Light Sport Aircraft Belt Reduction Drive

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Light Sport Aircraft
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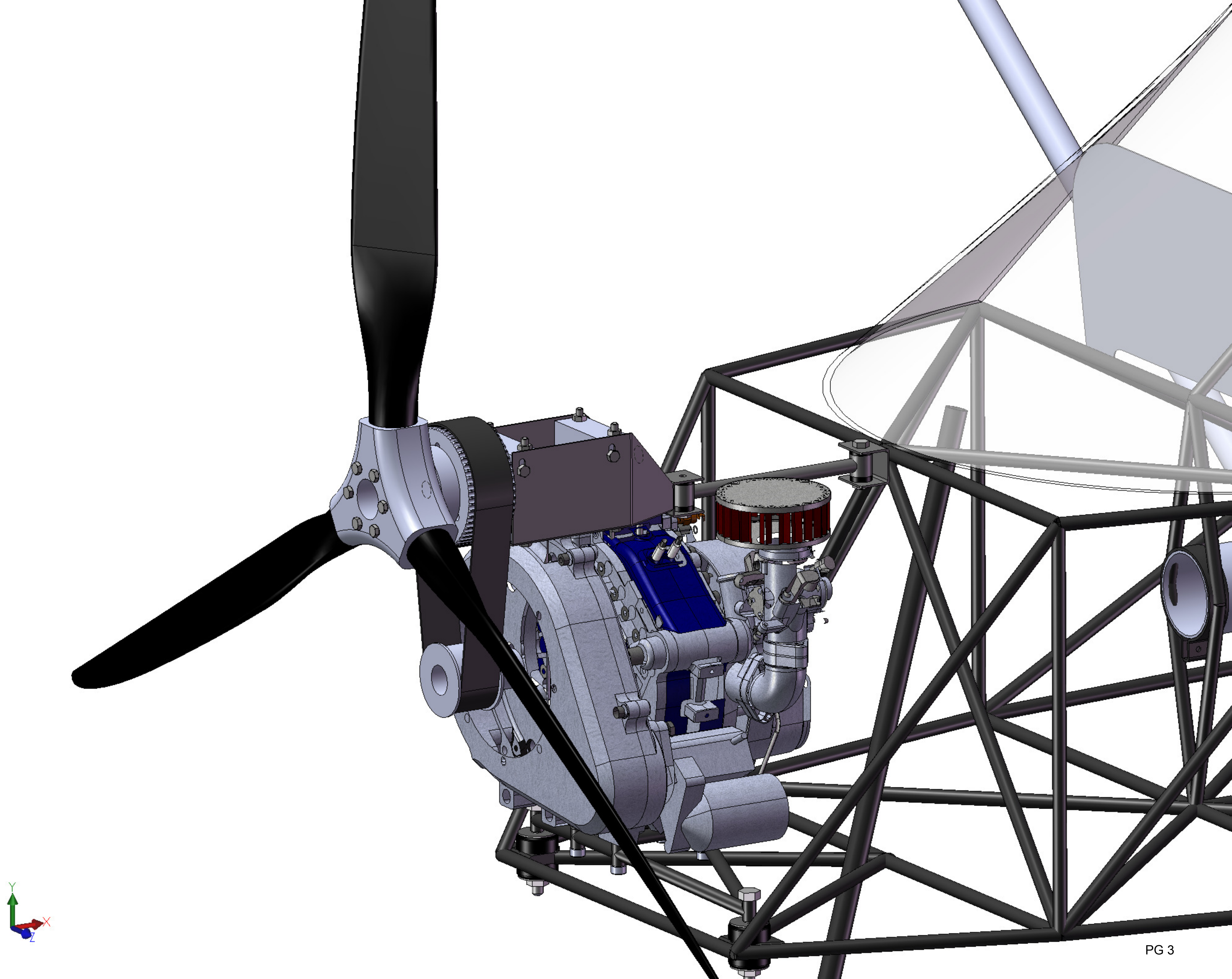
Project overview

The belt reduction drive (re-drive) project was proposed shortly after the conclusion of the LSA integration senior project, which mounted the Rotamax Generation II engine to the fuselage. At the end of this senior project, the group did several engine run tests. During these tests it was determined that the engine was producing excessive vibration. We suspected that the vibration was being caused by the gearbox which came installed on the Gen II engine. In the fall 2008 semester, we were able to take the gearbox apart and noticed that there was a rubber flexible coupling between the engine output shaft and the gearbox input. We suspected that the vibration was originating from a resonance caused by that coupling and created a new coupling made out of aluminum to test our theory. We did several engine run tests with the new coupling and found that the vibration was indeed reduced (and its frequency increased) but not to a level that we felt was acceptable. Having done several engine run tests on the Rotamax Gen I engine, which had a belt re-drive system, we decided to revisit the idea and create flight quality one for the Gen II engine. It seemed that the vibration that we experienced with the Gen I engine was always significantly less than what we experienced on the Gen I engine with the gearbox. The belt driven design also reduces the weight of the engine by quite a bit and eliminates the need for a separate gear oil system.

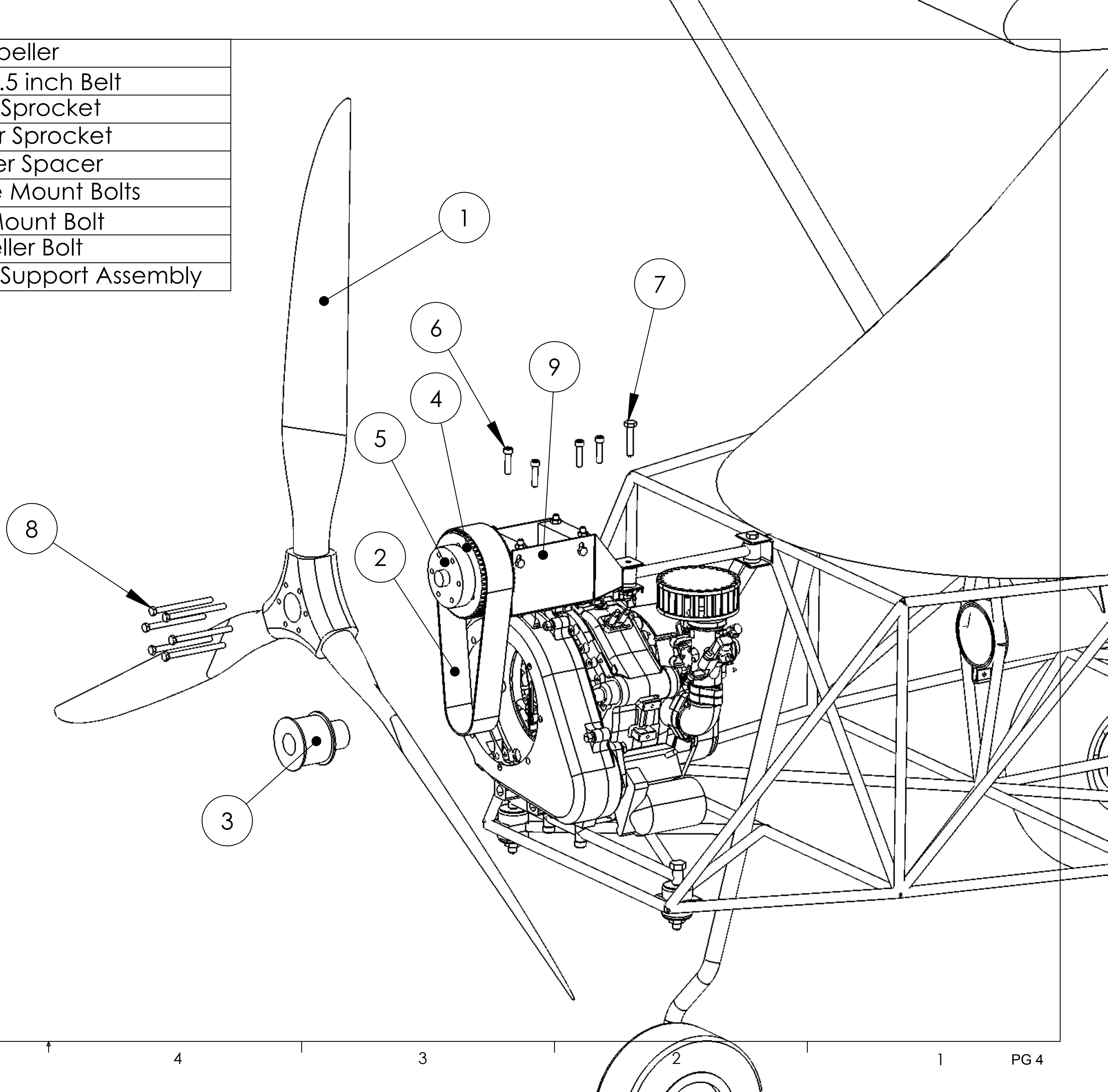
When we proposed the belt re-drive project, we set out several objectives for it. First, we wanted a system that could be able to handle interchangeable propeller sprockets (the large sprocket that attaches to the propeller) so that we could change the reduction ratio if required. Second, we wanted to be able to tension the belt easily without the use of an idler wheel. An finally, we wanted a minimum of 1000 hours between overhauls and a mean time between failure of no more than 2 years. In the subsequent sections I discuss and show all related documents for the re-drive design, analysis and component specifications.

Design

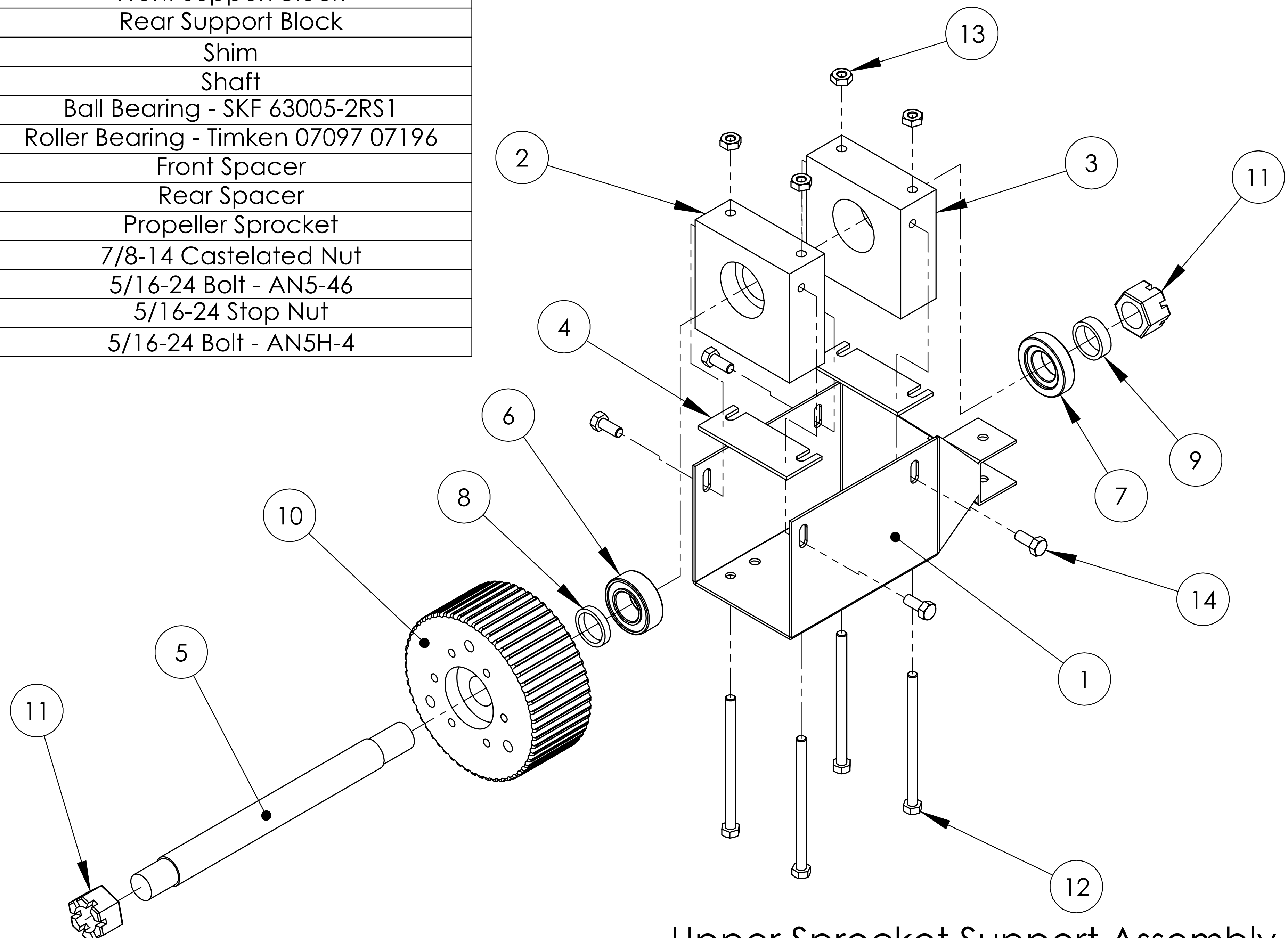
Our design for the reduction drive and all its components are covered in this section. The design consists of a belt, 2 sprockets and an upper sprocket support assembly. The upper sprocket support assembly consists of a shaft, which the propeller sprocket attaches to, and components that allow the shaft to rotate freely and support it, such as bearings, bearing support blocks etc. An explosion view of the upper sprocket support assembly is included in this section. The backbone of the upper sprocket support assembly is the base bracket. This bracket acts to support the shaft and doubles as a top engine mount. The bracket bolts to the top of the engine and the back of the bracket connects, with a single bolt, to the top engine mount link. This design creates a one piece system that transmits the thrust loads from the upper sprocket support assembly directly to the fuselage. To tension the belt, shims are placed under the front and rear support blocks to raise the entire shaft and therefore tighten the belt. The bearings used in the design are a ball bearing at the front of the shaft near the sprocket and a tapered roller bearing at the rear. The tapered roller bearing takes all of the thrust load as well as some radial loads where the ball bearing only takes radial loads. A tapered roller bearing can take large loads in both the axial and radial direction and was chosen for that reason to take the thrust loads produced by the propeller.


Y
X
Z

1	Propeller
2	Gates 31.5 inch Belt
3	Engine Sprocket
4	Propeller Sprocket
5	Propeller Spacer
6	Top Engine Mount Bolts
7	Thrust Mount Bolt
8	Propeller Bolt
9	Upper Sprocket Support Assembly

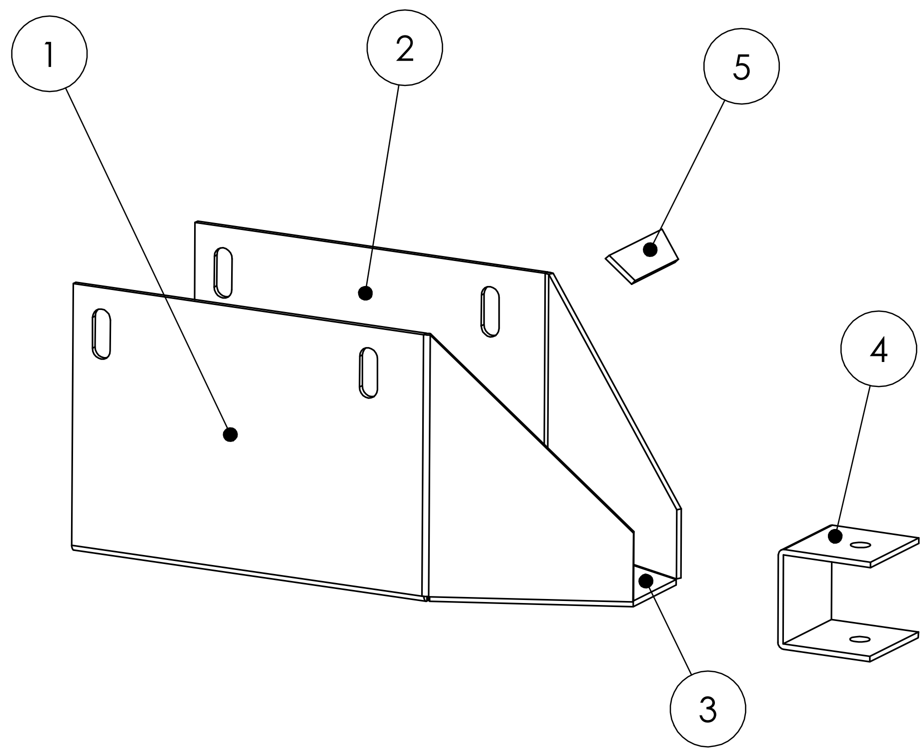


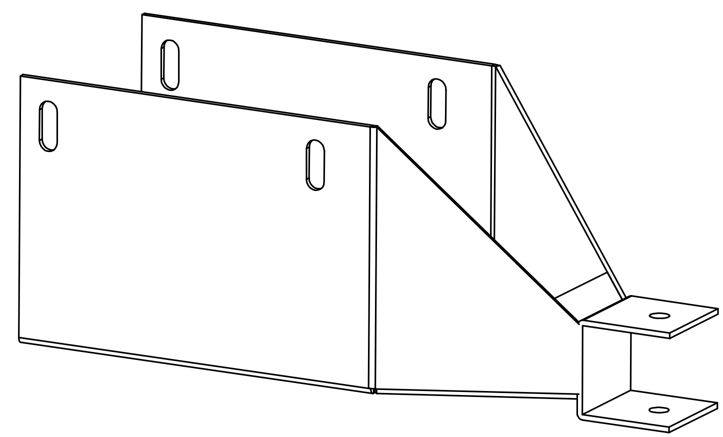
1	Base Bracket
2	Front Support Block
3	Rear Support Block
4	Shim
5	Shaft
6	Ball Bearing - SKF 63005-2RS1
7	Roller Bearing - Timken 07097 07196
8	Front Spacer
9	Rear Spacer
10	Propeller Sprocket
11	7/8-14 Castelated Nut
12	5/16-24 Bolt - AN5-46
13	5/16-24 Stop Nut
14	5/16-24 Bolt - AN5H-4



Upper Sprocket Support Assembly

1	Left Bracket Side
2	Right Bracket Side
3	Bottom
4	Thrust Mount C-bracket *
5	Upper Strengthener





* Part cut to size to interface with the thrust mount

All components are TIG welded together

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TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

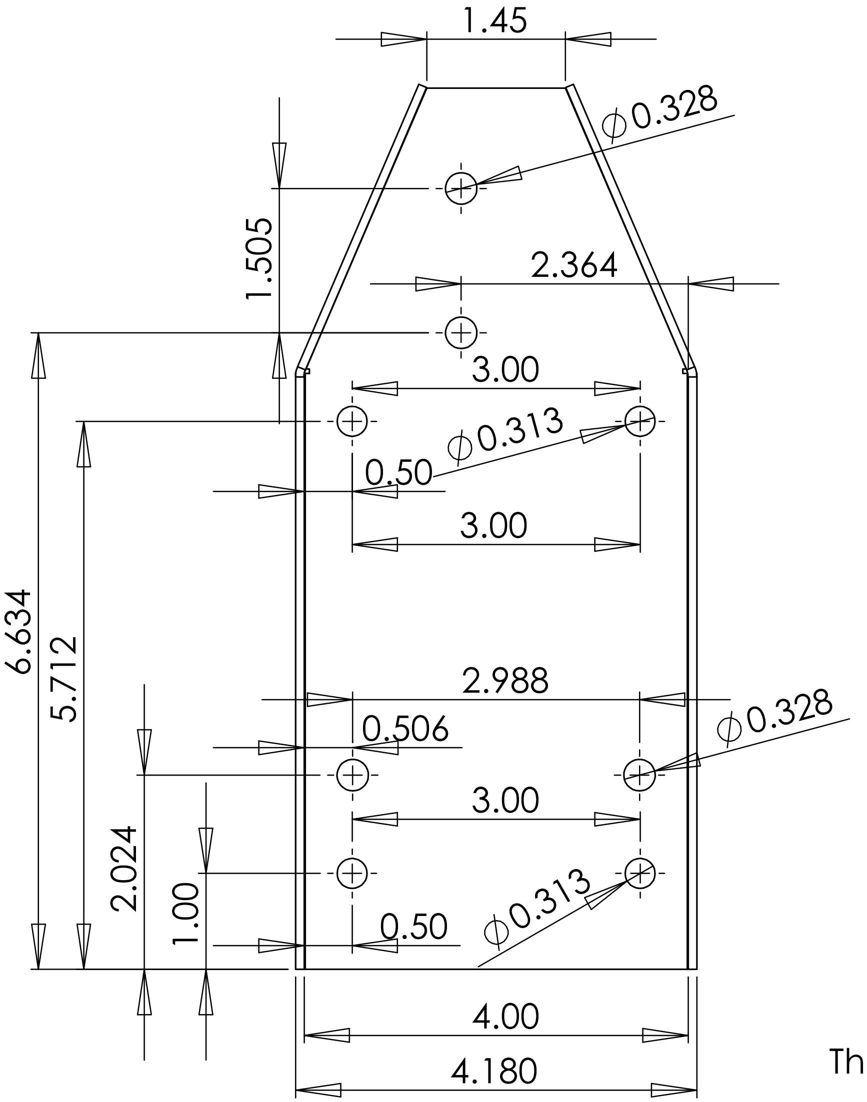
TITLE:

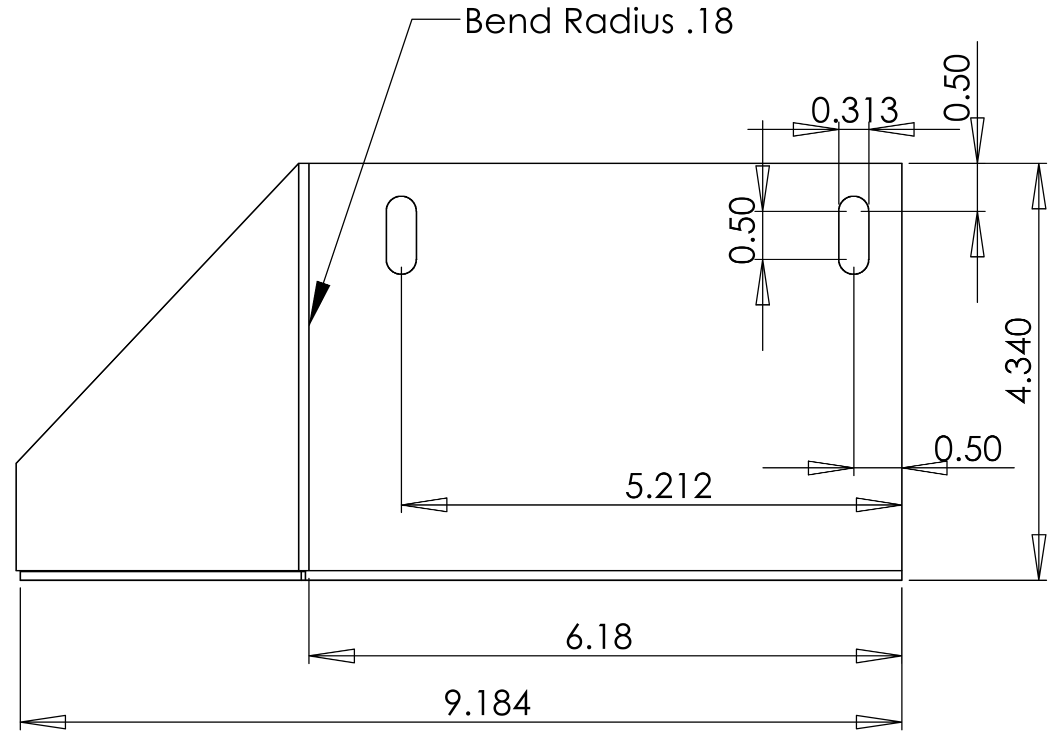
Base Bracket Parts

SIZE	DWG. NO.	REV
A		

SCALE: 1:3 WEIGHT: SHEET 1 OF 1

5 4 3 2 1





Sheet metal thickness is 0.09

Thrust Mount C-Bracket and Upper Strengthener left out for clarity

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL 4130 Steel	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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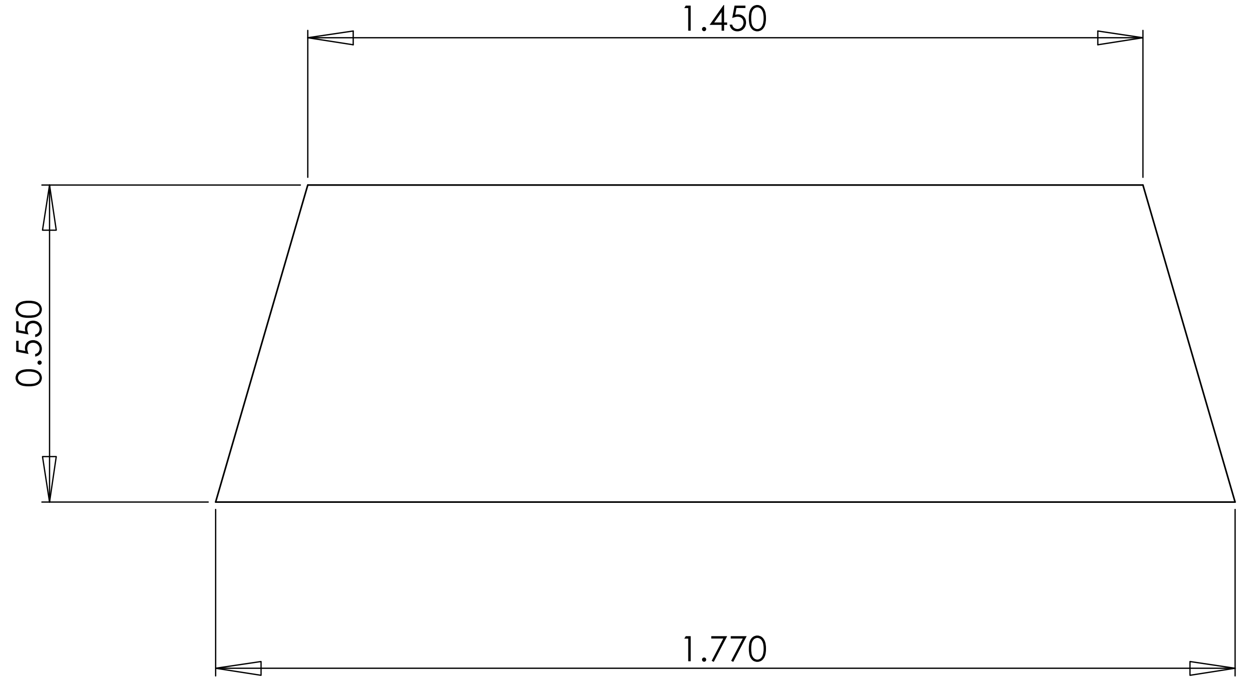
TITLE:

Support Bracket

SIZE	DWG. NO.		REV
A			
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1	

5 4 3 2 1



Sheet Metal Thickness is .09

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
	CHECKED			Upper Strengthener
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL 4130 Sheet Metal	COMMENTS:			SIZE A · DWG. NO. · REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 3:1 · WEIGHT: · SHEET 1 OF 1

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APPLICATION	

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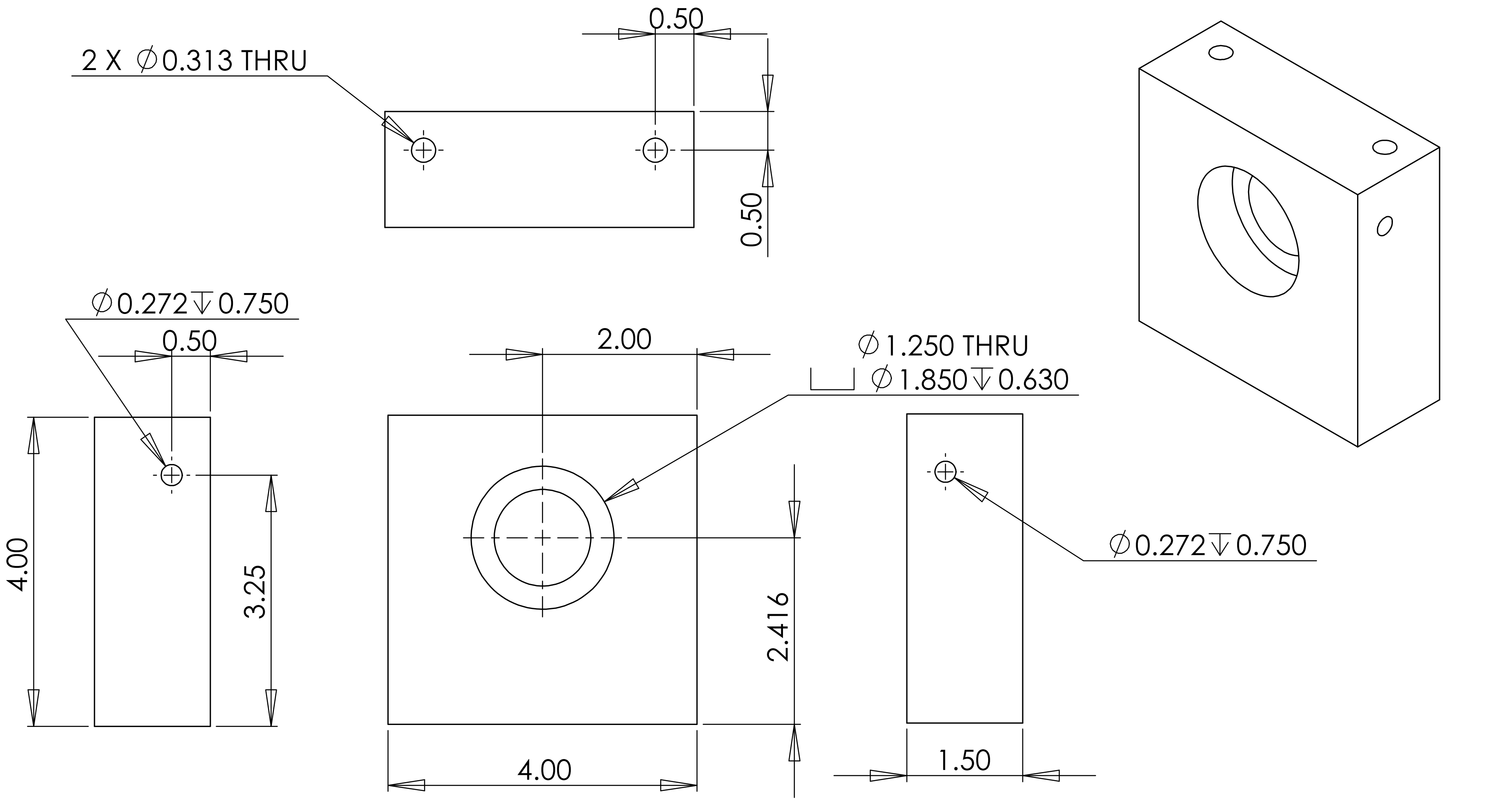
5 4 3 2 1



0.272 holes are tapped with 5/16-24 tap

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		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL 6061 Aluminum	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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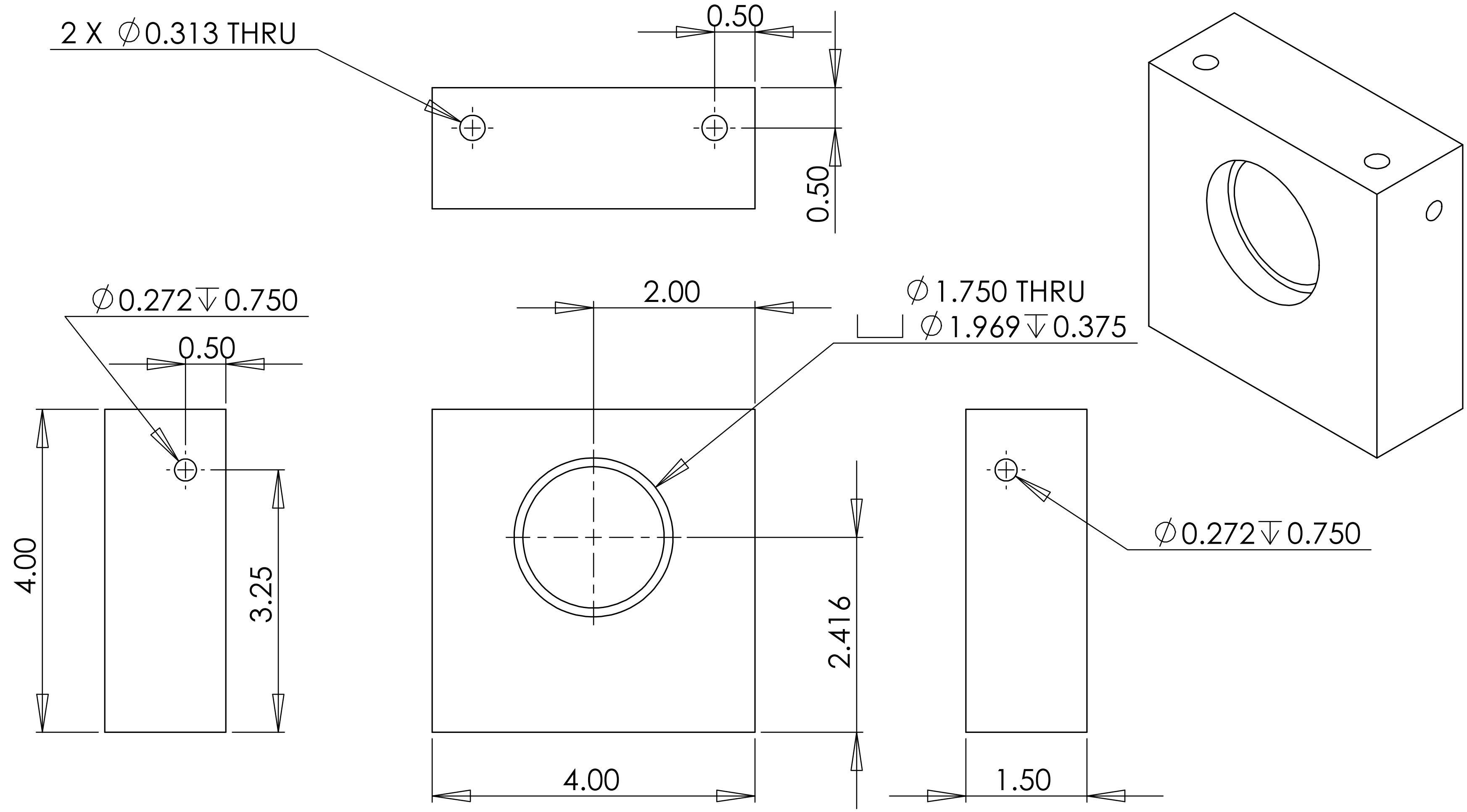
TITLE:

Front Support Block

SIZE	DWG. NO.	REV
A		

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1



∅0.272 holes are tapped with 5/16-24 tap

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APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
6061 Aluminum

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

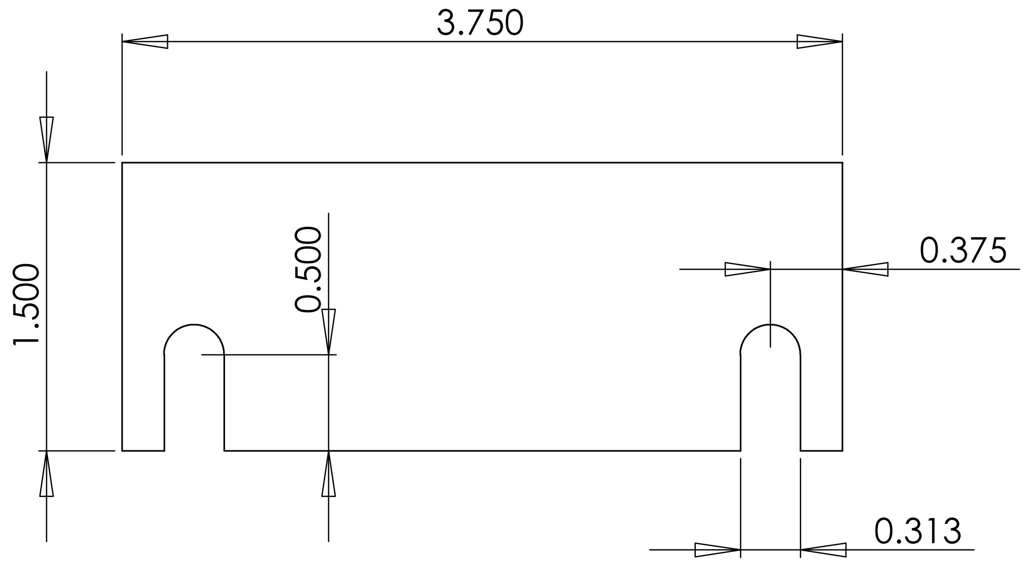
TITLE:

Rear Support Block

SIZE	DWG. NO.	REV
A		

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



Use desired sheet metal thickness for proper belt tensioning

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

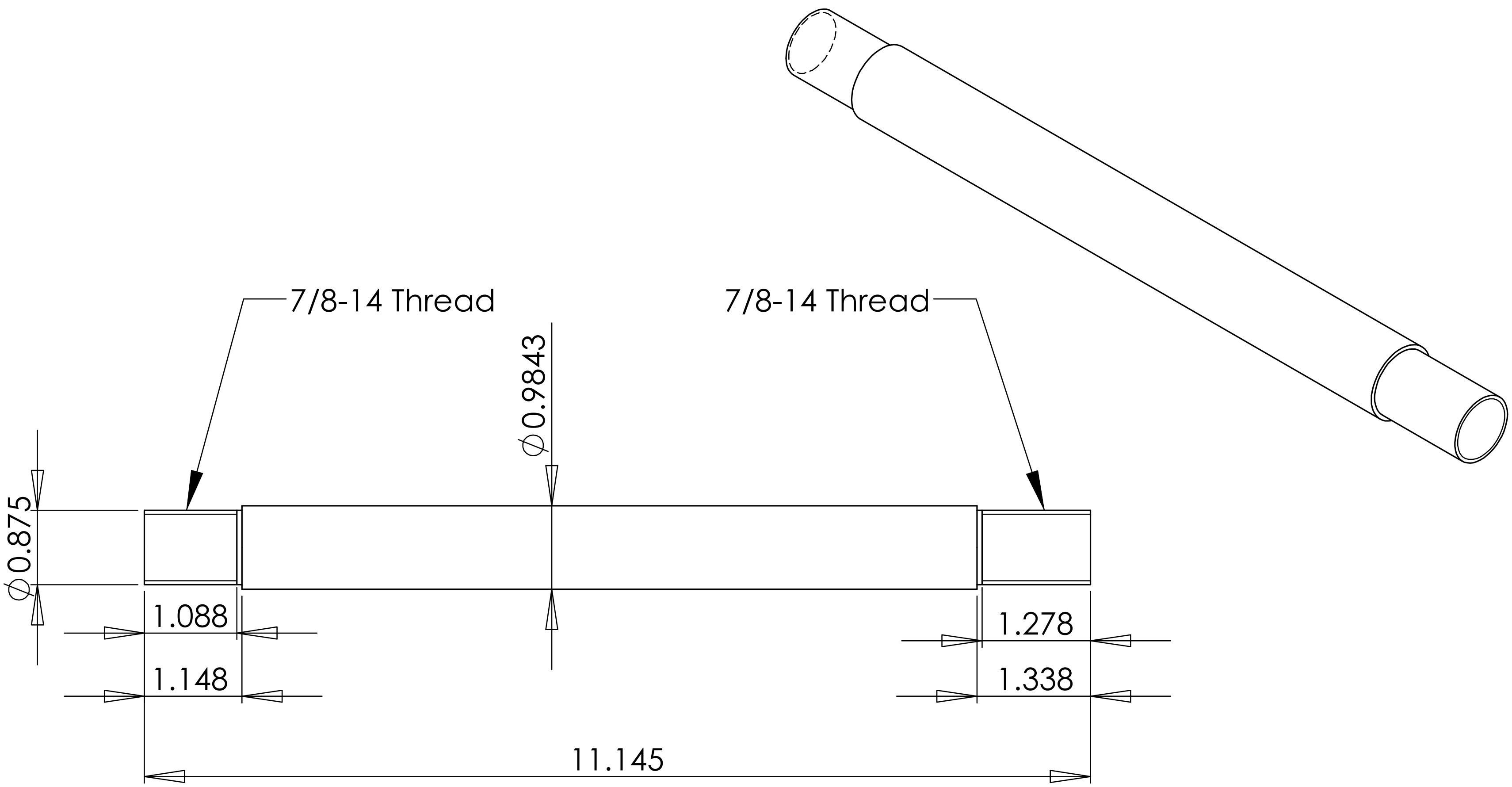
TITLE:

Shim Profile

SIZE **A** | DWG. NO. | REV

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Mild Steel

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

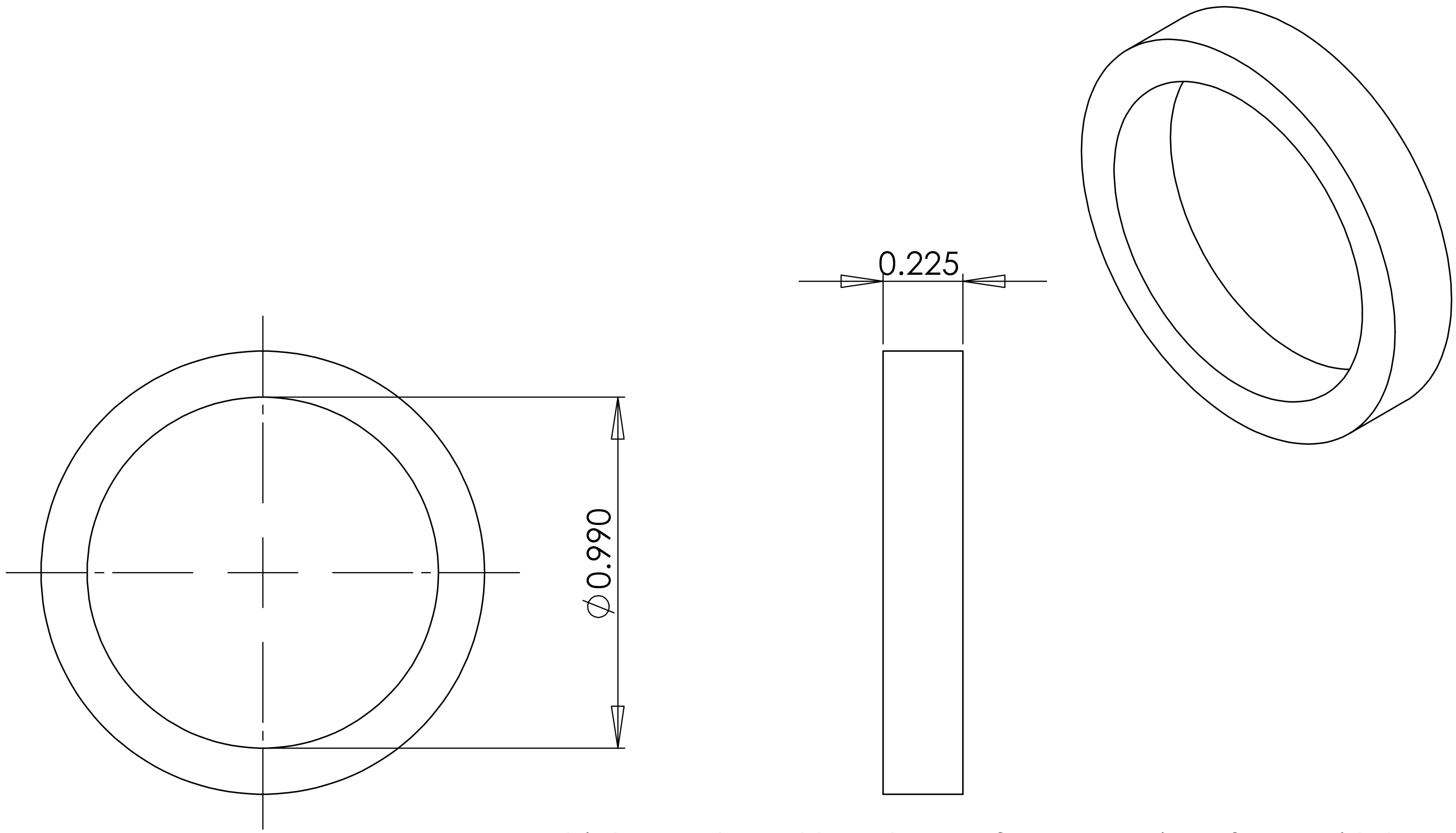
TITLE:

Shaft

SIZE A | DWG. NO. | REV

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

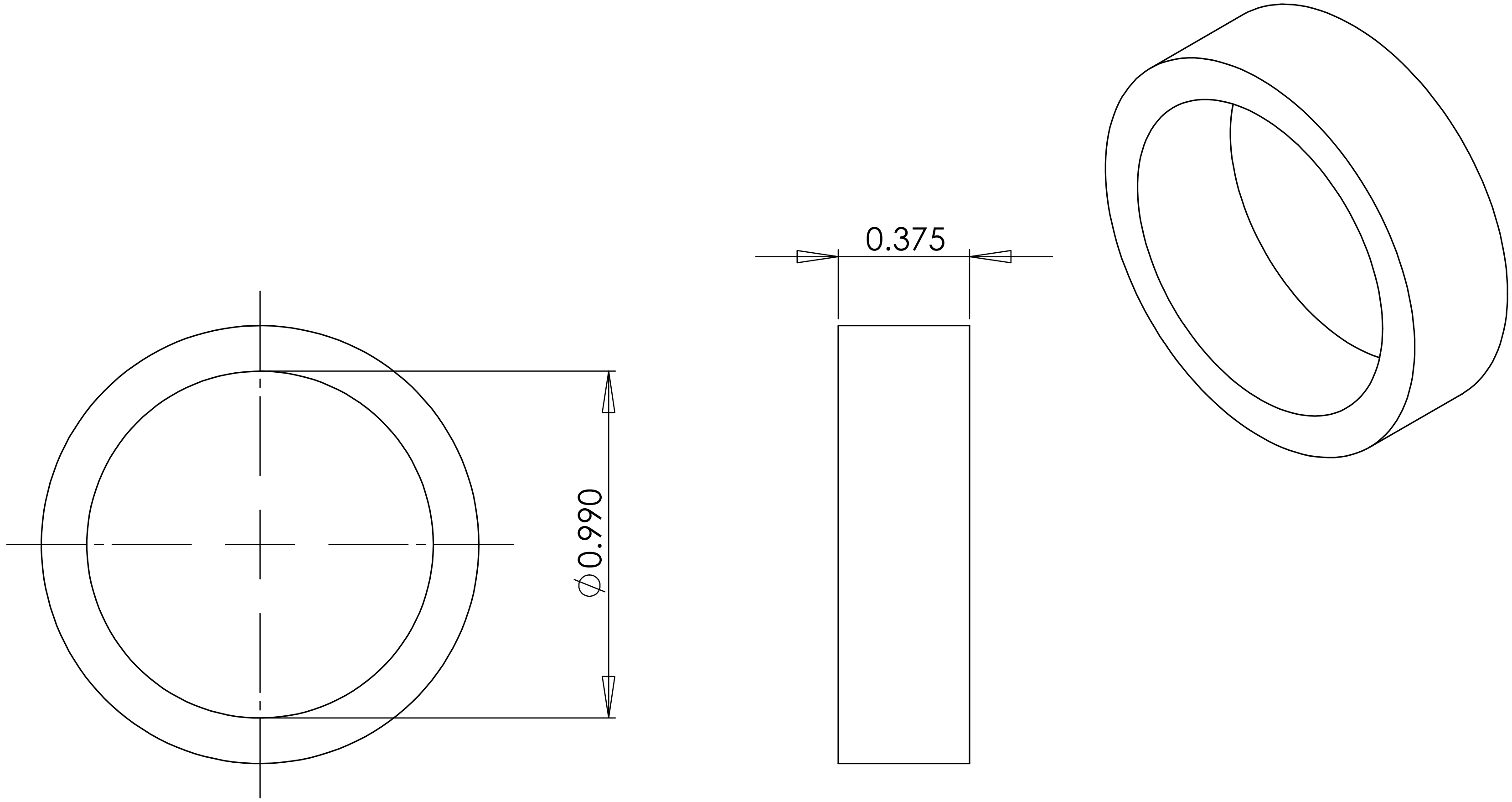
5 4 3 2 1



Thickness should be chosen for proper interface with bearing race
Inside diameter can vary slightly to accomodate available tubing

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE:
			ENG APPR.			Front Spacer
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS: Use available 4130 steel tubing			SIZE A | DWG. NO. | REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 2:1 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1



Thickness should be chosen for proper interface with bearing race
Inside diameter can vary slightly to accomodate available tubing

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
Use available 4130 steel tubing

TITLE:

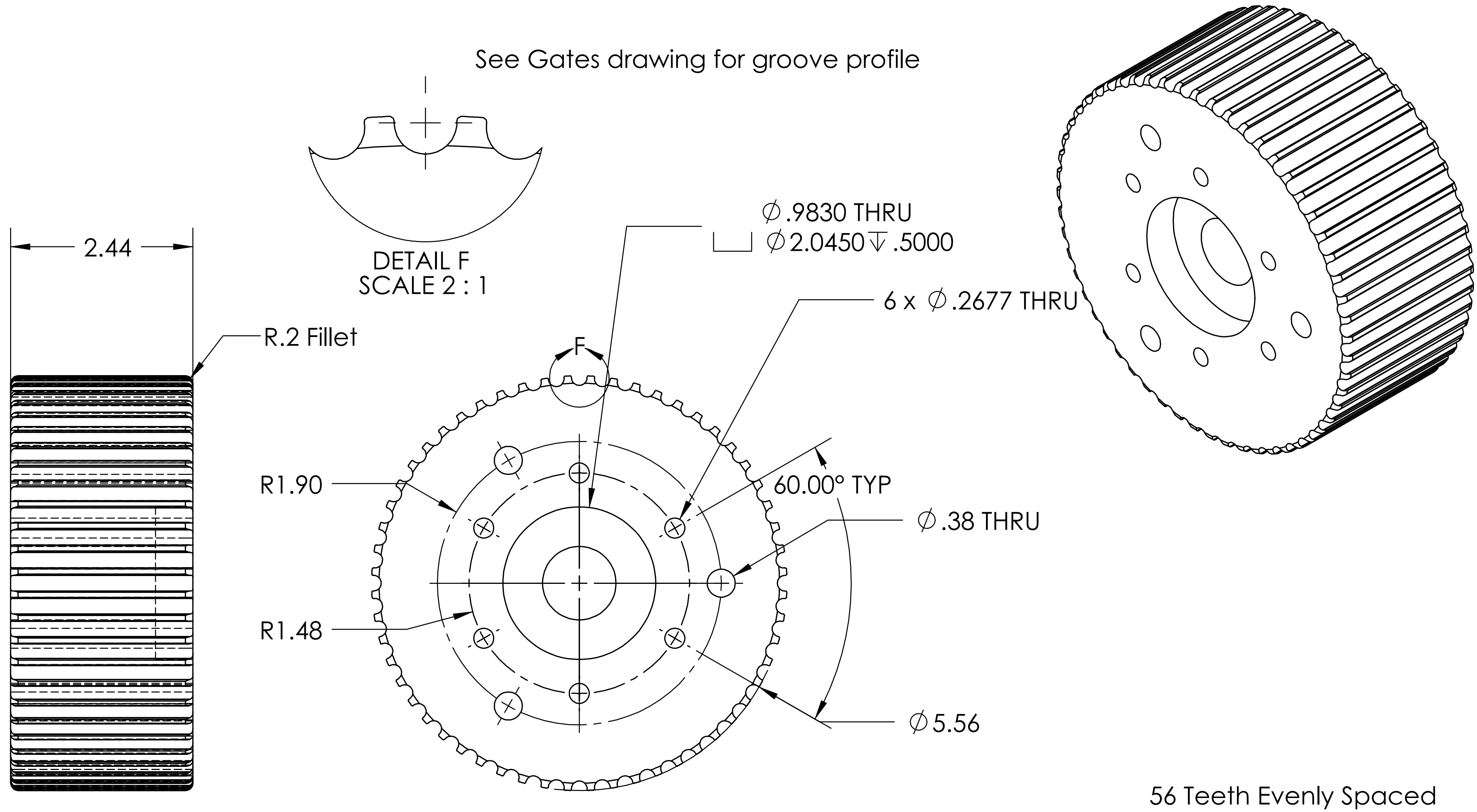
Rear Spacer

SIZE **A** | DWG. NO. | REV

SCALE: 2:1 | WEIGHT: | SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1



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			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL 6061 Aluminum	COMMENTS: Drawn By: Ben Horst Nate Cross Tim Bourgeois		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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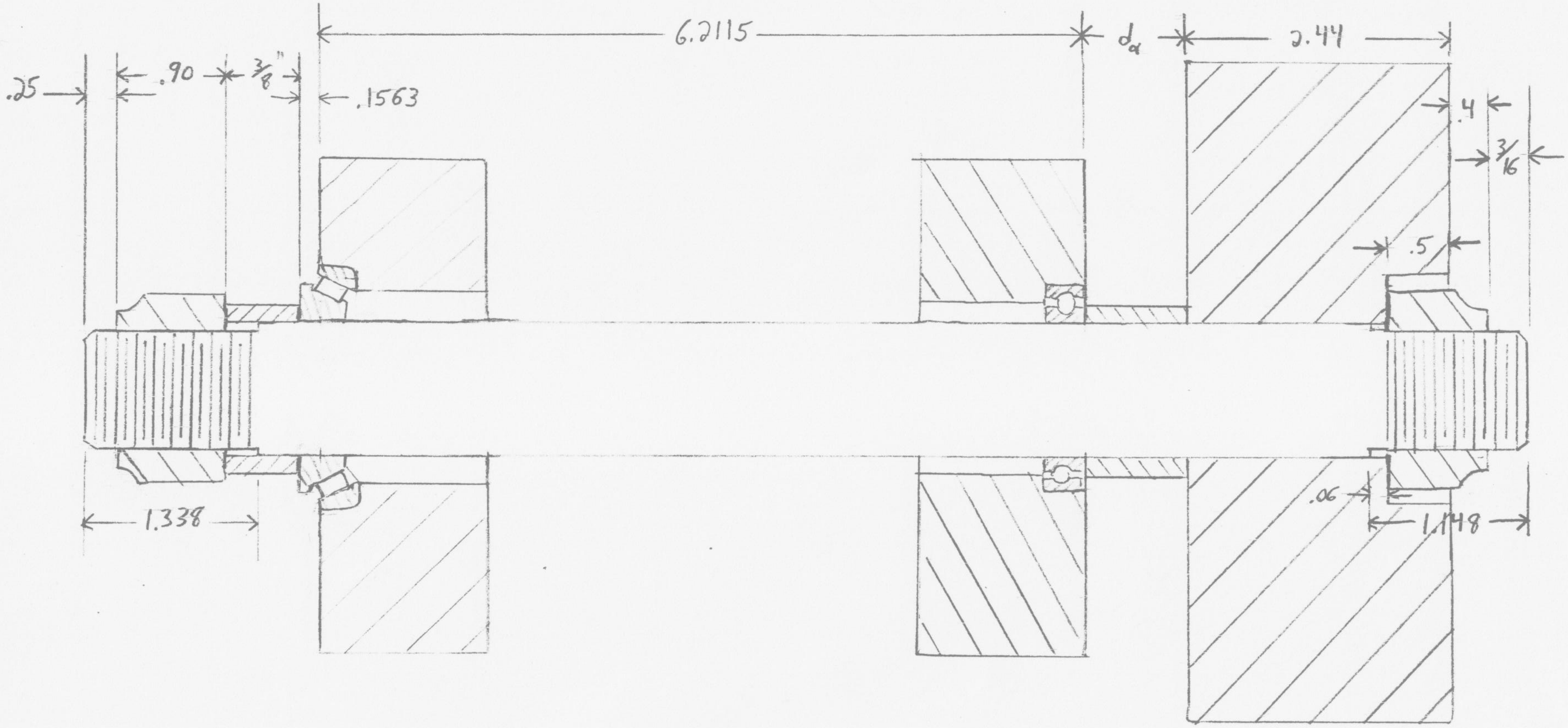
TITLE:

Propeller Sprocket

SIZE	DWG. NO.	REV
A		

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



d_α = Dist. Sprocket Center to Front Eng. Mnt. Hole Center − Dist. Hole Center to Support Block Front − Prop. Sprocket width/2

$d_\alpha = 3.469 - 2.024 - 2.44/2 = .225$ in

Total Shaft Length = 11.145 in

Specifications

All the specifications for the bearings, belt, and sprocket are covered in this section. The bearing specifications cover bearing dimensions, rated loads, maximum speeds and weights for both the ball bearing and the tapered roller bearing. The belt specifications cover the number of teeth, pitch length, weight and the price. The sprocket specifications cover all of the required dimensions to make the sprocket. As a note, we increased the width of our propeller sprocket to be able to work with a 50 mm wide belt. All these specification are located at the following web addresses:

http://www.skf.com/portal/skf/home/products?maincatalogue=1&lang=en&newlink=1_1_0

http://www.timken.com/en-us/products/Pages/Catalogs.aspx

http://www.gates.com/catalogs/index.cfm?requesting=ptcatalog&location_id=2999
Note: you must create a login account to see this catalogue

Ball bearing

Manufacturer	SKF
Part Number	63005-2RS1

Dimensions (inches)			Basic Load Ratings (lbf)			
Inside Diam.	Outside Diam.	Width	Dynamic	Static	Limiting Speed (RPM)	Mass (lbm)
0.9843	1.8504	0.6299	2520	1470	9500	0.0221

Tapered Roller Bearing

Manufacturer	Timken
Cup P/N	07097
Cone P/N	07196

Dimensions (inches)			Load Factors		Load Ratings (lbs)			
Inside Diam.	Outside Diam.	Width	e Factor	Y Factor	Dynamic C90	Dynamic C1	Static C0	Weight (lbf)
0.9843	1.9687	0.5313	0.4	1.49	1570	6060	6650	0.26

Note: The C1 load rating is the load that will yield an expected life of 1X10^6 revolutions
The C90 load rating is the load that will yield an expected life of 90X10^6 revolutions

Belt

Manufacturer	Gates
Part Number	800-8MGT-50

List Price	Nomber of Teeth	Pitch Length (inches)	Weight (lbf)
91.89	100	31.5	0.5

Propeller Sprocket

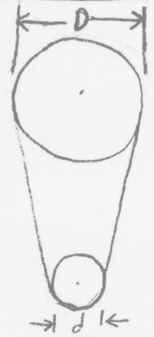
Number of Teeth	Outside Diam.
56	5.56

Analysis

All analysis calculations that we did on our project are covered in this section. The analysis that we completed for this project was a belt pull force calculation, moment of inertia and gyroscopic moment calculation, bearing support loads calculation, tapered roller bearing calculations, ball bearing calculations and base bracket finite element analysis. All of these calculations and their results are shown in this section.

Belt Pull Calculation

Known: a 2 Pully belt drive experiences a given drive power
Find: Force applied to large pully
Schematic and Given Data:



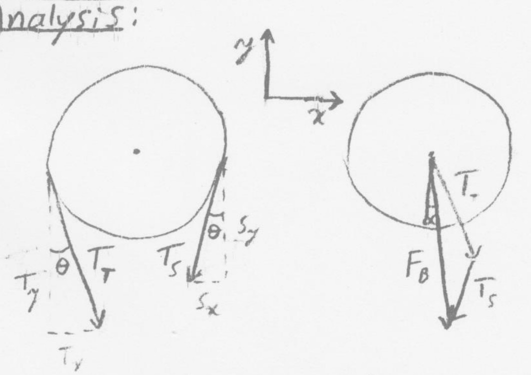
Max HP = 70 HP
D = 5.615 in
d = 2.945 in
PD = Pitch diam. = 31.5 in
RPM(engine) = 6000 RPM

From Gates design manual:

$$T_T = \frac{144{,}067(HP)}{(PD)(RPM)} \qquad T_S = \frac{18{,}008(HP)}{(PD)(RPM)}$$

where T_T = Tight side tension
T_S = slack side tension

Assumptions: Formulas for T_S and T_T apply
Estimate: $F_{Bx} = 10$ lb $\quad F_{By} = 70$ lb
Analysis:



$$T_T = \frac{144{,}067(70\,HP)}{(31.5\,in)(6000\,RPM)} = 53.36\ lbf$$

$$T_S = \frac{18{,}008\ (70\ HP)}{(31.5\,in)(6000\,RPM)} = 6.670\ lbf$$

From logbook we have: $\theta = \sin^{-1}\frac{r_1 - r_2}{d_{c2c}}$ and $d_{c2c} = 8.928$ in

$$\theta = \sin^{-1}\left(\frac{2.807 - 1.473\ in}{8.928\,in}\right) = 8.593°$$

$$T_y = T_T\cos\theta = 53.36\,lbf\cos(8.593°) = -52.76\ lbf$$

$$T_x = 53.36\ lbf\ \sin(8.593°) = 7.973\ lbf$$

$$S_y = 6.670\,lbf\ \cos(8.593°) = -6.595\ lbf$$

$$S_x = 6.670\,lbf\ \sin(8.593°) = -.9966\ lbf$$

$$F_{Bx} = 7.973\,lbf - .9966\,lbf = \boxed{6.976\,lbf} \qquad \|F_B\| = \sqrt{6.976^2 + 59.36^2} = 59.77\,lbf$$

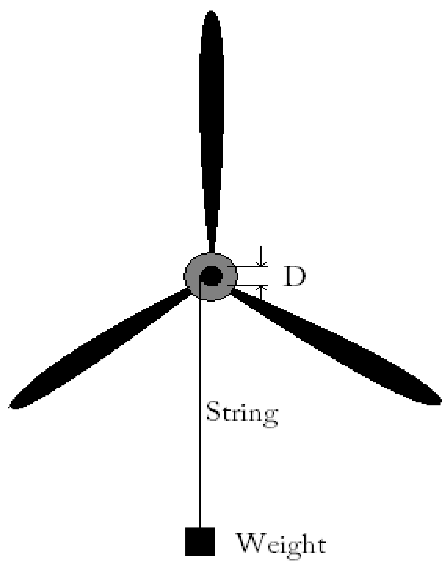
$$F_{By} = -52.76\,lbf - 6.595\,lbf = \boxed{59.36\ lbf} \qquad \alpha = \tan^{-1}\left(\frac{6.976}{59.36}\right) = 6.703°$$

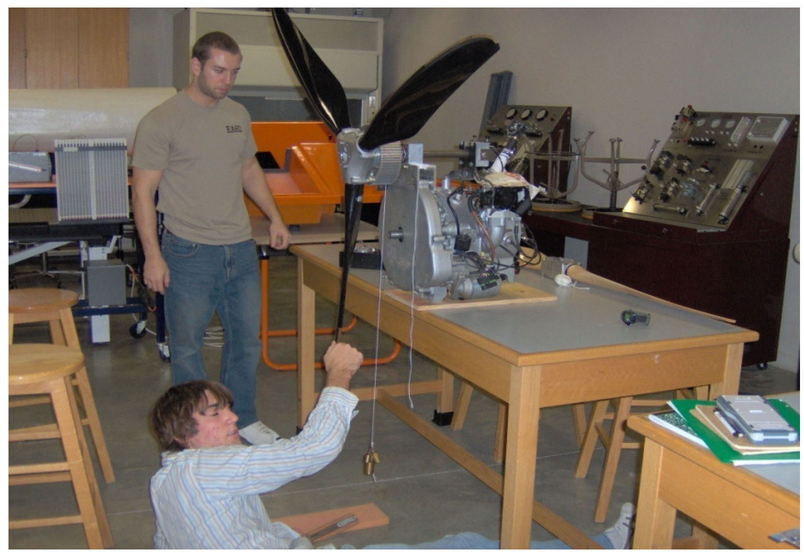
Assess: - answer vs. estimate ✓
Units - ok based on assumption
Reasonableness ✓
assumptions

Moment of Inertia Calculation

	inch	meters
radius	0.5	0.0127
Distance	12.875	0.327026

	1st set up			2nd set up			3rd set up		
Trial	1	2	3	1	2	3	1	2	3
Added Mass (kg)	0.65	0.65	0.65	1.15	1.15	1.15	0.35	0.35	0.35
Time (sec)	15.29	15.03	15.72	11.37	11.68	11.65	21.19	21.37	21.47
Moment of Inertia (kg*m^2)	0.367616	0.35522	0.388584	0.359654	0.379533	0.377586	0.380186	0.386673	0.3903
Average MOI	0.370473459			0.372257887			0.385719595		





The moment of inertia was measured by finding the time it took for a weight attached to a string ,which was wrapped around the shaft, to move down a certain distance. The weight supplied a constand torque to the shaft. We then used this time and the assumption that there was constant acceleration to calculate angular acceleration (α). With this, we were then able to calculate the moment of interia (I) using the formula: Torque = I*α

Gyroscopic Moment Calculation

Propeller RPM	2700
Rate of Turn (deg/sec)	45
Moment of Inertia (kg*m^2)	0.3903

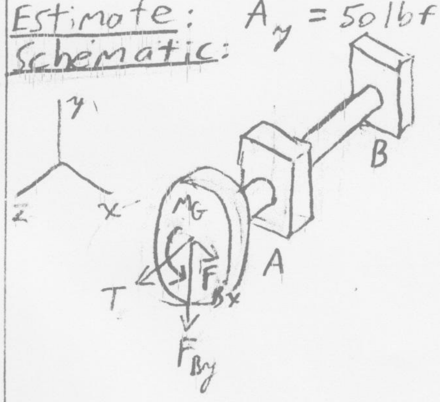
Propeller Ang. Speed (rad/sec)	282.7433
Processional Speed (rad/sec)	0.785398
Moment (N*m)	**86.6724**
Moment (ft*lbf)	**63.9258**

Source: \\collab-main\collabtransportation\LSA_Stuff\Redrive_work\Prop Gyro Calc.xls

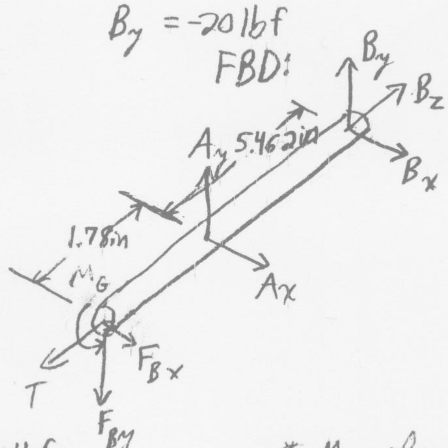
Bearing Support Loads Quick Turn

Find: Reaction loads at the front and rear bearings
Assumptions: Bearings do not take moments in any direction

Estimate: $A_y = 50\,lbf$ $B_y = -20\,lbf$
Schematic:



FBD:



$F_{Bx} = 6.976\,lbf$ $M_G = 63.93\,ft\cdot lbf$
$F_{By} = -59.36\,lbf$
$T = 400\,lbf$

* M_G shown for left turn. This will yield higher loads in bearings

Analysis: $M_G = 63.93\,ft\cdot lbf\left(\frac{12in}{1ft}\right) = 767.2\,in\cdot lbf$

$\Sigma M_{xB} = 767.2\,in\cdot lbf + 59.36\,lbf(1.78 + 5.462in) - A_y(5.462in) = 0$

$A_y = 219.2\,lbf$

$\Sigma F_y = -59.36\,lbf + 219.2\,lbf + B_y = 0$

$B_y = -159.8\,lbf$

$\Sigma M_{yB} = 6.976\,lbf(1.78 + 5.462\,in) + A_x(5.462in) = 0$

$A_x = -9.249\,lbf$

$\Sigma F_x = 6.976\,lbf - 9.249\,lbf + B_x = 0$

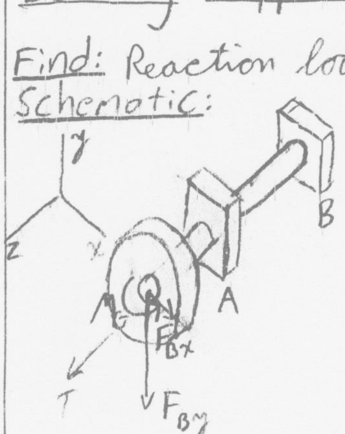
$B_x = 2.273\,lbf$

$T = B_z$ so $B_z = 400\,lbf$

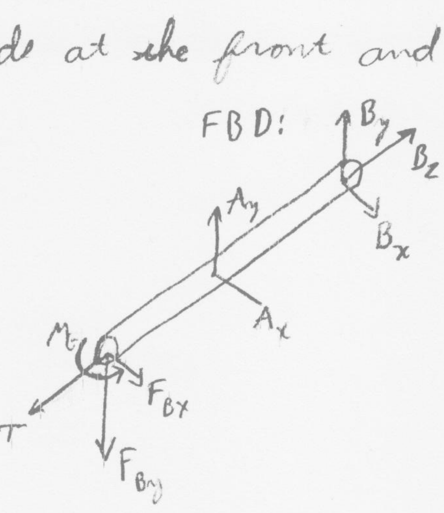
Assess: answers vs. estimates ✓
units ✓
Reasonableness ✓
assumptions

Bearing Support Loads Quick Climb

Find: Reaction loads at the front and rear bearings
Schematic:



FBD:



* M_G shown for pitch up. This will yield higher loads

see above for applied loads

Assumptions: Bearings do not take moments in any direction

Estimate: $A_x = -100\ lbf$ $B_x = 100\ lbf$

Analysis:

$\Sigma M_{x_B} = 59.36\ (1.78 + 5.462\ in) - A_y(5.462\ in) = 0$

$A_y = 78.70\ lbf$

$\Sigma F_y = -59.36\ lbf + 78.70\ lbf + B_y = 0$

$B_y = -19.34\ lbf$

$\Sigma M_{y_B} = 767.2\ in \cdot lbf + 6.976\ lbf\ (1.78 + 5.462\ in) + A_x(5.462\ in) = 0$

$A_x = -149.7\ lbf$

$\Sigma F_x = 6.976\ lbf - 149.7\ lbf + B_x = 0$

$B_x = 142.7\ lbf$

Assess: answers vs. estimate ✓

units ✓

Reasonableness ✓

assumptions

Find: The maximum radial and axial loads exerted on Bearings A and B

Estimate: $A_r = 100\ lbf$ $B_r = 100\ lbf$

Analysis: Quick Turn:

$A_r = \sqrt{A_x^2 + A_y^2} = \sqrt{9.249\ lbf^2 + 219.2\ lbf^2} = 219.4\ lbf = A_r\ max$

$B_r = \sqrt{2.273\ lbf^2 + 159.8\ lbf^2} = 159.8\ lbf = B_r\ max$

Quick climb

$A_r = \sqrt{149.7\ lbf^2 + 78.7\ lbf^2} = 169.1\ lbf$

$B_r = \sqrt{142.7\ lbf^2 + 19.34\ lbf^2} = 144.0\ lbf$

$B_a = 400\ lbf$ in both cases

Static:

$A_r = 78.70\ lbf$

$B_r = 19.34\ lbf$

Ball Bearing

Bearing Properties		
C0	1470	lbs
Fa/C0	0.068027	
X	0.56	
Y	2.3	
e	0.19	
D	47	mm
d	25	mm
Kr	0.025	
v	62.75	mm^2/s
C	2520	lbf

Bearing Loads			
	Dynamic	Static	
Radial (Fr)	219.4	78.7	lbf
Axial (Fa)	100	100	lbf
Fa/Fr	0.4557885		

Propeller Properties		
Max RPM	2500	RPM
Avg RPM	2200	RPM

Bearing Mfr.	SKF
Part Num.	63005-2RS1

Calculations		
P	352.864	lbf
P0	97.22	lbf
dm	36	mm
Fr min	94.24265	N
Fr min	21.1866	lbf
L10	364.2332	10^6 Revs.
L10 h	2759.343	Hours
Safety Fac.	7.141562	

Source: \\collab-main\collabtransportation\LSA_Stuff\Redrive_work\Re-drive Bearing Loads.xls

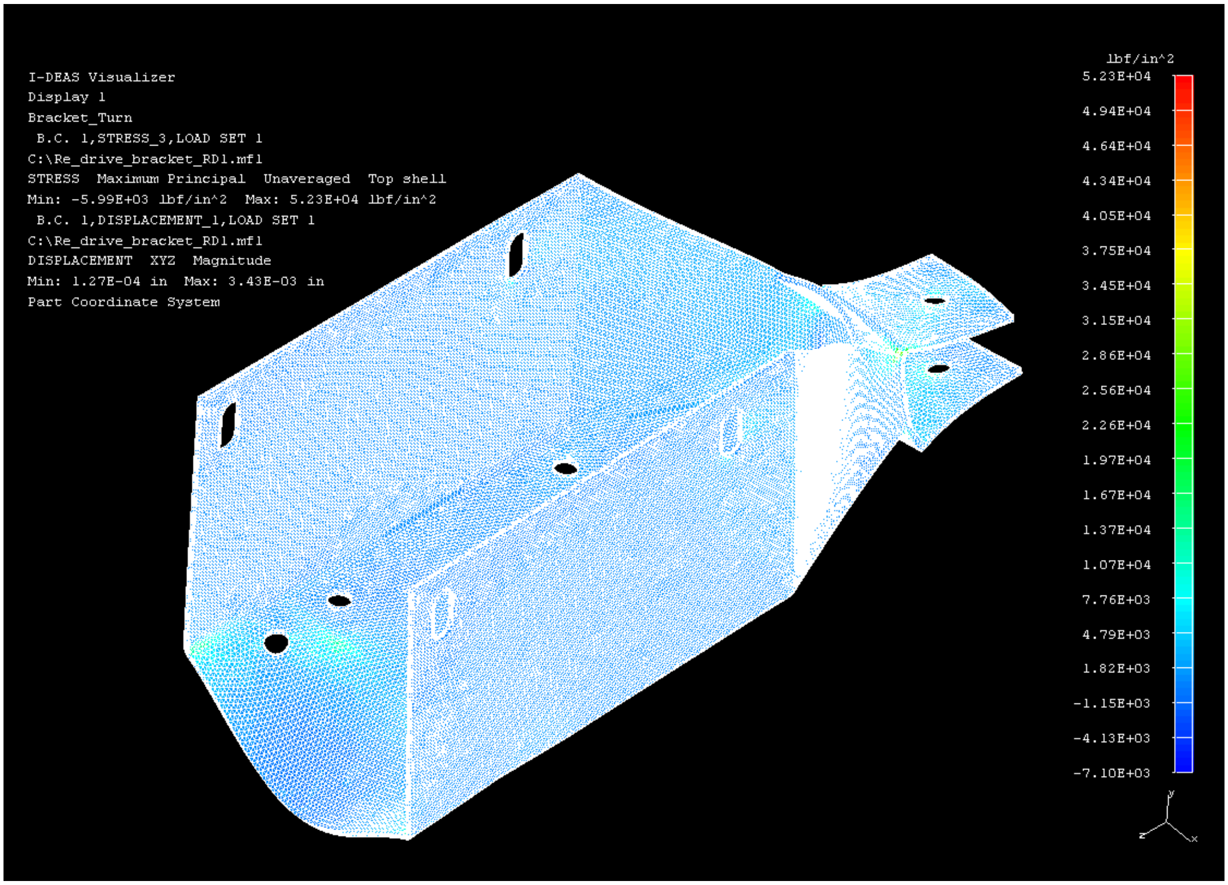
Tapered Roller Bearing

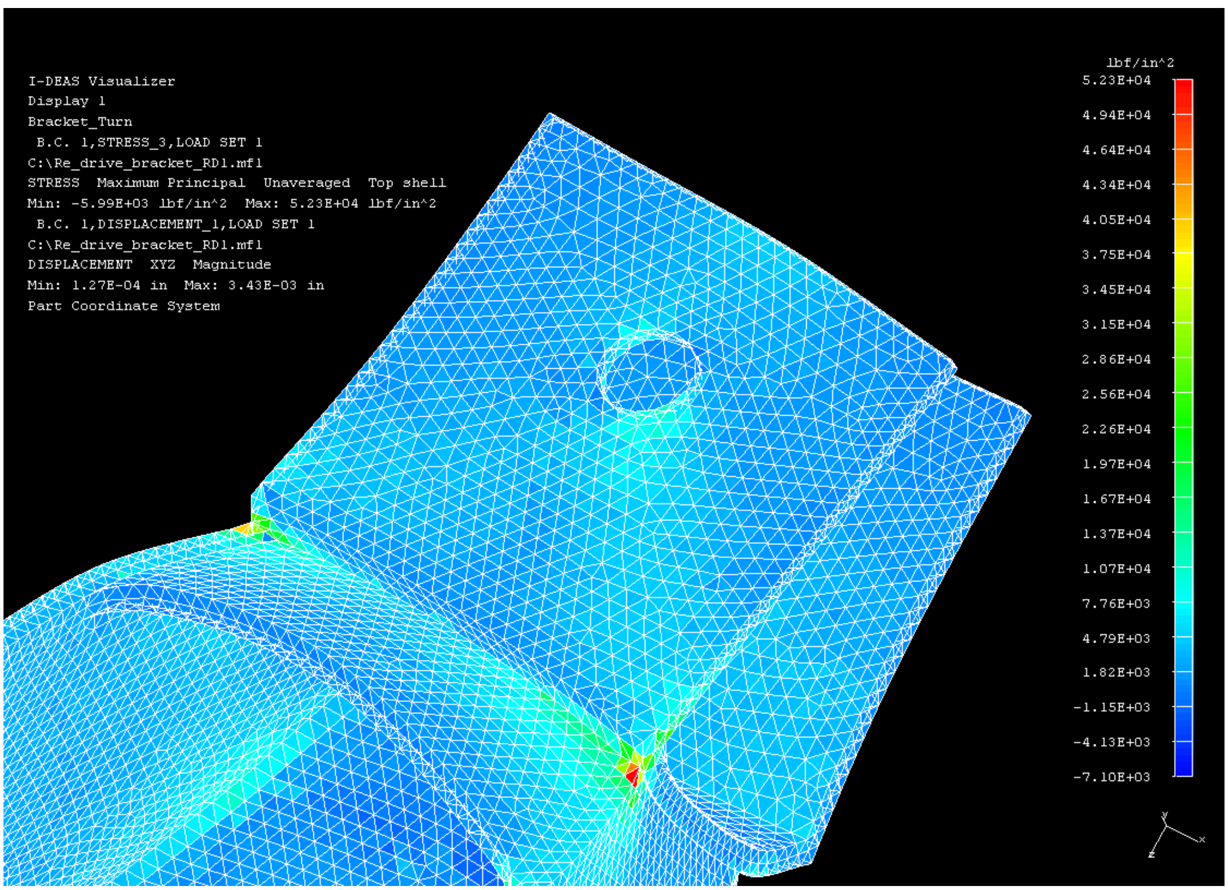
Bearing Properties			Bearing loads			Propeller Properties		
K	1.45		Radial	159.8	lbf	Avg. RPM	2200	RPM
C90	1570	lbf	Axial	400	lbf			

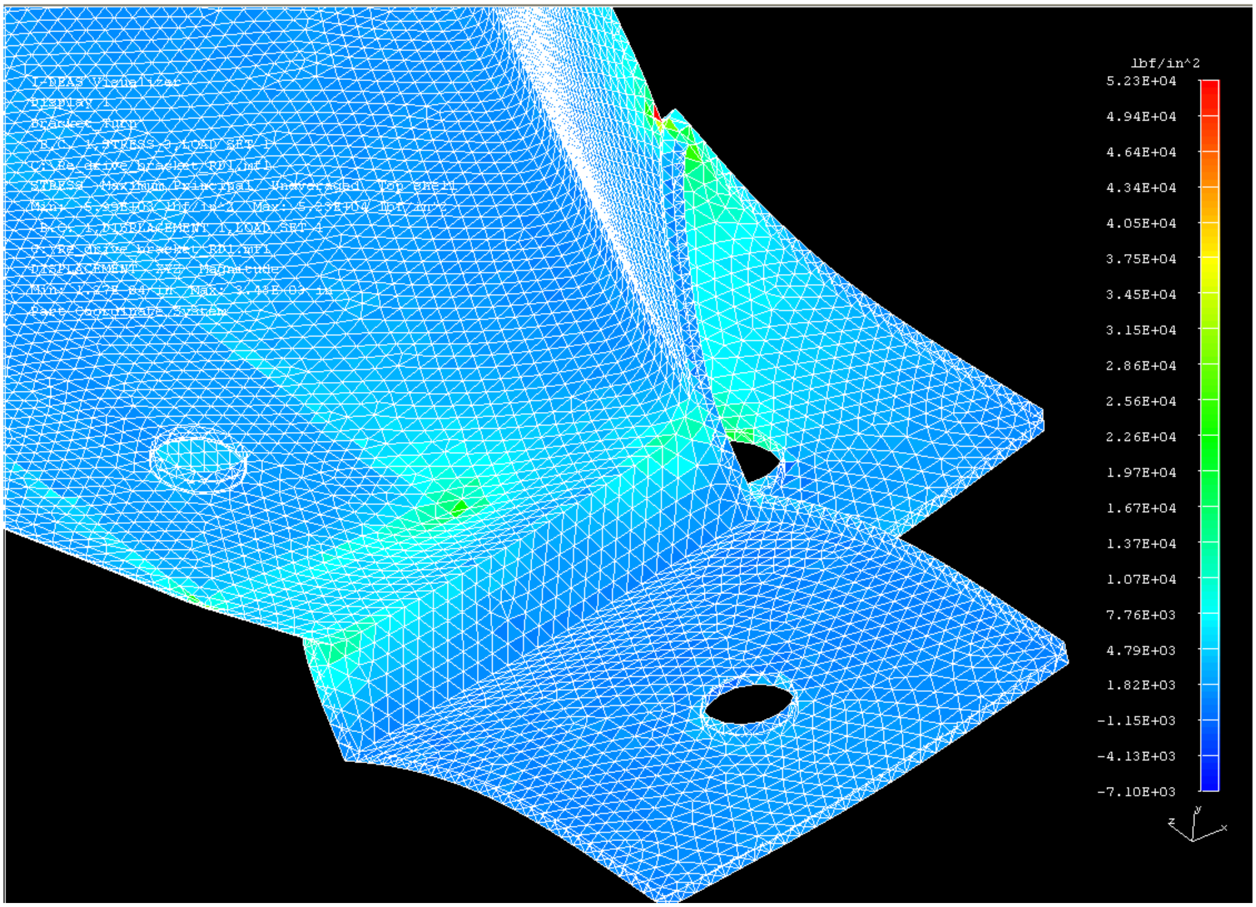
Calculations		
Induced thrust	51.79724	lbs
Pr	643.92	lbs
L10	19.50859	90E6 Revolutions
Life	13301.31	Hours
Safety Fac	2.438191	

Bearing Mfr.	Timken
Cup P/N	07196
Cone P/N	07097

Bracket Finite Element Analysis Overview



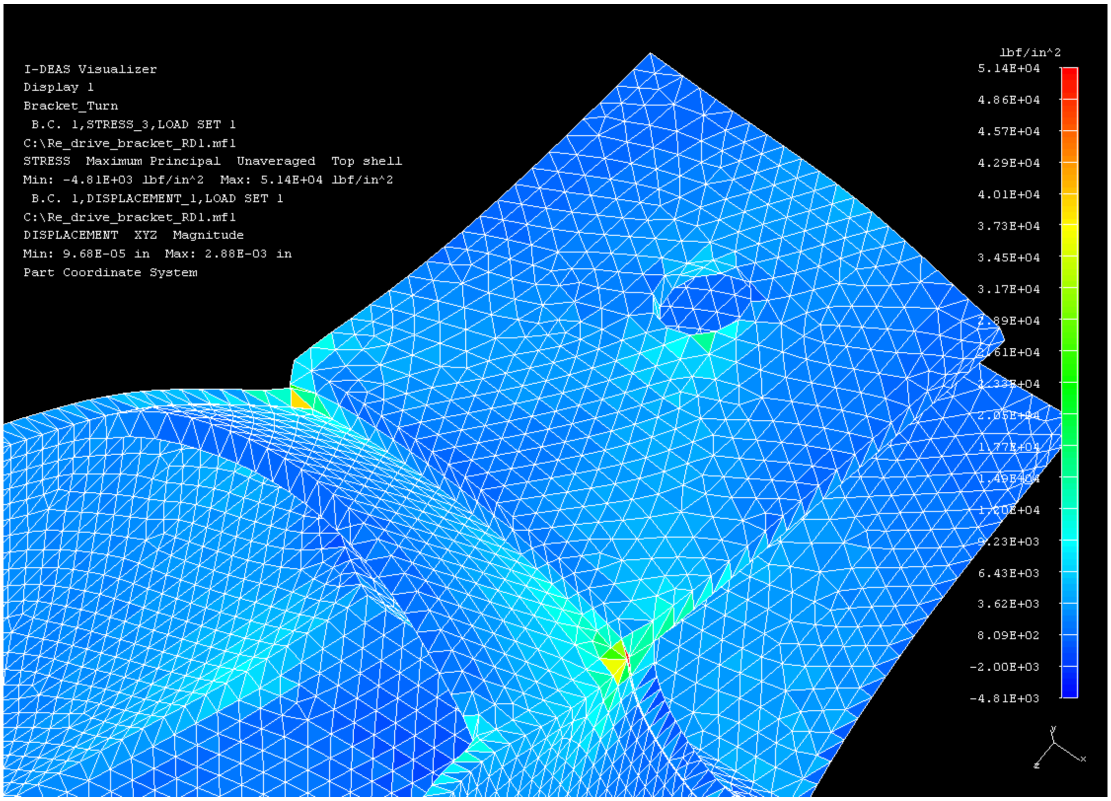




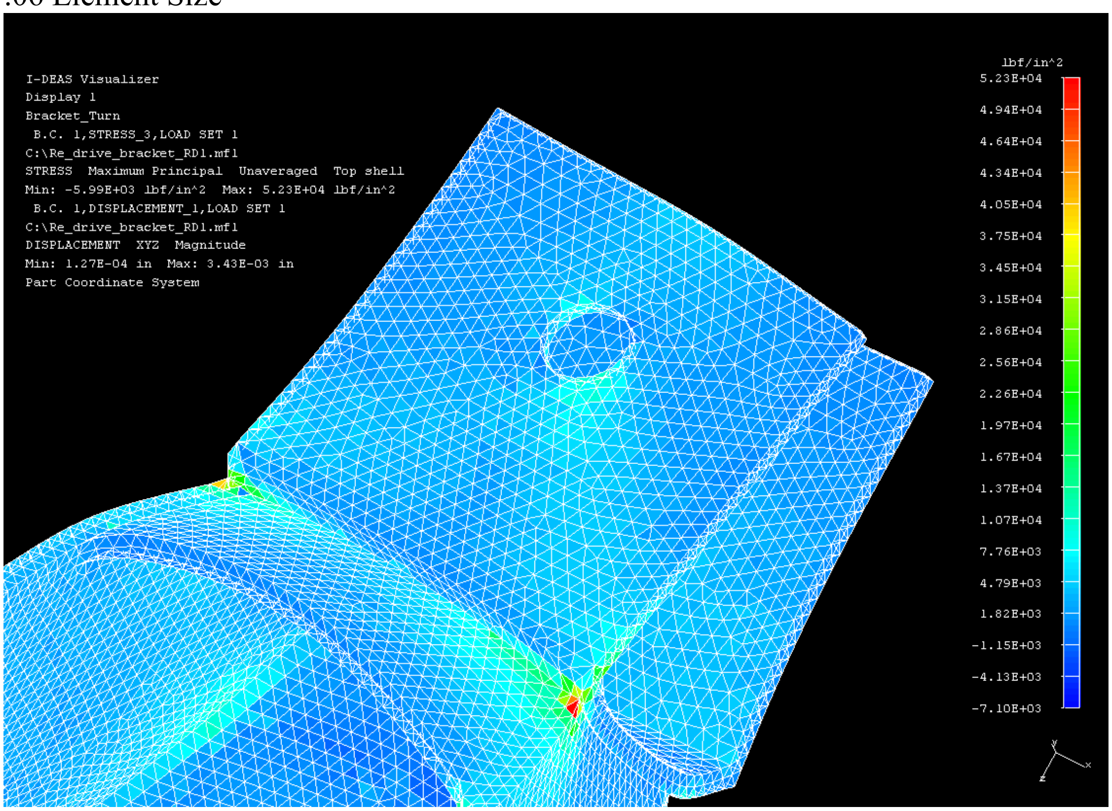
Source: [\\collabmain\collabtransportation\LSA_Stuff\Redrive_work\IDEAS\Bracket](\\collabmain\collabtransportation\LSA_Stuff\Redrive_work\IDEAS\Bracket) FEA Overview.doc

FEA Convergence Study

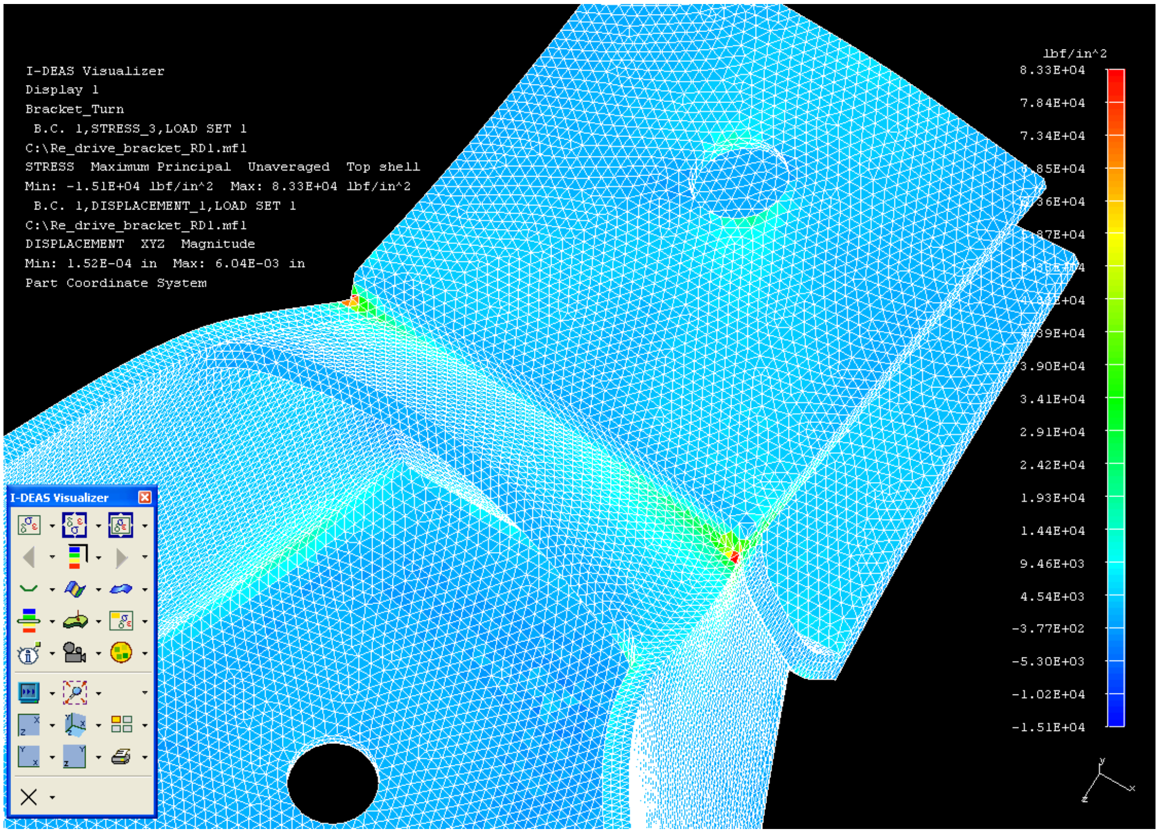
.08 Element Size



.06 Element Size



.04 Element Size



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IDEAS files also located in that directory

Belt Reduction Drive Budget

Item	**Cost**
Gates Power Grip GT-2 Belt	$ 77.37
Timken Tapered Roller Bearing Cone	$ 23.48
Timken Tapered Roller Bearing Cup	$ 8.65
SKF Sealed Ball Bearing	$ 45.95
2 Castellated Nuts	$ 12.62
Aluminum Stock	$ 76.23
4130 Steel Sheet Metal	$ 29.72
Hardware	$ 19.48
1018 Steel Rod	$ 28.00
Total	$ 321.50

Required Future Work

- Finish construction of reduction drive components (shaft, front and rear spacer and propeller sprocket)
- Remove excess material from support blocks and propeller sprocket to save weight
- Complete extensive engine run tests
- Disassemble re-drive and do a complete diagnostic to look for wear, fatigue cracks etc.

Manufacturing Photographs

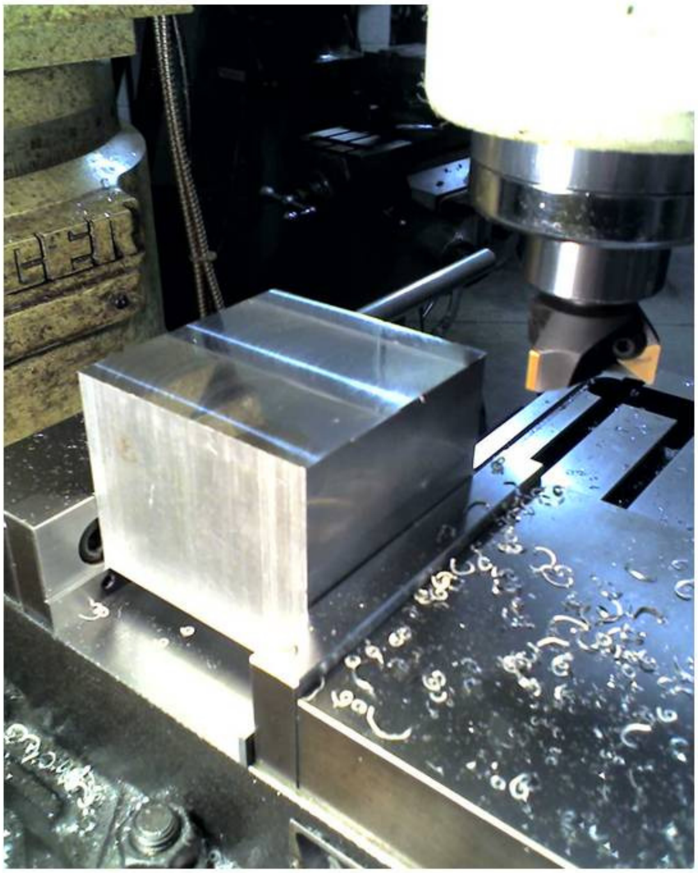

Figure 1 - Face milling the large block

Figure 2 - Face milling a support blocks

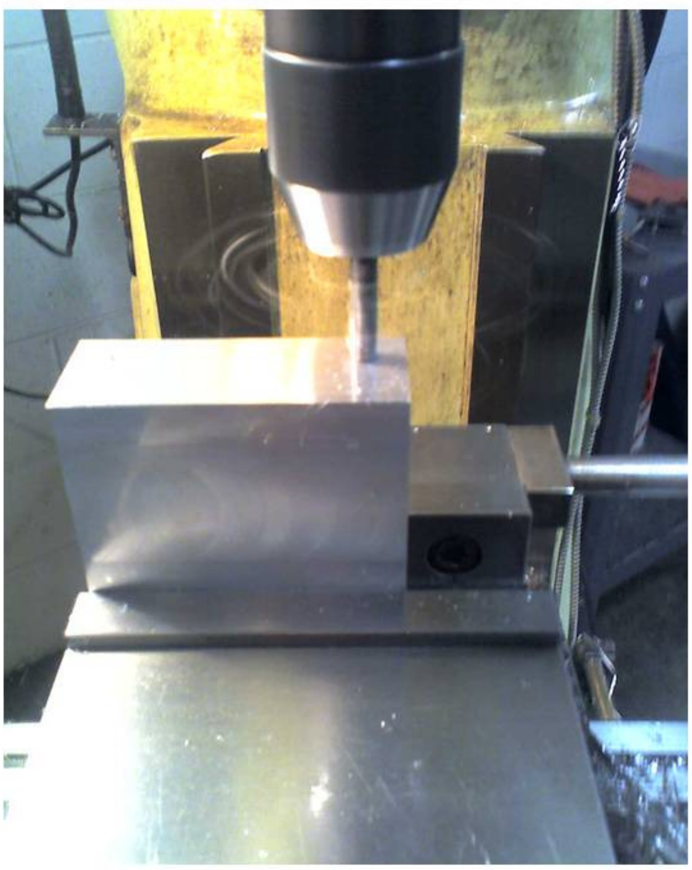

Figure 3 - Drilling the vertical holes in a support block

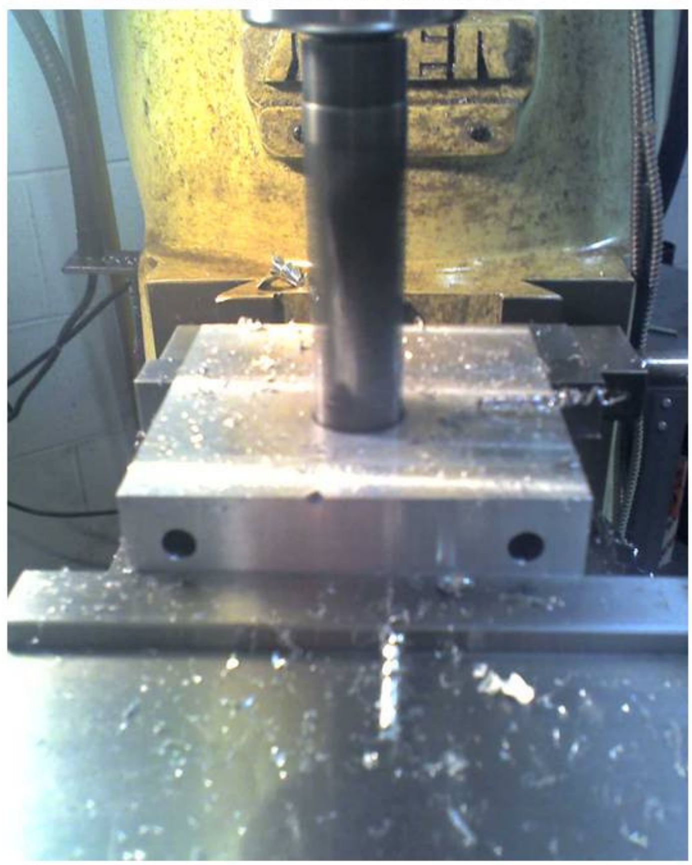

Figure 4 - Rough drilling the center hole in a support block

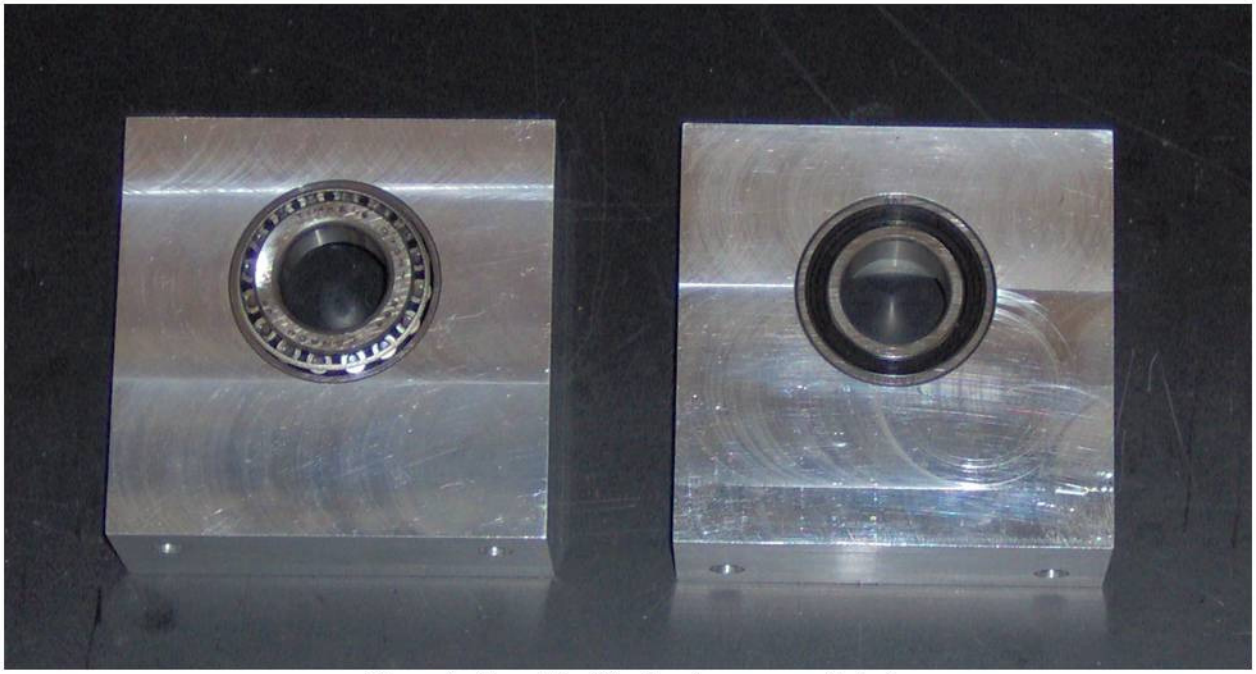
Figure 5 - Completed front and rear support blocks


Figure 6 - Wooden propeller sprocket mock-up

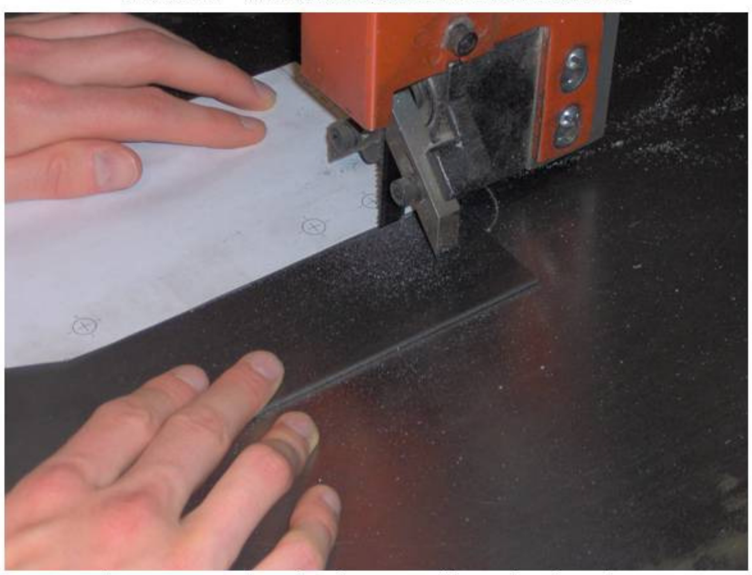
Figure 7 - Cutting the sheet metal base bracket pieces

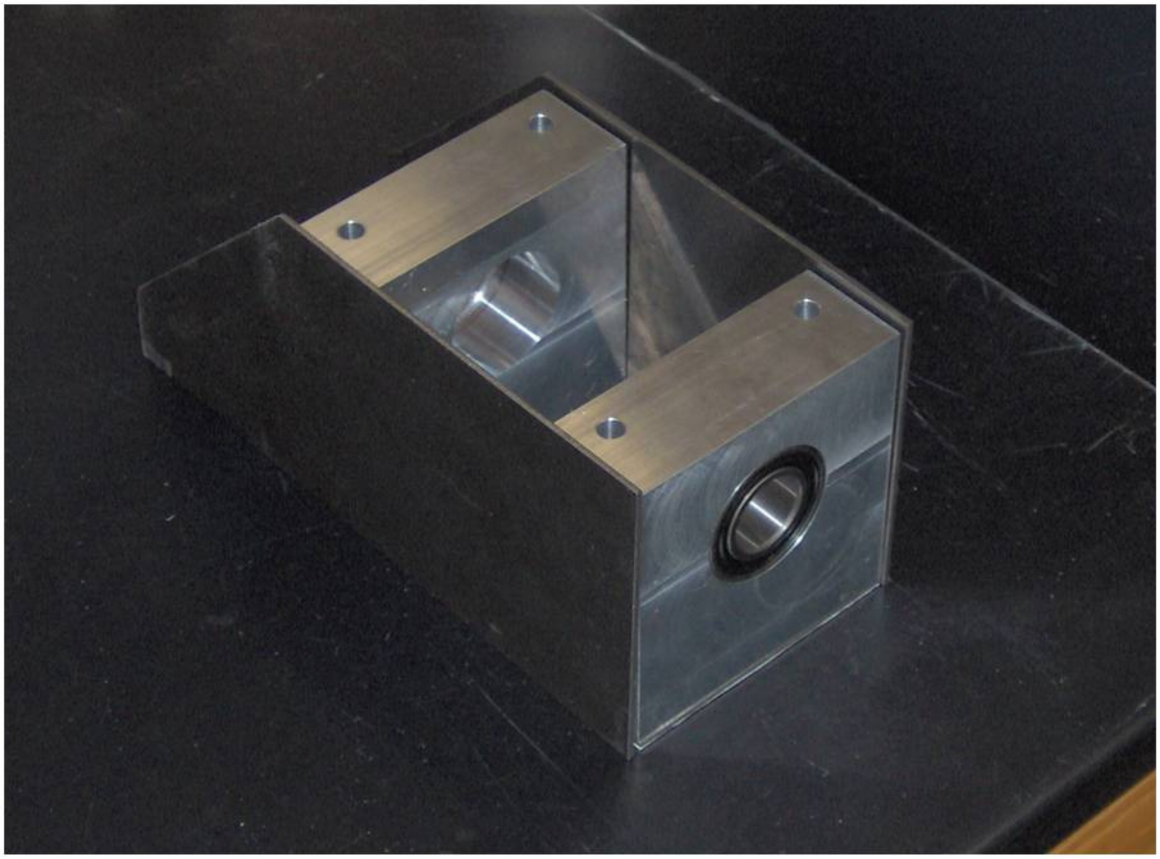

Figure 8 - base bracket and support blocks trial fit

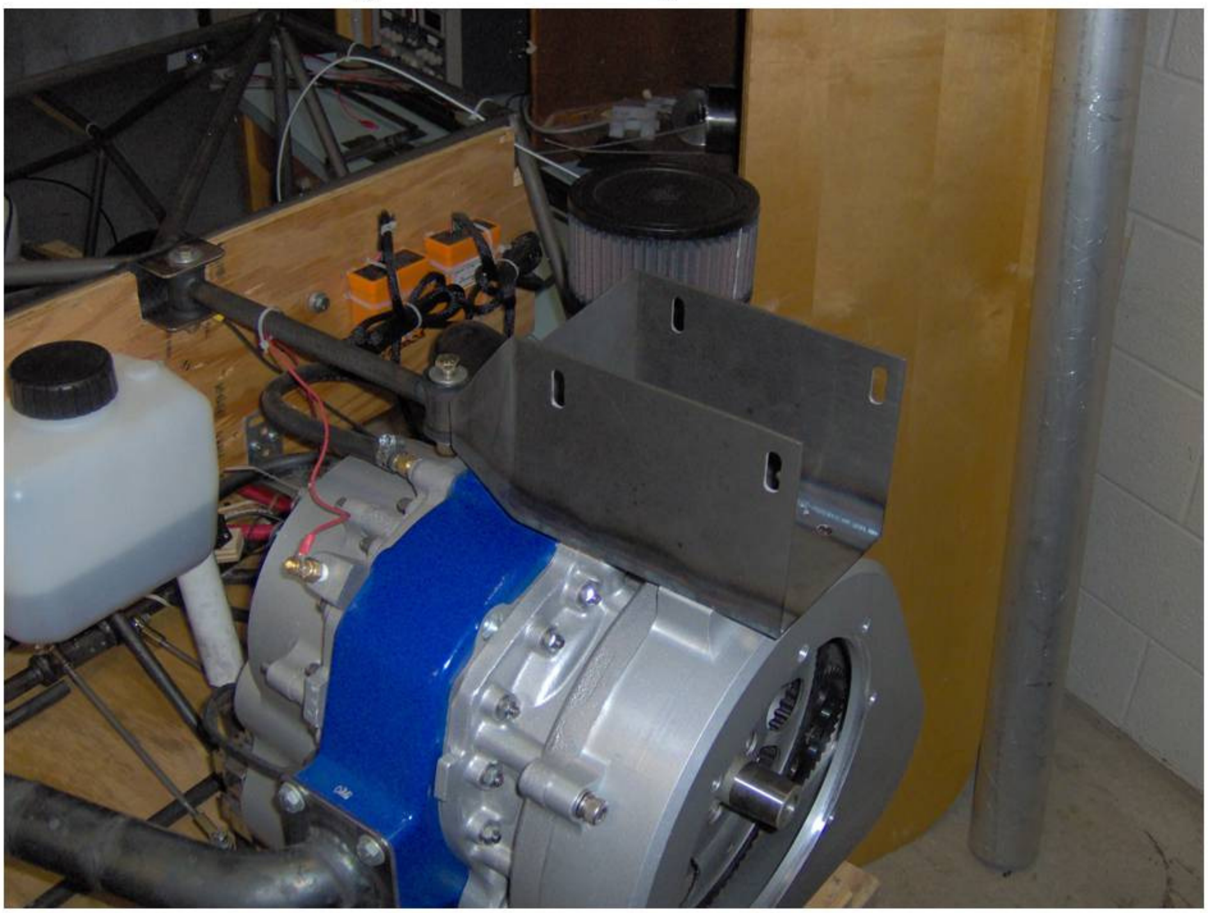

Figure 9 - Base bracket attached to engine

Figure 10 - Testing the propeller sprocket tooth profile CNC program