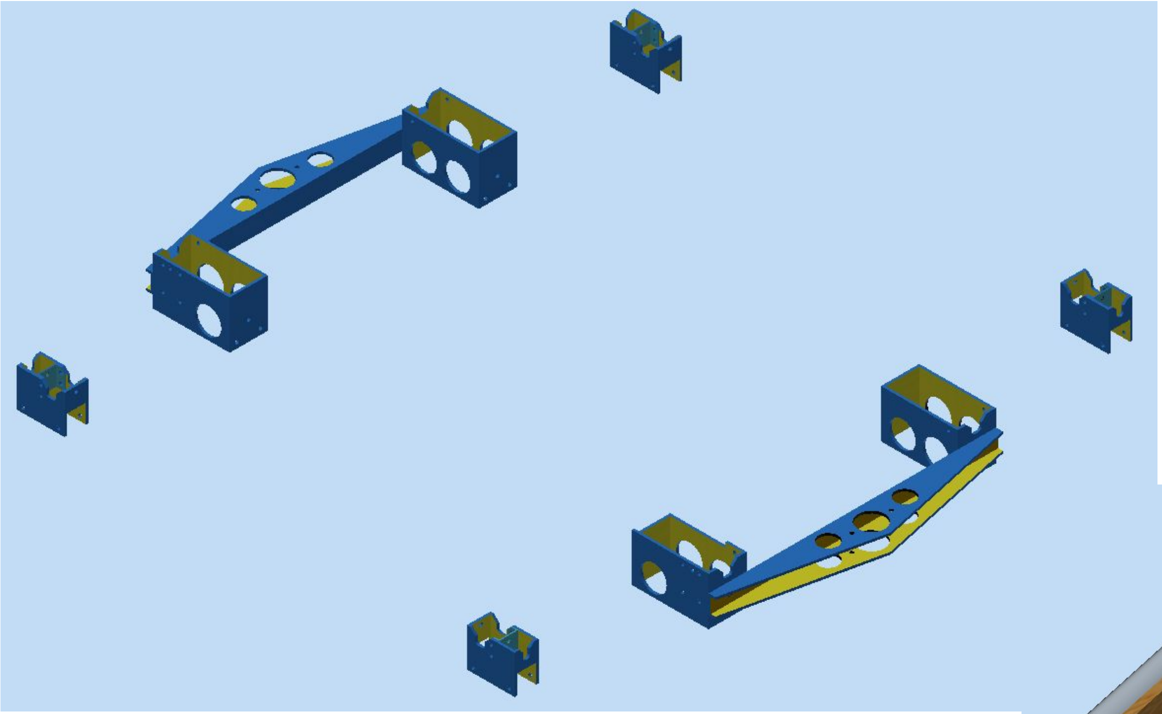
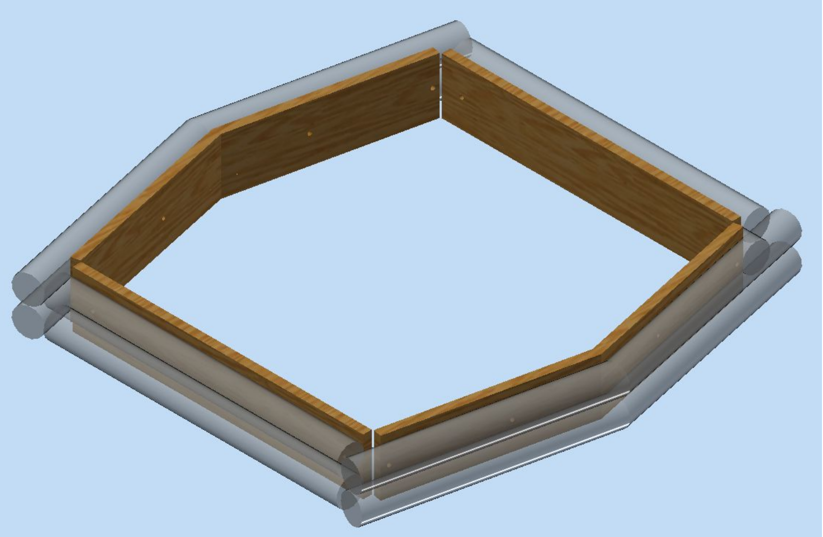
Bumpers

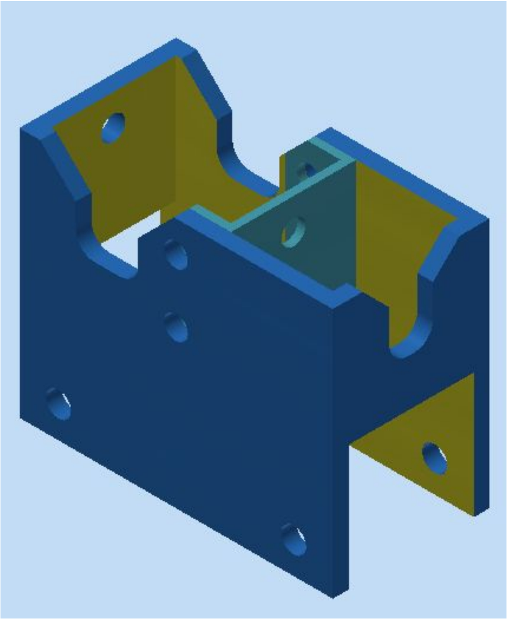
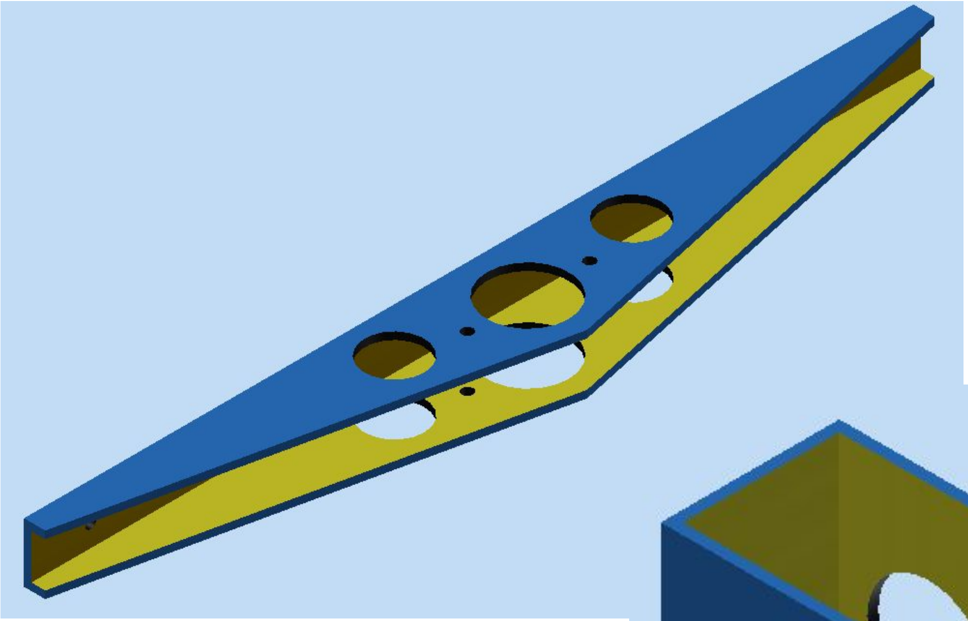
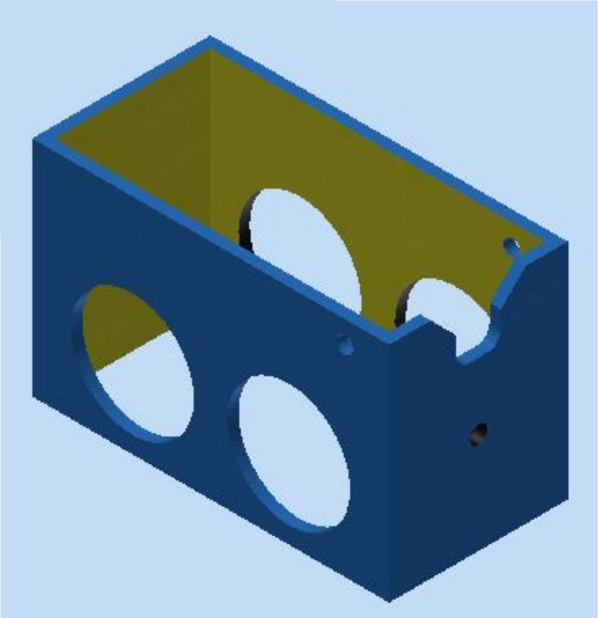
MAKE SURE YOU CHECK THE RULES IN THE HANDBOOK, THEY CHANGE EACH YEAR

Two parts, bumper themselves and the bumper standoffs

Bumper - Made of wood, pool noodle, and cloth. Protects the robot. Specific rules one height and how “open” it is as well as it’s distance away from the frame. Specific screw used to dig into the wood. Shape is can be useful for defense.

Standoffs - Connects the bumpers to the frame. Needs to line up with the bumper attachment mechanisms (usually just a nail) with enough slack for machining error

Machining

Bumper - can be made with CNC or manually. Specific screw used to dig into wood.

Standoffs - machined accurately, needs to match up with both the frames and the bumper screws

We usually make 3 sets of bumpers, one for practice, one red and one blue for competitions

Dolly

Custom made, keys that lock into opening in the frame

Best if it is symmetrical, if not, make sure to indicate front and back

Keys on front and back so the robot does not rock back and forth

Same as bumper, specific screw that digs into the wood

2, one for comp, one for practice