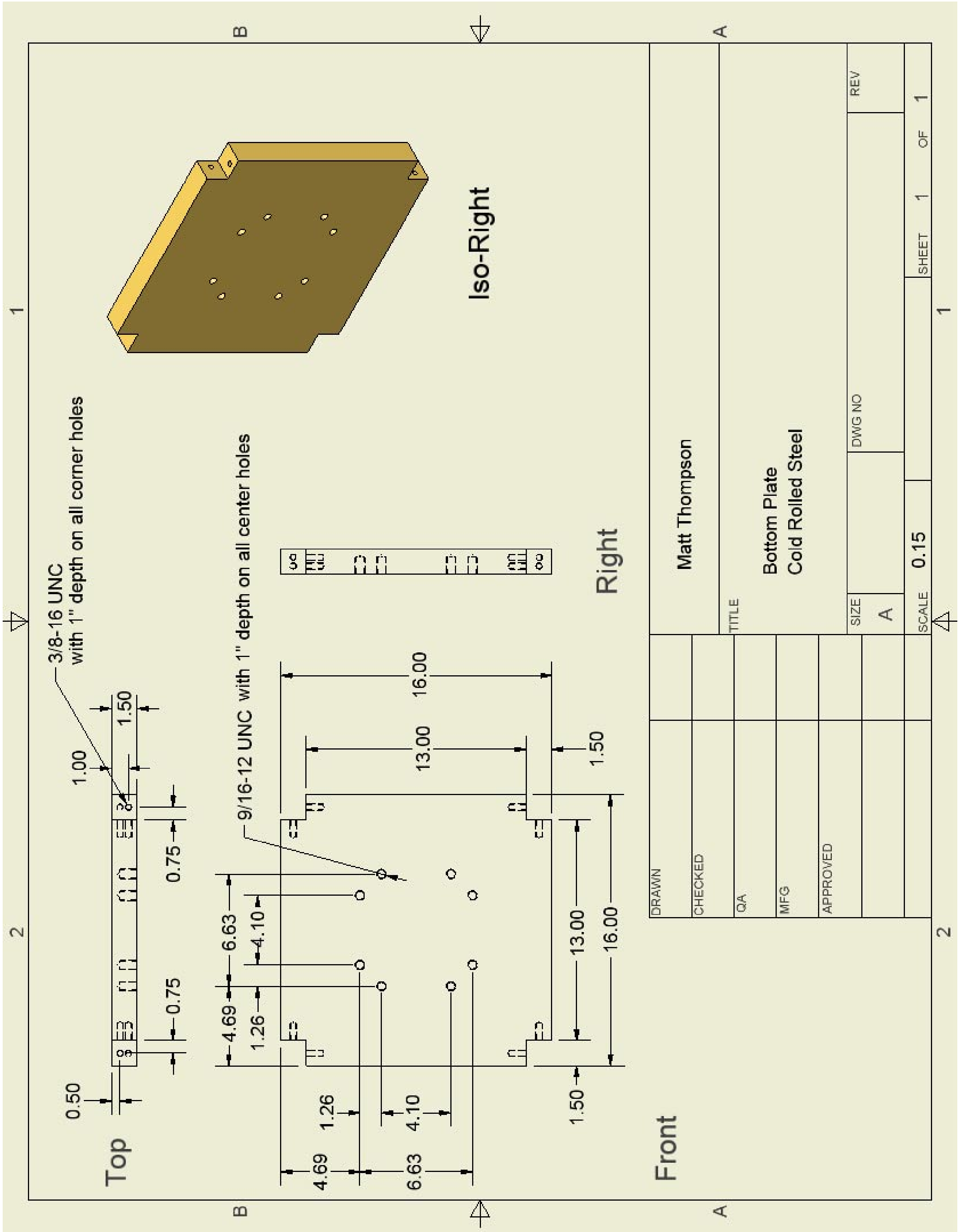
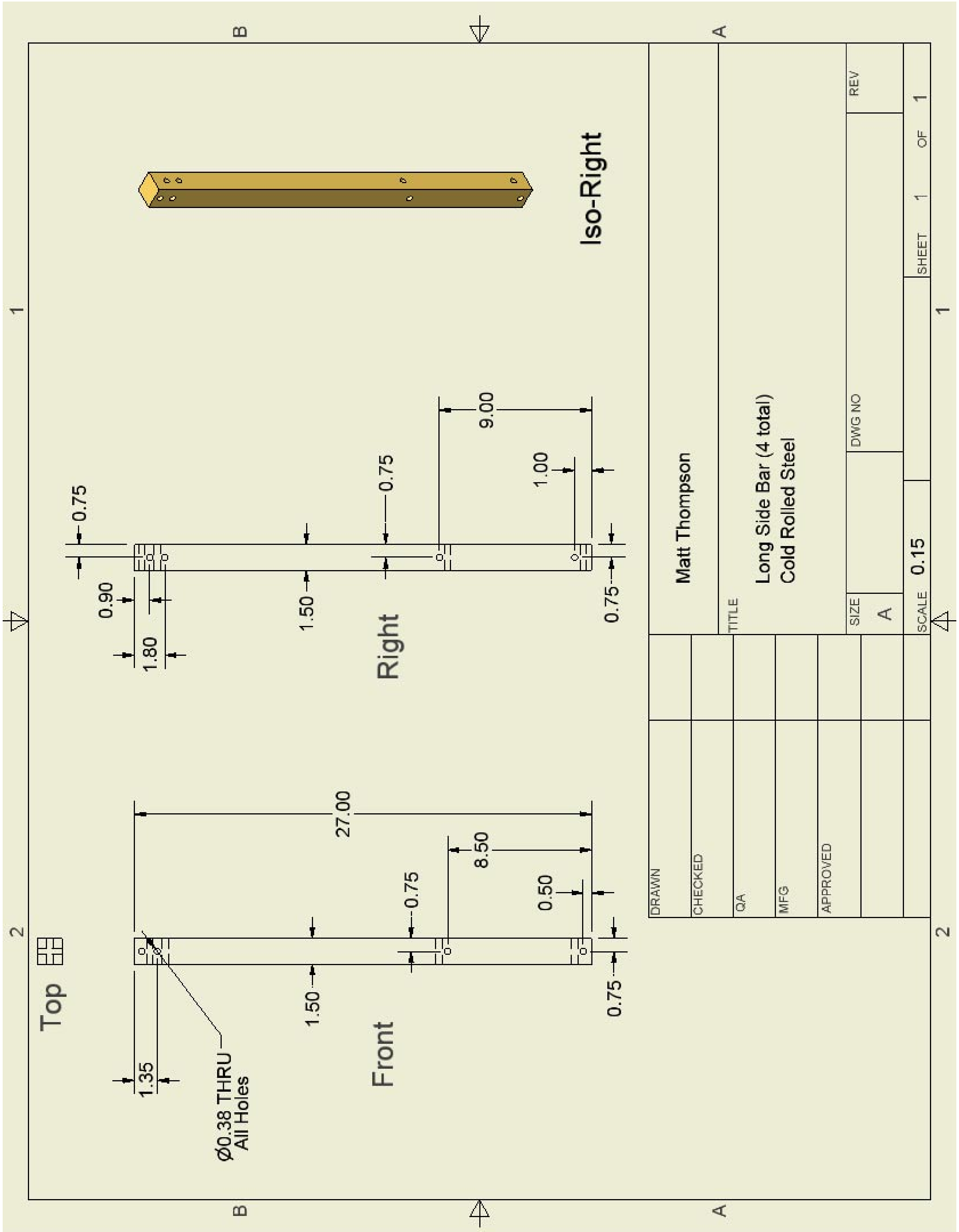
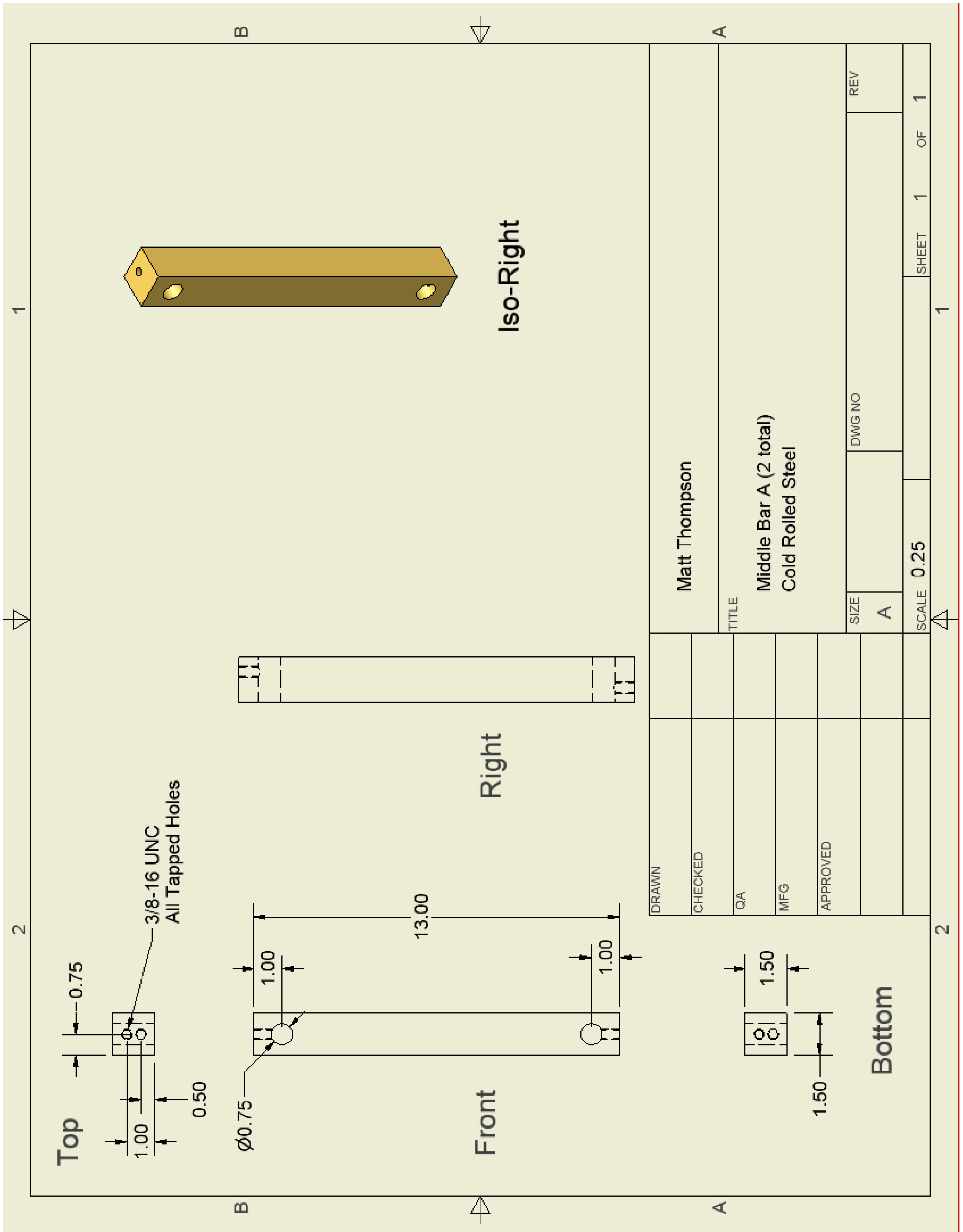
Appendix A
Apparatus CAD Drawings

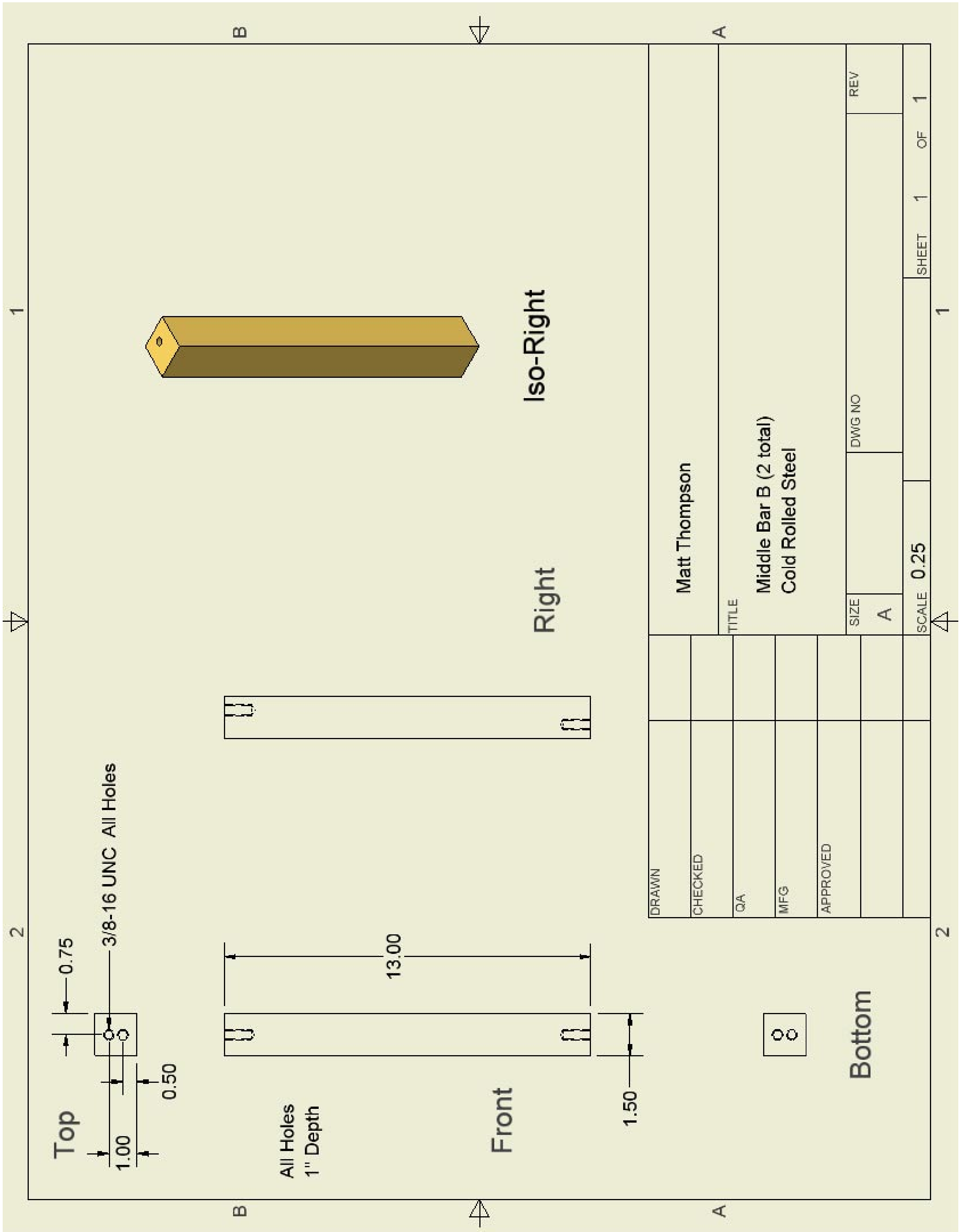
The specimen tray, motor mount, tray spacer, table support, and all of the frame parts were machined by the ESM Machine Shop (Department of Engineering Science and Mechanics, Virginia Tech, Blacksburg, VA).

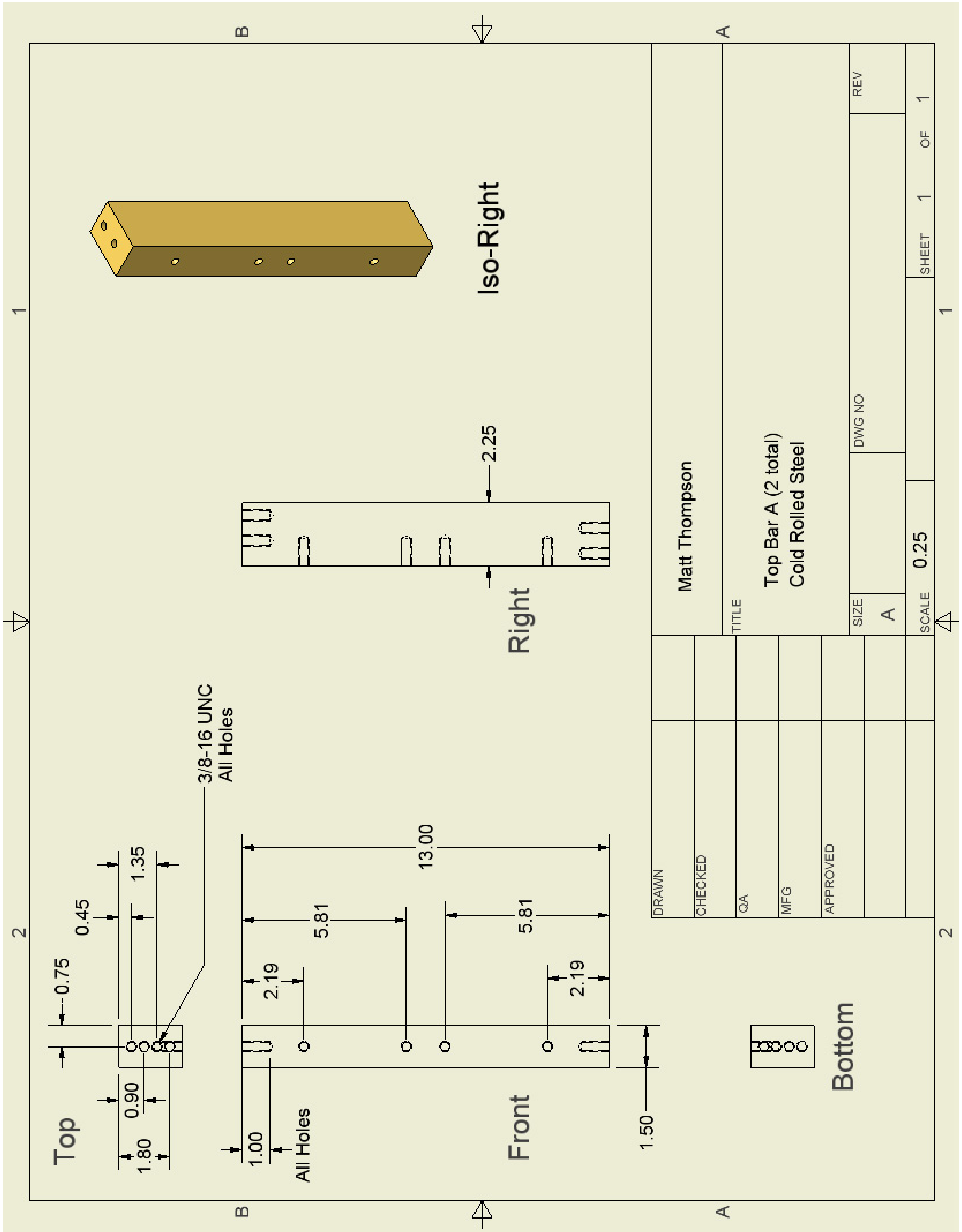


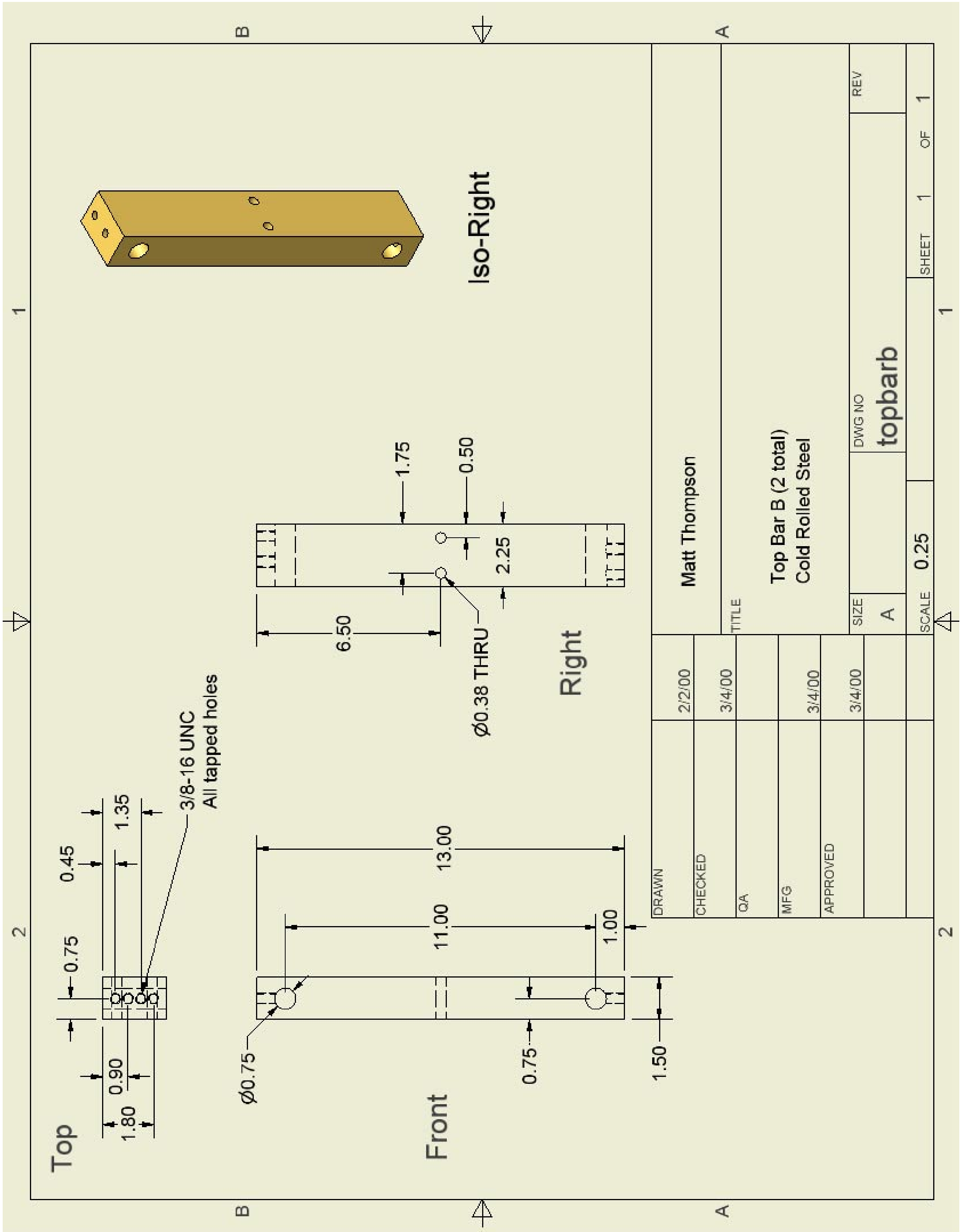
Top
Front
Right
Iso-Right
3/8-16 UNC
with 1" depth on all corner holes
9/16-12 UNC with 1" depth on all center holes
0.50
1.00
1.50
0.75
0.75
4.69
6.63
1.26
4.10
13.00
16.00
1.50
Matt Thompson
Bottom Plate
Cold Rolled Steel
DRAWN
CHECKED
QA
MFG
APPROVED
TITLE
SIZE
A
DWG NO
REV
SCALE
0.15
SHEET
1
OF
1


Top
Front
Right
Iso-Right
Ø0.38 THRU
All Holes
1.35
1.50
0.75
27.00
8.50
0.50
0.90
1.80
9.00
1.00
DRAWN
CHECKED
QA
MFG
APPROVED
Matt Thompson
TITLE
Long Side Bar (4 total)
Cold Rolled Steel
SIZE
A
DWG NO
REV
SCALE 0.15
SHEET 1 OF 1

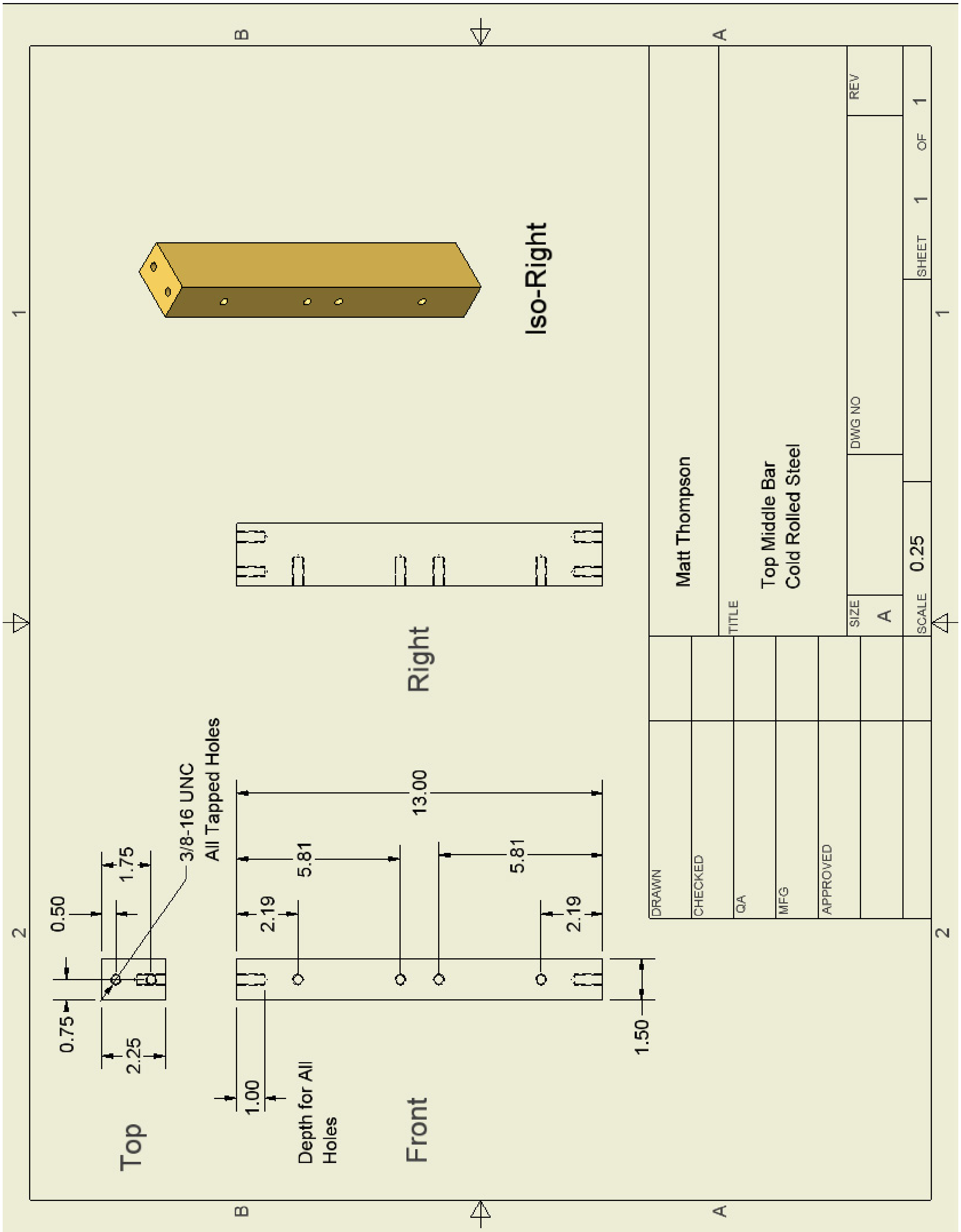

Top
0.75
1.00
0.50
3/8-16 UNC
All Tapped Holes
Ø0.75
1.00
13.00
1.00
Front
Right
Iso-Right
1.50
1.50
Bottom
DRAWN
CHECKED
QA
MFG
APPROVED
Matt Thompson
TITLE
Middle Bar A (2 total)
Cold Rolled Steel
SIZE
A
DWG NO
REV
SCALE 0.25
SHEET 1 OF 1

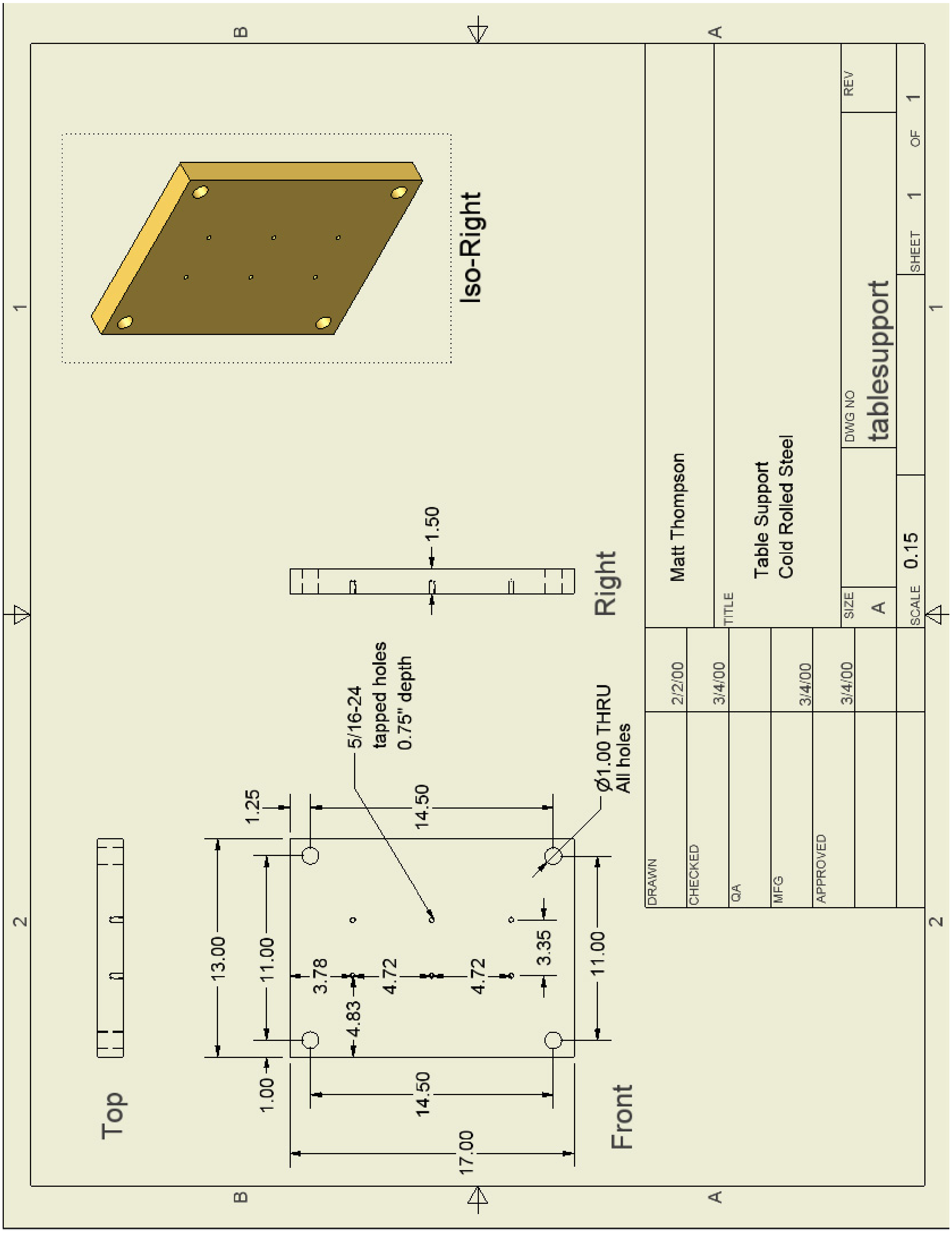

Top
0.75
3/8-16 UNC All Holes
0.50
1.00
All Holes
1" Depth
13.00
Front
1.50
Bottom
Right
Iso-Right
DRAWN
CHECKED
QA
MFG
APPROVED
Matt Thompson
TITLE
Middle Bar B (2 total)
Cold Rolled Steel
SIZE
A
DWG NO
REV
SCALE 0.25
SHEET 1 OF 1

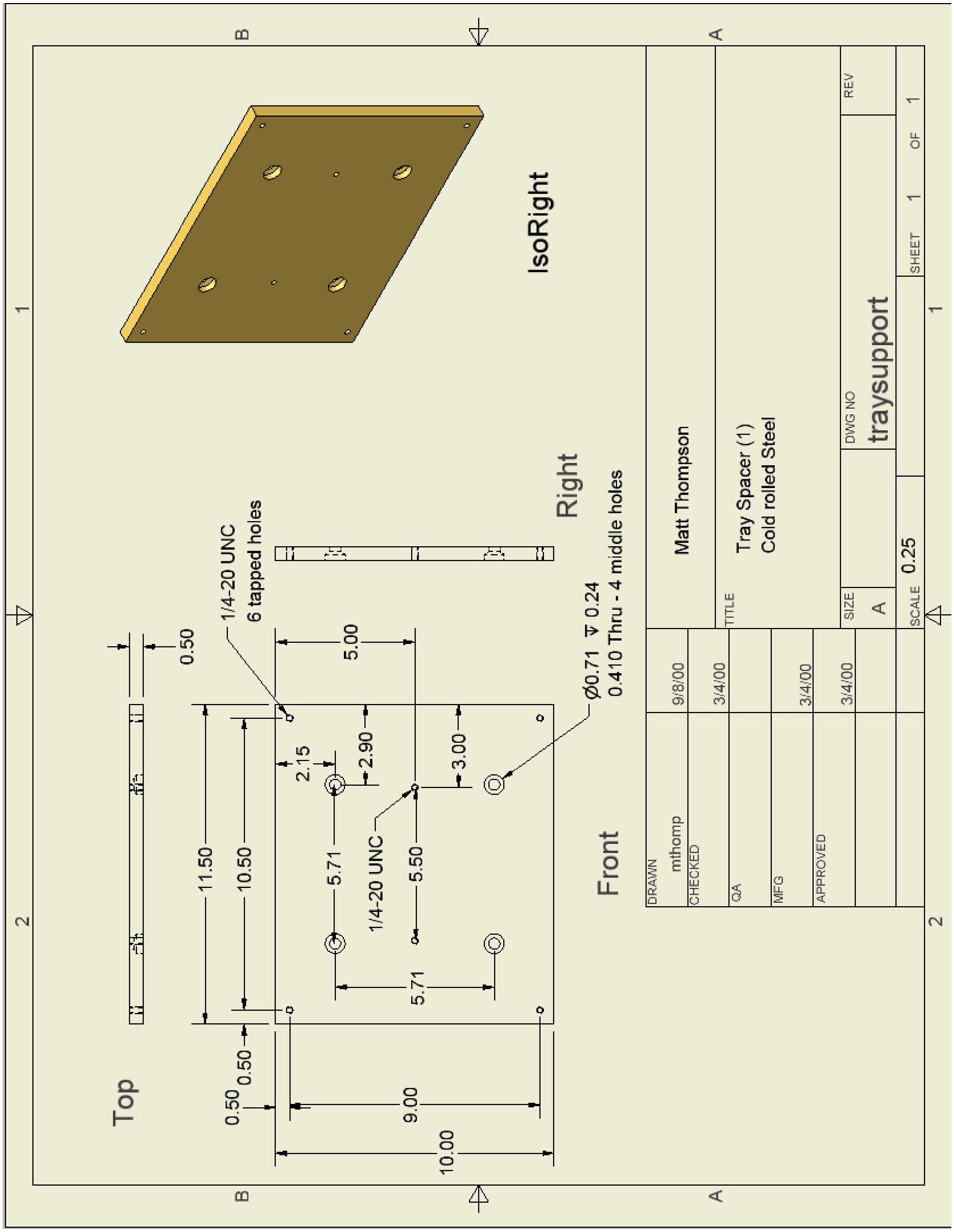

Top
Front
Bottom
Right
Iso-Right
3/8-16 UNC
All Holes
0.75
0.45
1.35
0.90
1.80
1.00
All Holes
2.19
5.81
13.00
5.81
2.19
1.50
2.25
DRAWN
CHECKED
QA
MFG
APPROVED
Matt Thompson
TITLE
Top Bar A (2 total)
Cold Rolled Steel
SIZE
A
DWG NO
REV
SCALE
0.25
SHEET 1 OF 1



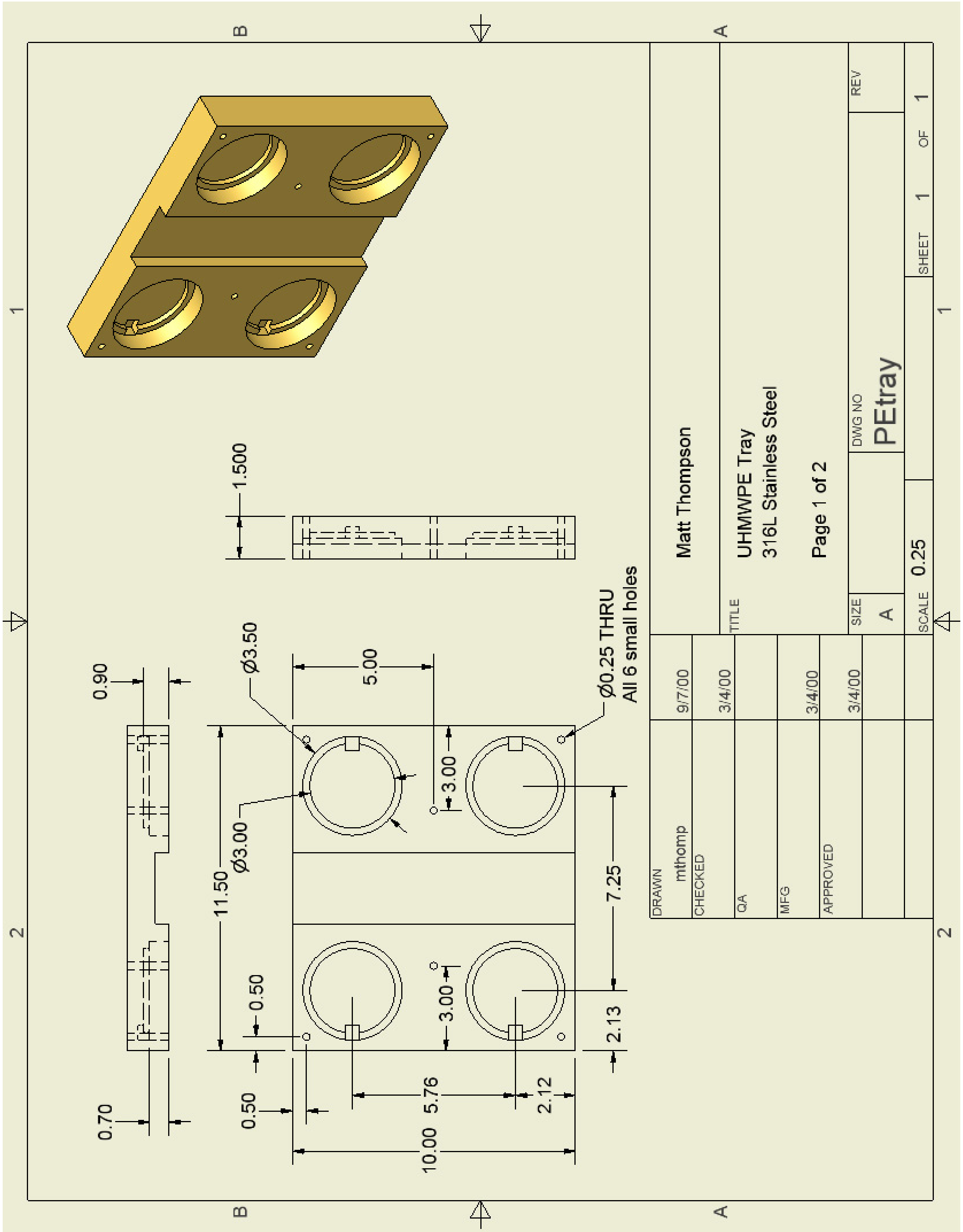
Top
Front
Right
Iso-Right
0.75
0.45
1.35
0.90
1.80
3/8-16 UNC
All tapped holes
Ø0.75
11.00
13.00
1.00
0.75
1.50
6.50
1.75
0.50
2.25
Ø0.38 THRU
DRAWN
Matt Thompson
2/2/00
CHECKED
3/4/00
QA
MFG
3/4/00
APPROVED
3/4/00
TITLE
Top Bar B (2 total)
Cold Rolled Steel
SIZE
A
DWG NO
topbarb
REV
SCALE
0.25
SHEET 1 OF 1

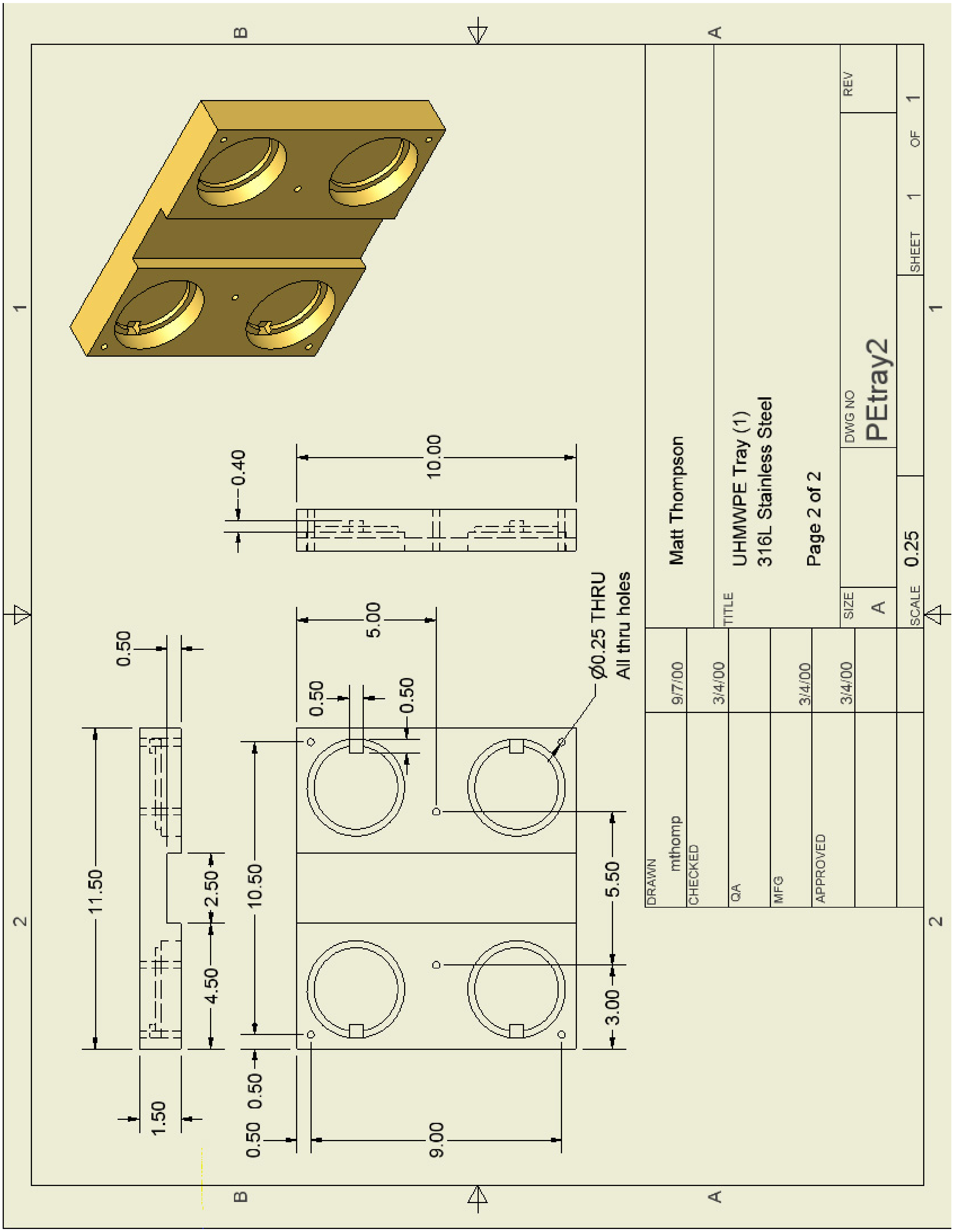

Top
Front
Right
Iso-Right
0.75
2.25
0.50
1.75
3/8-16 UNC
All Tapped Holes
1.00
Depth for All
Holes
2.19
5.81
13.00
5.81
2.19
1.50
DRAWN
CHECKED
QA
MFG
APPROVED
Matt Thompson
TITLE
Top Middle Bar
Cold Rolled Steel
SIZE
A
DWG NO
REV
SCALE
0.25
SHEET
1
OF
1
A
B
1
2


Top
Front
Right
Iso-Right
17.00
14.50
1.00
13.00
11.00
4.83
3.78
4.72
4.72
3.35
11.00
14.50
1.25
1.50
5/16-24
tapped holes
0.75" depth
Ø1.00 THRU
All holes
DRAWN
2/2/00
Matt Thompson
CHECKED
3/4/00
QA
MFG
3/4/00
APPROVED
3/4/00
TITLE
Table Support
Cold Rolled Steel
SIZE
A
DWG NO
tablesupport
REV
SCALE
0.15
SHEET 1 OF 1

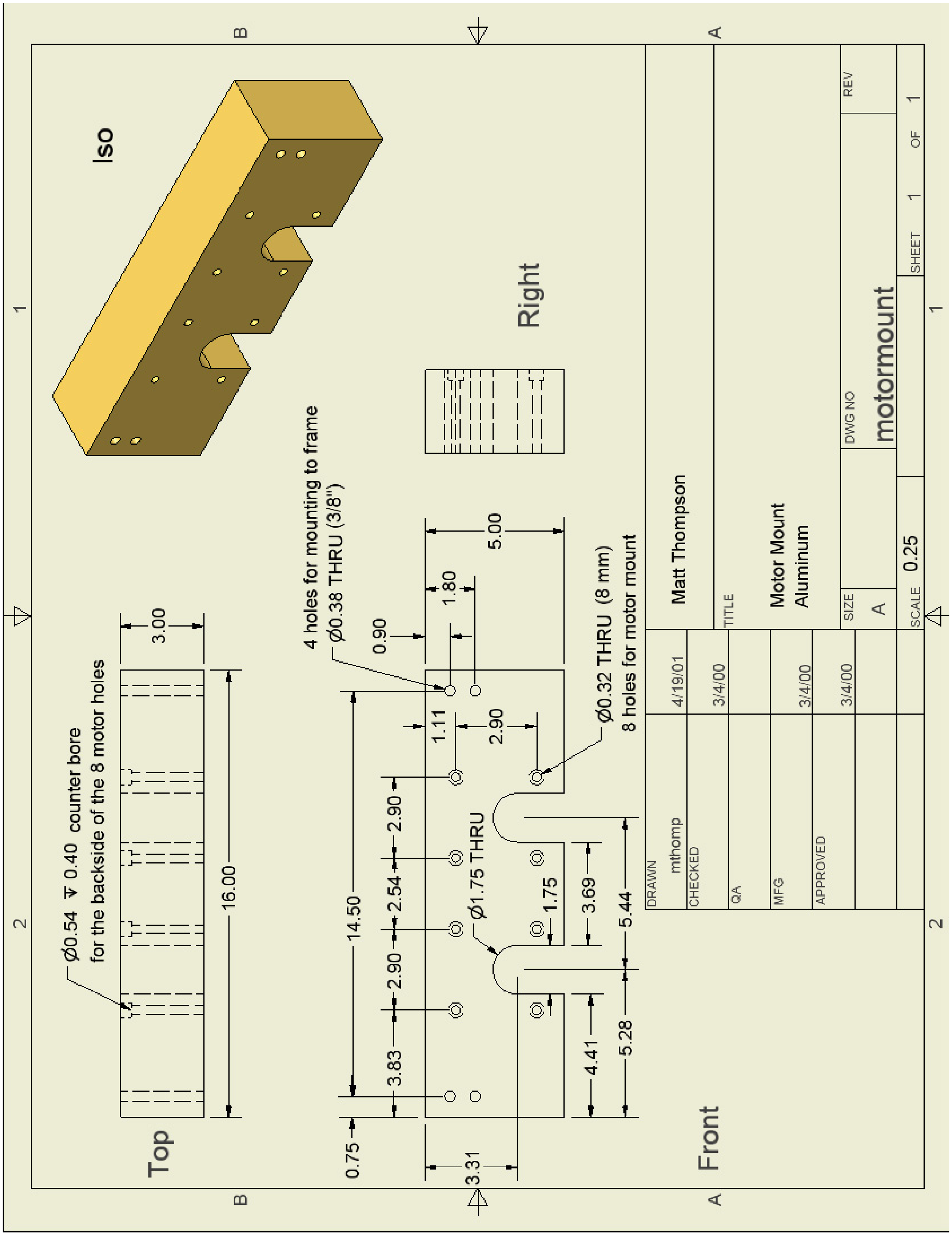


Top
Front
Right
IsoRight
1/4-20 UNC
6 tapped holes
⌀0.71 ↧ 0.24
0.410 Thru - 4 middle holes
1/4-20 UNC
0.50
5.00
11.50
10.50
2.15
2.90
3.00
5.71
5.50
5.71
0.50
0.50
9.00
10.00
DRAWN
mthomp
9/8/00
CHECKED
3/4/00
QA
MFG
3/4/00
APPROVED
3/4/00
Matt Thompson
TITLE
Tray Spacer (1)
Cold rolled Steel
SIZE
A
DWG NO
traysupport
REV
SCALE
0.25
SHEET 1 OF 1

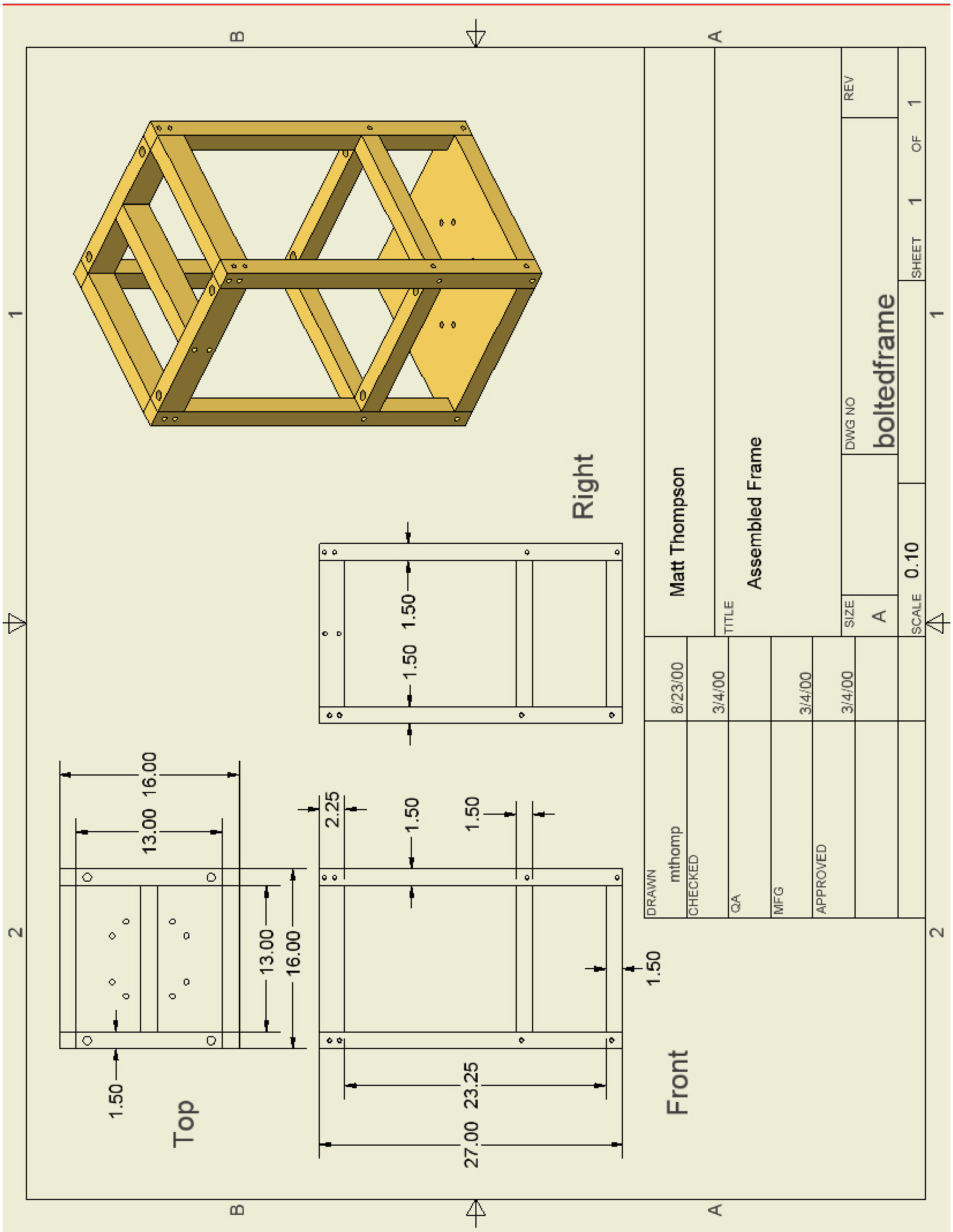

0.90
Ø3.50
5.00
Ø0.25 THRU
All 6 small holes
3.00
11.50
Ø3.00
7.25
0.50
3.00
2.13
0.70
0.50
5.76
2.12
10.00
1.500
DRAWN
mthomp
9/7/00
CHECKED
3/4/00
QA
MFG
3/4/00
APPROVED
3/4/00
Matt Thompson
TITLE
UHMWPE Tray
316L Stainless Steel
Page 1 of 2
SIZE
A
DWG NO
PEtray
REV
SCALE
0.25
SHEET
1
OF
1



Ø0.25 THRU
All thru holes
11.50
1.50
0.50
2.50
4.50
10.50
0.50
0.50
9.00
5.00
5.50
3.00
0.40
10.00
DRAWN
mthomp
9/7/00
CHECKED
3/4/00
QA
MFG
3/4/00
APPROVED
3/4/00
Matt Thompson
TITLE
UHMWPE Tray (1)
316L Stainless Steel
Page 2 of 2
SIZE
A
DWG NO
PEtray2
REV
SCALE 0.25
SHEET 1 OF 1



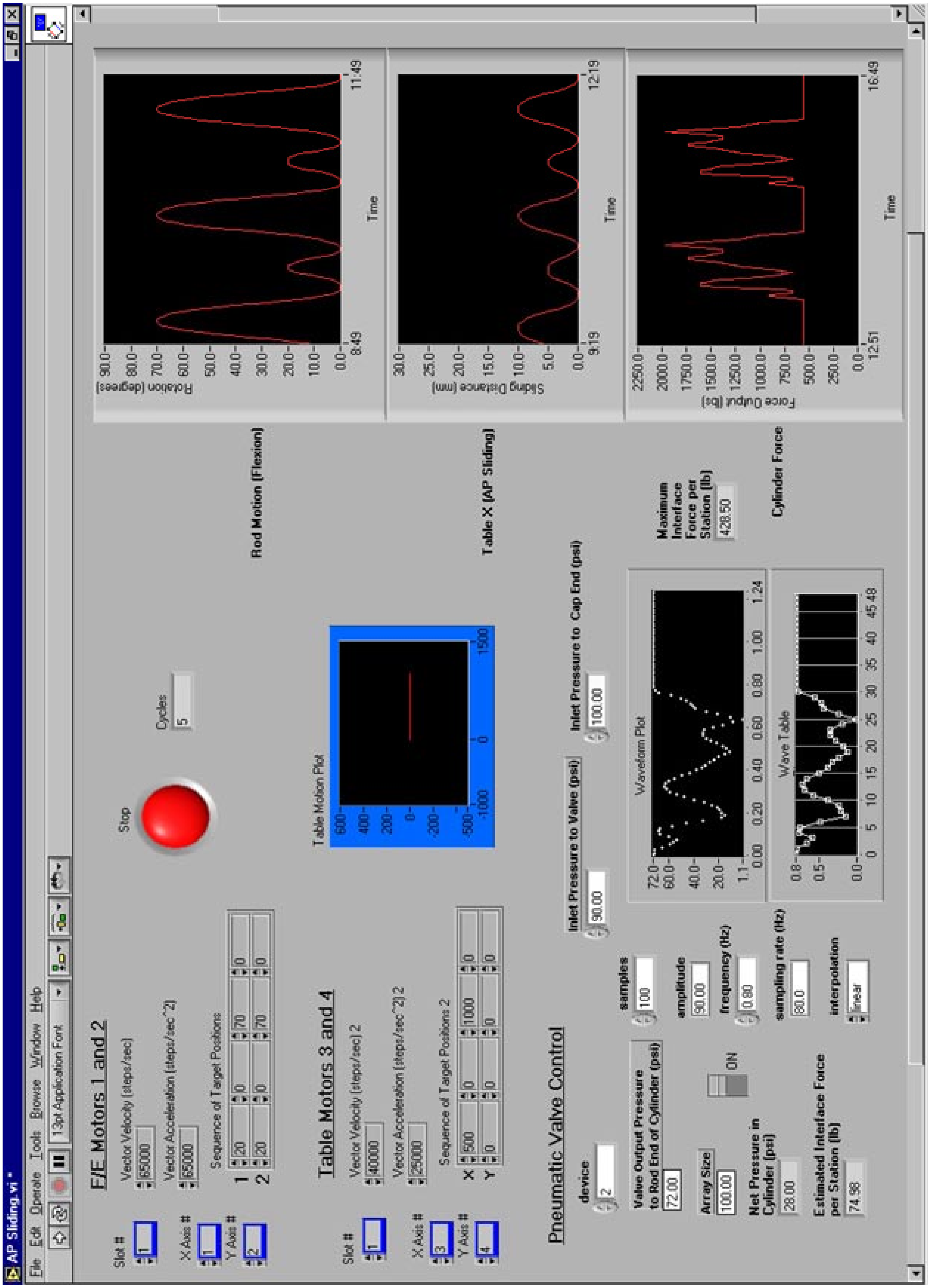
Iso
Right
Top
Front
Ø0.54 ↧ 0.40 counter bore
for the backside of the 8 motor holes
4 holes for mounting to frame
Ø0.38 THRU (3/8")
Ø0.32 THRU (8 mm)
8 holes for motor mount
Ø1.75 THRU
3.00
16.00
14.50
0.75
3.31
3.83
2.90
2.54
2.90
1.75
3.69
4.41
5.28
5.44
1.11
2.90
0.90
1.80
5.00
DRAWN
mthomp
4/19/01
CHECKED
3/4/00
QA
MFG
3/4/00
APPROVED
3/4/00
Matt Thompson
TITLE
Motor Mount
Aluminum
SIZE
A
DWG NO
motormount
REV
SCALE
0.25
SHEET
1
OF
1

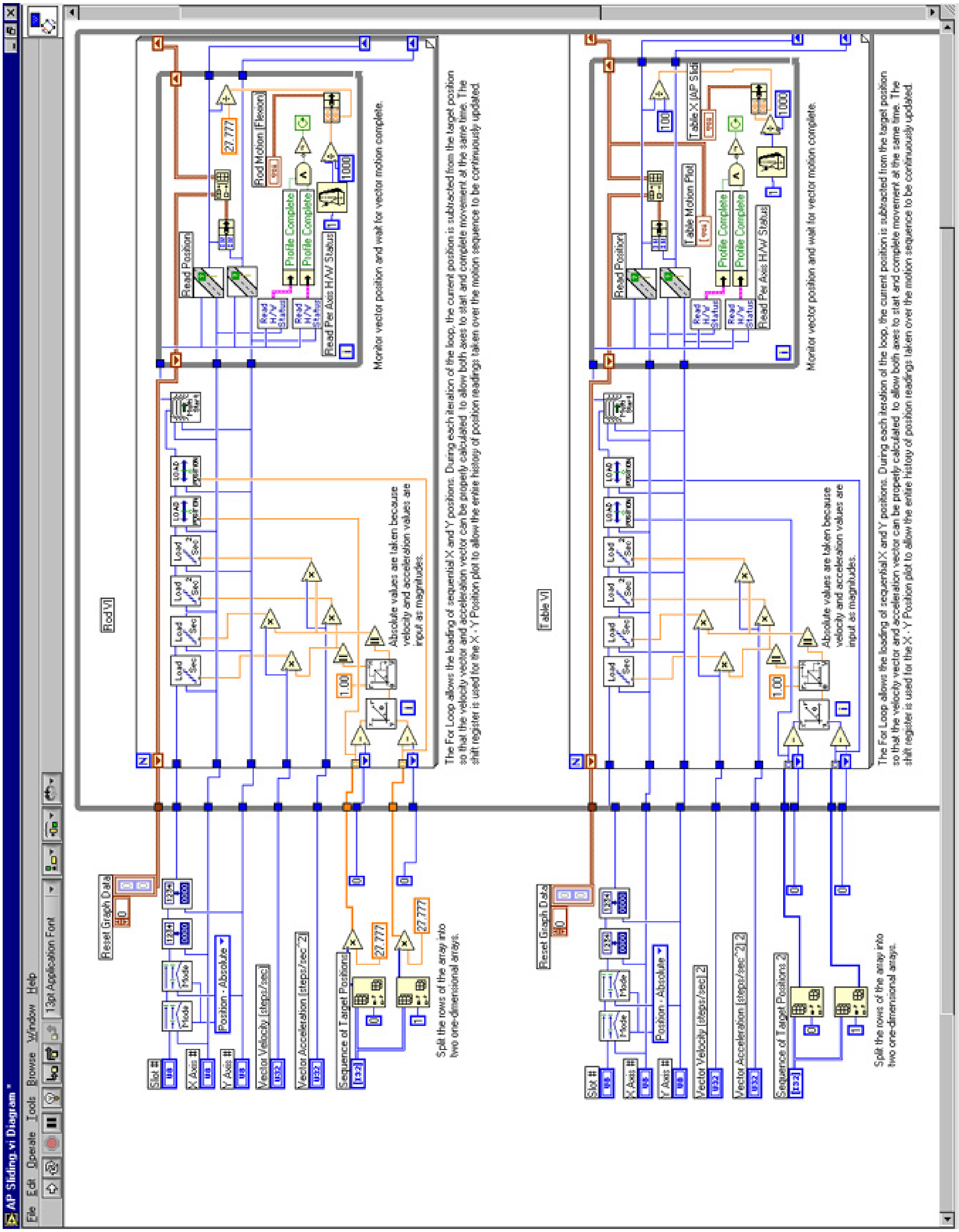

Top
Front
Right
27.00
23.25
16.00
13.00
1.50
2.25
DRAWN
mthomp
8/23/00
CHECKED
3/4/00
QA
MFG
3/4/00
APPROVED
3/4/00
Matt Thompson
TITLE
Assembled Frame
SIZE
A
DWG NO
boltedframe
REV
SCALE
0.10
SHEET
1
OF
1

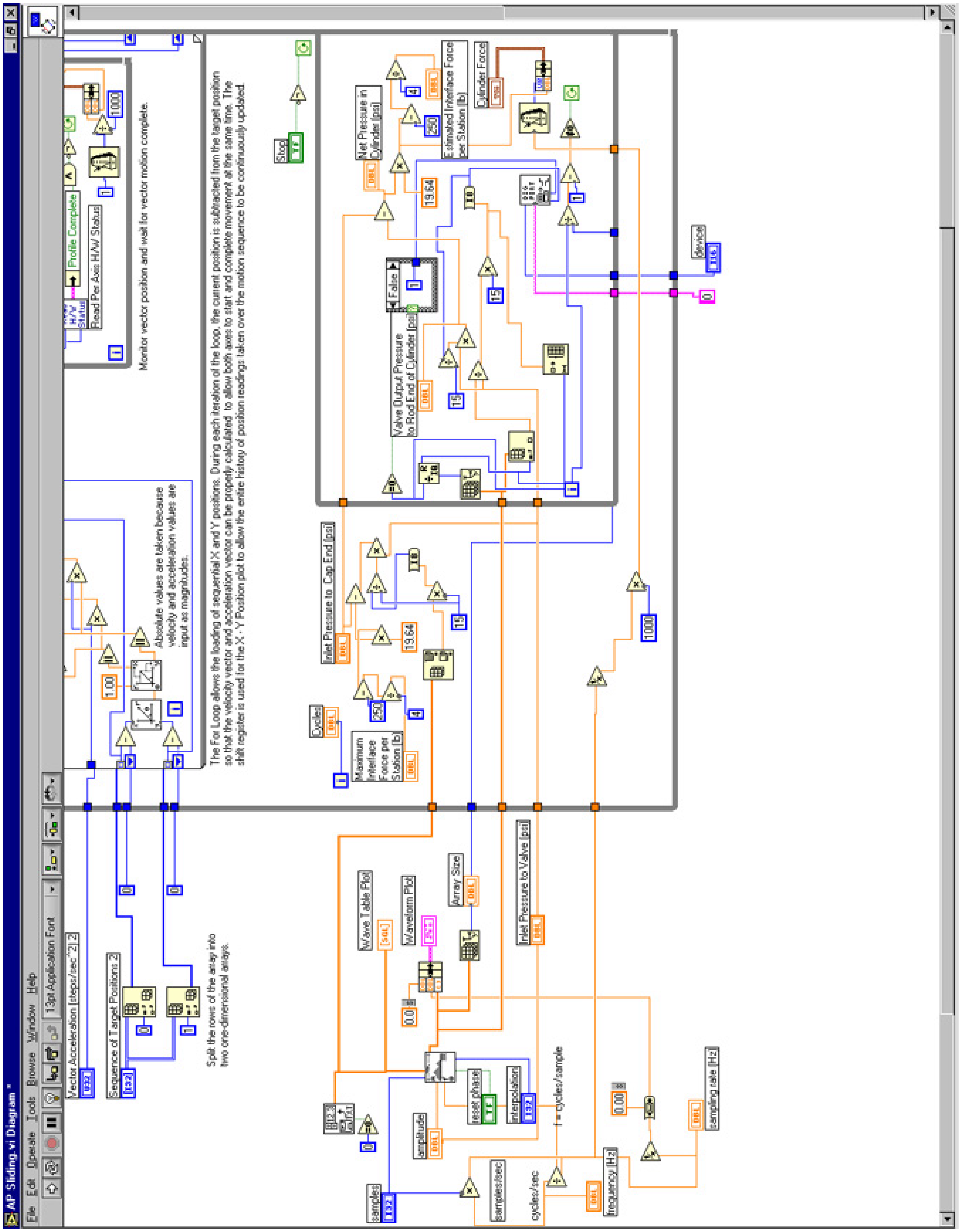
Appendix B
LabView^{TM} Screenshots and VI Diagrams

The Labview^{TM} Virtual Instrument (VI) responsible for control and synchronization of the wear testing device consists of two parts: the user interface and the VI diagram. The user interface is where parameters, such as the AP sliding distance and loading curve can be adjusted or imported, and where the output of the instrumentation can be seen visually. The VI diagram is essentially the source code of the program, but unlike typical computer languages, Labview^{TM} uses graphical programming to build instrumentation and data acquisition systems.

Note: Due to its large size, the VI diagram would not fit on one screenshot and is shown in two parts on the screenshots on pages 114 and 115.


AP Sliding.vi *
F/E Motors 1 and 2
Vector Velocity (steps/sec)
Vector Acceleration (steps/sec^2)
Sequence of Target Positions
Slot #
X Axis #
Y Axis #
Table Motors 3 and 4
Vector Velocity (steps/sec) 2
Vector Acceleration (steps/sec^2) 2
Sequence of Target Positions 2
Pneumatic Valve Control
device
samples
amplitude
frequency (Hz)
sampling rate (Hz)
interpolation
Value Output Pressure to Rod End of Cylinder (psi)
Array Size
Net Pressure in Cylinder (psi)
Estimated Interface Force per Station (lb)
Inlet Pressure to Valve (psi)
Inlet Pressure to Cap End (psi)
Stop
Cycles
Table Motion Plot
Waveform Plot
Wave Table
Maximum Interface Force per Station (lb)
Rod Motion (Flexion)
Table X (AP Sliding)
Cylinder Force
Rotation (degrees)
Sliding Distance (mm)
Force Output (lbs)
Time


AP Sliding.vi Diagram *
File Edit Operate Tools Browse Window Help
13pt Application Font
Rod VI
Reset Graph Data
Slot #
X Axis #
Y Axis #
Position - Absolute
Vector Velocity [steps/sec]
Vector Acceleration [steps/sec^2]
Sequence of Target Positions
27.777
Split the rows of the array into two one-dimensional arrays.
Read Position
Rod Motion (Flexion)
Profile Complete
Profile Complete
Read Per Axis H/W Status
1000
Monitor vector position and wait for vector motion complete.
Absolute values are taken because velocity and acceleration values are input as magnitudes.
The For Loop allows the loading of sequential X and Y positions. During each iteration of the loop, the current position is subtracted from the target position so that the velocity vector and acceleration vector can be properly calculated to allow both axes to start and complete movement at the same time. The shift register is used for the X - Y Position plot to allow the entire history of position readings taken over the motion sequence to be continuously updated.
Table VI
Vector Velocity [steps/sec] 2
Vector Acceleration [steps/sec^2] 2
Sequence of Target Positions 2
Table Motion Plot
Table X (AP Slidi



AP Sliding.vi Diagram *
File Edit Operate Tools Browse Window Help
13pt Application Font
Vector Acceleration [steps/sec^2] 2
Sequence of Target Positions 2
Split the rows of the array into two one-dimensional arrays.
Absolute values are taken because velocity and acceleration values are input as magnitudes.
Monitor vector position and wait for vector motion complete.
Read Per Axis H/W Status
Profile Complete
The For Loop allows the loading of sequential X and Y positions. During each iteration of the loop, the current position is subtracted from the target position so that the velocity vector and acceleration vector can be properly calculated to allow both axes to start and complete movement at the same time. The shift register is used for the X - Y Position plot to allow the entire history of position readings taken over the motion sequence to be continuously updated.
Stop
Net Pressure in Cylinder [psi]
Estimated Interface Force per Station [lb]
Cylinder Force
Valve Output Pressure to Rod End of Cylinder [psi]
False
Inlet Pressure to Cap End [psi]
Cycles
Maximum Interface Force per Station [lb]
Wave Table Plot
Waveform Plot
Array Size
Inlet Pressure to Valve [psi]
samples
samples/sec
cycles/sec
amplitude
reset phase
interpolation
f = cycles/sample
frequency [Hz]
sampling rate [Hz]
device

Appendix C
Pneumatic Valve Validation

In order to calibrate the Par-15™ pneumatic valve, a pressure gauge was attached to the output of the valve. Using a simple Labview™ VI, several desired output pressures were converted to their binary equivalent and sent to the valve under various input pressures. Once we had accounted for error in the pressure gauges, we found the valve to perform accurately. Table C-1 lists a few of the input and desired pressures that were used to validate the valve.

Table C-1. Several measurements taken to ensure the valve was properly pressurizing the cap end of the cylinder. Inaccuracies between the two pressure gauges led to the erroneous output. For instance, with a 60 psi input and the normally-open valve turned off, the output gauge should have read 60 psi, but read 65 psi instead. Gauge #1 was found to behave nonlinearly and inaccurately. An adjustment factor was introduced to compare the output with the desired pressure.

Valve Input Gauge #2 (psi)	Desired Pressure (psi)	Binary Equivalent	Valve Output Gauge #1 (psi)	Adjustment Factor (psi)	Adjusted Output (psi)	Percent Error Using Adjustment Factor
60	60	1111	65	-7	58	3.3%
60	52	1101	60	-7	53	1.7%
60	36	1001	45	-7	38	3.3%
60	12	0011	19	-7	12	0.0%
60	44	1011	51	-7	44	0.0%
75	75	1111	82	-7	75	0.0%
75	15	0011	20	-7	13	2.7%
75	30	0110	33	-7	26	5.3%
75	60	1100	65	-7	58	2.7%
90	90	1111	97	-7	90	0.0%
90	18	0011	25	-7	18	0.0%
90	36	0110	41	-7	34	2.2%
90	72	1100	79	-7	72	0.0%
90	60	1010	70	-7	63	3.3%

Appendix D

Strain Gage Calibration

Calibration of the applied forces using a single strain gage is described in detail in Chapter 5. This appendix displays example data taken during calibration of the strain gauge using estimated interface forces (Table D-1) and known weight (Table D-2).

Table D-1. Data taken during the calibration of the pneumatic cylinder. The estimated interface force and the strain gage reading (in bold) were used to show the linearity of the strain gage at high loads, and were also compared with data from Table D-2 to examine the accuracy of using the estimated forces during testing.

Cap End Pressure (psi)	Rod End Pressure (psi)	Net Pressure (psi)	Estimated Cylinder Force (lbf)	**Estimated Interface Force (lbf)**	**Strain Gage Reading (microstrain)**	Estimated Force per Station (lbf)
0	0	0	0.0	**0.0**	**0**	0.0
10	0	10	196.3	**0.0**	**0**	0.0
20	0	20	392.7	**142.7**	**4**	35.7
30	0	30	589.0	**339.0**	**10**	84.8
40	0	40	785.4	**535.4**	**16**	133.8
50	0	50	981.7	**731.7**	**21**	182.9
60	0	60	1178.1	**928.1**	**27**	232.0
70	0	70	1374.4	**1124.4**	**33**	281.1
80	0	80	1570.8	**1320.8**	**40**	330.2
90	0	90	1767.1	**1517.1**	**46**	379.3
100	0	100	1963.5	**1713.5**	**52**	428.4

Table D-2. Strain gage calibration data using known weight. Although the strain indicator (P-3500, Measurements Group, Raleigh, NC) did not read to a resolution of 0.5 microstrain, one half microstrain measurements were estimated when the indicator consistently drifted between two numbers.

Weight (lbf)	Gage Reading (microstrain)
0.0	0.0
39.3	1.5
96.7	3.5
115.2	4.0
138.4	4.5
160.9	5.5
199.9	6.5
261.9	9.0
284.4	9.5
365.2	12.0
394.9	13.0

Appendix E

Operating Procedure

The operation process of the wear testing device depends a great deal on the type of testing that is desired. As described in Chapter 6, flexibility of the device allows for independent control of many testing scenarios. The operating procedure described below outlines the steps involved in device setup, VI control, termination of testing, and post-testing procedure.

D-1. DEVICE SETUP

1. Press fit UHMWPE specimens into the four chambers of the stainless steel tray using a hammer and a cushioned wooden dowel.

2. Using a graduated cylinder, pour approximately 30 ml of thawed bovine serum into each specimen chamber. Carefully pour additional serum into each chamber until each UHMWPE specimen is completely submersed.

3. Turn on the power strips to the left and right of the computer. This in turn powers the motor drivers, motion controller, backplane, and pneumatic valve.

4. Turn on the computer and open Labview™.

5. Align the specimen chambers with the four CoCr discs using the SimpleMove VI in Labview™. When running SimpleMove, remember these parameters:

    a. The motor responsible for movement in the AP sliding direction is on axis 3.
    b. The motor responsible for movement in the cross shear direction is on axis 4.
    c. The two motors responsible for rotation of the CoCr discs are on axes 1 and 2.
    d. 1000 pulses to the F/E motors results in 36˚ of rotation.
    e. 1000 pulses to the linear guide motors results in 10 mm of movement.

6. Input the desired axis and number of pulses, and then select the white arrow in the upper left corner to run the VI and align the device.

7. Open the bottom valve on the air tank and rotate the regulator clockwise until the desired valve pressure is reached.

8. Open the top valve on the air tank and SLOWLY rotate the regulator clockwise until the desired pressure to the cap end of cylinder is reached. This should be done carefully. Once the pressure in the cap end slightly exceeds the valve pressure, the cylinder will begin to push the UHMWPE tray upwards. Gradually, adjust the pressure until the UHMWPE specimens come in contact with the CoCr disk, and then adjust the regulator to the desired cap end pressure

D-2. RUNNING A TEST

1. Open the AP Sliding VI in Labview™.

2. Double check to ensure all sliding distances (in number of pulses) and rotation angles (in degrees) are properly set for AP sliding and F/E, respectively.

3. Input the valve and cap end pressures. All of the slot numbers, axes, velocities, accelerations, and frequencies should already be set accordingly.

4. Turn on the fan responsible for cooling the F/E motors.

5. To start the VI, select the white arrow in the upper left corner.

6. A window will automatically appear requesting the data file that represents the physiologically correct loading curve. Select the text file named Modified Inverted Seireg.

7. Testing will begin immediately. The motors and the tables should be moving, and the pressure changes in the valve should be audible. Look for any noticeable problems, such as:

    a. contact between the CoCr discs and the edges of the specimen chambers,
    b. loss of contact between the CoCr discs and the UHMWPE,
    c. any sounds that are not cyclical, and
    d. excessive vibration of the table support or the frame.

8. If there is a problem, hit STOP on the Labview™ user interface and turn off the two power strips. Realign the stainless steel tray using the SimpleMove VI.

9. If the test appears to be running properly, the device can be left alone to run for the desired number of cycles. Check the level of the bovine serum a few times a day. Refill if necessary.

10. Once the test has reached the desired number of cycles, hit STOP on the VI, and the program will terminate after the completion of its current cycle.

D-3. POST-TESTING PROCEDURE

1. Turn off the two power strips to the left and right of the computer.

2. Close Labview™ and turn off the computer.

3. Close the top valve of the air tank and turn the regulator counterclockwise to decrease the pressure in the cap end of the cylinder. Continue letting air out until the pressure gauge reads 0 psi.

4. Close the bottom valve of the air tank and turn the regulator counterclockwise to decrease the pressure in the valve. Continue letting air out until the pressure gauge reads 0 psi.

5. Extract as much bovine serum as possible from each specimen chamber using a squeezable plastic bottle with a cone tip.

6. Remove the six socket head screws that secure the stainless steel tray to the tray support.

7. Slide the tray out from under the CoCr discs.

8. Rinse and dry the tray in the sink..

9. To remove the UHMWPE specimens, place the bent end of a modified paint cap remover into the notches of the tray, and pull out the specimens.

10. At this point, any desired post-testing analysis should be done, such as:

    a. properly rinsing the specimens using deionized water,
    b. visually inspecting the specimens for wear,
    c. examining the extracted bovine serum for wear particles, and
    d. comparing the results among the four different specimens.

D-4. OTHER TESTING SCENARIOS

Other testing scenarios can be run with little change to the operating procedure. For instance, if a test involving cross shear with a constant load is desired, only the following steps need to be corrected:

1. In step 1 of RUNNING A TEST, open the Cross Shear VI, rather than the AP Sliding VI.
2. In step 6 of RUNNING A TEST, select the Constant Load data file rather than the Modified Inverted Seireg.
3. The power strip supplying the pneumatic valve may be turned off during constant load testing, but is not required to be.

More unique testing procedures will require some modification to the original Wear Device VI input variables. Once the sliding distances, F/E angles, velocities, accelerations, and the imported data file are altered to reproduce the desired test, the VI can be saved under a different name for future use.

Appendix F
Parts, Vendors, and Cost Analysis

One of the primary objectives of this project was to design a wear testing device that could be built at reasonable cost in comparison to expensive knee simulators. The cost and vendor of each of the device's parts as well as the machining costs are listed in Table F-1. The total cost of the project on the following page is at a fraction of the cost of a commercial knee simulator (approximately $200,000) (AMTI, 2000). The total cost does not include that of the PC and the installation of the air supply and tank since these aspects of the project are also used for other purposes in the Orthopaedics/Biotribology laboratory.

Table F-1. List of vendors and prices for all parts and services related to the device. The list continues on the following page.

PART or EXPENDITURE	VENDOR	PART #	QTY	PRICE EACH	TOTAL
Parker Par-15 Series Valve	Applied Fluid Power	W21542583B	1	$714.15	$714.15
Parker Series 2AN Air Cylinder	Applied Fluid Power	5.00 HB2ANU19AX2.00	1	537.80	537.80
Frame - Cold rolled Steel	ESM Machine Shop	N/A	1	256.02	256.02
Machining Costs	ESM Machine Shop	N/A	1	2,800.00	2,800.00
SS UHMWPE Tray + machining	ESM Machine Shop	N/A	1	2,500.00	2,500.00
Motion Controller PCI 7324	National Instruments	777977-14	1	985.00	985.00
Motion Controller Kit, Cable	National Instruments	18638102	1	135.00	135.00
UMI 7764 wiring kit	National Instruments	777978-01	1	265.50	265.50
PCI-6503 NI-DAQ kit for valve	National Instruments	777690-01	1	112.50	112.50
8 channel SSR series backplane	National Instruments	776290-908	1	76.50	76.50
Type NB1 50-pin ribbon cable	National Instruments	180524-10	1	27.00	27.00
SSR-OAC-5A output modules	National Instruments	776240-03	4	10.80	43.20
SB/6B series power supply	National Instruments	776237-35	1	234.00	234.00
F/E Motors and drivers	Oriental Motors	UPK596AW-T20	2	1,250.00	2,500.00
Table motors and drivers	Oriental Motors	CSK596-NATA	2	578.00	1,156.00
Motor Couplings	Oriental Motors	MC4014F10C	2	76.00	152.00
Torrington VAK bearings (5/8")	Motion Industries	VAK - 5/8	6	20.72	124.32
Shipping	Motion Industries	N/A	1	7.00	7.00
Accuslide 2HB ProfileRail System	Thomson Industries	2HB-M20 325mm	2	2,544.55	5,089.10

PART or EXPENDITURE	VENDOR	PART #	QTY	PRICE EACH	TOTAL
Motor Couplings for Accuslide	Thomson Industries	MCM-14-34	2	62.00	124.00
CoCr bar stock	Carpenter	ASTM 5799	1	322.44	322.44
CoCr machining	ESM Machine Shop	N/A	1	200.00	200.00
UHMWPE	HSS, PolyHi Solidur	4150HP Ram Extruded	1	0.00	0.00
Rulon J sleeve bearings	Small Parts	Y-SBP-12/24	4	14.44	57.76
Steel Bars for plate sliding	Small Parts	Y-ZRS-12-24	4	9.58	38.32
Miscellaneous bolts and washers	McMaster-Carr	N/A	1	101.43	101.43
Exhaust muffler (heavy duty)	McMaster-Carr	4440K44	1	6.11	6.11
5/8" diameter cold-rolled steel bar	Small Parts	O-ZRS-10-24	2	6.30	12.60
Shipping	Small Parts	N/A	1	6.00	6.00
Bovine calf serum (500 ml)	Hyclone Laboratories	SH30073.03	3	25.50	76.50
PVC hose (3/8" ID, 5/8" OD)	McMaster-Carr	54075K44	20	0.51	10.20
Steel hose nipples (1/2" NPT), 4ct	McMaster-Carr	5350K59	2	5.89	11.78
Steel hose nipples (1/4" NPT), 10ct	McMaster-Carr	5350K36	1	9.82	9.82
TOTAL DEVICE COST					**$18,692.05**

Appendix G
Estimation of Lifted Weight

An estimate of the weight of the lifted parts (table support, linear guides, SS tray, etc.) was needed to predict the force at the material interface. Table G-1 lists the known or estimated (through density and volume calculations) weight of the most contributory parts lifted by the pneumatic cylinder.

Table G-1. Known and estimated weights of parts that are lifted by the pneumatic cylinder.

Part	Volume	Volume	Density	Weight	Weight
	(in^3)	(m^3)	(kg/m^3)	(kg)	(lbs)
Table Support	*321.8	0.00527	7850.0	41.4	91.1
Stainless Tray	*151.7	0.00249	8000.0	19.9	43.8
Tray spacer	*57.50	0.00094	7850.0	7.4	16.3
Tray support	*57.50	0.00094	7850.0	7.4	16.3
Linear guide 1				15.0	33.0
Linear guide 2				15.0	33.0
2 guide motors				7.5	16.5
			Lifted Weight	**113.6**	**249.9**

***Estimated volume from known dimensions**

Appendix H

Finite Element Results and Boundary Conditions

The finite element results shown in Chapter 3 were calculated using IDEAS CAD software. The created mesh had the following characteristics and boundary conditions:

- Material modulus of elasticity = 29,000 ksi
- Grounded bottom plate
- 500 lbf applied vertically to each outer top bar using 5 equally distributed line loads per bar
- 1000 lbf applied vertically to the top middle bar using 5 equally distributed line loads
- 1" x 1" x 1" triangular element size

The IDEAS finite element analysis output the following results:

- Maximum Von Mises stress = **1.64 ksi**
- Maximum displacement = **0.00185"**

Vita

Matthew Thompson was born in Pittsburgh, Pennsylvania on March 19, 1974. Upon graduation from Montour High School in McKees Rocks, Pennsylvania in June 1992, he began his studies at Virginia Tech. He completed his Bachelor's degree in Engineering Science and Mechanics (ESM) with a minor in Mathematics in December of 1996. He remained in Blacksburg for the next eight months as a graduate researcher in the Department of Materials Science and Engineering. Sixteen months later in January of 1999, Matthew returned to Virginia Tech to pursue his Master's degree in Mechanical Engineering (ME). Working under Dr. Jonette Foy of the ESM Department, his focus of study was in biomedical engineering, particularly orthopedics. In addition to his research, Matthew served as teaching assistant in ME for four semesters. He plans to begin work in the total knee replacement laboratory at the Institute of Orthopedic Research and Education in Houston, Texas this fall.