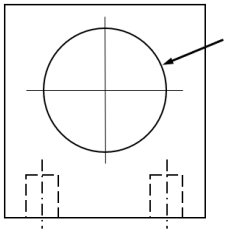
THE GUIDE FOR ME250: DRAWINGS, MFG PLANS, APPROVAL PACKS, DRILL CHARTS AND TABLES, ALUMINUM AND STEEL SPEEDS

A: Engineering Drawings

1. At least **two** views (except for waterjet and lasercut parts – only top view required)
2. Use ONE datum point, preferable top right corner (reference spot from which all dimensions should originate)
3. NO hidden lines in **isometric** view, YES hidden lines in **non-isometric** view
4. Centerlines AND centermarks for all holes and slots
5. Text orientation is horizontal (ANSI format)
6. For more than 5 or so holes in one part, use a **HOLE TABLE** <howtoaddholetable> http://help.solidworks.com/2016/english/solidworks/sldworks/t_create_hole_table.htm
7. Mill and lathe parts need a **drawing and manufacturing plan** (use solidworks template file on Canvas)
8. Lasercut, waterjet, and 3D printed parts need just a **drawing (NO mfg plan)**
9. Export dwg and mfg plan to pdf using solidworks, and print. DO NOT screenshot and print!
10. Diameter AND location of holes (OD) needs **3 decimals**
11. Diameter of holes should **match intended use** (free fit vs. tapped for specific fastener)
12. Tapped holes have dimension as "#4-40 Tapped"
13. Clearance holes have dimension "4X Ø.250"
14. Press fit holes are dimensioned as "Measure OD of {diameter} bearing/bushing/shaft {part number here} and ream for interference fit of 0.001" **in place of diameter dimension on drawing (see image)**
15. Tap drills are NOT the screw size, they are smaller **(see "imperial drill/tap chart" at end)**
16. Free fit/clearance drills are NOT the screw size, they are bigger **(see "imperial drill/tap chart" at end)**

Quick Look-Up for Fasteners				
	Tapped into Aluminum		Free Fit	
Type of screw	OD on drawings	Drill bit # in Manu. Plan	OD on drawings	Drill bit # in Manu. Plan
#4-40	0.089	43	0.1285	30
#6-32	0.1065	36	0.1495	25
#8-32	0.136	29	0.177	16
#10-24	0.1495	25	0.201	7
#1/4 - 20	0.201	7	0.266	H



Measure OD of ½" bearing (57155K304) for interference fit of 0.001"

17. E-clip groove has tolerance of +0.003/-0.000 **on depth AND axial location**
18. Title block has team # **and** part # **corresponding to BOM**
19. Machined gears must have **fully dimensioned** dwg and mfg plan **(do not dimension teeth, just pitch dia)**
20. Drill press parts do **NOT** need approval package
21. Sheet metal part dwg must be shown in FLAT state, ISO should be shown in BENT state
22. Sheet metal part will have dashed line for bend, dimension that line AND write bend angle along line
23. Waterjet parts must have **at least one** repeated weight saving features dimensioned
24. Waterjet parts do NOT need **artwork or text dimensioned**
25. Waterjet parts need ONE dwg, even if waterjet then mill. **Call out milled featured on dwg.**
26. Tapped holes can NOT be done on Waterjet, ONLY clearance holes
27. State "Waterjet", "Lasercut", or "3D printed" in dwg title block for parts
28. Waterjet, lasercutter, and 3D printed parts ONLY need GSI signoff to work in shop. Will have "N/A" in "shop approval" field.

B: Manufacturing Plans

1. If machining is required post-waterjet, state **in the mfg plan** "Outside shape has been waterjetted"
2. Label holes and other features as "waterjet" or "milled", if there is a mix of features
3. First step, "cut raw material on vertical band saw >.125"
4. Second step, machine **both ends of part** to get **fully machined surfaces for measuring accurately**
5. Special steps for bushing/bearing *(note: 0.015" undersize, round to nearest 1/64" drill size!)*

Step #	*Process Description*	*Machine*	*Fixture(s)*	*Tool(s)*	*Speed (RPM)*
X	Measure OD of bearing/bushing	-	-	Caliper	
X	Select drill bit and pre-drill 0.015" below measured diameter	Mill	Vise	Selected drill bit	1000
X	Select reamer 0.001" below measured diameter	Mill	Vise	Selected reamer	100

7. Typical first steps for mill part:

Step #	*Process Description*	*Machine*	*Fixture(s)*	*Tool(s)*	*Speed (RPM)*
1	Cut (using band saw) **>.125"** of finish length and deburr	Band Saw	-	-	300 ft/min
2	Mill both ends of the part, just enough to provide a fully machined surface	Mill	Vise	3/4" two flute endmill, collet	400
3	Measure the part with caliper and bring to the certain dimension, taking several passes at **.050"** or less per pass	Mill	Vise	3/4" two flute endmill, collet	400

8. Typical first steps for lathe part:

Step #	*Process Description*	*Machine*	*Fixture(s)*	*Tool(s)*	*Speed (RPM)*
1	Cut (using band saw) **>.125"** of finish length and deburr	Band Saw	-	-	300 ft/min
2	Face one end to create a flat surface	Lathe	Collet	Cutting tool	750

9. Edge finder = 1000 RPM, Centerdrill = 1000 RPM, ream, counterbore, countersink = 100 RPM
10. When reaming, use **low gear and one smooth downward motion** to ream hole
11. Recommended milling, drilling, and cutting speeds

Milling Aluminum		Drilling Aluminum		Turning Aluminumm	
End Mill Diameter	Speed	Drilling	Speed	Drill Diameter	Speed
0.125	1800 or less	0.125	1600 or less	0.125	2000 or less
0.1875	1600 or less	0.1875	1400 or less	0.1875	1800 or less
0.25	1400 or less	0.25	1200 or less	0.25	1600 or less
0.3125	1200 or less	0.3125	1000 or less	0.3125	1400 or less
0.375	1000 or less	0.375	800 or less	0.375	1200 or less
0.5	800 or less	0.5	600 or less	0.5	1000 or less
0.625	700 or less	0.625	400 or less	0.625	600 or less
0.75	500 or less	0.75	350 or less	0.75	400 or less
0.875	500 or less	0.875	350 or less	0.875	300 or less
1	400 or less	1	300 or less	1	300 or less

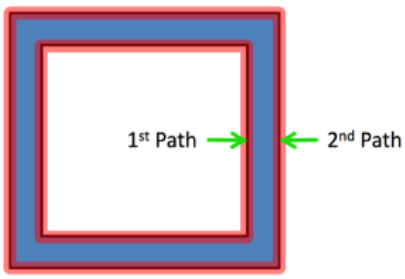
Milling Plain Carbon Steel 1006-1026		Drilling Plain Carbon Steel 1006-1026		Turning Plain Carbon Steel 1006-1026	
End Mill Diameter	Speed	Drilling	Speed	Drill Diameter	Speed
0.125	1500 or less	0.125	1500 or less	0.125	2000 or less
0.1875	1300 or less	0.1875	1300 or less	0.1875	1800 or less
0.25	1100 or less	0.25	1000 or less	0.25	1600 or less
0.3125	1000 or less	0.3125	850 or less	0.3125	1000 or less
0.375	950 or less	0.375	850 or less	0.375	900 or less
0.5	800 or less	0.5	700 or less	0.5	700 or less
0.625	700 or less	0.625	650 or less	0.625	600 or less
0.75	550 or less	0.75	450 or less	0.75	450 or less
0.875	500 or less	0.875	400 or less	0.875	400 or less
1	400 or less	1	350 or less	1	300 or less

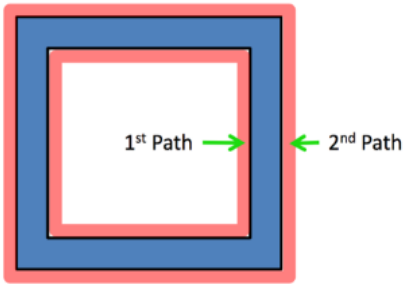
C: Approval Process

1. Create ONE approval packet (drawing and mfg plan) using the Solidworks drawing template on Canvas for EACH UNIQUE PART on your RMP (it's a lot, we know)
2. Follow the Online Approval Process explained in the DW6 Lab Slides and the Document "DRAWING APPROVAL PROCESS" in Files -> Project Resources
3. Wait for GSI and Shop Approval
4. If either GSI OR MACHINE SHOP reject, comments will be added to the pdf and your team should make the changes and resubmit following the process guidelines.
5. Allow 3 school days to get packages graded.
6. Will not be allowed to work in machine shop if you don't have **both GSI and machine shop signatures**
7. DO NOT use other machine shops to do work (i.e. Wilson center). **We will know and there are penalties.**

D: Waterjet and Lasercutter

1. Lasercutter beam is 0.008" in diameter. Will cut **on the toolpath! (left)**
2. Waterjet stream is 0.030" in ¼" aluminum. Will cut on **outside of toolpath! (right)**



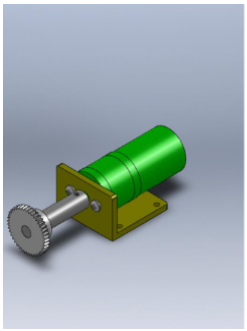


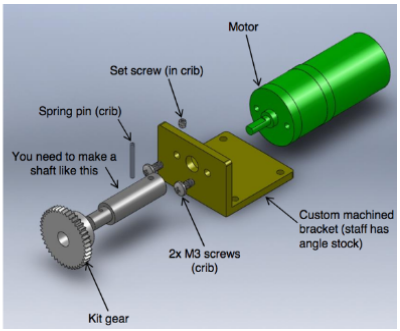
3. Lasercutter material is wood, delrin, acrylic. Check staff for others. **NO PVC OR METALS!!!**
4. Waterjet material is aluminum, steel, basically any plastic. Check with staff to make sure.
5. Lasercutter is first come first serve basis, you do the process. Instructions at lasercutter.
6. To prep waterjet file, see instructions on Canvas under project resources.
7. Waterjet run by shop staff. Each team gets **ONE 30-min slot per day**. Locked in at 8am each day.

E: Assembly of Components

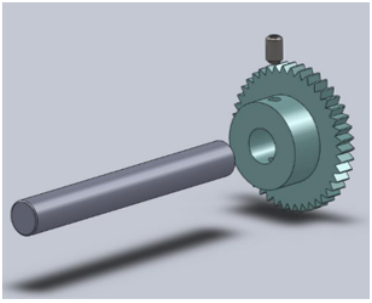
1. For attaching a BaneBots wheel, use ArborPress to press fit hex stock into wheel hole
2. For attaching polypropylene wheel:
   a. Measure OD of shaft, and OD of bushing, with micrometer
   b. Ream inside of bushing to 0.001 interference fit with shaft OD
   c. Ream inside of wheel hole to 0.001 interference fit with bushing OD
   d. Press fit bushing into wheel, and shaft into bushing, using the ArborPress

3. Use M3 screws to mount metal motor (two holes **on front face**)

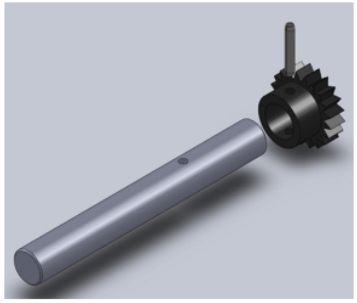




4. Using spring pin to attach axles or gears to motors (center image)
   a. Drill hole in end of axle to fit snugly over motor shaft
   b. Slide axle or gear onto shaft, and clamp in fixture provided by machine shop
   c. Clamp in vise on mill, and drill a 1/16" hole through both parts
   d. Use hammer to pound spring pin into hole, fastening axle/gear to motor shaft
5. Using set screw to attach axles or gears to motors (left image)
   a. Drill hole in end of axle to fit snugly over motor shaft
   b. Use an endmill to machine a flat surface onto motor shaft
   c. Drill and tap a hole for a #4-40 screw into the axle or gear hub
   d. Ensure flat portion of motor shaft is under the set screw hole, and tighten set screw
6. If gear hole is too big to fit over motor shaft OR there is not enough material to tap into on hub, machine a "sleeve" to account for this. (right image)



Set screw assembly



Spring pin assembly

Plastic spur gear with brass insert

7. Set screws **good** because disassemble, **bad** because they loosen very easily and don't constrain axial motion.
8. Spring pins **good** because will not come out and constrain all degrees of motion, but **bad** because cannot disassemble parts

F: General Professionalism and Best Practices

1. Bolts should NOT protrude **more than 1.5 times the bolt diameter**
2. Shafts that extend greater than **3x the diameter** MUST be double-supported
3. Do not stack washers as spacers
4. Do not leave any sharp edges
5. Use a drop of solder to attach wires and capacitor to motor terminals

6. Do not let leads of capacitor touch each other, OR motor terminal. **Will short circuit the motor!**
7. Provide strain relief to wires, to prevent wires from ripping off motor
8. Cover any bare wire with shrink tubing
9. To prevent nuts from falling off, use two nuts, locknuts, or locktite fluid

H: Tables and Charts

Imperial Tap Drill Chart

Machine Screw Size		Number of Threads Per Inch	Minor Dia.	Tap Drills				Clearance Hole Drills			
				Aluminum, Brass & Plastics 75% Thread		Stainless Steel, Steels & Iron 50% Thread		All Materials			
								Close Fit		Free Fit	
No. or Dia.	Major Dia.			Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.
0	.0600	80	.0447	3/64	.0469	55	.0520	52	.0635	50	.0700
1	.0730	64	.0538	53	.0595	1/16	.0625	48	.0760	46	.0810
		72	.0560	53	.0595	52	.0635				
2	.0860	56	.0641	50	.0700	49	.0730	43	.0890	41	.0960
		64	.0668	50	.0700	48	.0760				
3	.0990	48	.0734	47	.0785	44	.0860	37	.1040	35	.1100
		56	.0771	45	.0820	43	.0890				
4	.1120	40	.0813	43	.0890	41	.0960	32	.1160	30	.1285
		48	.0864	42	.0935	40	.0980				
5	.1250	40	.0943	38	.1015	7/64	.1094	30	.1285	29	.1360
		44	.0971	37	.1040	35	.1100				
6	.1380	32	.0997	36	.1065	32	.1160	27	.1440	25	.1495
		40	.1073	33	.1130	31	.1200				
8	.1640	32	.1257	29	.1360	27	.1440	18	.1695	16	.1770
		36	.1299	29	.1360	26	.1470				
10	.1900	24	.1389	25	.1495	20	.1610	9	.1960	7	.2010
		32	.1517	21	.1590	18	.1695				
12	.2160	24	.1649	16	.1770	12	.1890	2	.2210	1	.2280
		28	.1722	14	.1820	10	.1935				
		32	.1777	13	.1850	9	.1960				
1/4	.2500	20	.1887	7	.2010	7/32	.2188	F	.2570	H	.2660
		28	.2062	3	.2130	1	.2280				
		32	.2117	7/32	.2188	1	.2280				

Metric Tap Drill Chart						
Tap size	Major Dia (mm)	Threads per	Tap Drill (mm)	Tap Drill (inch)	Clearance (mm)	Clearance (inch)
M1.6x0.35	1.6	0.35	1.25	#55	1.8	#49
M2x0.4	2.0	0.40	1.60	#52	2.4	#41
M2.5x0.45	2.5	0.45	2.05	#46	2.9	#32
M3x.05	3.0	0.50	2.50	#39	3.4	#29
M3.5x0.6	3.5	0.60	2.90	#32	3.9	#23
M4x0.7	4.0	0.70	3.30	#30	4.5	#16
M5x0.8	5.0	0.80	4.20	#19	5.5	7/32
M6x1	6.0	1.00	5.0	#8	6.6	G
M8x1.25	8.0	1.25	6.8	H	9.0	T
M8x1	8.0	1.00	7.0	J	9.0	T

ALUMINUM 6061 SPEEDS:

Endmill/Drill Dia	Milling (RPM)	Drilling (RPM)	Turning (RPM)
0.125 (1/8")	1800 or less	1600 or less	2000 or less
0.188 (3/16”)	1600 or less	1400 or less	1800 or less
0.250 (1/4”)	1400 or less	1200 or less	1600 or less
0.313 (5/16”)	1200 or less	1000 or less	1400 or less
0.375 (3/8”)	1000 or less	800 or less	1200 or less
0.500 (1/2”)	800 or less	600 or less	1000 or less
0.625 (5/8”)	700 or less	400 or less	600 or less
0.750 (3/4”)	500 or less	350 or less	400 or less
0.875 (7/8”)	500 or less	350 or less	300 or less
1.000	400 or less	300 or less	300 or less

STEEL SPEEDS:

Endmill or Drill Dia.	Plain Carbon Steel (1027-1052)			Stainless Steel (302, 303, 304, 308, 316)		
	Milling	Drilling	Turning	Milling	Drilling	Turning
0.125 (1/8")	≤ 1300	≤ 1300	≤ 1800	≤ 1000	≤ 1000	≤ 1200
0.188 (3/16”)	≤ 1200	≤ 1100	≤ 1600	≤ 900	≤ 850	≤ 1000
0.250 (1/4”)	≤ 950	≤ 900	≤ 1400	≤ 850	≤ 750	≤ 1000
0.313 (5/16”)	≤ 900	≤ 700	≤ 900	≤ 800	≤ 600	≤ 750
0.375 (3/8”)	≤ 850	≤ 700	≤ 800	≤ 650	≤ 500	≤ 750
0.500 (1/2”)	≤ 700	≤ 500	≤ 600	≤ 450	≤ 400	≤ 500
0.625 (5/8”)	≤ 600	≤ 400	≤ 550	≤ 350	≤ 300	≤ 450
0.750 (3/4”)	≤ 500	≤ 350	≤ 400	≤ 350	≤ 300	≤ 350
0.875 (7/8”)	≤ 400	≤ 300	≤ 350	≤ 300	≤ 250	≤ 250

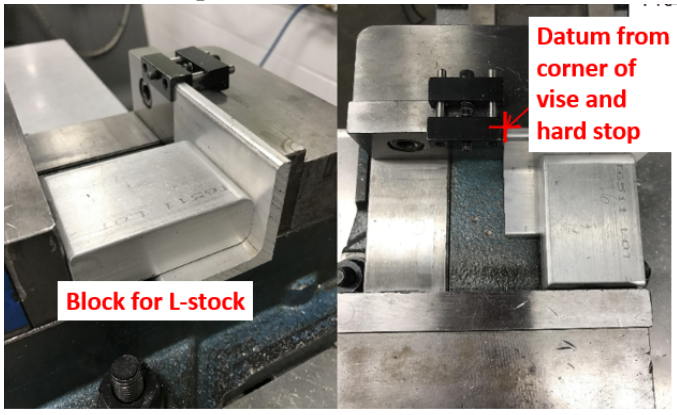
1.000	≤ 400	≤ 250	≤ 300	≤ 350	≤ 200	≤ 200

Fractional reamers available from Tool Crib:
1/16”, 5/64”, 3/32”, 7/64”, 1/8", 9/64”, 5/32”, 11/64”, 3/15”, 13/64”, 7/32”, 15/64”, 1/4", 17/64”, 9/32”, 19/64”, 5/16”, 21/64”, 11/32”, 23/64”, 3/8", 25/64”, 13/32”, 27/64”, 7/16”, 29/64”, 15/32”, 31/64”, 1/2", 9/16”, 19/32”, 5/8", 21/32”, 11/16”, 23/32”, 3/4", 25/32”, 13/16”, 27/32”, 7/8", 29/32”, 15/16”, 32/32, 1”

Off size reamers available from Machine Shop Staff:
.050’’, .0938’’, .1240’’, .1243’’, .1260’’, .1265’’, .1280’’, .1575’’, .1610’’, .1654’’, .1865’’, .1885’’, .1960’’, .1990’’, .2020’’, .2030’’,.2350’’,.2355’’,.2360’’,.2365’’,.2490’’,.2495’’.2503.2510’’, .2520’’, .2525’’, .2530’’, .2540’’, .3725’’, .3740’’, .3745’’, .3760’’, .3775’’, .3920’’, .3937’’, .3940’’, .4365’’, .4385’’, .4985’’, .4990’’, .4995’’, .5005’’, .5010’’, .6245’’, .6260’’, .7495’’, .8732’’, .8740’’, 8760’’, .9062’’,.9375’’, 1.005’’.

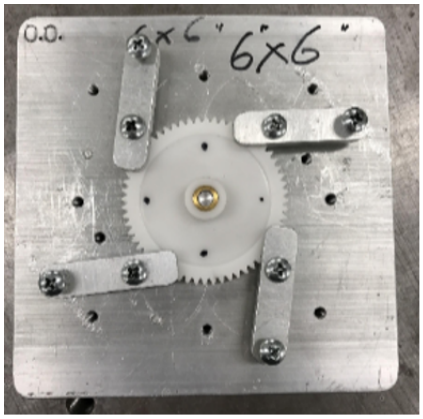
Two flute end mill sizes, available from Tool Crib:
1/8", 3/16”, 1/4", 5/16”, 3/8", 1/2", 5/8", 3/4", 7/8", 1”

I: Machine Shop Fixtures

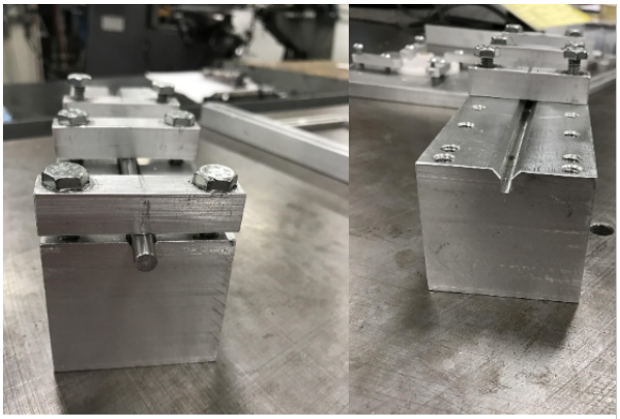


Block and Stop: always use this to grip L stock in vise, so it is not deformed! Don’t drill into it, move to the side when creating any holes in part

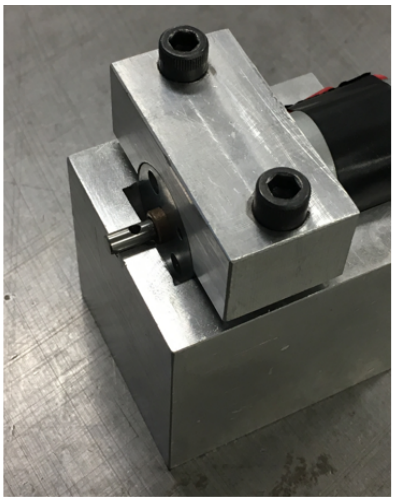
Punch: Use for hole locations on drill press, or approximating hole locations on mill



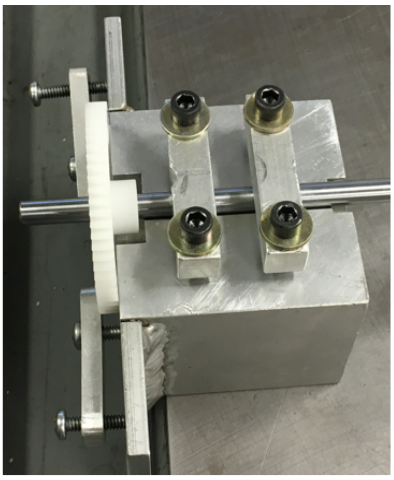
Gear Fixture: use to drill hole in face of gear. Datum off edges of fixture, and move 3” in X and Y for center.



Shaft Fixture: use to drill hole in the side of a shaft. Clamp in the mill, and datum off the sides of the fixture.



Motor fixture: use to clamp motor and drill hole in shaft, or face shaft. Can also have axle clamped, to drill spring pin hole



Gear and Axle Fixture: use to drill spring pin hole through a gear and axle at the same time