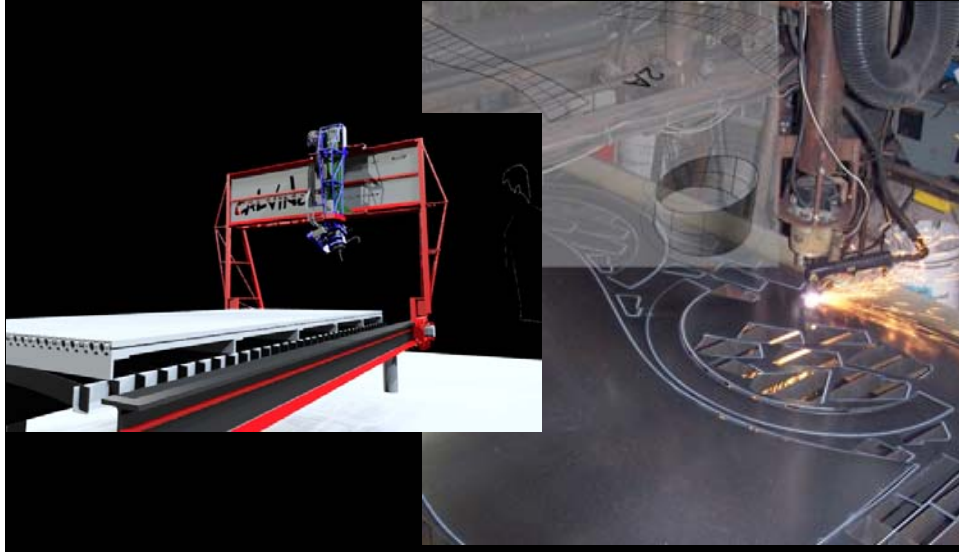# Applied CNC technology

The intent of this set if images is to attempt to convey the importance of the depth of the investigation into all endeavors. Many times, creative thinking and processes are a way to deal with constraints, including budget. The more one acquires knowledge, skills and abilities about systems and materials, the more possible a design concept and design may become.
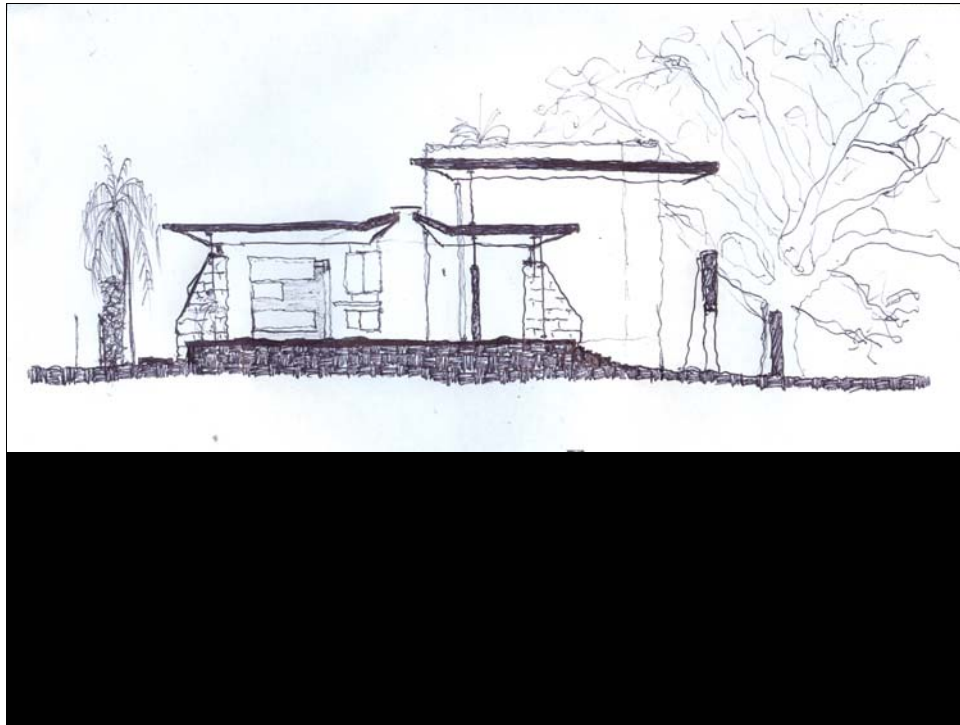
The concept sketch is the first step and serves to get the idea from the realm of the mind and imagination to the real world.

North-South section sketch of the 6330 project focusing on how the overhead plane will control light and allow cross ventilation through the space.
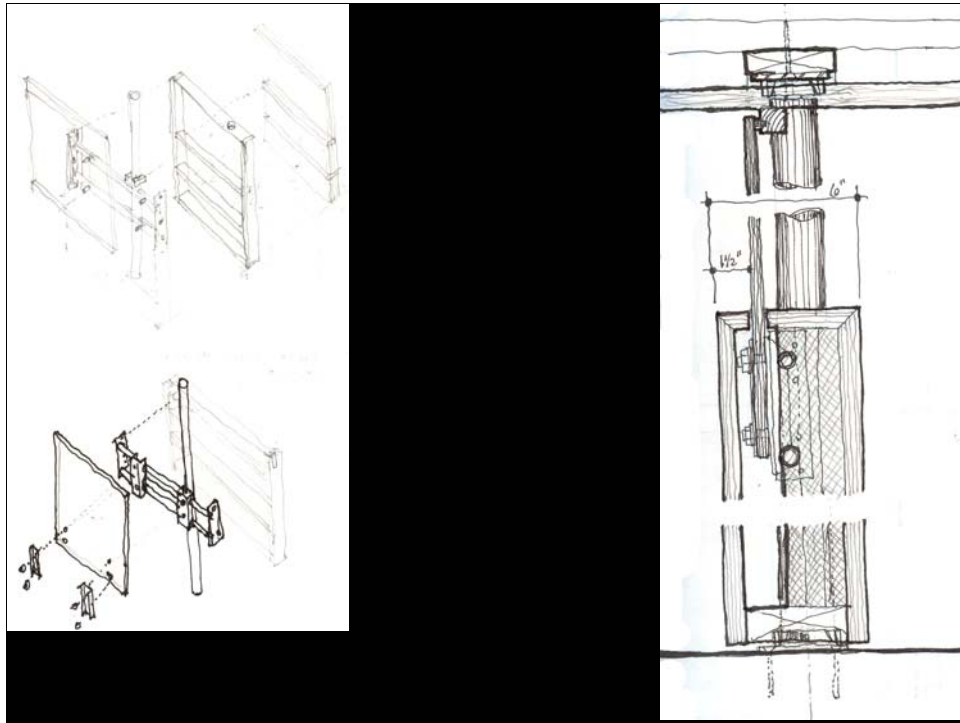
Succesive sketches in greater detail develop the idea and begin to define the parts and pieces that will enable the concept to become a reality.

These two sketches are of an entry door to the 6330 project. A cantilevered piece of ½" tempered glass protruding from a birch plywood base panel.
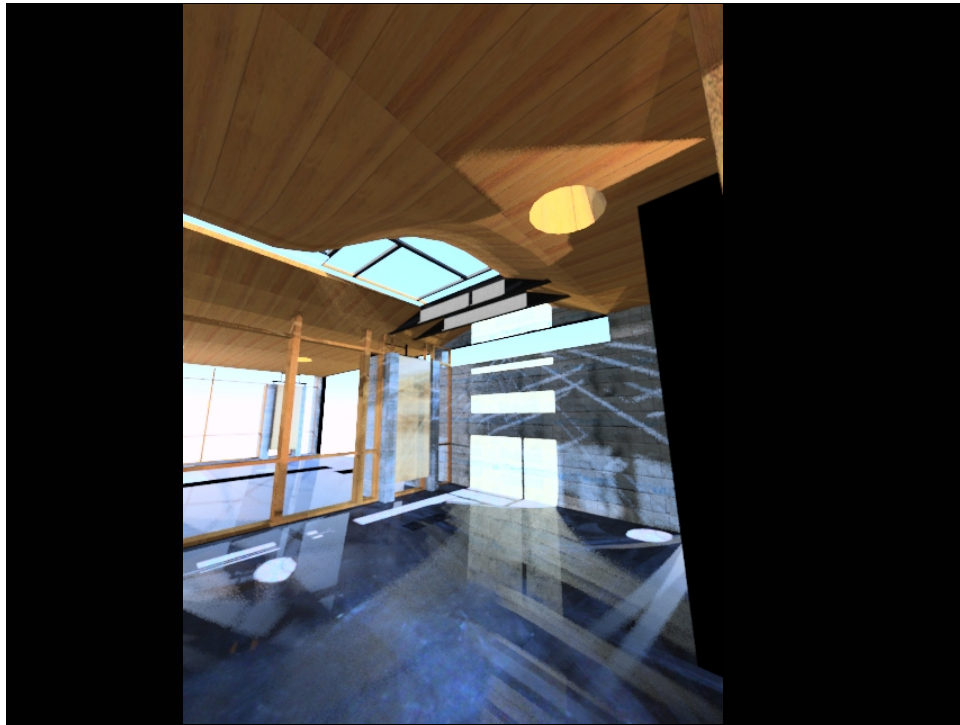
Another tool is the digital model. This quick rendering is made in AutoCad with a 3d solids model and rendered using ArNxt rendering plugin from http://nxt.accurender.com/

The 3d model is also used to generate the 2d drawings by using the command SECTIONPLANE and exporting a 2d file of the cut plane and elements beyond.

The 3d model also is used to generate dxf drawings (taken directly from the actual size parts of the model) to generate G-code for cutting parts and pieces for fabricating the project.
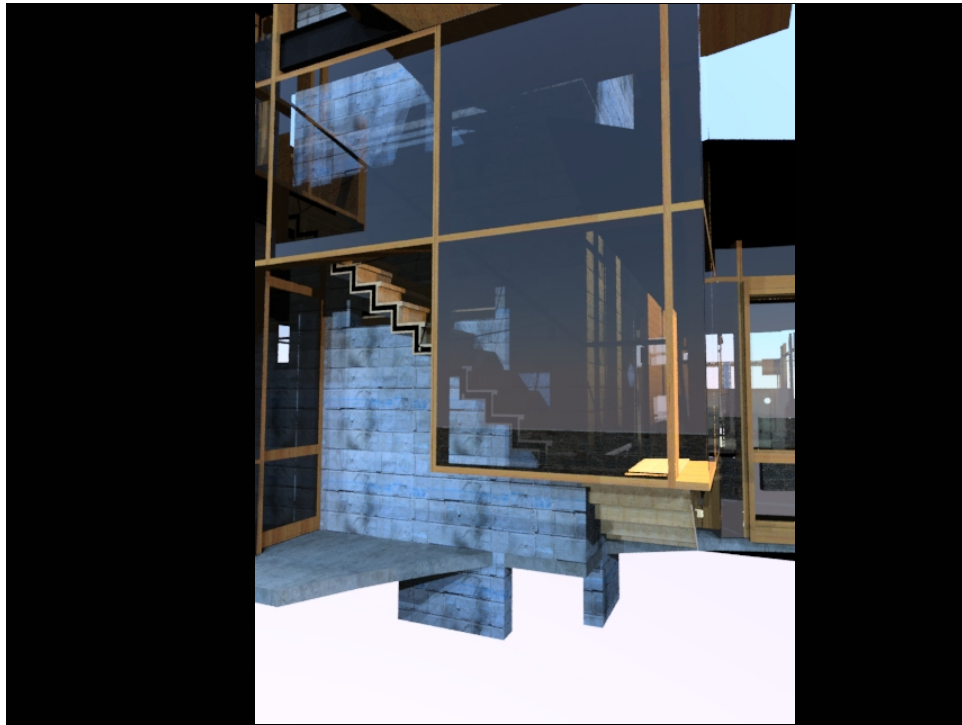
3d model view. Model is used to resolve issues quickly.

Quick render showing how the skylights will define the space. The East-West slot provides a changing line of light through the seasons while the round ones provide daily changing lights as spots directed to specific parts of the spaces.
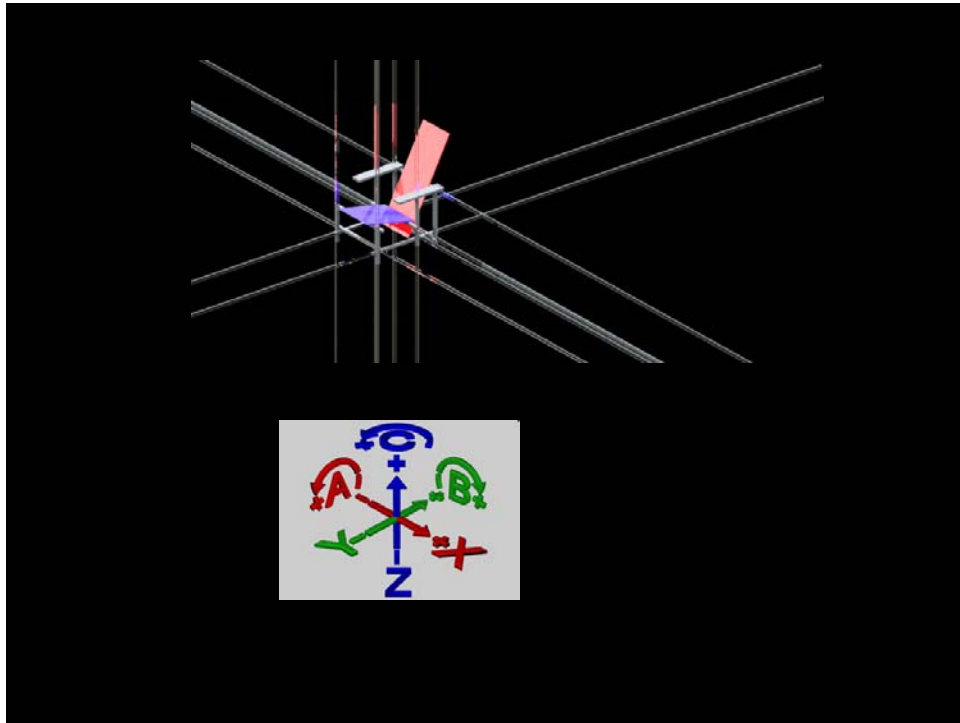
Rietveld and the DeStijl group of the early 1920's modernists defined all spaces as an intersection of an infinite cartesian grid. Much like cnc technology used cartesian coordinates to define toolpath to cut any shape in space.

2009-02-19RoofPlaneSunStudy.mpg
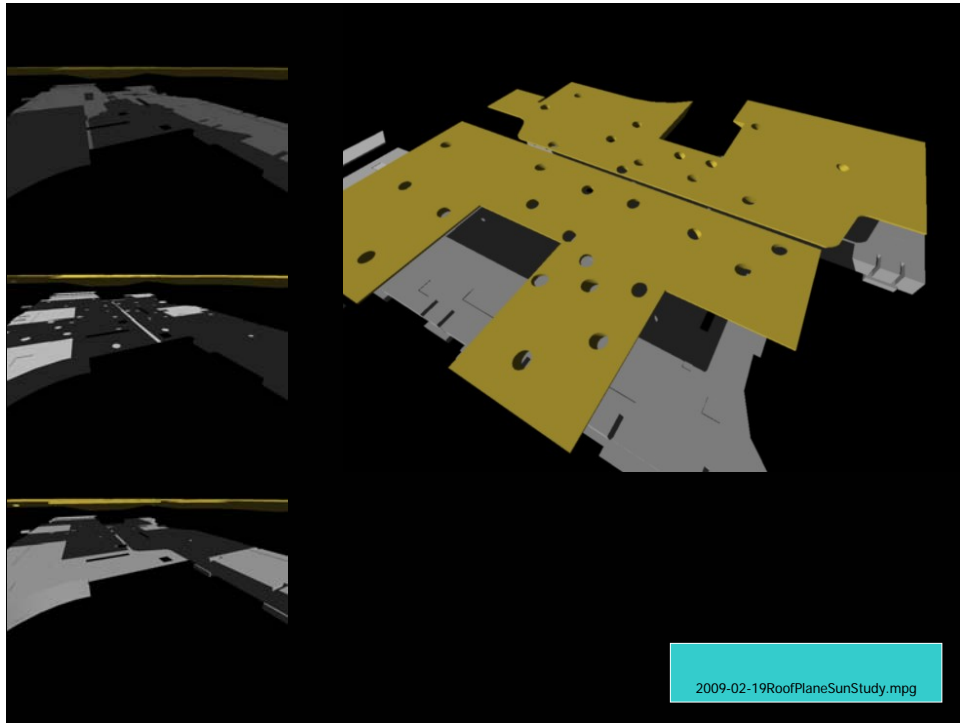
A light study, made into a .wmv file by rendering every hour from sunrise to sundown on each the summer and winter solstice to get the light conditions created by the "polka-dot" skylights at peak summer and peak winter months. The skylights are angled to allow more direct light in winter and less direct in summer to control heat gain.

Adaptability and use "hyperlinking" of the imagination to break things down to their essence and treat them as "raw materials". The skylight lenses are stadium light lenses recycled from the USF Sundome when it was re-roofed. The skylight bases were designed to accept the exsiting, tempered glass lenses which had their own epdm gaskets and stainless steel rings. The rings bolt to the bases via tabs designed and welded to the top of the sheet-metal "can".
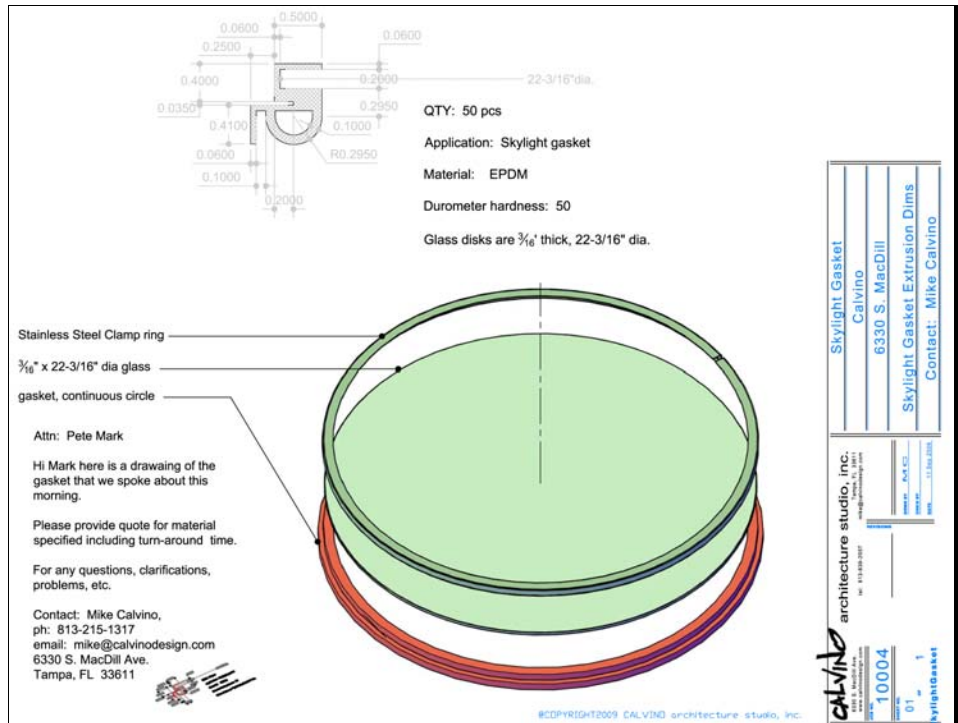
Drawing of the glass lens. The glass is sealed to the steel base via an epdm gasket (corss section shown above) and is clamped down via a Stainless steel ring to provide a water-tight seal. Epdm is a standard material to make gaskets for building materials – namely glass – providing water tight seals. The use of Stainless steel by the light manufacturer (Musco Lighting) is self explanatory however, it should be noted that two grades of stainless are generally used in construction (many more exist). 308 stainless steel is the most standard grade of stainless used and is highly durable but can begin to show and orange tint over time in harsh environments, namely salty air and water. For marine applications or projects near salt-water grade 316 should be specified and grade 316L is an even better choice. 316L is a Low Carbon stainless and has even higher resistance to corrosion.

(very quick) render showing the skylight "can" as a straight can, not angled. First concept. The problem with this would be that the solar heat gain would be maximum in the middle of the summer when the sun is at the greatest azimuth angle and would be at a minimum during the winter months. This is the opposite of the goal. Angling the skylight cans would be a better solution to allow more sunlight/heat in winter and less in summer.

Overall plan showing spaces. Public, screened spaces at the south, public, enclosed spaced across the middle, private, enclosed spaces along the north edge. To show basis for skylight placement.
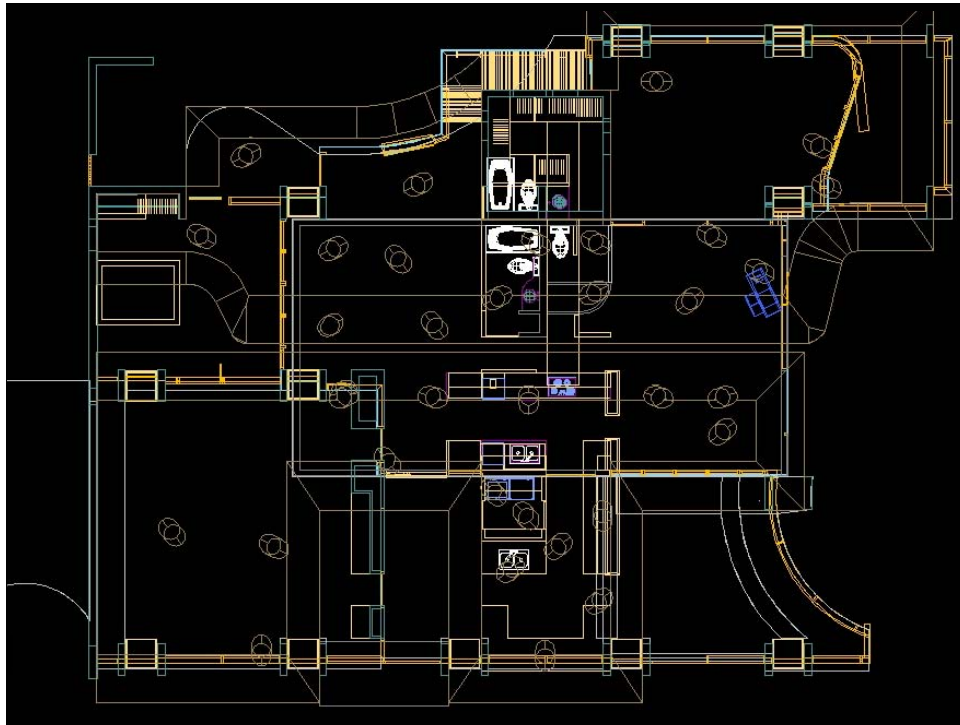
Locations and placement of skylights. Seemingly random, however, the angle is considered to allow more light in the morning or evening and the placement is based on providing even light while minimizing glare in critical spaces. This is all setup for defining the skylight cans to be fabricated.
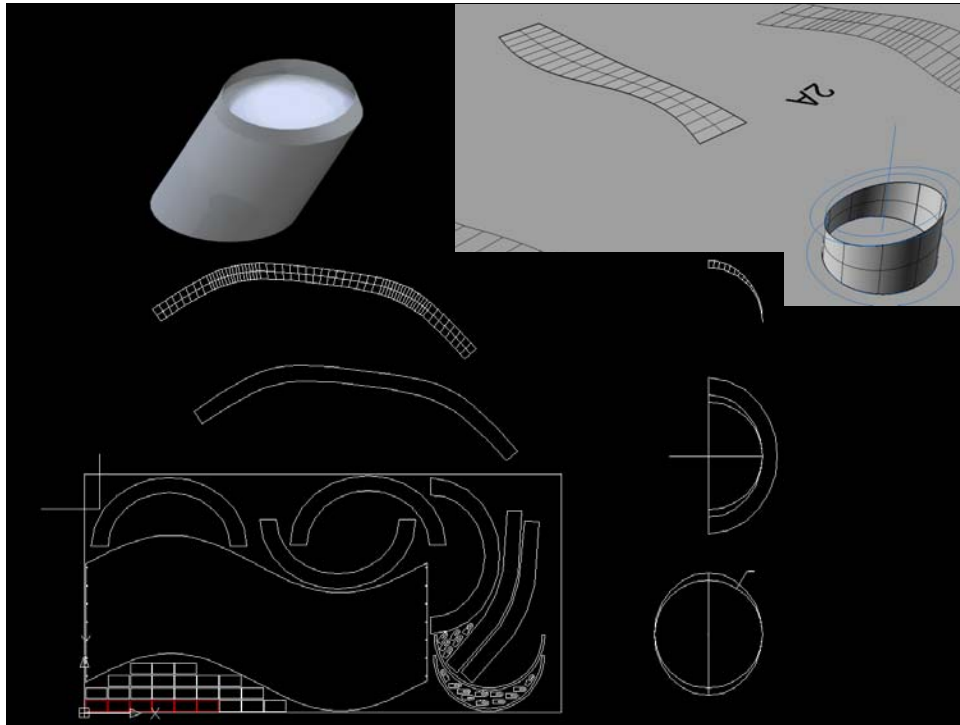
The skylight can design.   Angled cylinder, cut off horizontally creates an ellipse. A transition piece is required. Use of Cad model allows the steel cylinder to be made full scale and the transition piece is made by creating the ellipse and the circle required by the design, diameter defined by the recycled glass lenses with their retaining rings and gaskets, and then using the command LOFT in AutoCad (same command in Rhino) Rhino is then used to unroll the surfaces (both the skylight can and the transition piece) to create a flat shape which can be exported as a .dxf drawing. The .dxf is the file type that most CAM programs can read to generate a "toolpath" for sending to the CNC equipment.
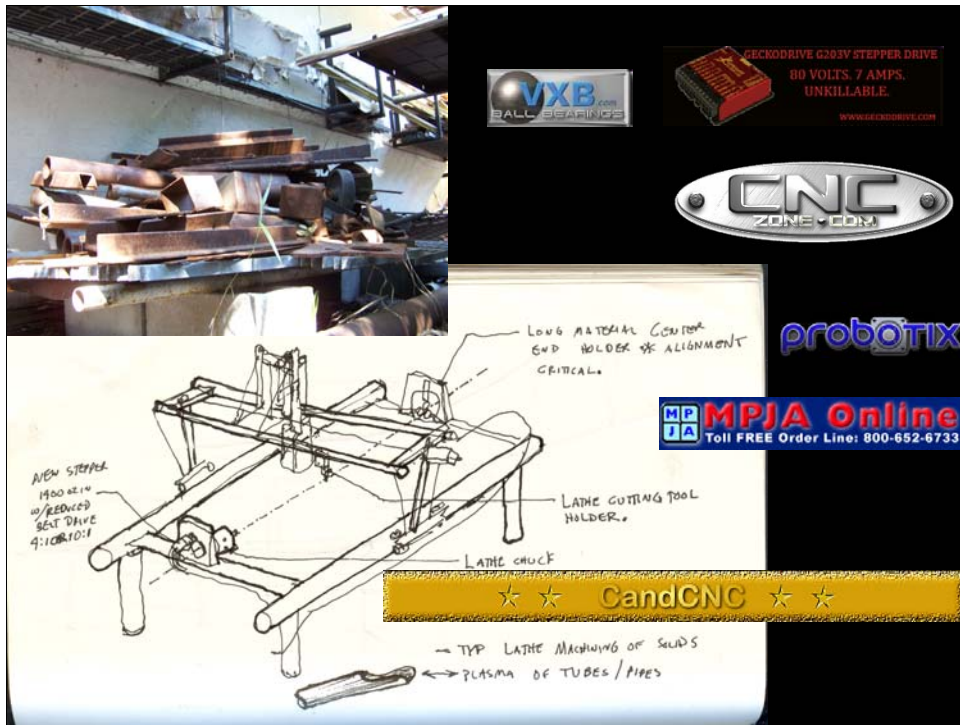
The CNC machine: None of this would be possible without a way to cut out the pieces accurately and efficiently . . . Time costs $. Could farm it out, but the cost would be astronomical and would prohibit the process and therefore the skylights themselves.

CNC machine 4'x8' min. plasma and router capabilities.

Concept sketch. Research into the anatomy of a CNC machine. Researched technology online and on CNCzone to define a design for the machine. Take note of these resources and investigate.
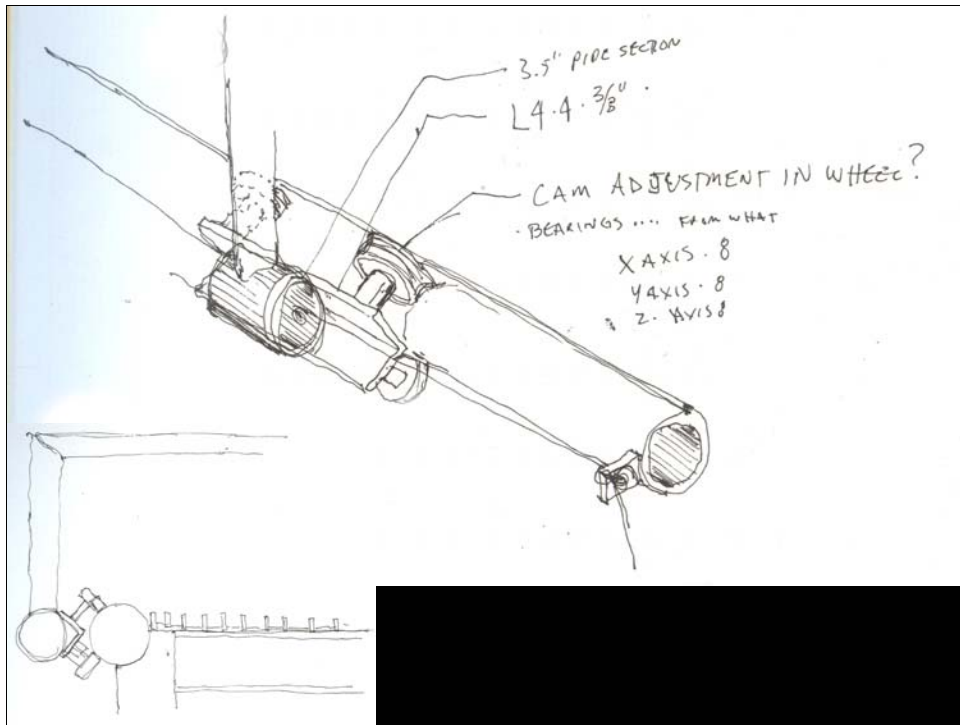
Critical element: the linear bearings providing the linear motion. The concept for this sketch came from other builds shown and discussed on CNCzone. The pipe shown for the track could be a piece of flat bar, square tube, solid bar, etc. As long as it provides up and down resistance with the bearings mounted to 2 sides of the angle.
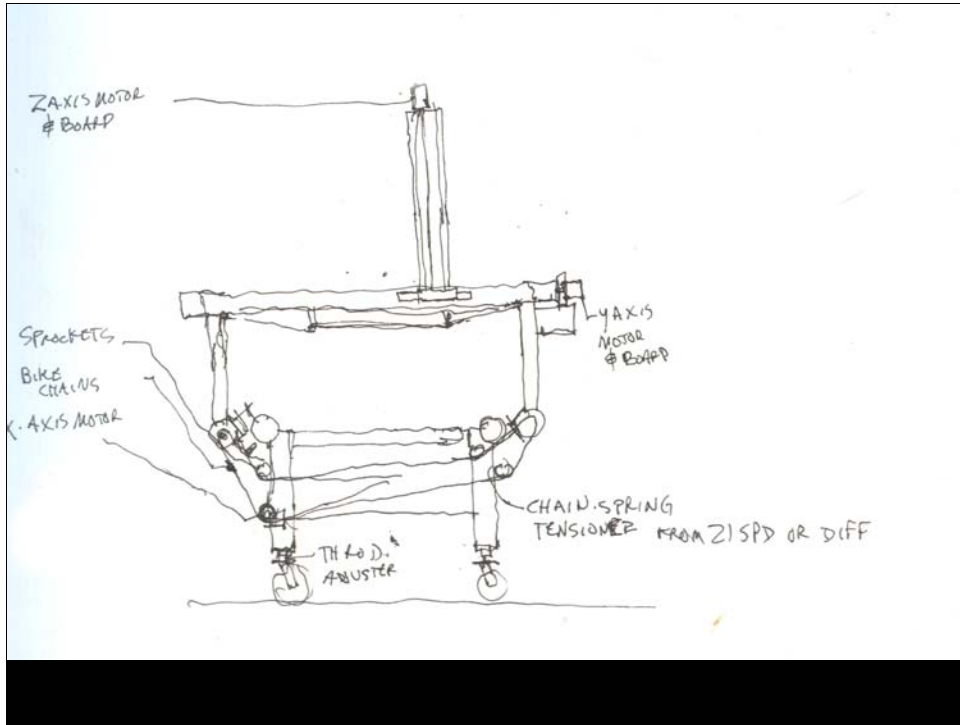
End view sketch.
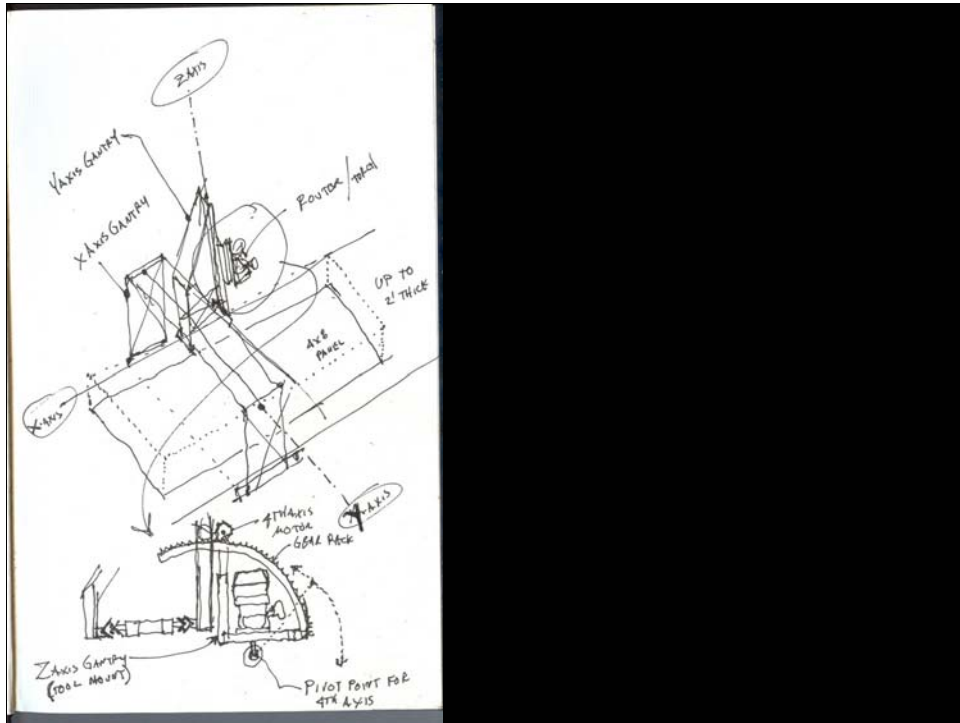
Concept sketch for a rotating router head. Would use a gear rack and pinion gear to angle the router head. Steel is the material of choice because is the most durable and I have plenty of drops in the racks in the shop.
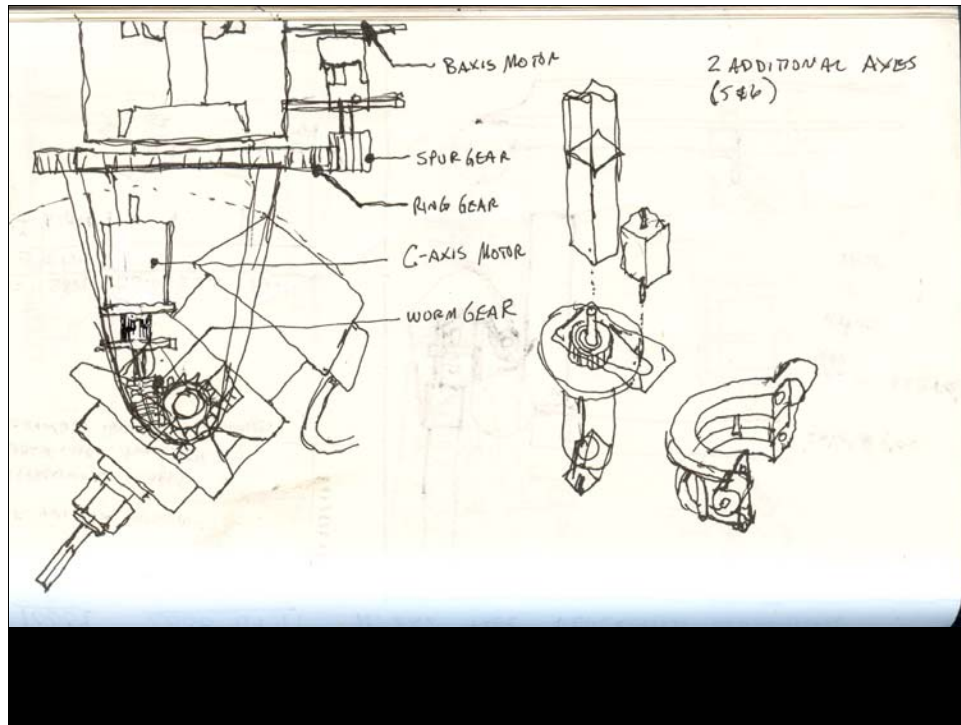
Second iteration sketch of the swivel router head, providing a 4th and 5th axis. This design uses a worm gear and spur gear for the B axis and a ring gear and pinion gear on the motor for the Z axis. Early sketches. Put the ideas down on paper to start.
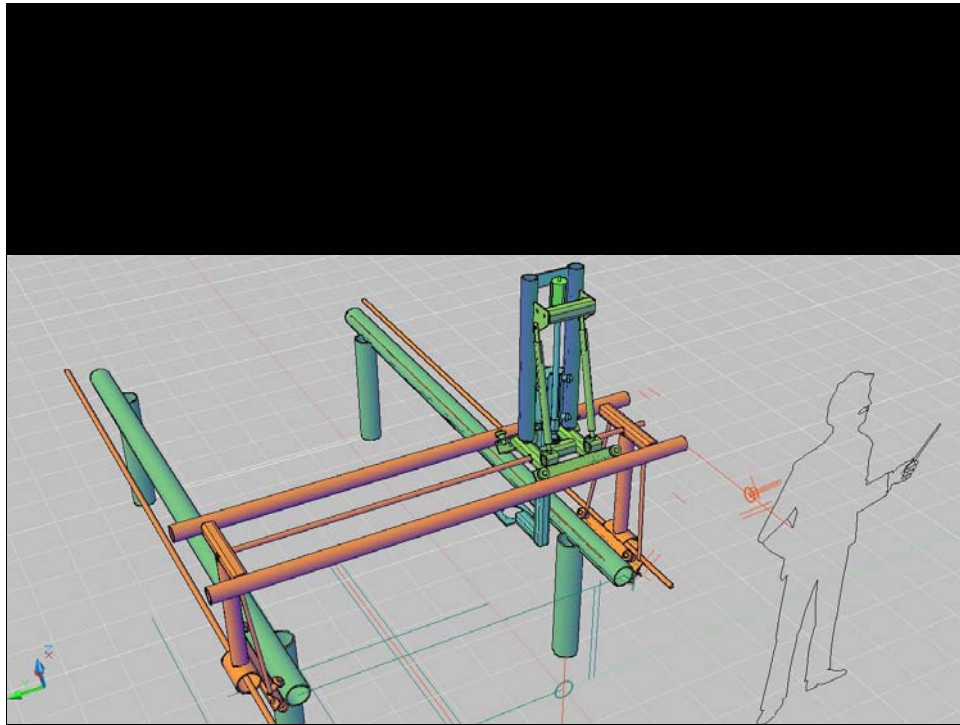
Digital model for further development. 3d model again is used to define shapes and exact sized for pieces and parts.
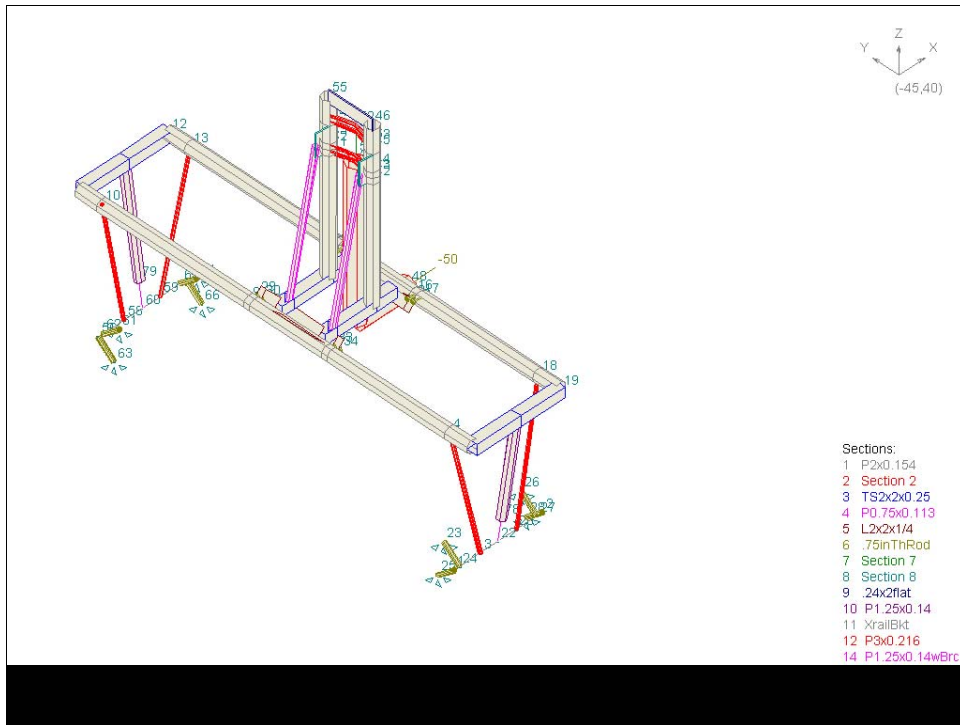
Digital model is also used to generate a 3d .dxf file which is used to import into "Space Gass" (www.spacegass.com) a structural analysis program which can be used to check deflections of complex structural frames and systems.
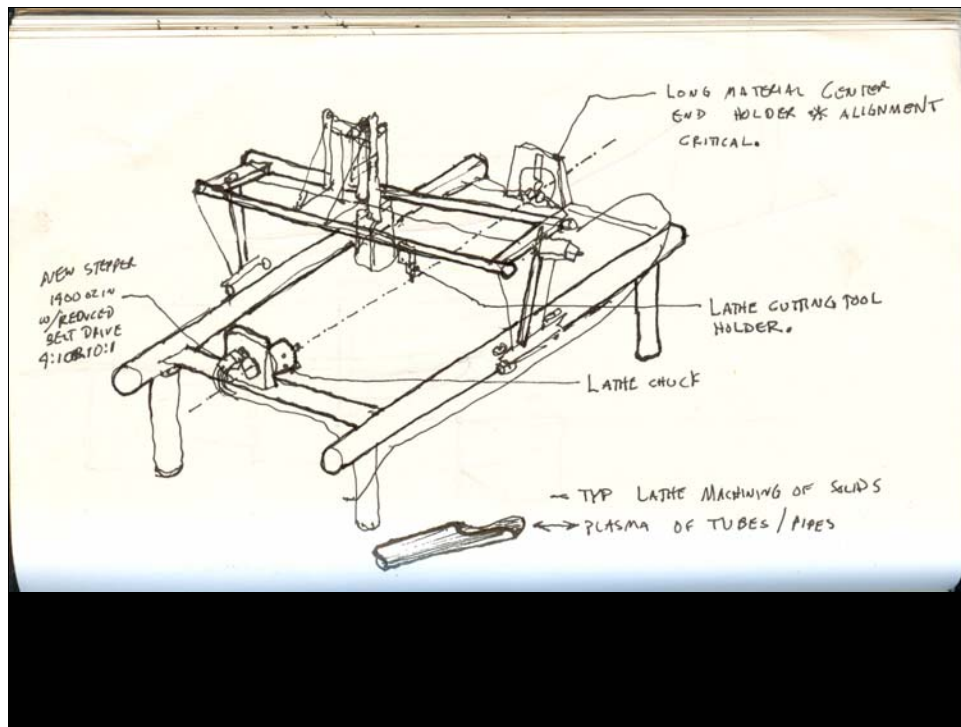
Concept sketch again, showing an A axis which would work like a lathe or indexing axis to cut all sides of a pipe or tube, etc. Some examples of rotary plasma and router machines can be found on youtube.
http://www.youtube.com/watch?v=aYDtnESRKYE

x axis	288	inch		3.65	/in	$	1,051.20
y	144	inch		3.65	/in	$	525.60
z	60	inch		3.65	/in	$	219.00
floating z	4	inch		3.65	/in	$	14.60
Rail Carriages							
X - wide	4	ea	$	59.00	ea	$	236.00
Y-wide	4	ea	$	59.00	ea	$	236.00
z-wide	4	ea	$	59.00	ea	$	236.00
floating z-narrow	1	ea	$	59.00	ea	$	59.00
						$ 2,577.40	

Cost comparison: linear bearings: approx. $2500 for hardened, machined precision linear bearings. Cost for the low-tech solution, approx: $100.

X & y axes tension struts to preload the x to the pipe rails, and adjustable to calibrate

Z-axis – adjustable for vertical alignment.
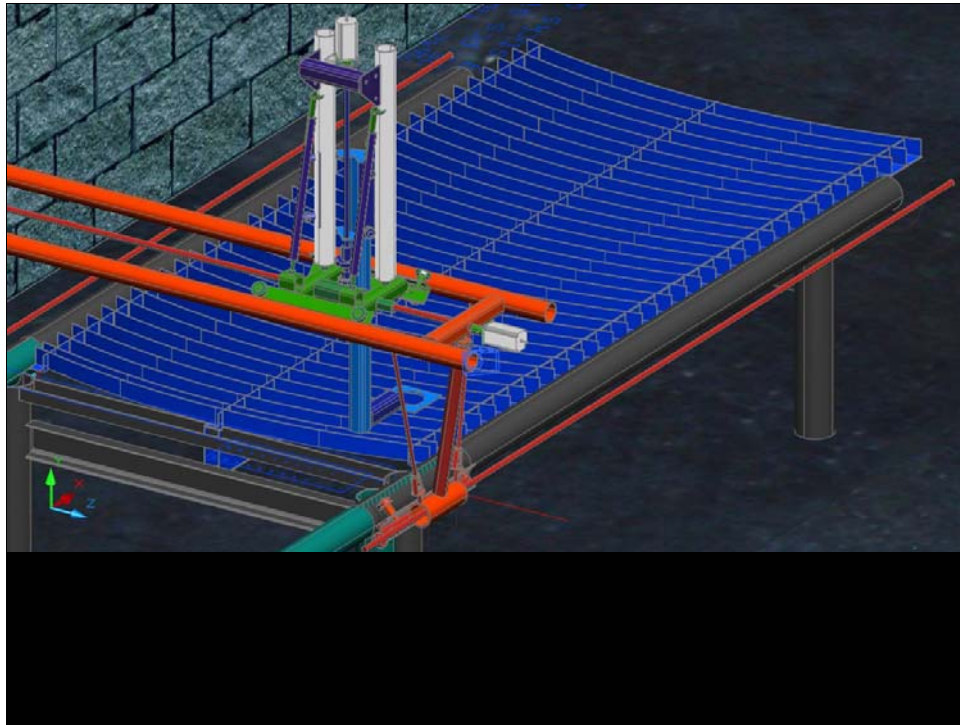
Cad model to develop "slats" for setting material to be cut. To allow sparks and slag to exit the material beneath while still supporting it.
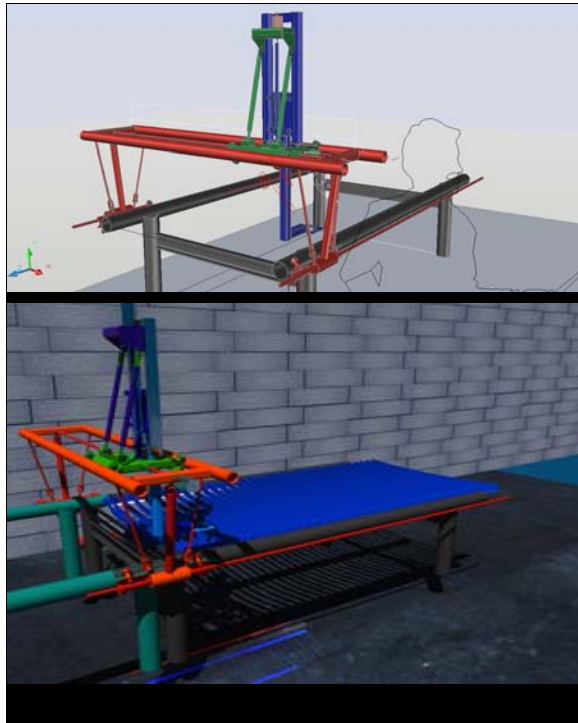
Table fab time lapse

Table fab video, :

http://www.youtube.com/user/calvinoArchitect#p/u/31/x4jPo5uaUi4
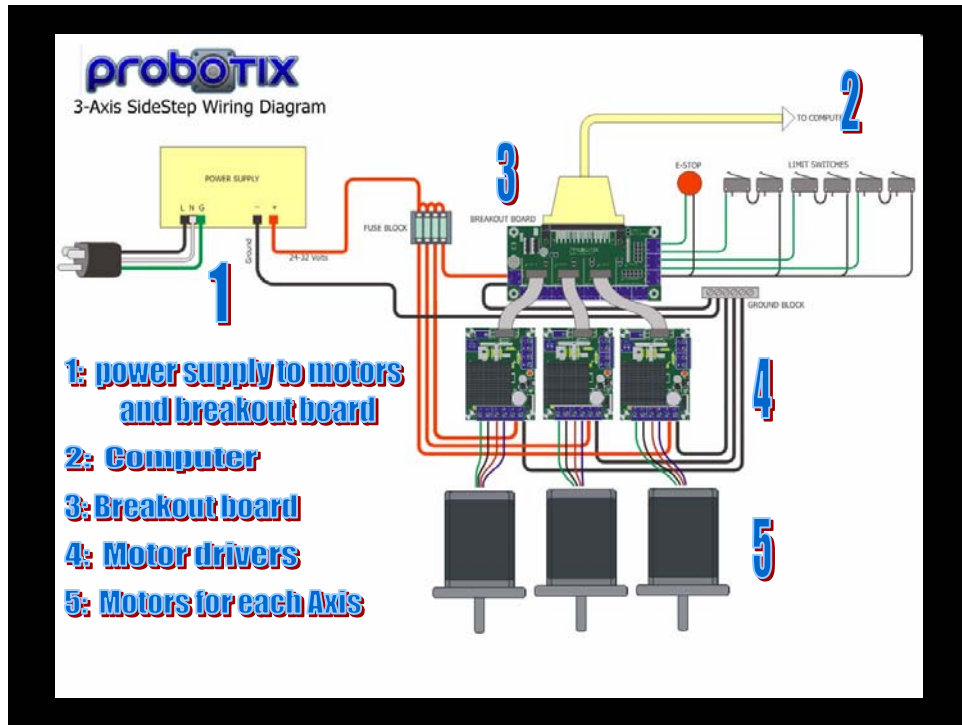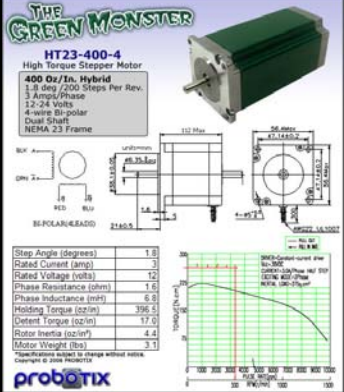
Now for the control electronics. Parts of the system, power supply, computer, breakout board, drivers, motors. That's it in a nutshell. Now look at each part aside from power supply and computer. www.probotix.com

Also view the manuals in the downloads section of www.CandCNC.com.
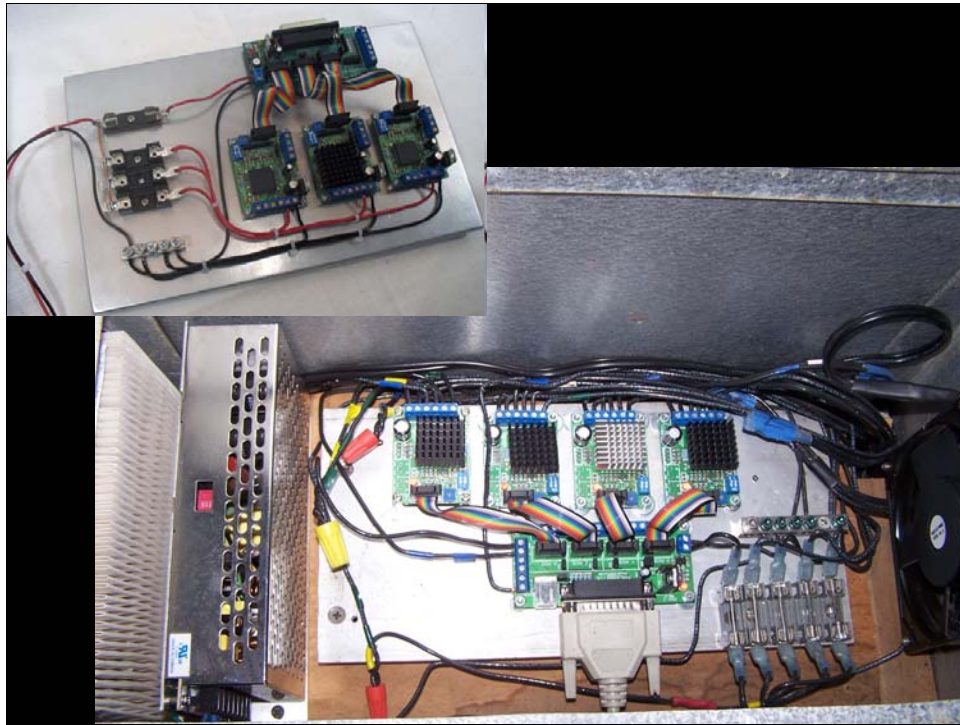
First control panel for 3 axis control, the X axis has 2 motors, hence 2 drivers. They are slaved together in the software controller, Mach3.

Mach3 available (trial version or commercial version) at www.machsupport.com

Components, motor – stepper (servo also, different talk) stepper has 200 magnetic "points" inside, around the rotor/stator that register +/- which gives 200 steps per revolution, this can register as a pulse and with an electronic controller you can control how many steps the motor turns in what amount of time and in what direction it turns.

Servo motors can be made from permanent magnet motors by adding an electronic encoder and an electronic driver. Ref. www.geckodrive.com for drivers and www.automationdirect.com for encoders etc.
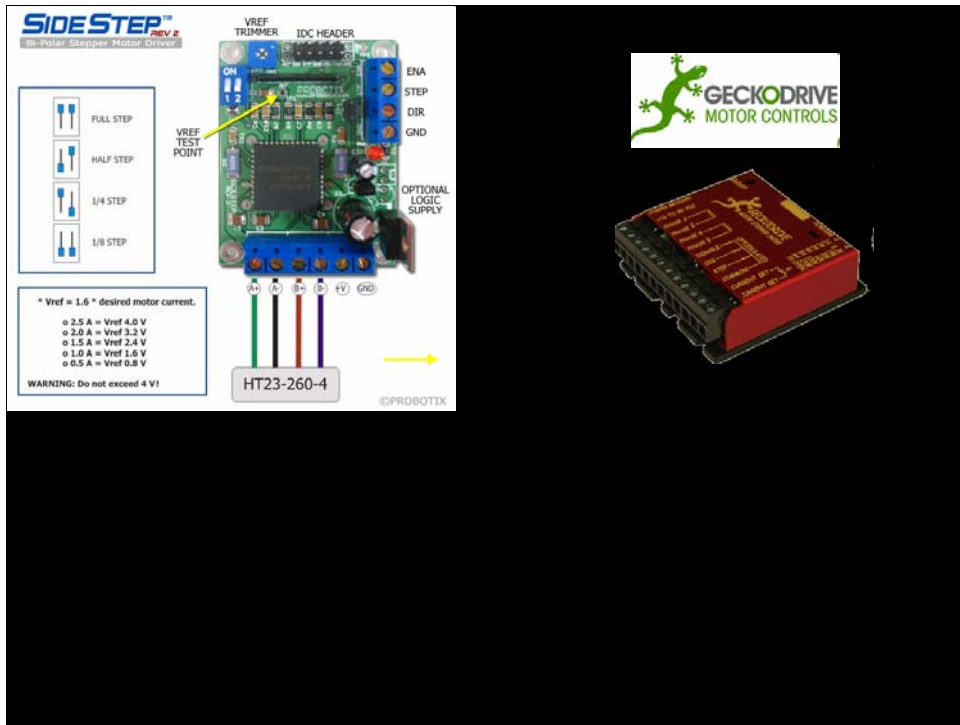
Step motor driver (servo motor driver is similar but has hookup for encoder – another discussion – more $ (considerable))

Figure 2: Board Diagram
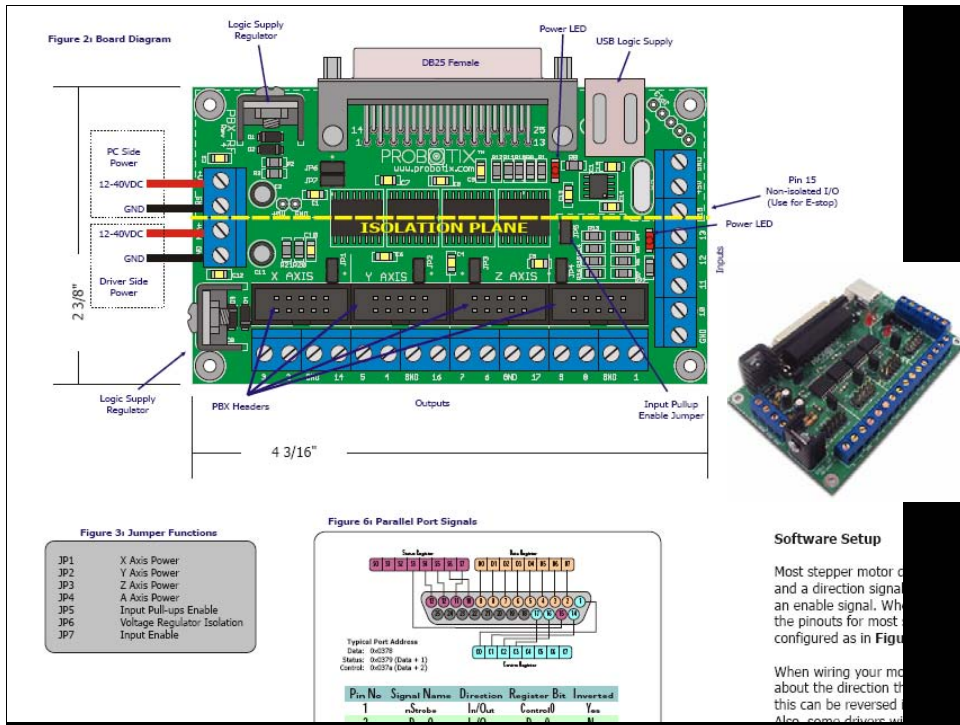
Simple breakout board plugs into parallel port and pins can be configured in Mach3 control software.

www.candcnc.com, www.probotix.com, www.cnc4pc.com
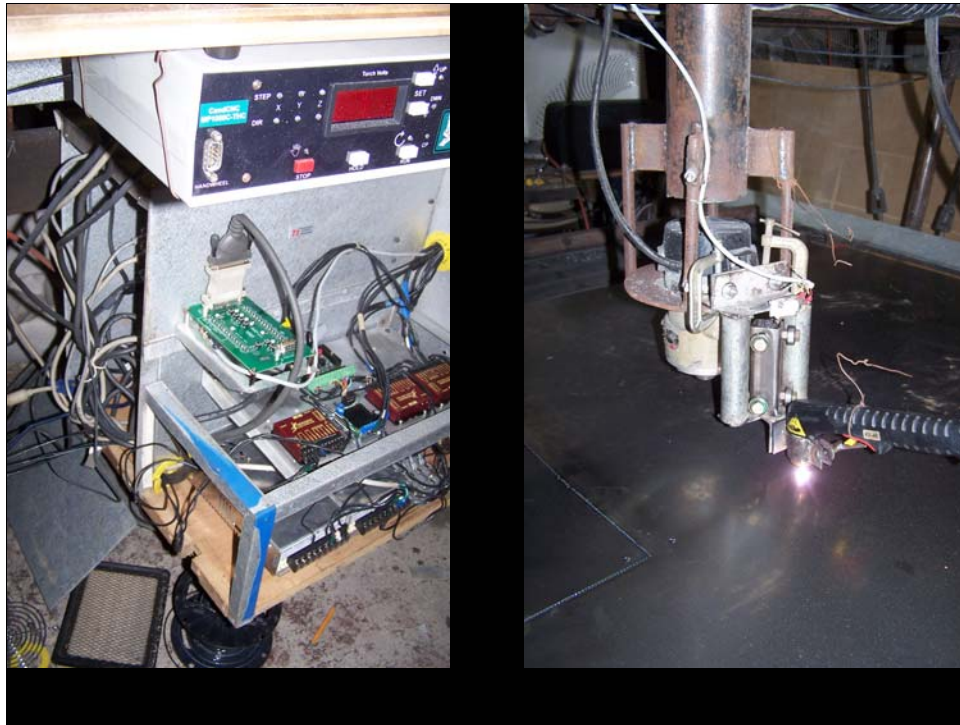
The simple system first installed was not capable with torch height control, upgraded electronics to include thc system, control card in the plasma unit. Enter torch height controller.
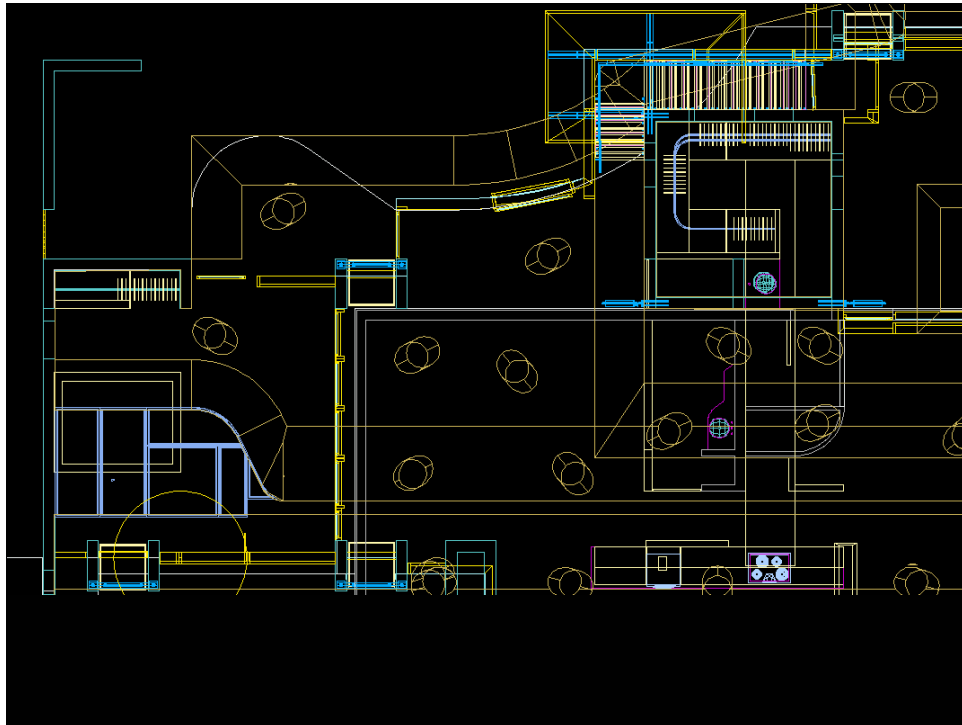

Ref: www.candcnc.com
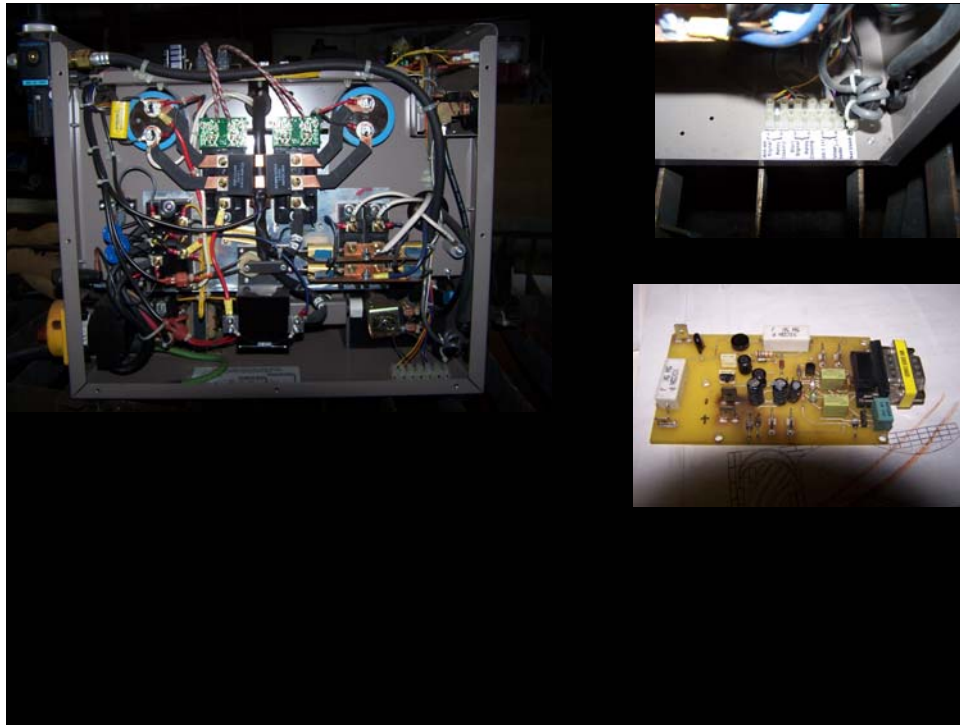
ESAB plasma unit, hi frequency start. The signals must be isolated to prevent the hi voltage, hi frequency from getting into the control electronics.
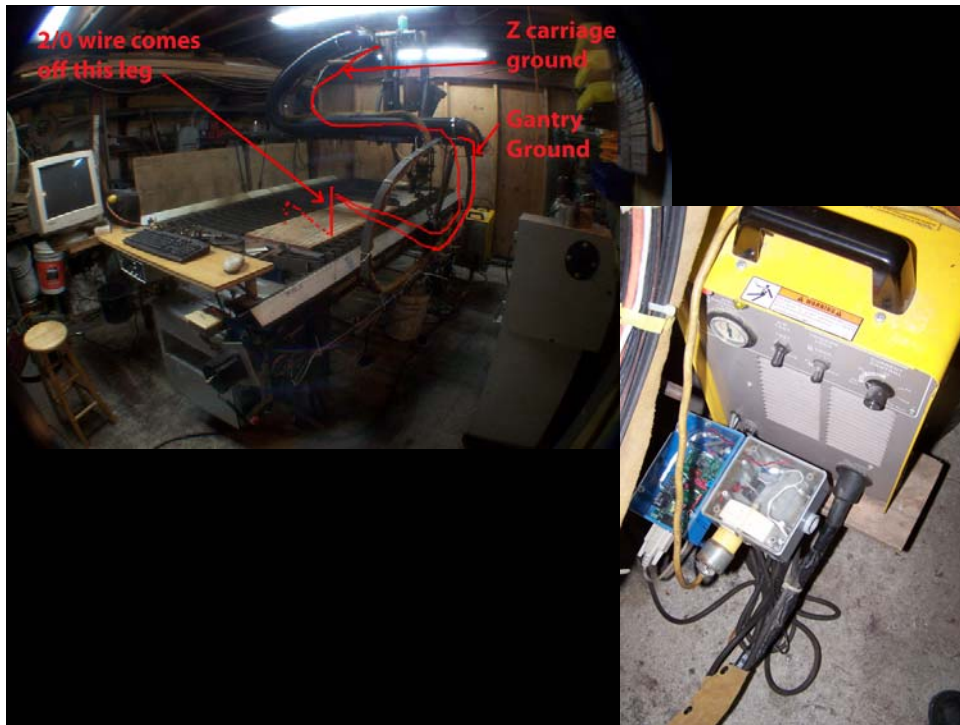
Hi frequency start – superior machine but must deal with RF noise & ~ 15,000Volts. Grounding and isolation of circuits.

Skylight layout.
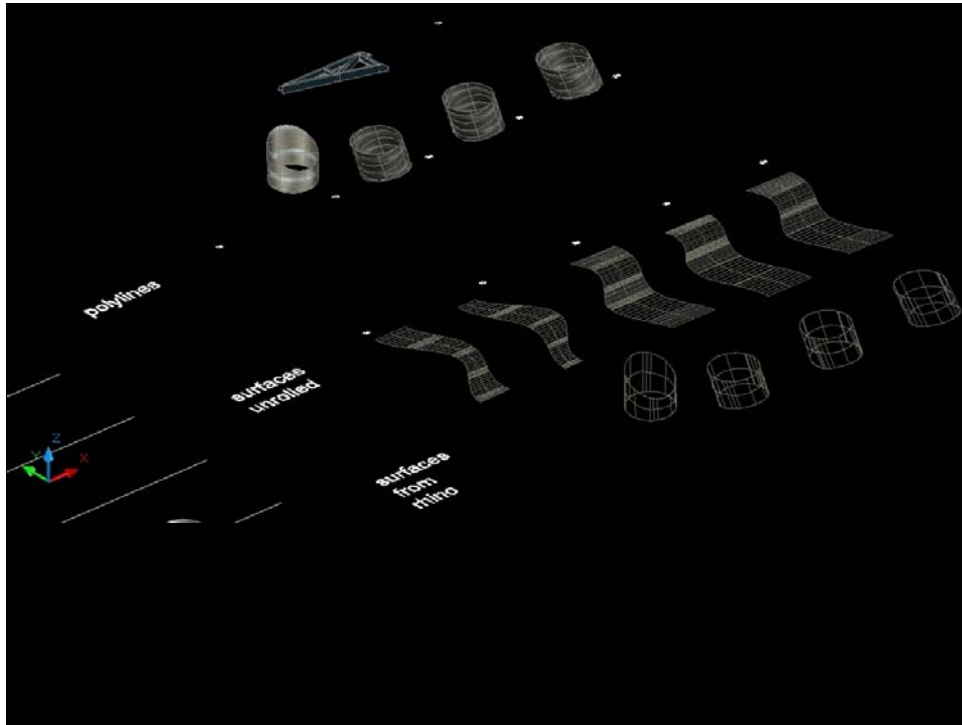
Sheetmetal cans with 2d unrolled shapes.
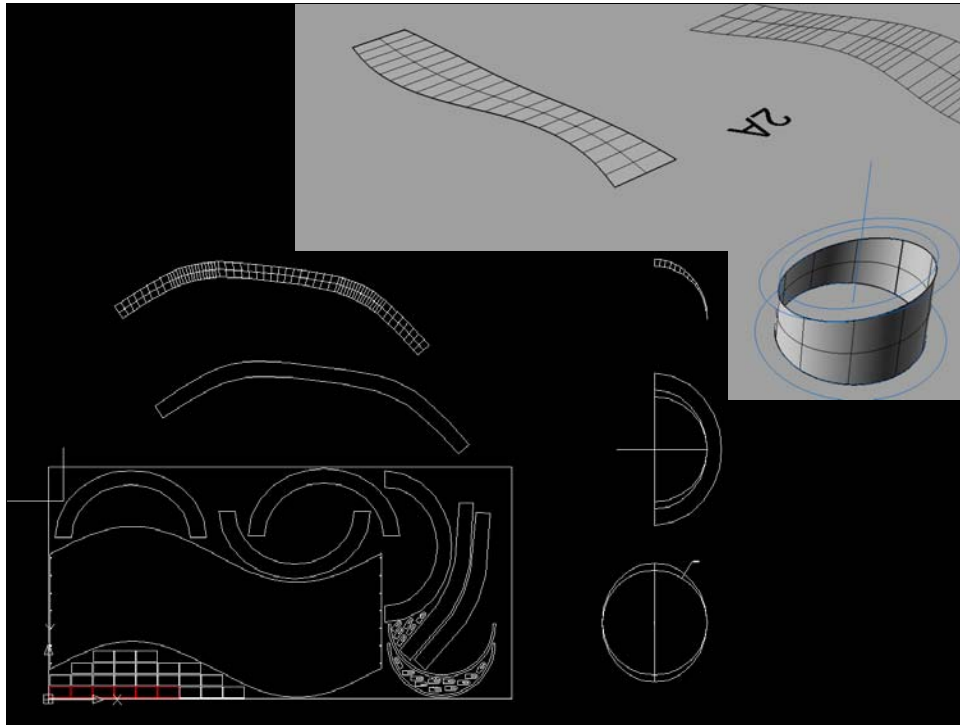
2d shapes to fabricate one skylight, plus additional pieces to make miscallaneous brackets for trusses etc. nested into a 4'x8' sheet in a cad drawing.
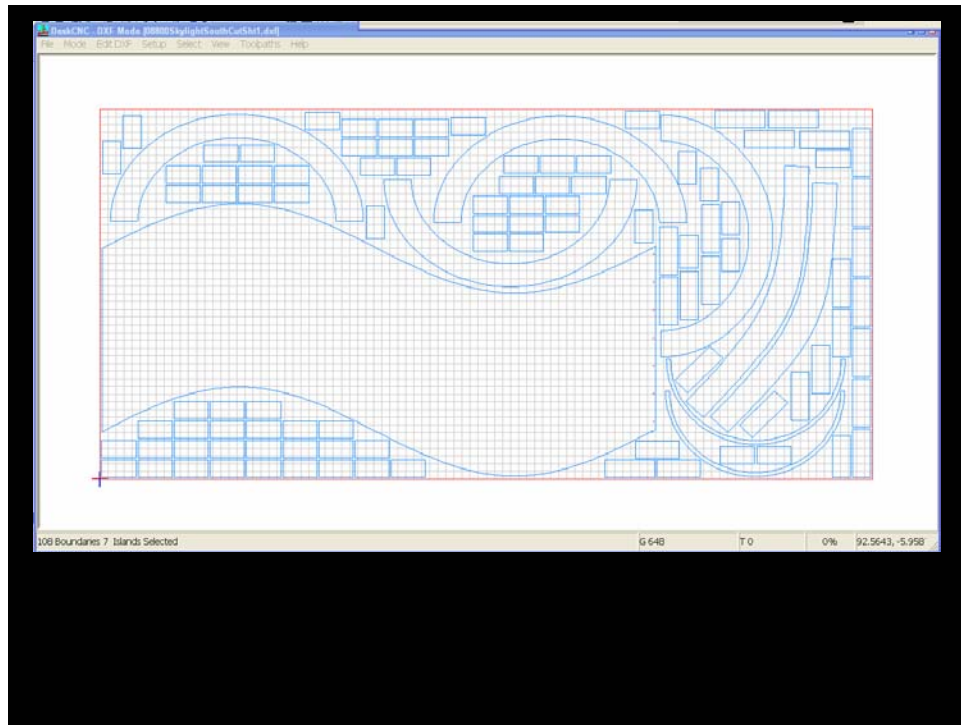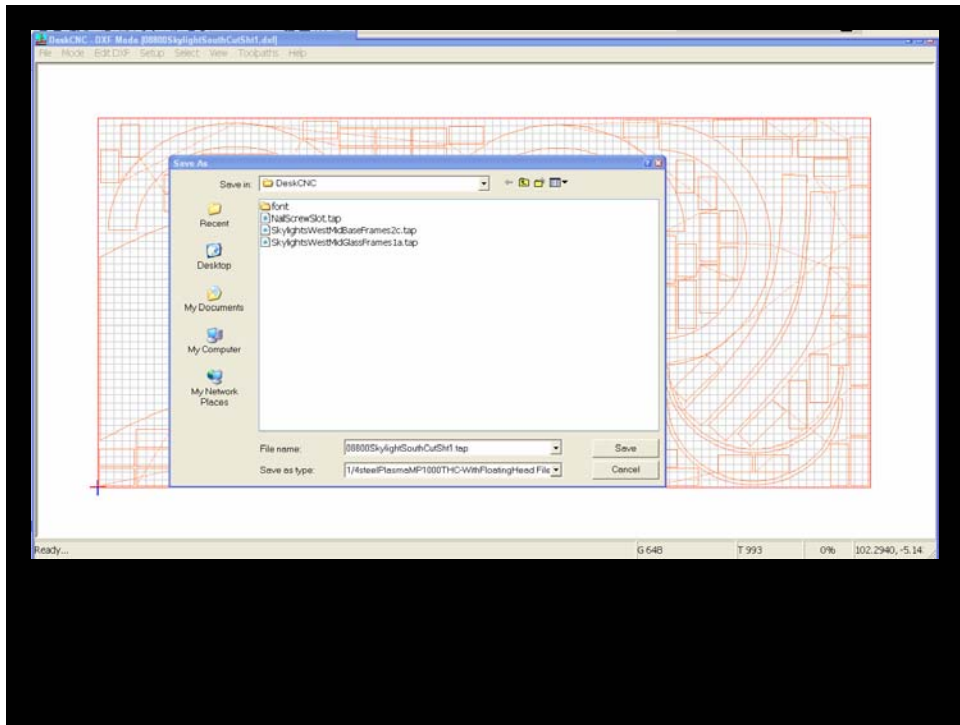
The nested drawing exported as a .dxf file and imported into CAM program.
DeskCNC in this case is the CAM program available at:
http://www.deskcnc.com/   30 day trial download, reasonable commercial
license cost. The CAM program takes the cad file and generates a "G-code"
file which is used by the control program to cut the parts with the machine.
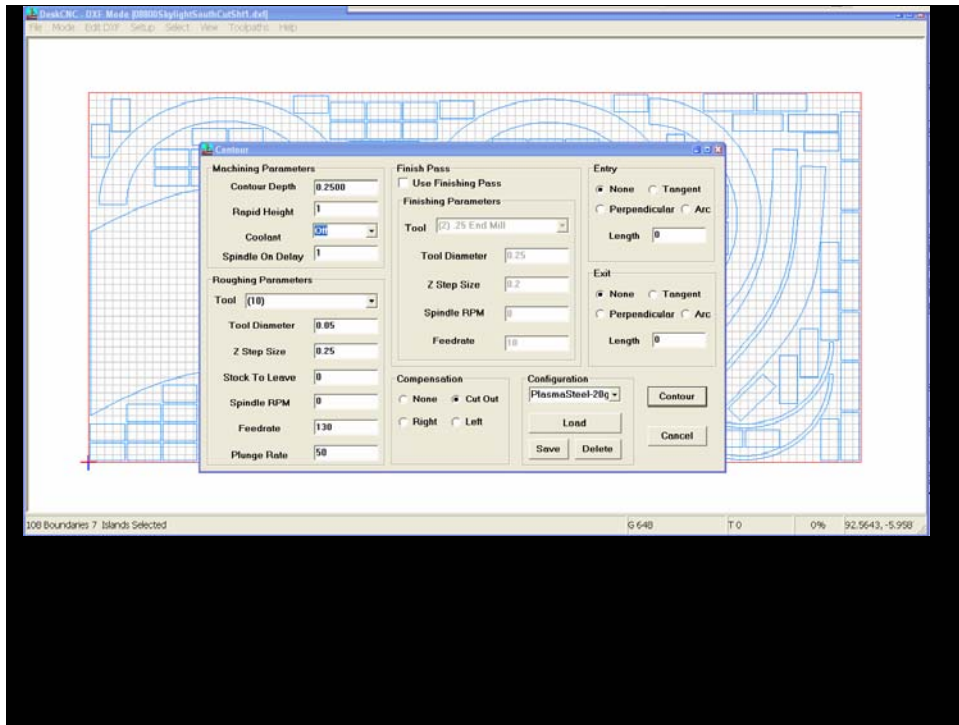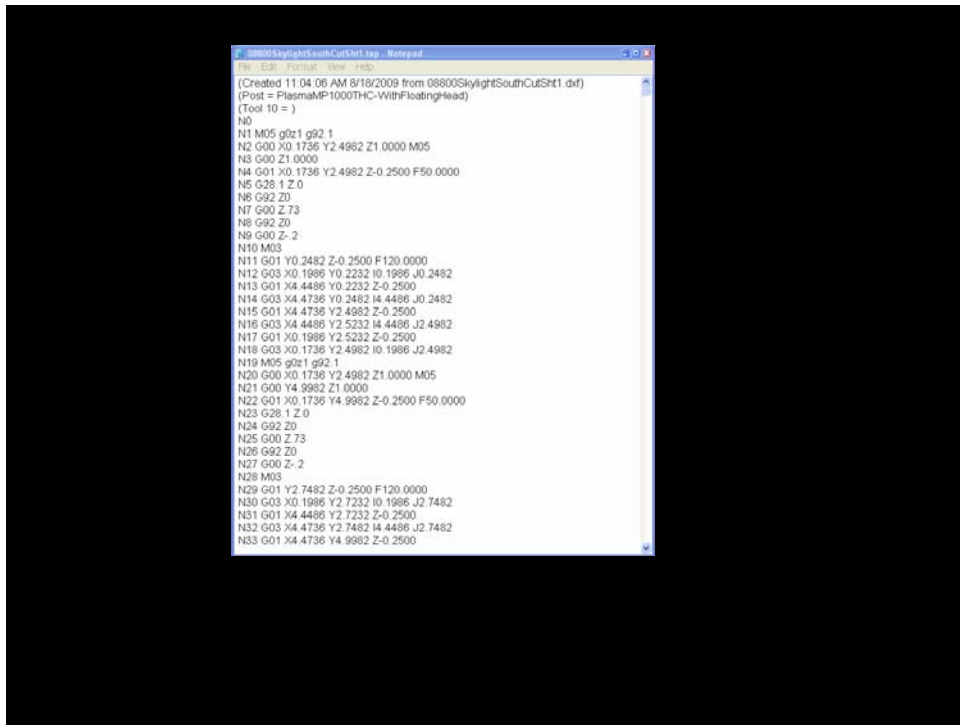
The "toolpath" parameters dialog box is where the cutting tool diameter, shape, feed speed, plunge speed, depth of pass, etc. are defined. DeskCNC offers an easily modified "post processor" which defines how it exports the g-code.
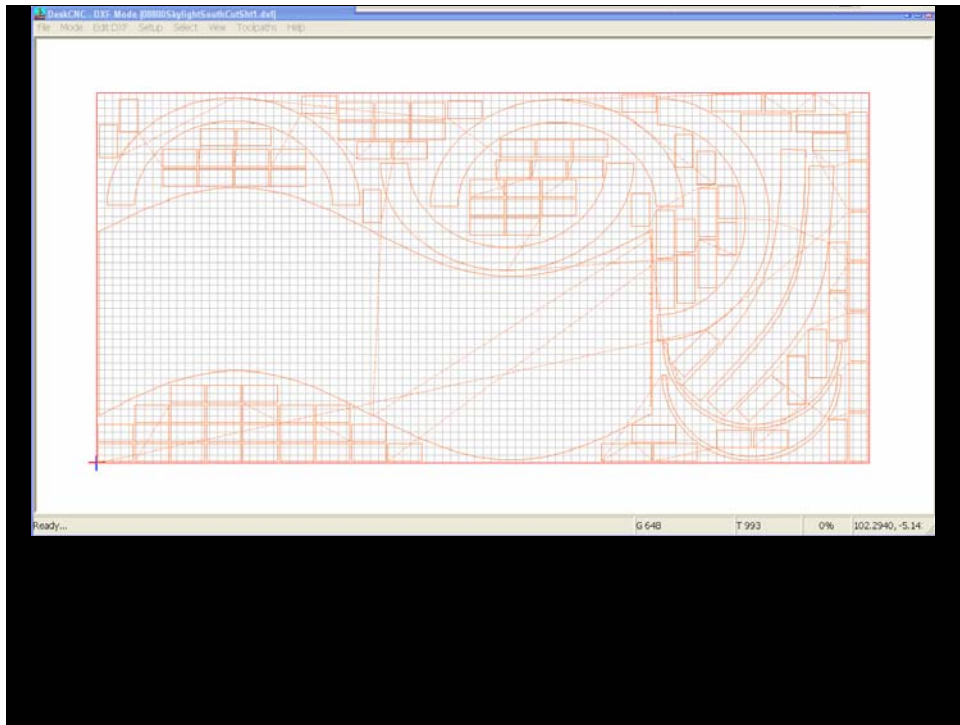
The toolpath generated, shown in red. The dotted red lines represent the "rapid" moves which take place between cuts.

Export g-code file dialog box (file>save toolpath CNC).

The g-code file. A simple text file with a .tap, .cnc, .dnc extension. Some machine control programs may require a specific file extension, DeskCNC allows you to define the file extension. Mach3 will open any of the above mentioned and more file extensions.

```
(Created 9:45:01 AM 3/12/2009 from
08800SkylightCutSht06.dxf)
(Post = PlasmaMP1000THC-WithFloatingHead)
(Tool 10 = )
N0
N1 M05 g0z1 g92.1
N2 G00 X43.3900 Y25.2710 Z1.0000 M05
N3 G00 Z1.0000
N4 G01 X43.3900 Y25.2710 Z-0.2500 F60.0000
N5 G28.1 Z.0
N6 G92 Z0
N7 G00 Z.73
N8 G92 Z0
N9 G00 Z-.2
N10 M03 G04 P.75
N11 G01 X43.3173 Y25.2027 Z-0.2500 F100.0000
N12 G03 X43.3166 Y25.1669 I43.3344 J25.1845
N13 G03 X57.4088 Y19.4804 I56.9549 J38.6602
N14 G03 X71.5449 Y25.2115 I57.8627 J38.6602
N15 G01 X71.5453 Y25.2119 Z-0.2500
N16 G03 X74.8426 Y33.3799 I62.6780 J33.5410
```

Desk CNC also allows users to customize the post processor, in this case code in red was inserted and made to be written in automatically before each feed move:

G28.1= reference home, travel to the home switch (0 location) of specified axis.

G92 sets location of specified axis to specified value
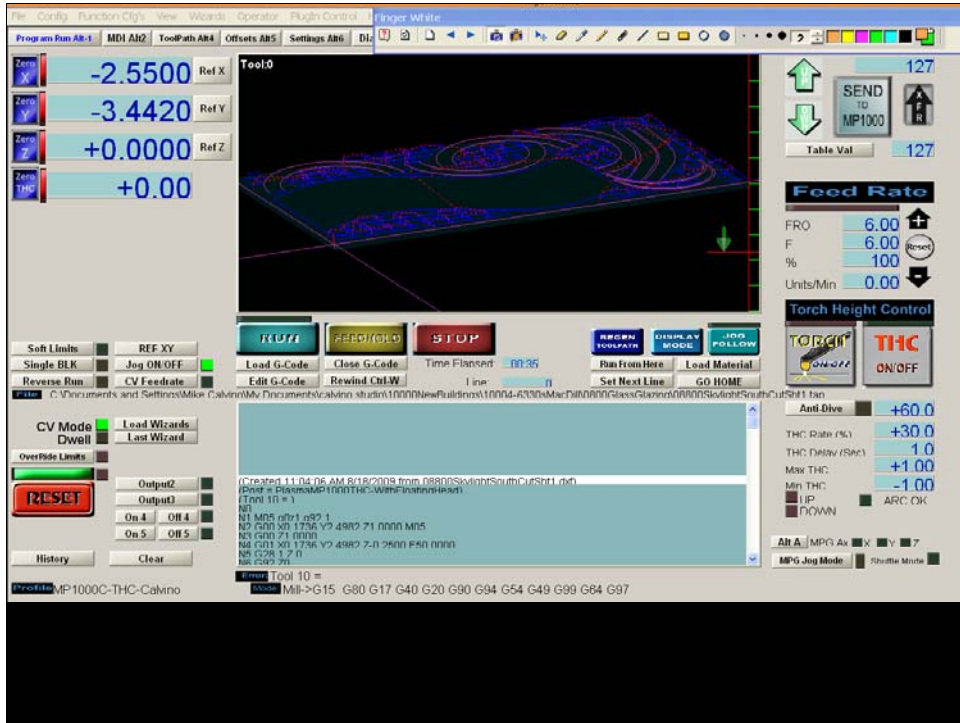
G00 = rapid move at current feed rate

.mov file: 2008-08-12-004.mov shows the effect of the g-code line set.
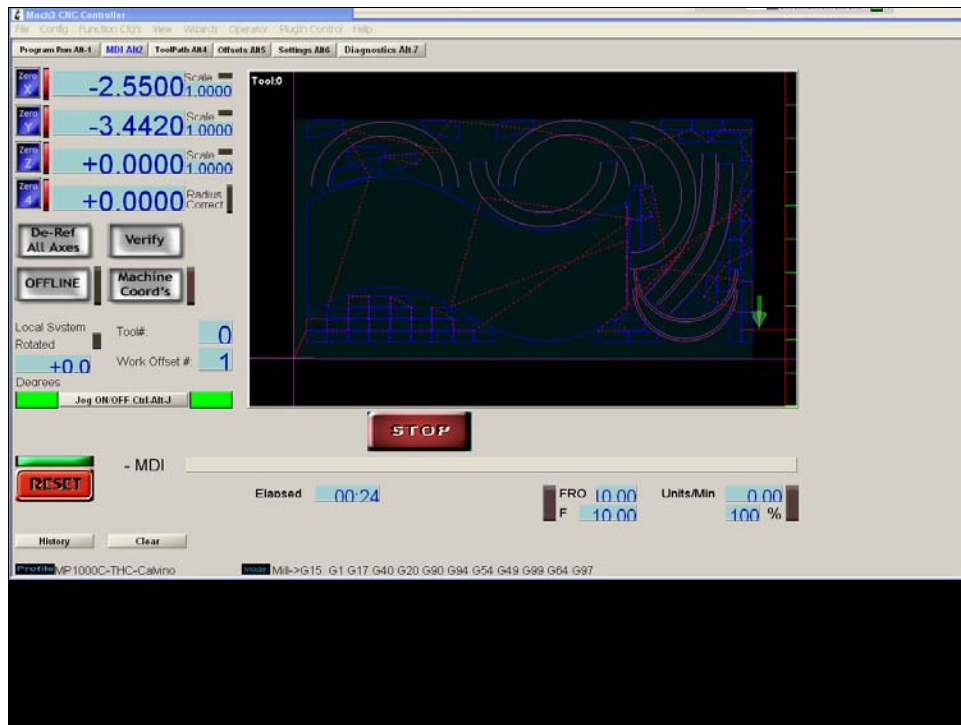
M03 = torch on

G04 – dwell
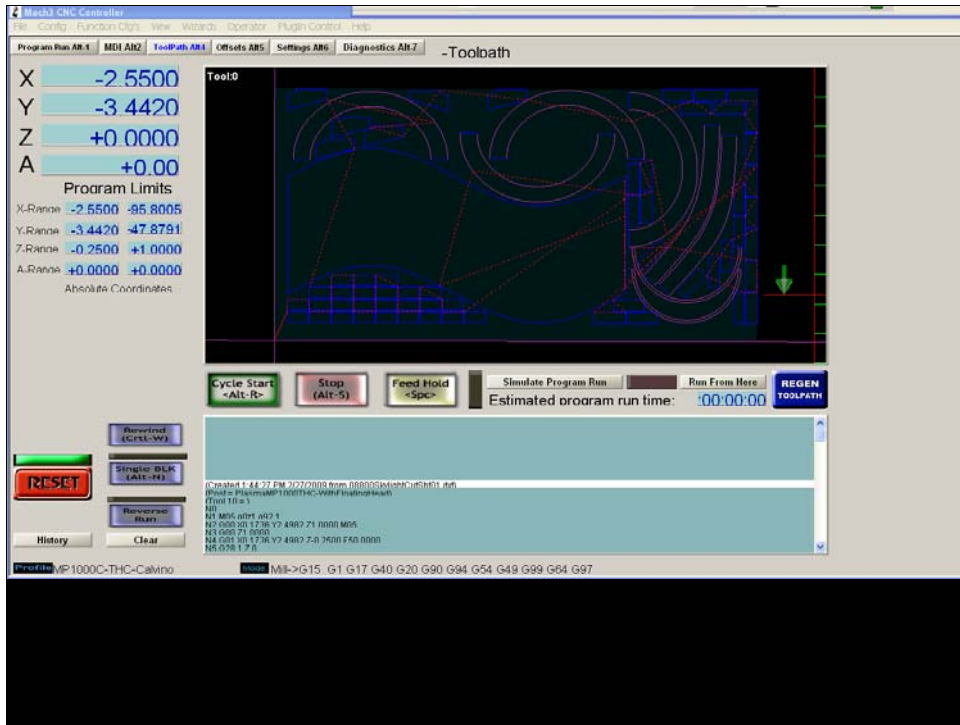
p.75 = pause for 0.75 seconds

The Mach3 manual available in downloads section of www.machsupport.com explains in great detail all of the M and G codes and the g-code language in general.
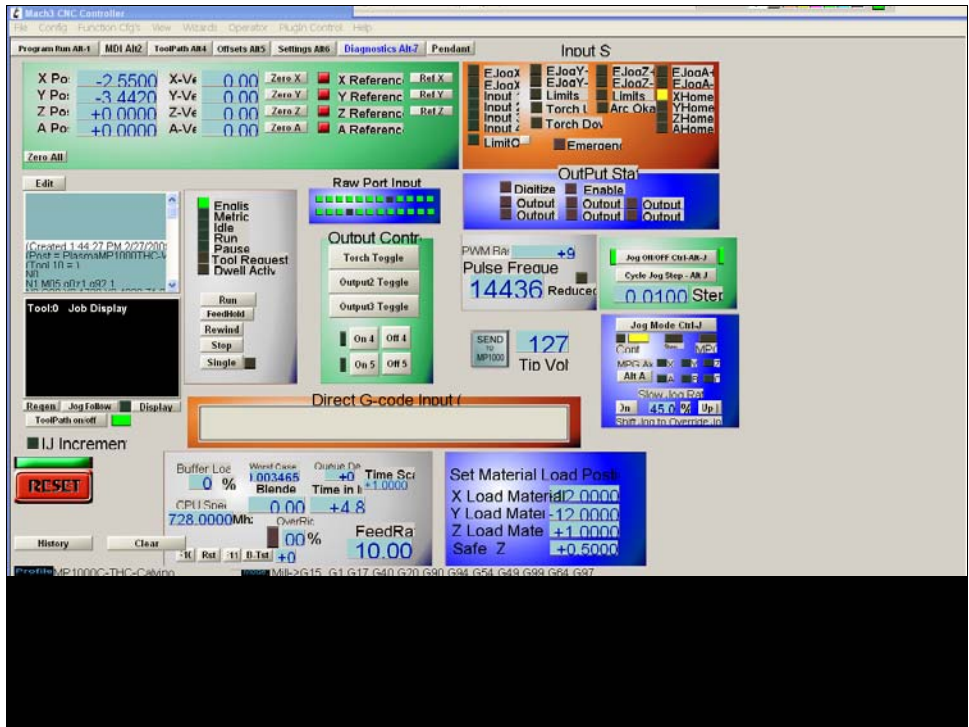
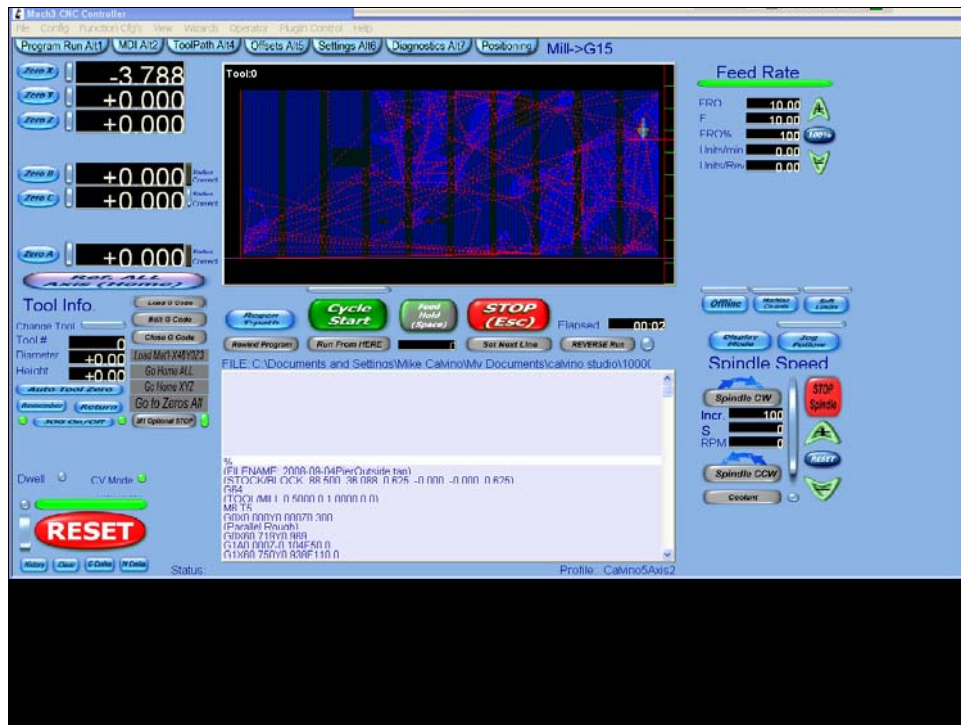Mach3 screen shot, main run screen for plasma cutting.

Second screen in mach3 allows user to enter code directly to control the machine.

This screen allows users to run a simulation of the cut file to estimate cutting time.

Diagnostics screen allows troubleshooting and monitoring of all circuits in the system.

Screen designer available for mach3 (from downloads section) allows users to re-arrange screen elements and even make custom buttons with code embeded in them to control the machine.
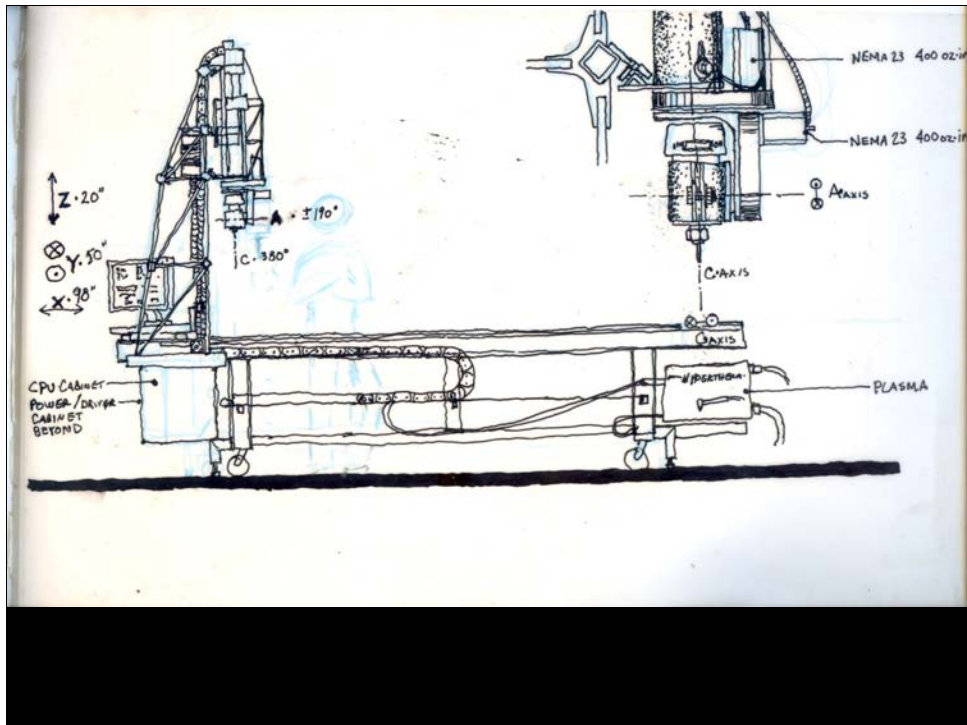
Mach3 can control up to 6 axes. This screen is for a 6 axis router.

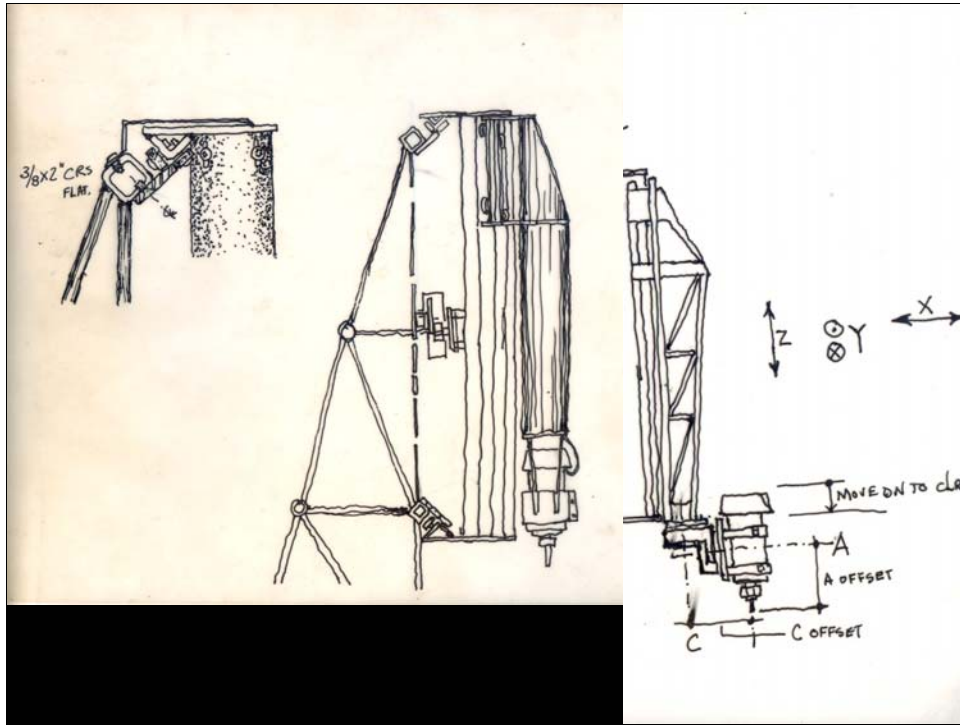6 axis router screen 2 showing coordinate limits for the cut file.

Motors upgraded, drive screws upgraded, should have used rack & pinion, would have even less $ . . . Live & learn.
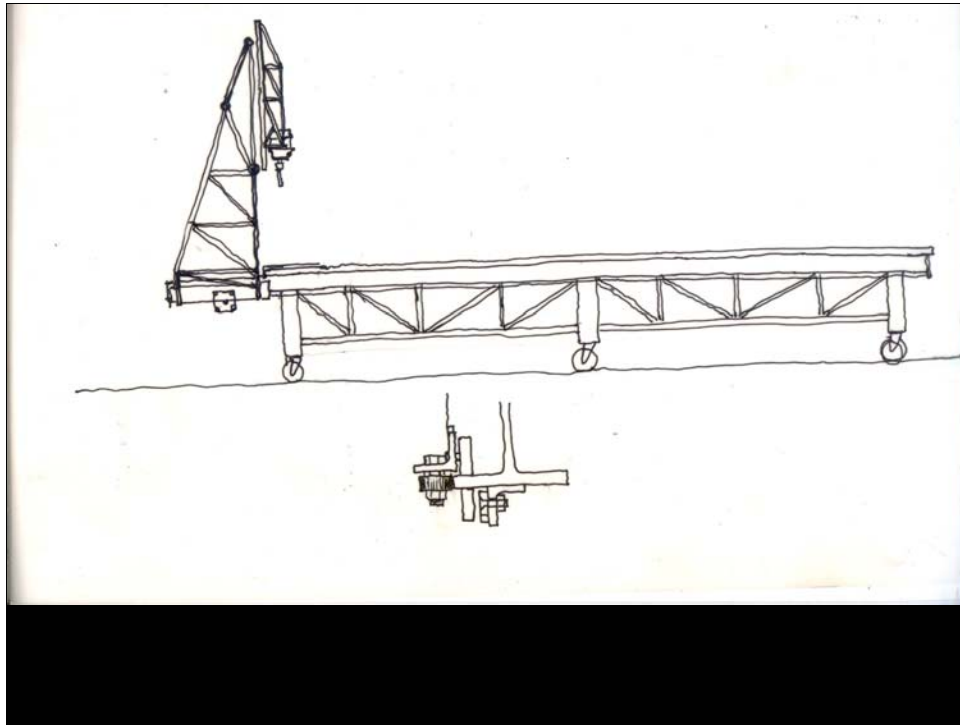
Torch height controller added.

Machine design and upgrade is infinite. Starts with a sketch and putting ideas on paper, then develop them through detail sketches.
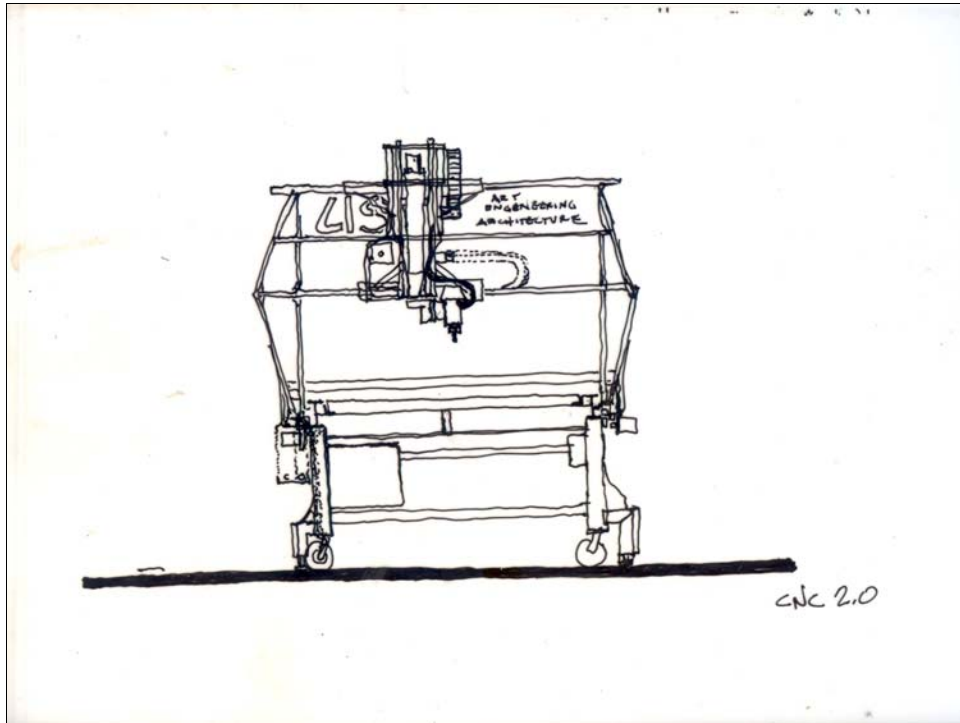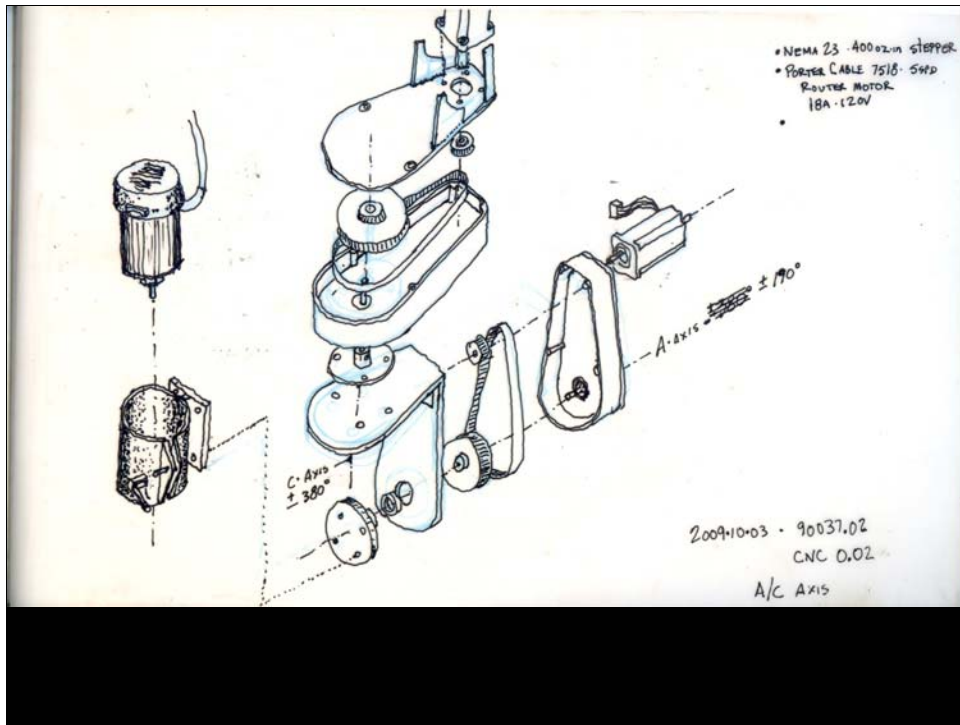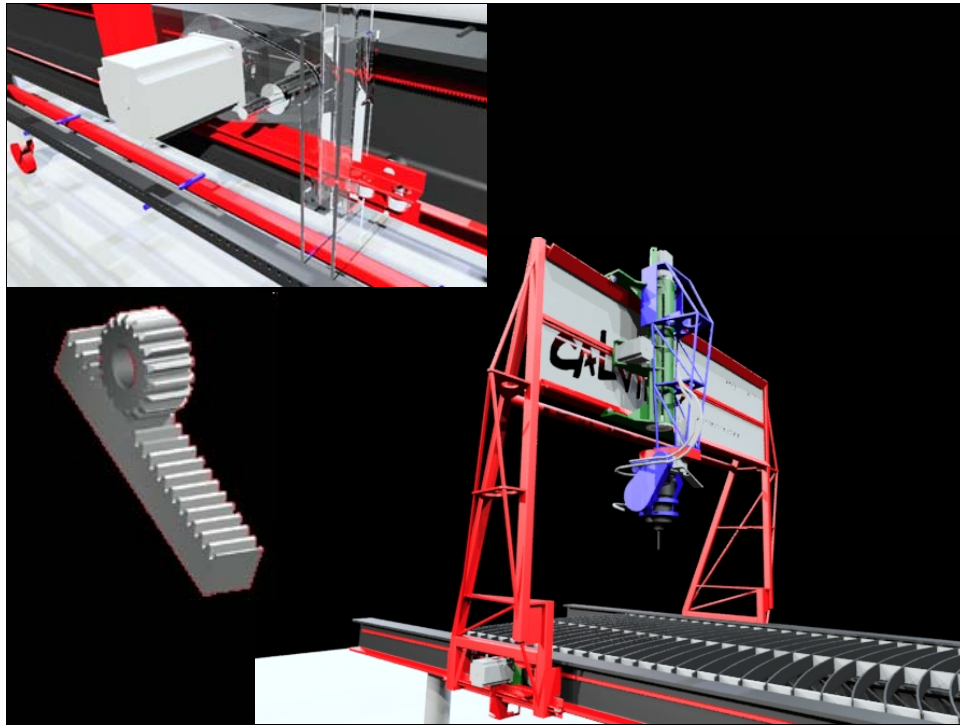
5 axis machine end sketch.

5 axis machine Z, B, C axes. Plus improved, lighter linear bearing on replaceable flat bar.
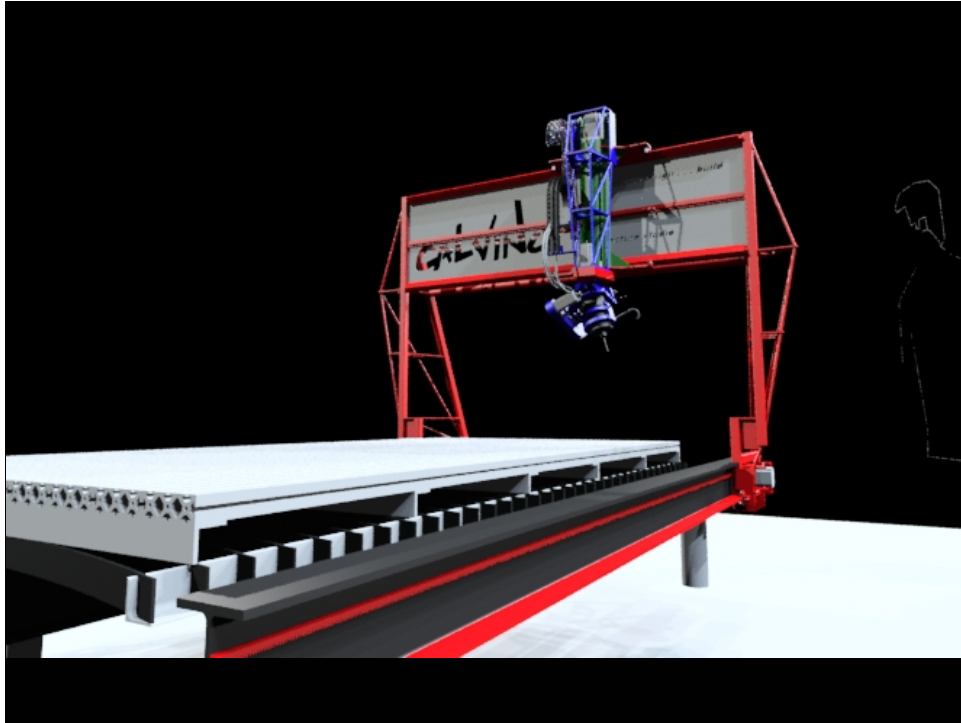
Long machine to load/unload second sheet of material while first is cutting.

Exploded axonometric sketch of b/c swivel head. Exploded axo is very useful to develop systems and details.

Rack & pinion, upgrades and modifications will be perpetual. – 3d cad model used for developing and defining parts to be fabricated and cut.

5 axis router with aluminum T-slot table. http://www.tslots.com

Lower left: Fabricated skylight.

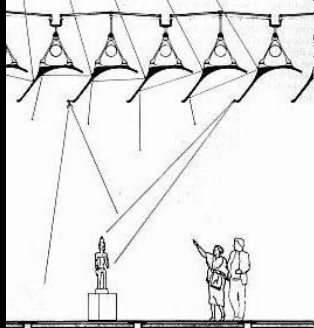Upper left 4'x8' sheet on cutting table with pieces cut.

Right: skylight can in roof framing.

Photos of installed skylights. The roof at lower right is a fluid applied acrylic membrane. This one is by Hydrostop® www.hydrostop.com.

Skylights beginning to define the quality of light in the space.

Renzo Piano DeMenil Collection, Houston

Nicholas Grimshaw, Waterloo Station.

Next class, glazing in overhead conditions.