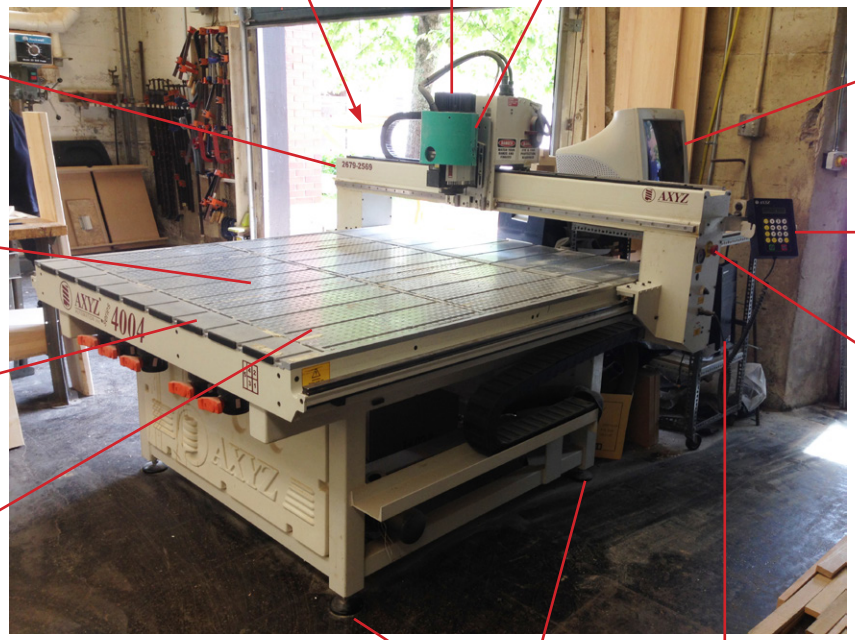
CNC ROUTER WORKSHOP

No. 1

MDF Model Base

- *Basic machine operation*
- *Basic control software functions*
- *Cutting out shapes*
- *Routing out recesses*



Power Panel (behind table)

Spindle (in home position)

Spindle Guard

Gantry (in home position)

Monitor, Keyboard, and Mouse

Checkered Surface (accessible)

Operator Pendant

Smooth Surface (inaccessible)

Emergency Shutoff (both ends of gantry)

T-Slot

Levelling Feet

Computer (below monitor)

ON/OFF

USB slot

V1.1 E.Jannasch, N. Merrithew, E. Wilson: May 2015

The process may seem really complicated for such a simple job, but do keep two things in mind. First, the biggest part of the process is setting up the job, and that will remain more or less constant as the job gets more complex. Second, it won't take long for the process to become a natural routine.

Emily Wilson and Beth Macleod / Spirit Spa Bench

CHECK YOUR FILE

- Is it drawn at 1:1?
- Are the units set to mm?
- Is it a 2d drawing rather than a 3d model?

EXPORT YOUR FILE

- Save it as a .dxf
- If given the option, select R12
- If given the option, select 'binary'

REMEMBER TO BRING

- A USB stick with your .dxf file
- Notes on how you created and exported your file
- A laptop with your active design
- A sheet of MDF at least 2" larger than your shape

OVERVIEW

In this workshop you'll direct the CNC machine to do two things: to router a shallow recess into a sheet of mdf, and then to cut out a shape that includes the recess. The shape can be regular or irregular, and it might serve as a model base. The recess will be rectangular and could accommodate a label.

This document will cover in detail what each group should bring:

I. A laptop with your active design
II. Your .dxf file on a USB stick
III. Notes describing how the file was made
IV. A piece of mdf big enough for the job

It will then show you how to use the CNC to execute your design, in twelve steps:

I. Turn on the CNC machine
II. Clamp the material
III. Turn on the computer; load the file
IV. Analyze and clean up the file
V. Group the shapes by action required
VI. Set actions or "output" (e.g. depth and speed of cut) for each group
VII. Sequence the shapes in order of cut
VIII. Send file to CNC Machine
IX. Install your bit
X. Register the machine to the material
XI. Run the job
XII. Put things away

DESIGNING FOR PRODUCTION

Architects can become accustomed to drawing whatever form they like and having someone else decide what actually gets built.

But if you want to stay in control your project, you have to understand any form as the consequence of specified operations.

In making a 2d file that you will then use to generate a 3d form, you are creating such a sequence of operations and taking complete control of the project.

WHY TRACK HOW THE FILE WAS MADE?

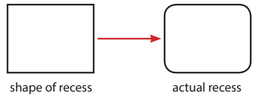
Sometimes the machine confuses inches and mm. It seems to make a difference how the .dxf was generated, so keeping track of your process will help us get to the bottom of the problem and save everyone time in the future.

Please track:

- What software(s) you used to generate the .dxf file
- Whether you started by importing anything to your program (e.g. a site plan)
- Whether the drawing was ever scaled up or down
- Whether the units were ever converted (e.g. between mm and inches),
- Whether you derived the file from a 3d model
- Other facts that you feel might be relevant

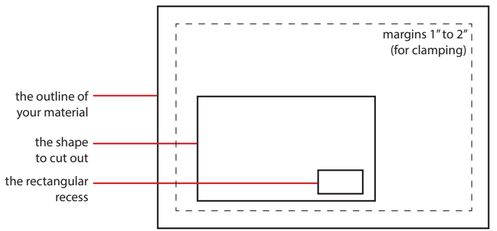
Even after we solve this issue, keeping a brief history of your file development can speed up all kinds of troubleshooting, so it's excellent professional practice.

WHAT YOU NEED TO BRING



The recess will turn out to be a rounded rectangle, because in the world of rotary tools an inside corner is limited by the radius of the bit. But for this project, just draw a rectangle.

Don't worry about the thickness of your material or the depth of the recess: these things will be set at the machine.



I. DESIGN

Your working drawing should consist of exactly three closed shapes:

1. The shape (any shape) you are cutting
2. The rectangular shape of your recess
3. The shape of your mdf stock, for reference

We'll work from a .dxf file on a USB stick, but bring your laptop with your active CAD project for possible troubleshooting.

II. FILE REQUIREMENTS

1. The design must be 1:1
2. It should be defined in mm
3. Make it 2d, not a 2d view of a 3d model
4. Export or back-save it as an R12. Graphics programs may not allow this option, but CAD programs like Vectorworks or Rhino should.
5. If you are given the option between 'text' or 'binary', choose 'binary'
6. If you are offered other save or export options, please consult Emanuel or the TA's
7. For troubleshooting purposes, please bring notes describing how your file was made

III. MATERIAL

1. Thickness min. 1/4", max. 1/2"
2. Length and width at least 2" bigger than your shape to allow for clamping

Feedback:

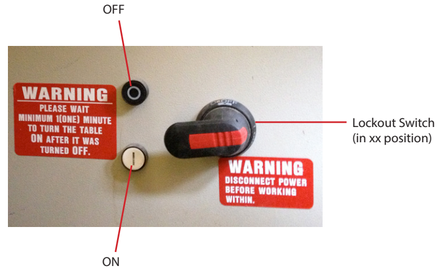
on computer screen

[ON OPERATOR PENDANT]

Instructions:

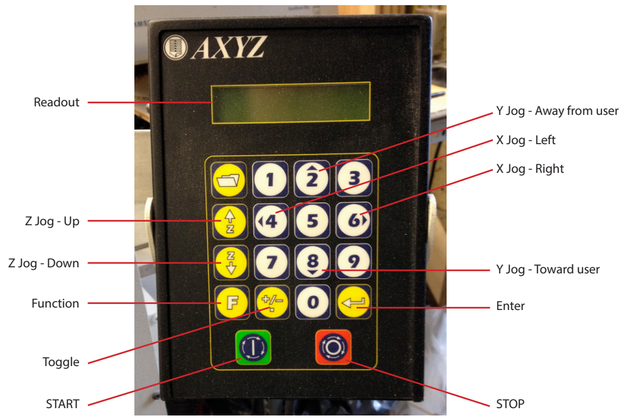
{K-E-Y-S-T-R-O-K-E-S} keyboard

• F • 9 • 2 • enter • pendant



0. ARE YOU IN FACT READY?

1. When preparing to use the CNC machine, carefully check each item listed on the previous page. Once you are ready, make an appointment with an instructor or TA.
2. If you have questions or need help preparing your file, consult one of the TAs
3. Make sure you have the proper safety equipment and training in the woodshop, including proper footwear and protective glasses.

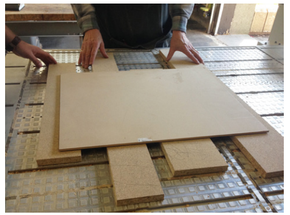


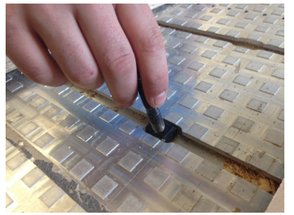
I. TURNING ON THE MACHINE

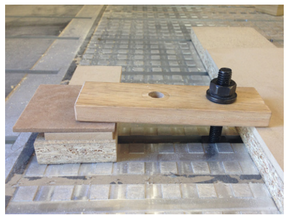
1. If the computer is on or asleep, turn it off
2. Turn the CNC • **on** • at the power panel
3. The pendant readout will say [RETURN TO TABLE ORIGIN?]
4. • **toggle** • to [NO] and • **enter** •
5. The pendant will read [WARM UP SPINDLE?]

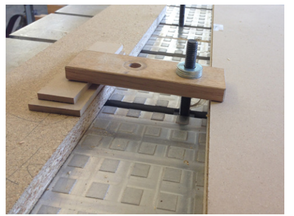
6 • **toggle** • to [YES] and • **enter** •

To remove a bolt from a T-nut, put the nut in a T-slot and use the narrow vise grips on the waist of the bolt. For tougher situations, or to remove a clamping nut, hold the nut in the machinist's vise by the sink.

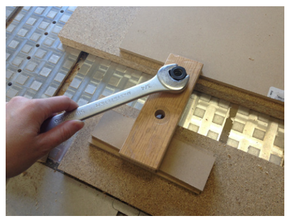

Lay waste strips under stock


Insert clamping bolts into slots


Position the clamp fingers with step blocks


Use washers to protect bolt thread (if necessary)

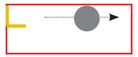

Keep the stock parallel to the table


Tighten the bolts to secure the stock

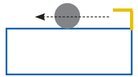
II. CLAMPING THE MATERIAL:

1. Place some waste strips on the table to support your stock. Make sure your completed part will also be supported when the cut is complete.
2. Find as many T-nuts as you'll need.
3. Select your clamping bolts. They must be long enough to accommodate the waste strips and the stock and to pass completely through the clamp nut, but NOT so long that the clamp nut bottoms out.
4. If necessary, add some washers to protect the bottom of the bolt thread.
5. Build a secure stack of step blocks just slightly higher than the waste strips and stock.
6. Place the clamp fingers so the bolt is close to the work, and the stepblocks are far from the bolt.
7. Use a combination square to keep your stock parallel to the long edge of the table.
8. Gradually tighten the clamp nuts, checking the alignment of the stock as you go.
9. Be sure NOT to have anything projecting into the path of the gantry.
10. At this point you should select the router bit for your project: no smaller than 1/4" diameter and no bigger than 3/8".

FOUR KINDS OF SHAPE



Red - Tool cuts to the inside to make a dimensioned hole



Blue - Tool cuts to the outside to make a dimensioned part

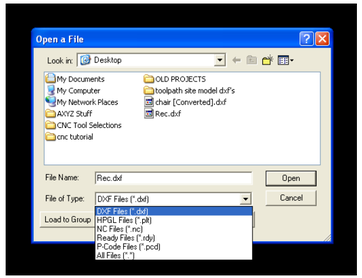
Green - Linear or 'open' shapes

Green X - Dimensionless points or loci. These are used to mark drill points.

The yellow L marks the starting point of a cut, the direction of cut, and the side of the line on which the router will cut.

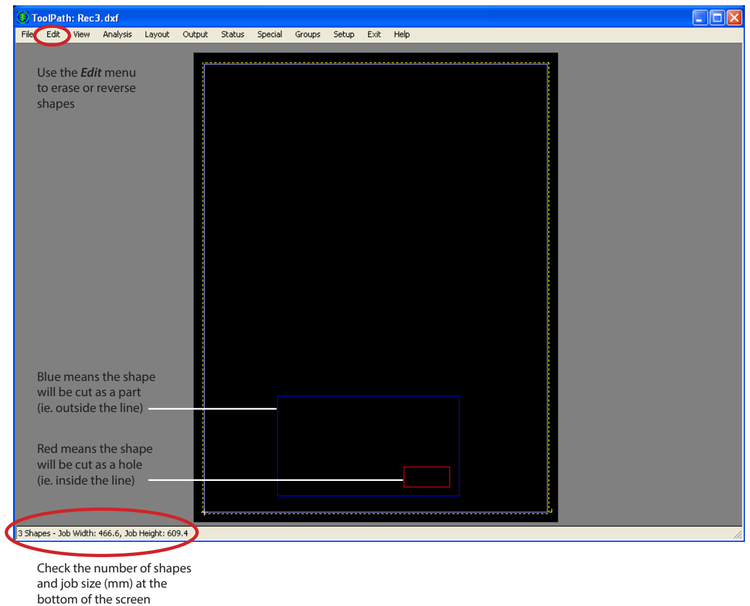
FOR SCALING YOUR DXF UP OR DOWN:

inches x 25.4 gives mm
mm x 0.03937 gives inches



III. LOAD YOUR FILE

1. Turn on the Computer
2. Go to the ***Emanuel*** side, not ***Student***
3. Insert your USB stick into the computer
4. Drag your .dxf to the desktop
5. Remove and pocket your USB stick
6. Click on the ***Toolpath*** icon
7. Under ***Look in***, pick ***Desktop***
8. In the ***Files of Type*** menu, pick ***.dxf***
9. Find your file and open it



IV. CHECK SIZE AND SHAPES

1. Check at the bottom of the window for ***job size in mm***. If it looks like you have a unit or scale error, you'll need to fix the file in your CAD program and re-export. If you see vertical magenta lines on the screen, the file is bigger than the table. There may also be stray shapes that are making the job too big. They can be erased as below.
2. Check the shapes - are there the correct number? Extra shapes that may be sitting on top of others can be erased.
3. To erase a shape:
   - Click on ***Edit*** then ***Erase***
   - Select the shapes by clicking on them (they turn white)
   - Click ***Undo 1*** if you've made a bad selection, or click ***Erase Shapes*** to erase
4. In the ***Edit*** menu you can also "reverse" a shape between red (inside shape or hole) and blue (outside shape or part):
   - Select a shape by using ***Next*** or ***Previous*** or keyboard **-N-** or **-P-**
   - Click on ***Reverse Shape***

OTHER OUTPUT FUNCTIONS

Multipass

Lead-in

Fillet

Tab Width

Lead-in

Knife Offset

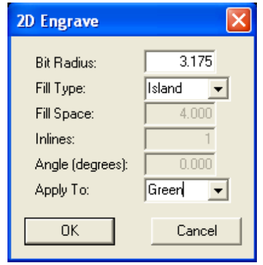
The middle column shows the mm equivalent of common fractions on the left, whether applied to bit diameter or radius.

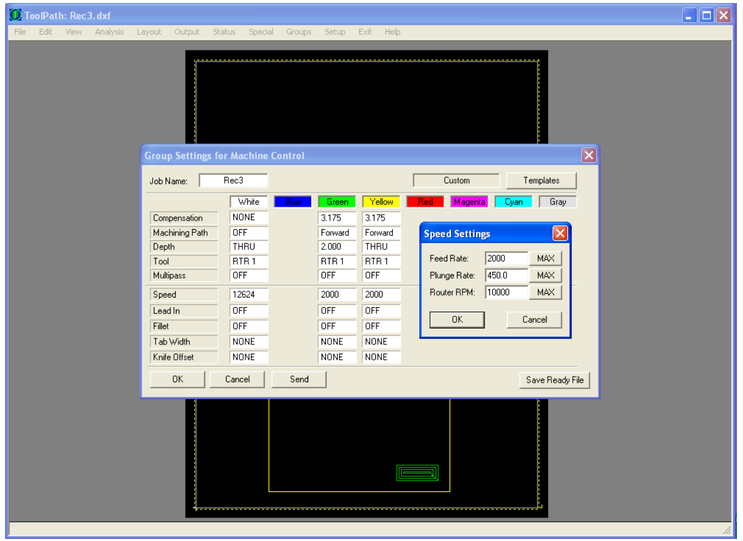
The 2/3 column shows an approximate value in mm of 2/3 of the fractional amount: this is useful when defining a 2d engrave.

fraction	mm.	2/3
1/64	0.3969	0.26
1/32	0.7938	0.5
1/16	1.5875	1
3/32	2.3813	1.6
1/8	3.175	2
5/32	3.9688	2.6
3/16	4.7625	3.1
1/4	6.35	4.2
5/16	7.9375	5.2
5/8	9.525	6.3
7/16	11.1125	7.3
1/2	12.7	8.4
9/16	14.2875	9.4
5/8	15.875	10.5
3/4	19.05	12.6
1	25.4	16.8

There are eight group colours that include red, blue, yellow, and green. However, when used as group labels these colours DO NOT affect whether the bit cuts to the inside or outside. For this exercise we are avoiding blue and red groups to remind ourselves which screen we are looking at at any given time, and which process we are working with.

For this project you have 3 functions: the reference shape will be ignored, the recess will be a 2d engrave, and the outline will be cut. Place your shapes in groups as follows:
- Leave the reference in the White group
- Put the recess in the Green group
- Put the outline in the Yellow group





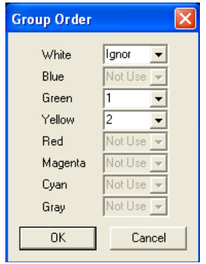
V. GROUP THE SHAPES

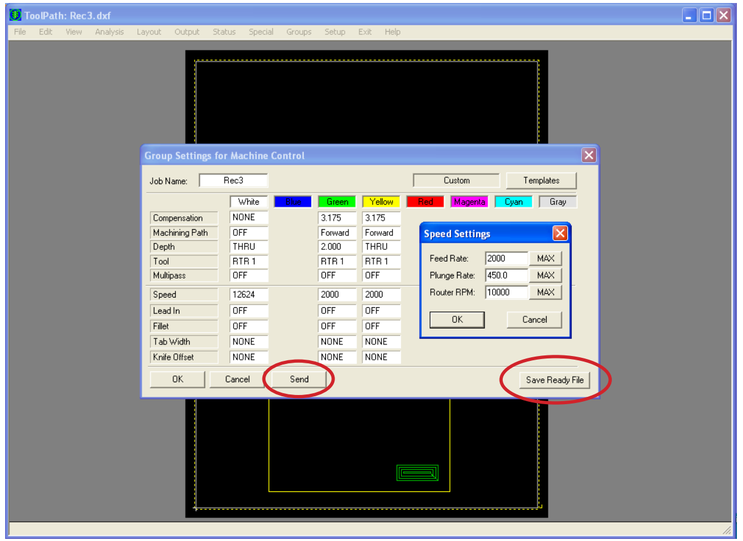
1. Group the shapes according to the machine operations required:
   - Click on the ***Groups*** menu
2. Create the first group:
   - Click ***Move to Group***
   - Select the shape(s) desired for one group
   - Click on ***To Group***
   - Click on the intended colour
3. Repeat step 2 for the other colours/groups

VI. SET THE OUTPUT

1. Define the depth and texture of the recess:
   - Go to ***Special***
   - Select ***Engrave 2D***
   - Enter the bit diameter
   - Choose the ***Island*** pattern
   - Select the group(s) you want to engrave
   - Click ***OK***
2. Set basic function for each group:
   - Go to ***Output***
   - Machining Path ***Forward***, except for white ***OFF***
   - Compensation is the bit RADIUS. Select the appropriate dimension and click +
   - If the correct compensation is not available, you can enter your own
3. Set depth and speeds for each group:
   - Set depth in ***mm*** for recess (Green)
   - Set depth to ***THRU*** for shape (Yellow)
   - Depth for off group (White) is irrelevant
   - Speeds for all groups:
     Feed Rate ***2000***
     Plunge Rate ***450***
     Router RPM ***12,000***
4. For this project, all other settings can be ignored

You can also sequence in the edit menu. Click on the shapes in forward or reverse order of cut, and then click on ***forward*** or ***reverse***, accordingly. This method allows you to sequence cuts within a group, which can also be useful.





VII. SEQUENCE THE SHAPES

It is critical that you perform the engrave before you cut the shape loose from the material:

1. In the edit menu, look at the ***Sequence*** option.
2. Click ***By Group***
3. The order shown under should be okay, because Green (the engrave) comes before Yellow (the cut). If it isn't, you can click on the various group numbers to change the group order.

VIII. SEND AND TRANSMIT FILE

1. Erase any existing files on the machine pendant by pressing • **F** • **9** • **2** • **enter** •
2. Go to ***Output***
3. ***Save Ready File***. Pay attention to the proposed name and modify as needed.
3. Then ***Send*** (this is actually more like "prepare to send"). The cyan lines you now see show the entire toolpath of the centre of the bit.
4. Now, try to ***Transmit***. If you fail to see the progress bars at the bottom right of the screen, and if the screen reverts quickly from the cyan to a more colourful version, the computer can't find the CNC. You probably need to restart the computer. When you re-open toolpath, look for your .RDY file - it has all the outputs saved.
5. If you do see the progress bars and if the cyan remains, you are transmitting.
6. Check the pendant to confirm that the file transmission is complete.

At this point, everyone in your group should practice jogging the gantry with the **• 2 •**, **• 4 •**, **• 6 •** and **• 8 •** keys.

Also jog through the speeds [MEDIUM], [SLOW], [INCREMENT], and back to [FAST].

Notice that [INCREMENT] has several functions:

- punching the key for **single steps** of 0.1mm
- **holding** a key, for repeating steps
- **continuing to hold** for accelerating steps

IX. INSTALL YOUR BIT

1. Prepare the tool holder fixture:
   - Secure it in the nearest woodworking vise
   - Use the plunger to lock it in a toolholder
2. Remove the existing collet:
   - Use the spanner to remove the collet nut
   - Push on one side of the collet to snap it out
   - Notice how the groove in the collet is captured by the internal thread on the nut. This allows the nut to press the collet into the cone, and extract it from the cone.
3. Install the bit:
   - Snap a 1/4" collet into the nut, and engage the nut with the holder
   - NEVER put the collet into the holder unless it is snapped into a nut
   - Insert the bit, so that as much of the shaft is in the collet as possible, but such that the helical grooves are fully exposed
   - Use the spanner to tighten the nut securely
4. Open the air valve on the dust-collector
5. Move the spindle to a convenient spot:
   - Move the gantry to the left **• 4 •**
   - Move the head towards you **• 8 •**
6. Mount the tool holder into the spindle:
   - With your right hand, hold the toolholder into the spindle cone
   - With your left hand, press the **green button** on the side of the spindle

If you are performing several jobs on the same piece of material, or the same job on repeat materials, you do not need to re-set F84 each time.

Similarly, when one job finishes, the spindle will return to the F3 job origin. The machine should retain this origin until you reset F3.

If you aneed to confirm that F3 has been maintained, use F13 “return to job origin.”

IX. REGISTRATION

1. Registration starts with function 84 which enables you to set three critical heights, starting with the material surface:
   - Key in • **F** • **8** • **4** • **enter** •
   - Then jog the spindle to a point over your material that you can see and reach
   - Lower the spindle with the • **Z Down** • key
   - As you approach the material, • **toggle** • down to lower speeds
   - Moving a piece of paper back and forth under the bit helps you to see when it just reaches the table
   - Punch • **enter** • to set the surface
   - Touch the • **Z Up** • key to clear the surface
2. Next, set the Lift Bottom. This is the level of a THRU cut. Cuts specified as deeper than Lift Bottom will not cut.
   - jog past the edge of the material
   - jog down to the desired lift bottom
   - Hit • **enter** •
3. Then, set the Lift Top, a height that clears the clamps and all other parts of the project.
   - Raise the spindle to a suitable height
   - Hit • **enter** •
4. Horizontal Registration works differently. First you move the head to the registration point, then you enter F3.
   - Jog to the lower left corner of the stock or wherever your registration point may be
   - Punch in • **F** • **3** • **enter** •

While you run the job

This job wont take much time but others will get quite boring...

- Cleanup
- Pay attention to the vacuum
- Tidying tools, materials, etc. prep for leaving
- Review this handbook, left hand pages
- Read the main manual. The information will make the most sense when you're closest to the machine.

XI. RUN THE JOB

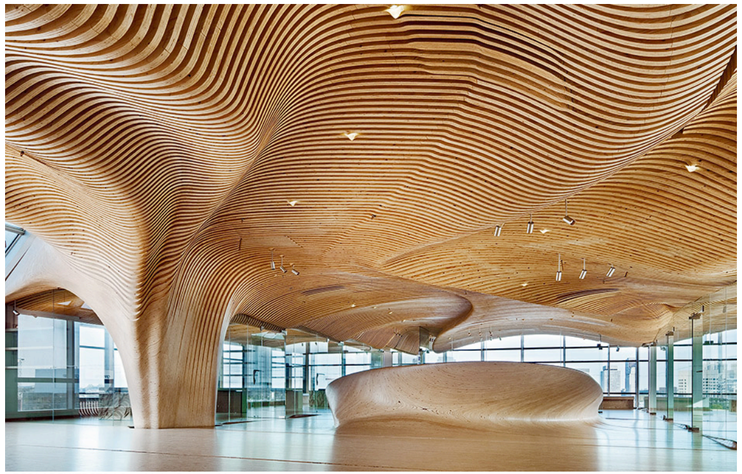
1. Press the • **green start button** •
   The readout will give you a last glance at the [HEIGHT AND WIDTH OF THE JOB IN MM]
2. if there is a problem with the dimensions or anything else, abort the job by pressing • **F** • **9** • **enter** •
3. If the dimensions look good:
   - Hover a finger or thumb over the STOP button and press • **start** •
   - If the bit is not going where you expected it to go, press • **stop** • and reconsider
   - Press • **F** • **9** • **enter** • to abort, or • **start** • to recommence

XII. PUT THINGS AWAY

1. Jog the bit to where you can remove the tool holder
2. Grasp the tool holder, push green button
3. Undo the collet, put away the bit, toolholder, and toolholder fixture
4. Jog spindle and gantry to home position
5. Push **OFF** on CNC main panel (lockout switch may be left on)
6. Turn the Computer **OFF**
7. Dispose of scrap, consider trimming usable pieces out of waste sheets for recycling or for the student store
8. Vacuum
9. Sweep

LOOKING AHEAD

Further workshops are being developed. A draft list is shown here. To get a reasonable handle on the 2.5d possibilities of a 3 axis machine, you should complete the Basic Operations workshops 1 to 4. At that point you can pick and choose between advanced 2.5d functions and starting in on the 3d option.



dECOi ARCHITECTS / One Main, Boston MA

1. BASIC OPERATIONS
1.1 Model Base (MDF)
a simple-as-possible project to get you started
1.2. Bolted Rings (Baltic Ply)
a hollow form made of stacked shapes
1.3 Stepped Form (Extruded Polystyrene)
open and closed valleys, peaks, and slopes
1.4 Complex Terrain
combining rings, steps, and inverted layers

2. ADVANCED 2.5d FUNCTIONS
2.1 Egg-Crate Joinery
cheating compensation for optimum fit
2.2 Direct Operator Control
working without a CAD file
2.3 Scarpa Joinery
mortises, tenons, cleared corners
2.4 Vee'd Forms
3d engrave and special bits
2.5 Machine Building
nonstandard file formats and materials

3. 3d FUNCTIONS
3.1 Contour Model
using the grain of the process to advantage.
3.2 Pattern-Making
smoothness, critical faces, and draft angle