Georgia Institute of Technology
George W. Woodruff School of Mechanical Engineering
ME 2110 - Creative Decisions and Design
Spring 2017

STUDIO III
MACHINING & MECHATRONICS

A detailed understanding of the capabilities and limitations of the available hardware, software and fabrication tools is a requirement for successful design and development programs. For example, knowledge of the capabilities and limitations of the motors and sensors is needed to design mechatronic systems. Knowledge of manufacturing processes, such as machining with milling machines, lathes, bandsaws, and drill presses, is required to guide the design and assessment of feasible, manufacturable design concepts. This studio will help develop an understanding of the equipment and manufacturing processes available in ME 2110.

Hoists are commonly utilized in engineering. Some useful hoist systems include cranes, elevators, and other forms of lifts. When designing a hoist, it is critical to choose mechanisms that provide the necessary mechanical advantage to safely lift the target weight at the desired speed. The goal of this studio is to build components necessary for a hoist system for a miniature elevator. These components will be useful for utilizing the motor in later efforts during the big design project for this course.

You will make drivetrain parts (coupler and mount) for a hoist mechanism. A photograph of an elevator hoist system is shown in Figure 1. A DC motor driving a spur gear and spindle mechanism powers the hoist. The goal of the hoist is to lift and stabilize the elevator platform at various heights. Once you have machined your parts, the parts will be measured to ensure they meet the tolerances on the attached drawings. Your efforts will be scored based on how close you are to the target dimensions specified.

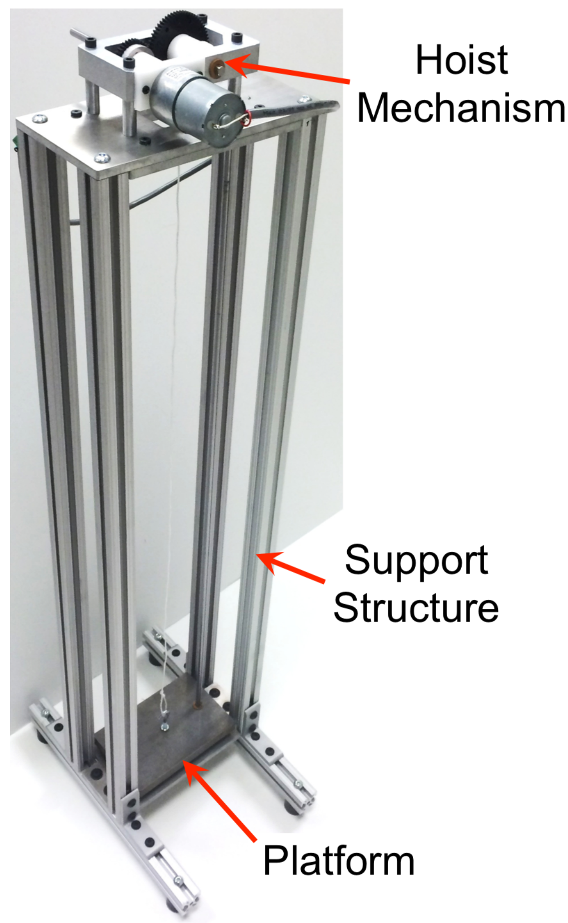


Figure 1 – Photograph of Miniature Elevator System

Your team will be split into two subgroups, *Group A* and *Group B*, and the subgroups will perform the mechatronics and machining components of this studio independently, with *Group A* beginning with mechatronics and *Group B* beginning with machining.

This studio is pass/fail. You must complete the assigned tasks to pass the course.

Reminder: *Note that the below schedule is concurrent with the introductory design project. You also have deliverables in Weeks 5 and 6 for the introductory design project (see Studio 2 handout).*

Week 3 (January 23 – January 27)

Group A:

In Week 3 of the semester, *Group A* will learn how to program the National Instruments myRIO controller to use sensors and actuators. The tasks found in **Mechatronics Lab Tasks: *Group A*** in the **Mechatronics Section** of this document will be completed. You will have to demonstrate proper execution of the tasks to your Studio Instructor or TA. They will sign your assignment sheet, indicating the tasks have been completed.

Group B:

In Week 3 of the semester, *Group B* will learn how to use the machine tools in the ME 2110 machine shop. An instructional seminar will take place in which the TA will instruct the group on proper lab safety, tool checkout procedures, and use of the machine tools. You will then begin to machine the components needed to complete the hoist. Process plans and mechanical drawings for the components are provided in the **Machining Section** of this document. You will receive plastic (Delrin) workpieces from which you will machine your components.

Week 4 (January 30 – February 3)

Group A:

In Week 4, *Group A* will move on to the machining section of the project. They will undergo the same machining seminar as *Group B* and receive their own workpieces.

Group B:

In Week 4, *Group B* will learn how to use the mechatronics kit. They will complete the **Mechatronics Lab Tasks: *Group B*** found in the **Mechatronics Section** of this document.

Week 5 (February 6 – February 10)

Week 5 gives you time to finish your parts and any remaining mechatronics exercises.

Week 6 (February 13 – February 17)

Week 6 gives you time to finish your parts and any remaining mechatronics exercises.

Outside of Studio

In addition to doing work during your scheduled studio time, the ME 2110 Machine Shop in MRDC 2202-03 will be open for other periods of time throughout the week. These periods are known as "Open Lab." Any ME 2110 student may use the ME 2110 Machine Shop during Open Lab. The Open Lab schedule is posted on the ME 2110 website. Due to limited time during scheduled studio, you most likely will need to utilize Open Lab to complete your deliverables.

Deliverables

Table 1 shows the deliverable schedule for this project.

Table 1 – Studio 3 Deliverables for Each Individual Student During Weeks 4 - 6

Deliverable Schedule	***Group A***	***Group B***
Week 4 Deliverables, due at the Beginning of Studio (January 30 – February 3)	1) 4 of 7 completed and *signed* **Mechatronics Lab Tasks: *Group A***	1) Motor Coupler
Week 5 Deliverables, due at the Beginning of Studio (February 6 - 10)	1) Motor Coupler 2) All 7 completed and *signed* **Mechatronics Lab Tasks: *Group A***	1) Motor Mount 2) 4 of 7 completed and *signed* **Mechatronics Lab Tasks: *Group B***
Week 6 Deliverables, due at the Beginning of Studio (February 13 - 17)	1) Motor Mount	1) All 7 completed and *signed* **Mechatronics Lab Tasks: *Group B***

Mechatronics Section

This lab will provide experience with integrating electrical, mechanical, and pneumatic systems. The lab comprises of two sections performed over four weeks. During the first week, *Group A* will complete one part of the lab, labeled "Mechatronics Lab Tasks: Group A"; during the second week, *Group B* will complete "Mechatronics Lab Tasks: Group B". Although the programming style will not be graded, the programs created during these two labs should be helpful in developing the programs for the final project. Therefore, it is important to program using standard structure and commenting practices so that the program will be easy to follow when used as a reference later in the semester.

Before attempting to perform these programming tasks, read the **Mechatronics and Pneumatics Manual** available on the course website. The manual provides background information on the layout of the National Instruments myRIO controller and explains how to implement the electro-mechanical-pneumatic components in a design. The manual also contains instructions for installing the required LabVIEW software on your computer.

At the time of each checkpoint shown in Table 1, each student is responsible for showing progress through the assignment as indicated by a signed task checklist. The tasks for *Group A* and *Group B*, and the associated checklists, are provided on the subsequent two pages. After each task is completed, the operation must be successfully demonstrated to either the section instructor or a TA. The instructor or TA will initial the checklist confirming that the team has successfully completed that task element. Remember that each individual needs a separately signed checklist. Feel free to ask the instructor, TA, or peers for help in completion of this assignment, however each student in the team must be prepared to answer questions about the program before the instructor or TA will initial the checklist.

Mechatronics Lab Tasks: *Group A,* Name:____

1. Connect 2 DC motors, 2 solenoids and 2 valves to the driver board. Connect all the sensors to the sensor board. Study the LabVIEW programming template, and use the template to **verify** that every component operates correctly. In addition, look at the other VIs that are in the template, run them, and be prepared to briefly discuss what they do.
2. Follow the steps in this video: https://youtu.be/Ak-N8o6C7C0. As with all programs you create, be prepared to answer any questions about it.
3. Connect a DC motor and the potentiometer. Make the speed of the motor proportional to the value you read from the potentiometer.
4. Connect a momentary switch to a Digital Input and have the DC motor run at full speed when the switch is held down and turn off when the switch is depressed. Each time the switch is pressed turn on LED1 for 1 second. The 1 second starts the moment when the switch is pressed, e.g the LED will turn off after 1 second even if the switch is still held down.

    − Hint: Connect the switch to a Digital Input, read in the value of the Digital Input when the button is pressed and the value of digital input when the button is released.

5. Connect two micro switches, the banana plugs and one pneumatic cylinder. The program starts with the cylinder retracted. The program starts by touching the banana plugs together. When switch one is pressed, the cylinder should extend and remain extended after the switch is released. When the other switch is pressed, the cylinder should retract and remain retracted. This loop continues while the banana plugs are held together. If the banana plugs are released at any time the cylinder is retracted immediately. The loop starts form the beginning when the plugs are retouched. **Set this program to run automatically on startup (without being connected to the computer).**
6. Connect two solenoids and two micro switches. When one micro switch is pressed, one solenoid is activated for 4 seconds and then released. When the other micro switch is pressed, the other solenoid is activated for 1750 ms and then released. When one actuator is active the other cannot be activated. Use LED1 and LED2 to indicate when each actuator is active.

    − Hint: It may help to use "Elapsed time" and "Time Delay" Express VIs.

7. Connect 2 solenoids and two micro switches. At the beginning, have 1 solenoid activated. Once each switch has been pressed at least once and in any order (they don't have to be held down together), the first solenoid will be deactivated and the second one will be activated for 5 seconds. After that, the cycle starts over. Two LEDs of your choosing will show the states of the switches **at all times (even when the first solenoid is off and the second is on)**.

*** Stop each program with a button you create on the front panel, unless stated otherwise.**

Checklist for *Group A*:

1. __________	DATE: __________	5. __________	DATE: __________
2. __________	DATE: __________	6. __________	DATE: __________
3. __________	DATE: __________	7. __________	DATE: __________
4. __________	DATE: __________		

Mechatronics Lab Tasks: *Group B,* Name:____

1. Connect 2 DC motors, 2 solenoids and 2 valves to the driver board. Connect all the sensors to the sensor board. Study the LabVIEW programming template, and use the template to **verify** that every component operates correctly. In addition, look at the other VIs that are in the template, run them, and be prepared to briefly discuss what they do.
2. Follow the steps in this video: https://youtu.be/Ak-N8o6C7C0. As with all programs you create, be prepared to answer any questions about it.
3. Connect both DC motors. Make them run clockwise for five seconds, stop for 2.5 seconds, run counter-clockwise for five seconds, and then stop for 2.5 seconds. Repeat this sequence four times.

   − Hint: It may help to use "Elapsed time" and "Time Delay" Express VIs.
4. Connect the IR distance sensor and one DC motor. Have the motor run if the reading is greater than 2.3 V and have the motor stop if the reading is less than 2.3 V. Use a chart to display the voltage data continuously, but change the speed of the motor at most every 2 seconds.

   − Hint: You can use a delay after you write to the motors. Use an indicator to plot sensor readings on the front panel continuously.
5. Connect the banana plugs and 2 DC motors. Run the first motor for 3 seconds after the banana plugs have been touched. Run the second motor for 4 seconds, 2 seconds after the banana plugs have been pressed. This loop continues while the banana plugs are held together. If the banana plugs are released at any time the motors stop. The loop starts form the beginning when the plugs are retouched. **Set this program to run automatically on startup (without being connected to the computer).**
6. Connect the encoder and the pneumatics. When the encoder is rotated 2 complete revolutions, the actuator should extend and remain extended until the encoder is rotated another 3 complete revolutions. Use an indicator on the front panel to display how many revolutions have been completed during each stage. The cylinder should only extend 4 times and then remain retracted regardless of how many times the encoder is rotated, but you should still show the encoder reading on the front panel.
7. Connect the 2 long-arm switches and one motor. At the beginning, the motor should run at 50% speed with all 4 LEDs turned on. After each switch has been pressed at least once and in any order (they don't have to be held down together), the motor must switch direction for 3.5 seconds. After that, the cycle starts over. Turn off LED 1 when the first switch is pressed, turn off LED 2 when the second switch is pressed. The LEDs will need to indicate the switch state **at all times (even when the motor has switched directions.)** LED 0 and LED 3 should be on the entire time.

*** Stop each program with a button you create on the front panel, unless stated otherwise.**

Checklist for *Group B*:

1. __________	DATE: __________	5. __________	DATE: __________
2. __________	DATE: __________	6. __________	DATE: __________
3. __________	DATE: __________	7. __________	DATE: __________
4. __________	DATE: __________		

Machining Section

Elevator Hoist System

In the machining section of this studio, you will machine the components needed to complete the elevator hoist system. Figure 3 shows a solid model of the elevator hoist with labeled components. The hoist mechanism is mounted atop a support structure. The hoist mechanism lifts the platform. Two guide rods allow the platform to be lifted without swinging or twisting.

Figure 4 shows the hoist mechanism with drivetrain components. The small DC motor powers the mechanism. It attaches to the mechanism frame via a motor mount. The motor coupler attaches to the motor shaft and engages with the pinion collar, locking their rotation together. Therefore, the motor directly drives the pinion. This transmits the motor's rotation to the output gear, which drives the spindle. As the spindle turns, a hoist string is retracted or unwound depending on the direction of rotation. This action raises or lowers the platform.

Each student will machine the motor coupler and the motor mount. Mechanical drawings for these two components and associated detailed machining instructions are provided on the last few pages of this handout. Assembly instructions for the drivetrain components are provided in the next section.

Review the machine shop safety rules in the **Machine Shop Safety** section at the end of this document before you attend the studio session. Be sure to familiarize yourself with these rules and arrive to studio dressed appropriately for working in the machine shop.

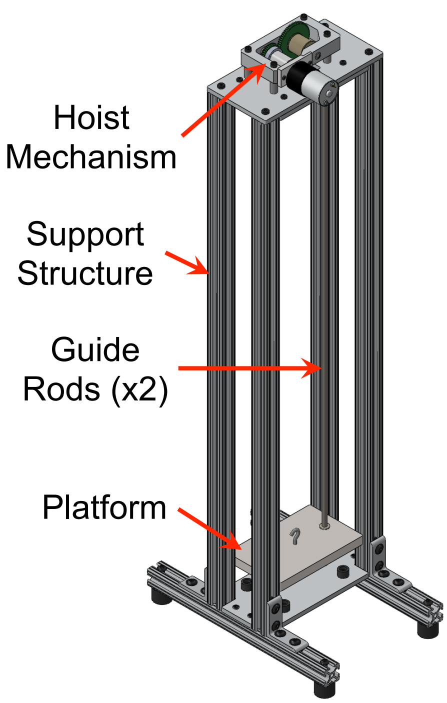


Figure 3 – Isometric Assembled View of the Elevator Hoist System

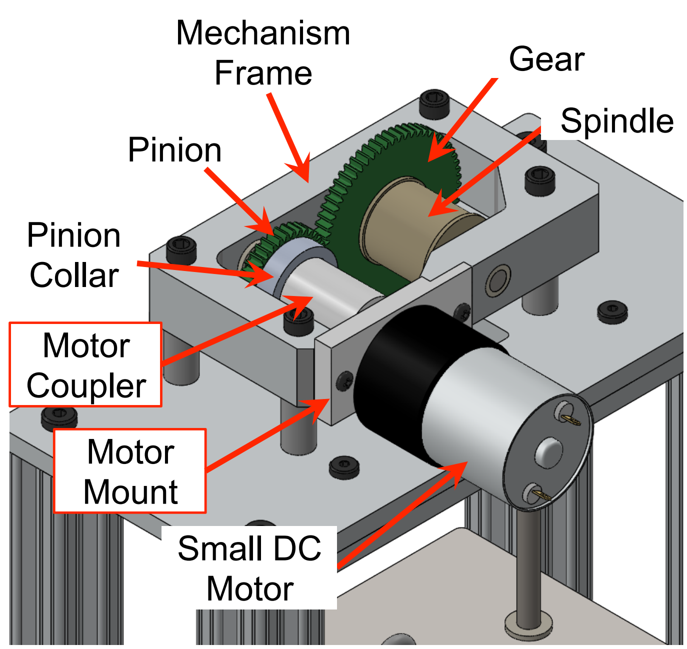


Figure 4 – Hoist Mechanism and Drivetrain Components

Hoist Drivetrain Assembly

An exploded view of the hoist drivetrain before assembly is shown in Figure 5. Assembly requires the motor mount and coupler you machined, the small DC motor from your team's mechatronics kit, three M3x0.5 screws to mount the motor, a #6-32 set screw for the coupler, and two #4-40 screws to attach the drivetrain to the hoist mechanism frame. The screws will be provided. They should be hand-tightened using a small Phillips screwdriver for the M3x0.5 and #4-40 screws and a 1/16" hex key for the #6-32 set screw. Care should be taken not to over-tighten any screws so that they do not they strip and become difficult to remove. The following steps detail the assembly process:

1. Insert the small DC motor shaft through the 1/2" hole in your motor mount.
2. Attach the small DC motor to the motor mount. Align the three 3/16" holes in your mount with the mounting holes on the motor, and then screw in the three M3x0.5 screws (stainless steel). It is best to loosely thread all three screws before tightening them in an alternating pattern.
3. Insert the motor coupler onto the motor shaft via the 0.242" hole drilled in coupler. Align the coupler such that the flat on the shaft is perpendicular to the axis of the radial set screw hole in the coupler.
4. Thread the #6-32 set screw into the radial hole in the coupler. Hand-tighten so that the screw grips the motor shaft and locks the rotation of the motor shaft and coupler.

   The drivetrain is now fully assembled, and can be mounted on the hoist mechanism frame. For the Elevator Contest, Steps 1 through 4 should be completed in advance of your turn, before your two-minute time limit begins.
5. Position the assembled drivetrain such that the motor mount lines up with the holes for the two #4-40 screws, and rotate the pinion gear such that the D-slot in the pinion collar aligns with the flat on the coupler shoulder. After aligning the parts, push the drivetrain together so that the coupler engages with the pinion collar.
6. Use the two #4-40 screws (*black* oxide stainless steel) to mount the drivetrain to the mechanism frame. Again, be careful not to over-tighten the screws, or they will strip.

An animation that demonstrates these assembly steps is available on the course website:
http://2110.me.gatech.edu/sites/default/files/documents/Studios/studio2_hoist_drivetrain_assembly.mov

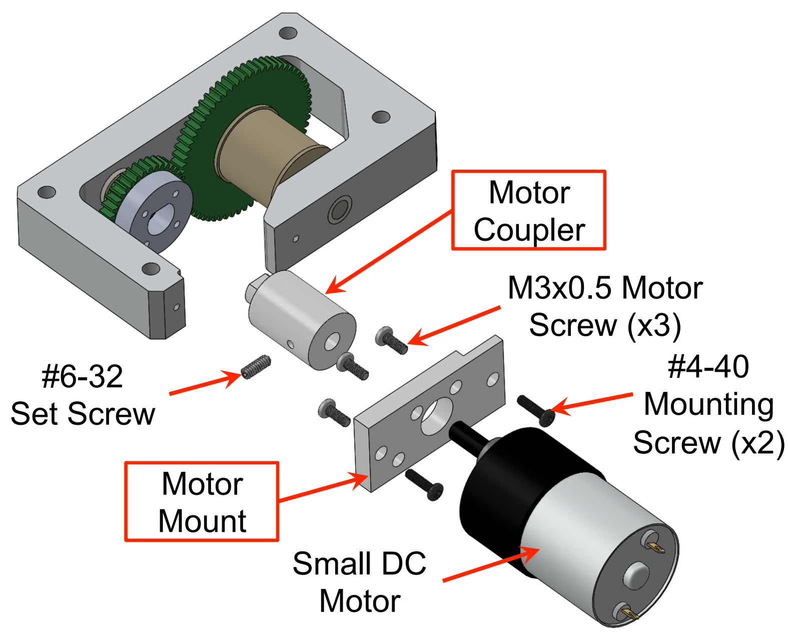


Figure 5 – Exploded View of the Hoist Mechanism Drivetrain Before Assembly

Suggested Process Plan for Small DC Motor Coupler:

Steps 1-6 require a Lathe and Lathe Machining Kit. Steps 7-9 require a Mill and Mill Machining Kit.

1. Obtain nominal 1.5” length of round 3/4” diameter Delrin stock.
2. Face one end on the lathe to make it perpendicular to the axis of rotation. Use no more than a 0.02” longitudinal depth of cut for each facing pass.
3. Flip the piece over and face the other end, leaving the final length of 1.25”.
4. Mount the tailstock onto the lathe. Chuck the larger center drill into the tailstock Jacobs chuck. Use the center drill to start a centered hole in the end of the workpiece.
5. Replace the center drill in the tailstock chuck with the size C drill bit. Use the tailstock and drill bit to bore a 0.242” diameter hole 0.5” deep along the cylindrical axis of the part. To keep track of the drill depth, use the graduated 1/16” markings on the tailstock. Multiple advances of the drill bit and tailstock may be required to obtain the required depth. Also, the drill bit should be advanced and retracted multiple times to clear machining chips from the drill flutes when performing each cut.
6. Flip the piece over, and turn down 0.25” length of the stock on one end to a diameter of 0.39”. Use multiple axial paths with no more than 0.02” radial depths of cut per pass.
7. Using the mill and 1/4” endmill, create the flat on the 0.39”-diameter end of the coupler. Determine the required cut depth from the drawings and the actual diameter of your workpiece.
8. Next, on the mill use the small center drill to start a radial hole 0.3” from the end with the size C hole. Then, use the No. 36 drill bit to drill a radial 0.1065” hole. This hole should terminate on the internal face of the size C hole, not clearing the entire piece. Reminder: do not use a drill bit or center drill when side-milling or face-milling.
9. Using the small tap wrench and #6-32 taps, cut internal threads in the 0.1065” hole. Start the threads with the tapered tap, cutting 5 to 8 threads (turns or revolutions). Then, finish the threads with the plug tap to ensure they are fully cut through the entire hole. This hole will house the provided #6-32 setscrew.

Suggested Process Plan for Small DC Motor Mount:

All steps require a Mill and Mill Machining Kit. Step 5 requires a drill/driver, and Step 7 uses the drill press.

1. Obtain nominal 2.4" length of 1"x1/4" Delrin bar stock.
2. Using the mill, side mill one end of the workpiece to make its face perpendicular to the longitudinal axis of the bar. With the parallels positioned below the workpiece, clamp the workpiece in the vise such that the side you are machining extends out from the vise jaws so you will not run the cutting tool into the vise. Use no more than a 0.02" depth of cut when milling.
3. Then, side mill the other end of the workpiece to the final length of 2.10".
4. Use a 3/16" drill bit to drill the two 0.1875" holes and a pilot hole for the 0.50" hole located along a straight line 0.50" from the edge of the part. Use the mill to drill these holes so that they are properly spaced as indicated in the drawing. Use the parallels or place backing material under the workpiece to avoid drilling into the vise.
5. Remove the workpiece from the mill vise and check out a drill/driver. Use the motor mount drill template and a 3/16" drill bit to drill the three 0.1875" holes for the motor mount screws. The template can be aligned off the edge of the part and using the 0.1875" pilot hole drilled in the center. At a workbench, clamp the template on top of the workpiece with some backing or scrap material underneath so as to not drill into the table, as shown in Figure 6. Then, the holes may be drilled as located by the template.
6. Next, end mill the shoulder feature. The final thickness of the shoulder should be 0.125".
7. Use the drill press and a 1/2" drill bit to bore out the center hole to 0.50". You may wish to use a smaller drill bit (e.g., 3/8") to further widen the pilot hole before using the 1/2" drill bit.

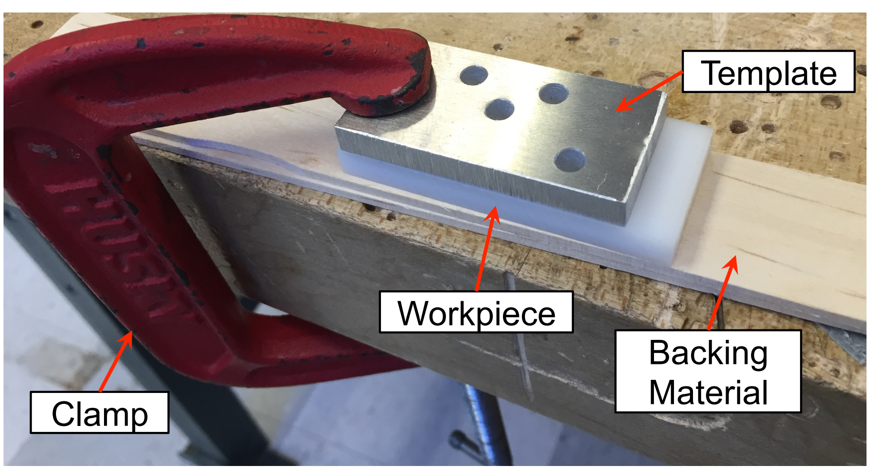
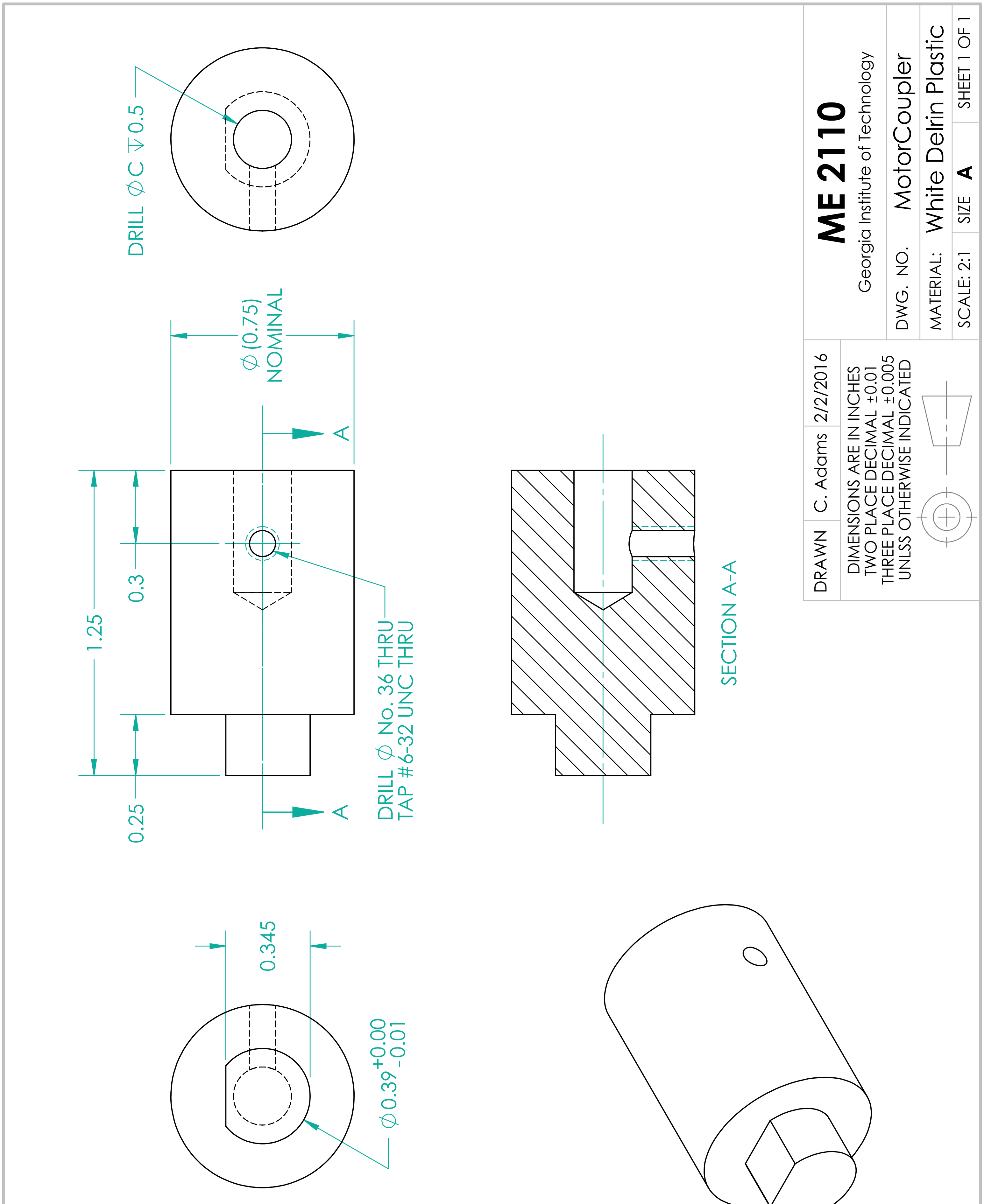
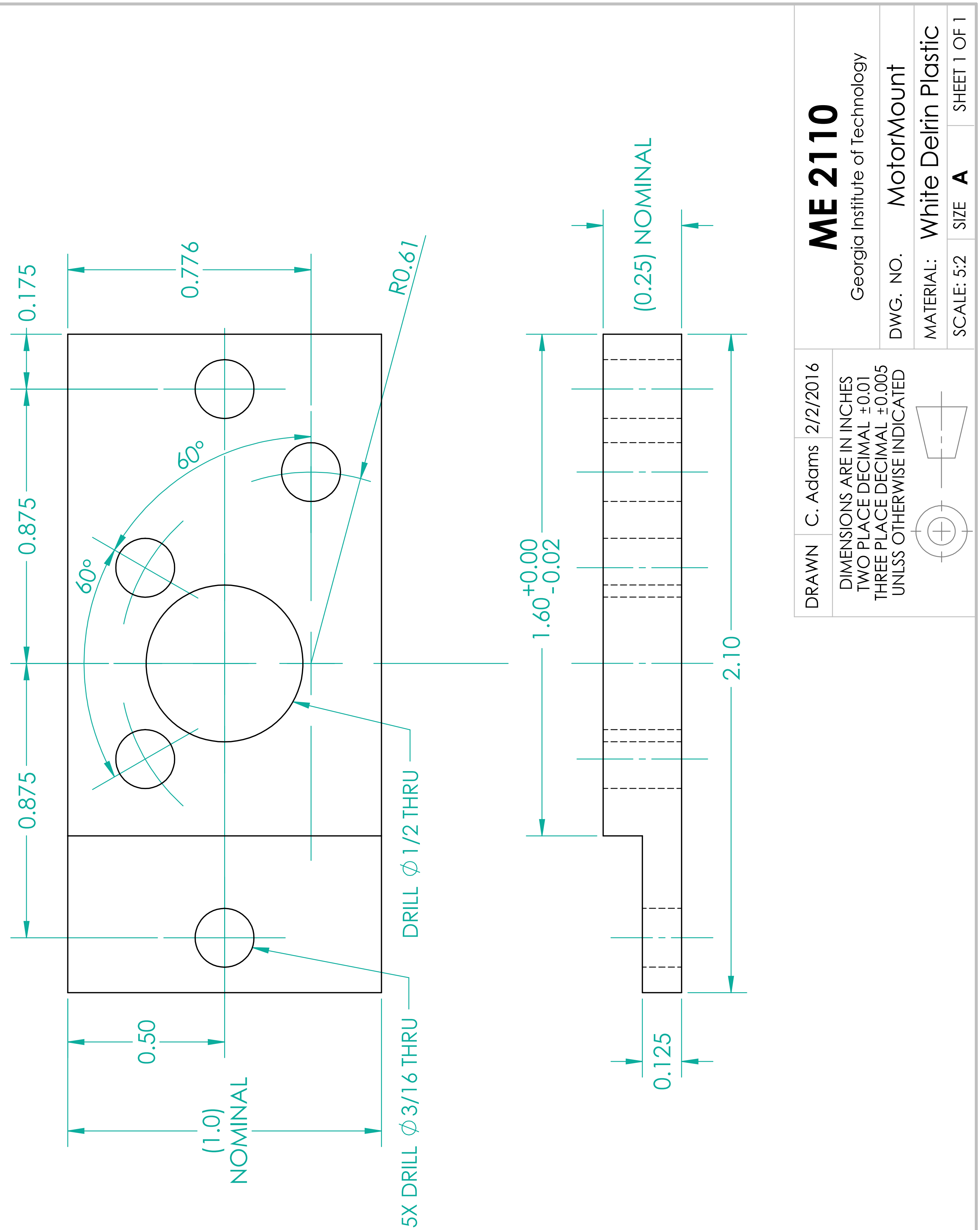


Figure 6 – Clamping Motor Mount Workpiece and Template Before Drilling


DRILL ⌀C ↧0.5
⌀(0.75)
NOMINAL
A
A
1.25
0.3
0.25
DRILL ⌀ No. 36 THRU
TAP #6-32 UNC THRU
SECTION A-A
0.345
⌀0.39 +0.00 -0.01
DRAWN
C. Adams
2/2/2016
DIMENSIONS ARE IN INCHES
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
UNLSS OTHERWISE INDICATED
ME 2110
Georgia Institute of Technology
DWG. NO.
MotorCoupler
MATERIAL:
White Delrin Plastic
SCALE: 2:1
SIZE
A
SHEET 1 OF 1



ME 2110
Georgia Institute of Technology
DWG. NO. MotorMount
MATERIAL: White Delrin Plastic
SCALE: 5:2
SIZE A
SHEET 1 OF 1
DRAWN C. Adams 2/2/2016
DIMENSIONS ARE IN INCHES
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
UNLSS OTHERWISE INDICATED
0.175
0.776
R0.61
60°
60°
0.875
0.875
0.50
(1.0) NOMINAL
5X DRILL ∅3/16 THRU
DRILL ∅1/2 THRU
1.60 +0.00 -0.02
(0.25) NOMINAL
2.10
0.125

MACHINE SHOP SAFETY

ALWAYS WEAR SAFETY GLASSES

• Even when you are not working on a machine, you must wear safety glasses. A chip from a machine someone else is working on could fly into your eye.

CLOTHING, JEWELRY, AND HAIR

• Wear short sleeves or roll up sleeves.
• Wear closed toe shoes and socks.
• Remove all jewelry - watches, bracelets, rings, necklaces, dangling earrings, etc.
• Long hair or beards must be tied back.
  •If your hair is caught in spinning machinery, it will be pulled out if you are lucky. If you are unlucky, you will be pulled into the machine.
• No ties, scarves, and dangling clothes.

SAFE CONDUCT IN THE MACHINE SHOP

• Be aware of what's going on around you.
  •For example, be careful not to bump into someone while they're cutting with the bandsaw (they could lose a finger!).
• Concentrate on what you're doing. If you get tired, leave.
• Don't hurry. If you catch yourself rushing, slow down.
• Don't let someone else talk you into doing something dangerous.
• Don't attempt to measure a part that's moving.
• No fooling around.

MACHINING

• Follow directions. If you don’t know how to do something, ask.
• Before you start the machine:
  • Study the machine. Know which parts move, which are stationary, and which are sharp.
  • Double check that your workpiece is securely held.
  • Remove chuck keys and wrenches.
• Don't rush speeds and feeds. You'll end up damaging your part, the tools, and maybe the machine itself.
• Listen to the machine/tool. If something doesn't sound right, turn the machine off.
• Do not leave machines running unattended.
• Clean up machines after you use them: a dirty machine is unsafe and uncomfortable to work on.
• Do not use compressed air to blow machines clean. This endangers people's eyes and can force dirt into machine bearings.
• Report all broken or non-working machines.

VIOLATIONS OF THESE RULES WILL RESULT IN IMMEDIATE EJECTION FROM THE MACHINE SHOP.