

## Lunar LRO Data to CNC Machine

### For the [Big Moon Dig](#)

Tom Riley  
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Copy write: Tom Riley

Beta Draft

#### 1. Purpose

This task is to convert scientific data from the LRO lunar mission into a solid object using a CNC milling machine as part of [The Big Moon Dig](#).

The lengthy process for obtaining the LRO lunar data and preparing it for this task is covered in:

Big Moon Dig / Lunar Surfaces  
<http://bigmoondig.com/Games/BMDSurface.html>

And as a .pdf file at:

“Lunar LRO Data to SketchUp Landscape”  
<http://bigmoondig.com/Games/BMDLROData.pdf>

This document specifically covers using a CNC Piranha machine and “Cut 3D” software to make blocks of wood or plastic up to 304 mm (12 inches) square.

The Big Moon Dig would like to thank NASA for the use of the LRO lunar data.



**CNC Piranha**

## **2. CNC Considerations**

This is detailed process for milling the lunar surface blocks in either secondary wood, fine hardwood, or plastic foam.

The CNC machine we have available is a CNC Piranha by Next Wave Automation (\$1600.00). The files were set up for milling with Cut3D software (\$300.00) which can read a STL file from SketchUp. The router used was a Makita RT0701C (\$99.00) with two bits: ¼" end mill and ¼" round nose (\$20.00 each).

The file generation is very like that for 3D printing but the second scaling factor, *Scale02*, is different. The second scaling, which is used only in last step in SketchUp V15, will result in a larger block than for the 3D printer.

This Cut3D program accepts STL files generated by SketchUp Version 15, *File/Export STL*. It helps you set up the machining process and then converts this file into three toolpath files to drive the CNC machine. These files are then transferred to the CNC machine with a memory stick through a port on the side on the CNC display.

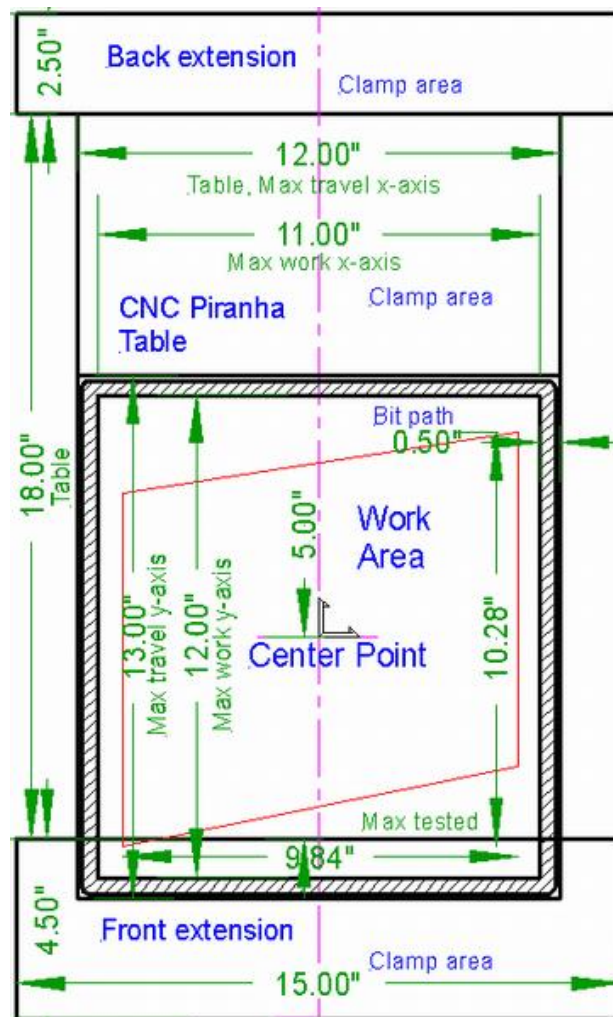
### **2.1. Technical Issues**

The main problem in using this machine comes from a limitation in the machine design. The machine does not have encoders so it cannot directly measure where it is at any time. It starts at a reference location, *Home*, and counts steps to know how far it has moved in three directions. This works well as long as its movement is not blocked or it hits its limits. In both cases step counts are lost and the machine no longer knows where it is.

Adding encoders to the three stepper motors would solve this but it would probably double the price of the machine. So what we need is a good, practical procedure to live with the step counting.

This we can do by most carefully setting up the reference point at the start of a work section and then taking care that we never command the machine off the defined work area or restrict its movements. Nothing bad happens if you do, beyond angry clicking, but you do lose your *Home* reference point and it is hard to reestablish it precisely.

Also note that the [Home] feature does not have a material avoidance feature when a specific *.tap* program is not running. This means that you have to manually, using the x, y, z buttons, move the carriage back to the Home position whenever stock material is clamped in the machine.



**CNC Piranha table layout with extensions**

## 2.2. Taking Care

I have had the movement blocked by (1) the cables catching on the clamps, (2) the movement hitting a clamp, (3) a block of scrap wood getting under the table, and (4) the buildup of dust on the x-ball screw. All these are avoidable.

Being careful not to send the carriage out of range is largely about (1) scaling the model to suit your machine, (2) centering the blank, and (3) being careful on manual movements. I find a waste margin of 2 times my tool width all the way around is just adequate. I commonly use a ¼" end mill for roughing so the effective working area is reduce from 12" x 13" to 11.0" x 12.0" (279 x 304 mm). I have adjusted my model Scale02 (to 1/85) to accommodate this limitation.

Also note that an *Emergency Stop* will usually cause the loss of *Home*. This also leaves some of the internal parameters in unknown position. You can best return to a clean starting position by turning the power off, wait, and turning it back on. This insures a clean reset after an *Emergency Stop*.

Just pausing and starting again without moving the carriage will not cause this loss. Moving the carriage in the y-direction between runs in order to change bits and then returning it to Home can be done with our loss of Home.

### 2.3. Safety Equipment

A CNC machine makes a lot of noise, can throw particles, and generates a cloud of dust. Hearing protection, eye protection with side shielding, and a basic dust mask are needed. A shop vacuum to periodically clean up the area is also needed.



**Cleaning and Lubrication equipment**

## 2.4. Cleaning Equipment

The milling generates a lot of dust and dust build up can definitely block movement and cause loss of steps.

You will need to use a shop vacuum with a small nozzle between mill runs. Just vacuuming the ball screws may not be enough. Use a small brush with the vacuum there.

## 2.5. Lubrication

Excessive noise may indicate the need for lubrication of the ball screws.

Never lubricate with oil or grease. It will cause dust to ball up and block movement.

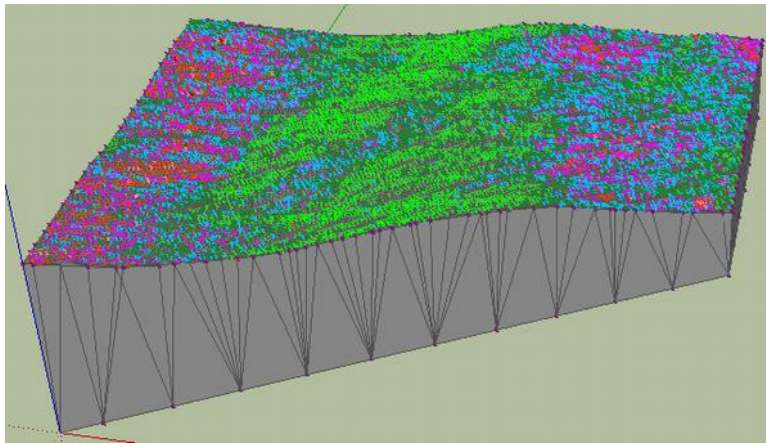
Use only a dry lubricant. The company sells a spray Teflon product, DuPont Teflon Silicone Lubricant, which is very good. If that is not available, you can use the graphite sold for locks.

## 2.6. Helpful Hints

Here are some small hints I have found to make using a CNC Piranha easier:

1. **Rubber Finger Stylus** – The touch screen is rather small for my big fingers. I bought a rubber tipped pin-like stylus from a computer store that lets me touch exactly what I want. (Why these cost \$14.00 I do not understand!)
2. **Foam Blocks** – I like to test my programs by milling foam blocks before using expensive hardwoods. The foam is available in big sheets from Home Depot to be used for insulation (example: pink Foamular by Owen Corning). It mills well but the dust generated is a mess and very electrostatic. Bring a tape measure and a utility knife. White granular Styrofoam makes such electrostatic dust that it is impossible to use.
3. **Glue Foam** -- You can glue foam slices together to better match wood thicknesses using spray adhesive or a special white glue (Amazon, StyroGlue). The spray adhesive is fast but can gum up your router bits. The white glue is very slow drying.
4. **Wooden Clamps** – Metal clamp parts scare me. I prefer clamps made from scrap plywood and wooden blocks. I still use the metal T-bolts and mostly plastic handles. I have so far hit one plywood piece and one plastic handle.
5. **Sacrificial Plywood** – Always keep a piece of thin, cheap plywood under you work to protect your table. Do this even when you do not expect to cut through the work and things can go wrong.
6. **Top-Dead Center Mark** – I always make the exact top-dead center as my reference point. I have marked the working center on the CNC table and mark each blank before milling. This minimizes the chance of going out of range and losing step counts.
7. **Tap the Bit** – If the bit does not come out easily when you have loosened the nut, you can often get it to fall out by simply taping on the shank of the bit just below the nut with the shank of another bit.
8. **Black out mistakes** – You can use a black Marks-a-Lot to darken any silver aluminum marks you accidentally make in your table.

9. **Add flat washers** – You should always use a flat washer on any bolt against soft material like wood or the plastic the CNC is made from. Any time you remove a bolt, such as for the router body mount, always add flat washers on both ends. In fact, it is even better if you look carefully at the flat washers and see that they are stamped and one side has rounded edges and the other sharp. The rounded edges should always go to the soft material.
10. **“P” is for “Proven”** – When I successfully mill a design, usually in foam, I add a “P” to the toolpath file names so I will know that it has been proven.



**Haworth601 scaled and rotated**

### 3. SketchUp Preparations

Start from the SketchUp V15 version of the model worked up in “Lunar LRO Data to SketchUp Landscape” <http://bigmoondig.com/Games/BMDLROData.pdf> .

Remember that at this point it has been scaled one time by a factor of  $Scale01 = 0.0001$  (1/1000) in the Excel program. You now need to scale it a second time and move it to the origin position. You also need to decide if you need to rotate it to put the wood grain in the right direction.

The maximum size you can mill with this machine is 11.0” (279mm) in the x-axis and 12.0” (304 mm) in the y-axis. The exact size of the blocks varies within a group so you need to scale for the largest block in the group. The workable range for the z-axis depends on the router bits you use.

I set  $Scale02$  to 0.0118 (1/85) for the blocks in Scott A 6 and Haworth 6 series.

For the ScottA600 and Haworth600 mosaics, I set  $Scale02$  to 0.004 (1/250).

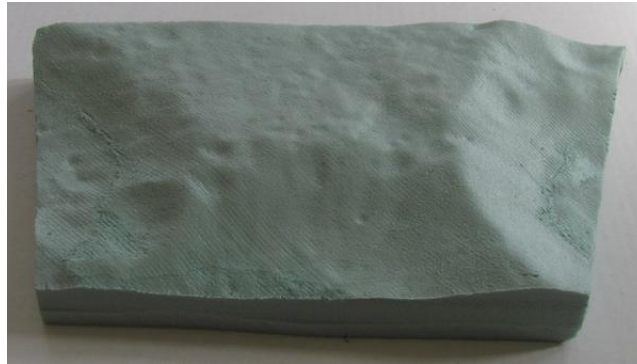
The y-axis has fewer physical restrictions so you can cut several pieces from one long board. The grain should therefore be running along the y-axis. This may require the model to be rotated in SketchUp.

In SketchUp, move the model so that the front left-hand point is on the origin. Scale the model using *Scale02*. Rotate the model if needed for grain considerations. Move the model again to be sure that the front left-hand point is on the origin.

Export the model as a STL file into the correct folder.

This is a good time for a size check. Draw a rectangle in the x-y plane starting at the farthest back point and ending on the point most to the right. This is the minimum size of the blank without any toolpath allowance. Note the x and y dimensions and if the block is rotated.

Erase the rectangle and save the SketchUp file as Sc (Scaled) and R (Rotated, if needed).



**Scott A 600 Mosaic in foam**

#### **4. Cut 3D Software:**

The Cut 3D software can read a .stl file written by SketchUp. It also provides a means of centering the design on the blank and then generating the toolpath files. Using the Cut 3D software:

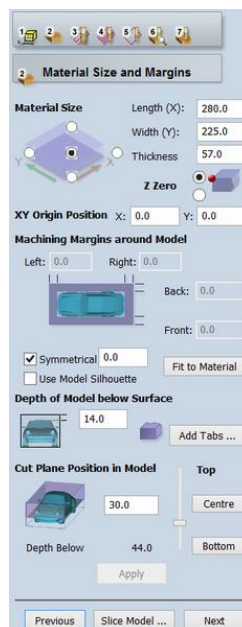
1. Import STL file through the box on the opening page



### Cut 3D Step 1

#### 2. Step 1, Orientate and Size Model

- a. Accept *Top Surface Top* and other standard selections
- b. Check box for *Units mm*
- c. Note size
  - i. Check that the xyz sizes shown in the small sketch at the top are close to those you recorded from the SketchUp file.
- d. *Next*

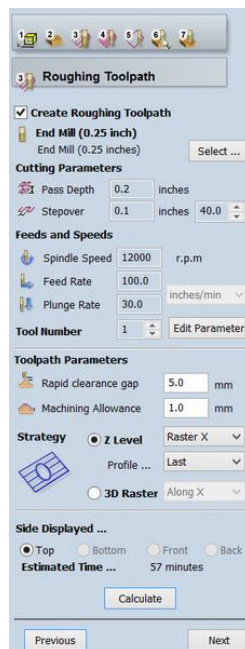




## Cut 3D Step 2

### 3. Step 2, Material Size and Margins

- a. Enter *Material Size* to size of blank in xyz
  - i. Be sure that there is at least 12 mm (1/2") around all four sides of the design. Note which areas that are safe for clamping.
- b. Center the reference point
  - i. Chose the *center dot* on the sketch, *Z Zero top dot*, *X: 0*, and *Y: 0*. This will place the reference point top dead-center.
- c. Select *Symmetrical* and *Use Model Silhouette*. This will mean excess material will be left which will save considerable milling time and making clamping easier.
- d. Set *Depth of Model below Surface*
  - i. The depth of model below surface until bottom of model is shown at bottom of blank. This is most easily seen in the x view. This parameter should be at least 1 mm to protect against flat spots.
- e. Set *Cut Plane Position in Model*
  - i. Set cut plane position to below level of land contour lowest edge
  - ii. Do not exceed length of the tool, 38 mm (1.5"), for the routing tools suggested.
  - iii. If this is not enough depth then slicing will have to be used (see below).
- f. Next

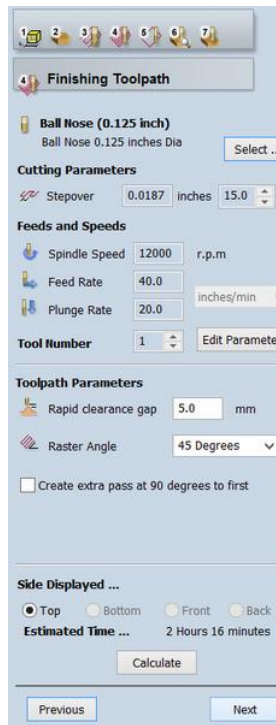


## Cut 3D Step 3

### 4. Step 3, Roughing Toolpath

- a. Select the *End Mill (.25 inch)* – Set *Feed and Speeds*:

- i. Set *Tool Info/ Feed Rate* for your specific material. Foam can be set at 80 inches/min to save time but for wood must be set much lower or the stress can ruin the piece. For wood I start this number at 30 inches/min to start. If the machine sounds like it is struggling, reduce this number. If the run is smooth then you can test a higher number. Reducing this number increases the time it takes for the run.
- ii. Set *Tool Info/Plunge Rate* for the material. This number has much less effect on mill time so I set it low at 20 inches/min to save stress on the equipment.
- b. Accept suggested parameters
- c. Calculate
  - i. Note time
- d. *Next*



### Cut 3D Step 4

#### 5. Step 4, Finishing Toolpath

- a. Select *Ball Nose (0.25 inch)* -- Set *Feed and Speeds*:
  - i. Set *Tool Info/ Feed Rate* for your specific material. Foam can be set at 80 inches/min to save time but for wood must be set much lower or the stress can ruin the piece. For wood I start this number at 50 inches/min to start. If the machine sounds like it is struggling, reduce this number. If the run is smooth then you can test a higher number. Reducing this number increases the time it takes for the run.

- ii. Set Tool Info/Plunge Rate for the material. This number has much less effect on mill time so I set it low at 20 inches/min to save stress on the equipment.
- b.
- c. Accept suggested parameters
- d. Check Create extra pass at 90 degrees to first
  - i. This refines the cut but takes extra time.
- e. Calculate
  - i. Note time
- f. *Next*



### Cut 3D Step 5

#### 6. Step 5, Create Cut Out Toolpath

- a. Check *Create Cut Out Toolpath*
- b. Select End Mill (0.25") -- Set *Feed and Speeds*:
  - i. Set *Tool Info/ Feed Rate* for your specific material. Foam can be set at 100 inches/min to save time but for wood must be set much lower or the stress can ruin the piece. For wood I start this number at 50 inches/min to start. If the machine sounds like it is struggling, reduce this number. If the run is smooth then you can test a higher number. The Cut process is does not take a long time.

- ii. Set Tool Info/Plunge Rate for the material. This number has much less effect on mill time so I set it low at 20 inches/min to save stress on the equipment.
  - c. Accept suggested parameters
  - d. Calculate
    - i. Note Time
  - e. *Next*
- 7. *Step 6, Preview Machining*
  - a. Review each level of machining
  - b. Review your clamping plan
  - c. *Next*
- 8. *Step 7, Save Toolpath*
  - a. Select post processor: *CNCShark-USB(mm)(\*tap)*
  - b. Save Roughing Toolpath with a short name (8.3)
  - c. Save Finishing Toolpath with a short name (8.3)
  - d. Save Cut Out Toolpath with a short name (8.3)
  - e. Save the main file
- 9. Transfer File Copies
  - a. Copy toolpath programs to a transfer finger drive.

## 5. Blank Preparation:

Cut your blank material to size adding about a 12 mm (1/2") margin all around the finished design. Inexpensive foam can be used for test runs and learning.

The wood grain normally runs in along the y-axis. You can make the y-axis of the blank as long as you like, but the finished design cannot exceed 300 mm (12.0").

The absolute maximum width of the blank in the x-axis is 380 mm (15") but the maximum for the finished design is 279 mm (11.00"). Blanks wider than 254 mm (10") become difficult to clamp.

Plan your clamping. For expensive hardwoods, you may want to glue strips of secondary wood to the sides just for the clamps. I much prefer clamp bodies made from scrap plywood than metal ones. Clamping from behind your *Away y+* mark on the table (see below) is safest but having only clamps on the back is not good enough, at least one clamp along the side is needed. Because the milling area exceeds the front of the table, clamping from the front is rare.

Place a clear x-cross on the blank where you want the exact top-center of the blank to be.

## 6. Setting Up the Machine

There are a number of things you need to do to set up your machine:

### 6.1. Marking the Table:

You needed two marks on the CNC table, (1) rear extent, and (2) dead center. Manually step the y-axis until it hit its stop in the *Away y+* position and marked the table with a metallic Sharpie at the back of the router bit. This mark aids camp location planning.

Then step it to the extreme *Near y-* direction. Note that the router bit is now off the table. Placed a small board on the fount of the table and mark the front of the router bit. Then measure between the two marks and divided by two. Mark the dead center of the working area of the table. The center in the x-axis is already shown by the lines built into the table.

### 6.2. Bit Changing:

The most difficult maneuver to do without losing your *Home* is changing bits. You will need to change bits between the course and fine passes and precision placement is needed.

You may manually move the carriage up in the z+ direction without losing *Home*, but be careful not to hit the upper limit. Be sure the CNC is fully stopped and the router is unplugged when changing bits.

The router body clamp does not have a very strong grip on the router. This means that you have to work the bit exchange without ever putting force on the router body. Always use two tools.

Most of the damage I have done to my table was the direct result of not having the bit tight enough in the router. The bit can then slip down and then mar the table.

My router has a hole through the shaft. A 7/32" drill bit will fit nicely through this hole. With the drill bit in place the router bit will slide into the chuck an exactly repeatable distance and you can then finger tighten the locking nut. You can then remove the drill bit and inspect that the end of the router bit is just visible in the hole. You can then tighten the locking nut with the two thin router wrenches, or one wrench and the drill bit.

## 7. Setting Zero:

All movements of the cutting tool are made with reference to this Home xyz zero setting.

Manually step the x and y axis until the router bit is dead centered over the mark. Choose your material blank and a thin piece of plywood to go under it. Step up in z+ until the bottom of the router bit just kisses the top surface of the blank material.

Set this is the zero reference by pressing:

*[Zero xyz] / [OK]*

### 7.1. Additional Information:

Once you have set zero, there are three bits of additional information that are helpful to note, (1) safe height for z-, (2) a second reference height, and (3) max z+.

- a. Safe height for z- -- Remove the blank but leave the thin piece of cardboard. Step the bit down until it just kisses the cardboard. Note the -z value. Enter this number under:
- b. Max z+ -- Step slowly up in the z+ until you hit the limit. Note the number just before you hit the limit. Later, as when changing bits, be careful not to exceed this limit.

Now return the z to the reference point where it just kisses the blank. Inspect the hole in the router shift to be sure that the bit has not shifted. If you are not at zero, then reset the *[Zero xyz] / [OK]*.

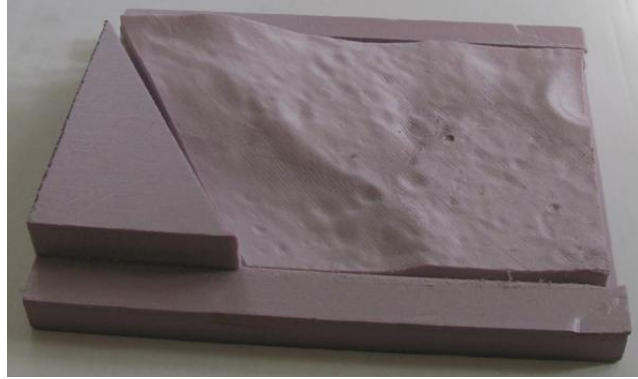
## 8. Set up Milling

Send the carriage home with *[Home xyz]*. Bump the z+ up just a little. Inspect that the bit is right over the center mark and the top of the bit just shows through the hole in the router shaft. Check that the nut is tight.

Carefully clamp the blank in position with a thin piece of plywood under it. Align the y-axis of the blank with the grooves in the table.

Be sure that no part of any clamp is more than 3.0" off the deck. Check that there is a little light between the planned bit path and any part of any clamp.

Power on the router. Send the carriage home again. It should now just touch the blank right on your X.



**Haworth 601 in Foam, untrimmed**

## 9. Run Toolpath Programs

Plug a finger drive with the toolpath programs into the USB port on the side of the display. Select *USB* (now blue).

Select the Rough Cut program.

Put on hearing, dust, and eye protection. Have a shop vacuum standing by.

Inspect your setup again. Be sure that the router is running.

*[Run]* program.

Watch progress. Particularly watch for clearance around the clamps. You can use Pause to stop the CNC movement to reposition the clamps.

Be ready to hit *Emergency Stop* if there is a problem.

When the roughing program is complete, turn off the router.

The carriage should have returned to the reference *Home* point. Check that it is at Home. I have found that the x and y axis are usually alright but the z-axis can be slightly off. Sometimes it returns to the home position but the z-axis shows a small positive number (this appears to be a software error). Check that the carriage is at the Home position. If not, move it there with small commands. When it is in the correct position reset the Home position to 0, 0, 0. The add-on plans below include a Centering Board to help with this positioning.

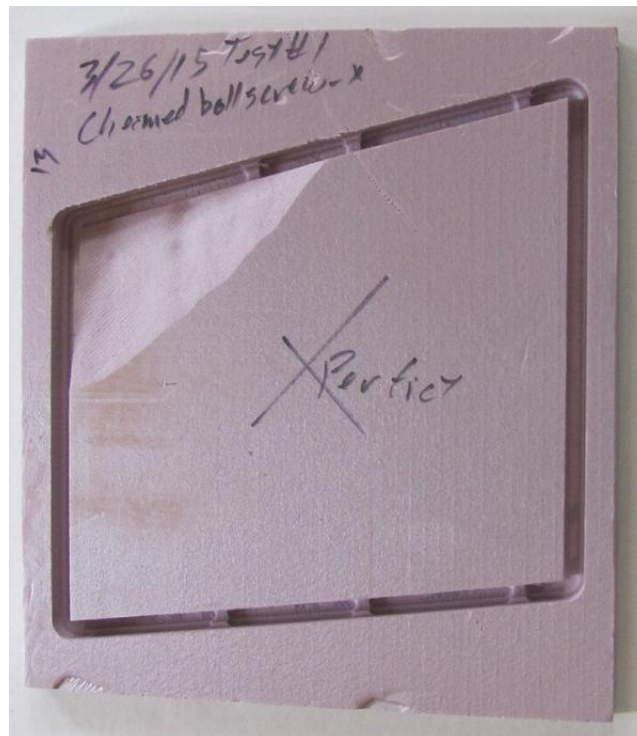
Clean the CNC thoroughly using the shop vac and a small brush. Be sure the x-ball screw is clean.

Change the bit if necessary. Repeat this process for each of the other toolpath programs.

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One setup can last for hours as long as you never exceed a limit or block the machine. However you need to check the Home position with each .tap program completion. If the carriage does not return to your original 0, 0, 0 then you will need to reset [*Home*] and clean the machine thoroughly. You do have to reset the *Home* for different blank thicknesses.

Always end in the *Home* position. Bump up the z+ just a little to facilitate removing the finished product, then *Home* it again. End the day at *Home*.



**Good Slice**

## 10. Running Slices

If the model is too thick to cut in with the available bit depths (1.5" 38mm), you can convert the model into a stack of several slices. This process is similar to the one above but requires several extra steps:

1. Start with the full sized program
2. Step 1
  - a. Check that the dimensions are correct
3. Step 2
  - a. Set the material size
  - b. Be sure the reference is top dead center
  - c. Zero out the x and y offset boxes



- d. Do **not** add tabs to this program!
  4. Save Slice Programs
    - a. Select material thickness, 19 mm ( $\frac{3}{4}$ " )
    - b. Make a folder for Slice programs
    - c. Save main program
    - d. Close the main program
  5. Open program for first Slice:
    - a. Check 11 inches is adequate for x-axis
      - i. Enter material size
    - b. Check 12 inches is adequate for y-axis
      - i. Enter material size
    - c. Note y-axis material requirements.
      - i. Divide by 2 to note y-center
    - d. Add Tabs
      - i. I use six 6 mm by 4 mm tabs.
    - e. Save rough cut path with short name and slice number
    - f. Save fine cut path with short name and slice number
    - g. Cut Path is probably not needed.
    - h. Repeat this process for each slice
  6. Save the cut path programs to a memory stick.
  7. Run the cut path programs as above.
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## 11. Add-Ons

We are currently working on plans and construction notes for several add-ons for you CNC Piranha:

1. Front Table Extension – a wooden bolt-on extension for the front of the table to improve clamping.
2. Wooden Clamps – Less a worry particularly when learning.
3. Foam dust and sound control box – Very helpful in doing show-and-tells.
4. Wooden router body clamp – Needed to accommodate other router brands.
5. Back Table Extension – A wooden bolt-on extension for the back of the table to improve clamping when working a long board.
6. Center Board – A wooden block to help you return the mill carriage to Home with material clamped in place.

Construction notes for these add-ons can be found at:

Woodware Designs / Shop Built Add-Ons for the CNC Piranha  
<http://woodwaredesigns.com/freebie/CNCAddOn.html>

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## 12. Conclusion

This is only a start.

We can now take real scientific data about the Moon and turn it into objects you can touch with your hands. Long live [The Big Moon Dig](#).

We can do this.

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### References:

1. The Big Moon Dig (internet)  
<http://bigmoondig.com/BigMoonDig.html>
2. The Big Moon Dig / Lunar Surfaces (Internet)  
<http://bigmoondig.com/Games/BMDSurface.html>
3. "Lunar LRO Data to SketchUp Landscape" (internet)  
<http://bigmoondig.com/Games/BMDLROData.pdf>
4. Vector Art 3D (Internet)  
<http://www.vectorart3d.com/>
5. Next Wave Automation (Internet)  
<http://shop.nextwaveautomation.com/shop/>