The Wednesday morning introduction: getting started

If the thought of laser-cutting, CNC machining, circuit design and prototyping fills you with excitement and/or confusion we may provide the antidote. Maybe you have seen cute acrylic jewellery somewhere, or delectable vinyl decals, or even a world-changing or personal-life-changing invention that you have to figure out how to make.

Here, in East London on the University of East London Docklands campus you can do just that.

http://maps.google.co.uk/maps?client=firefox-a&hl=en&ie=UTF8&ll=51.507447,0.064341&spn=0.003212,0.009549&t=k&z=17

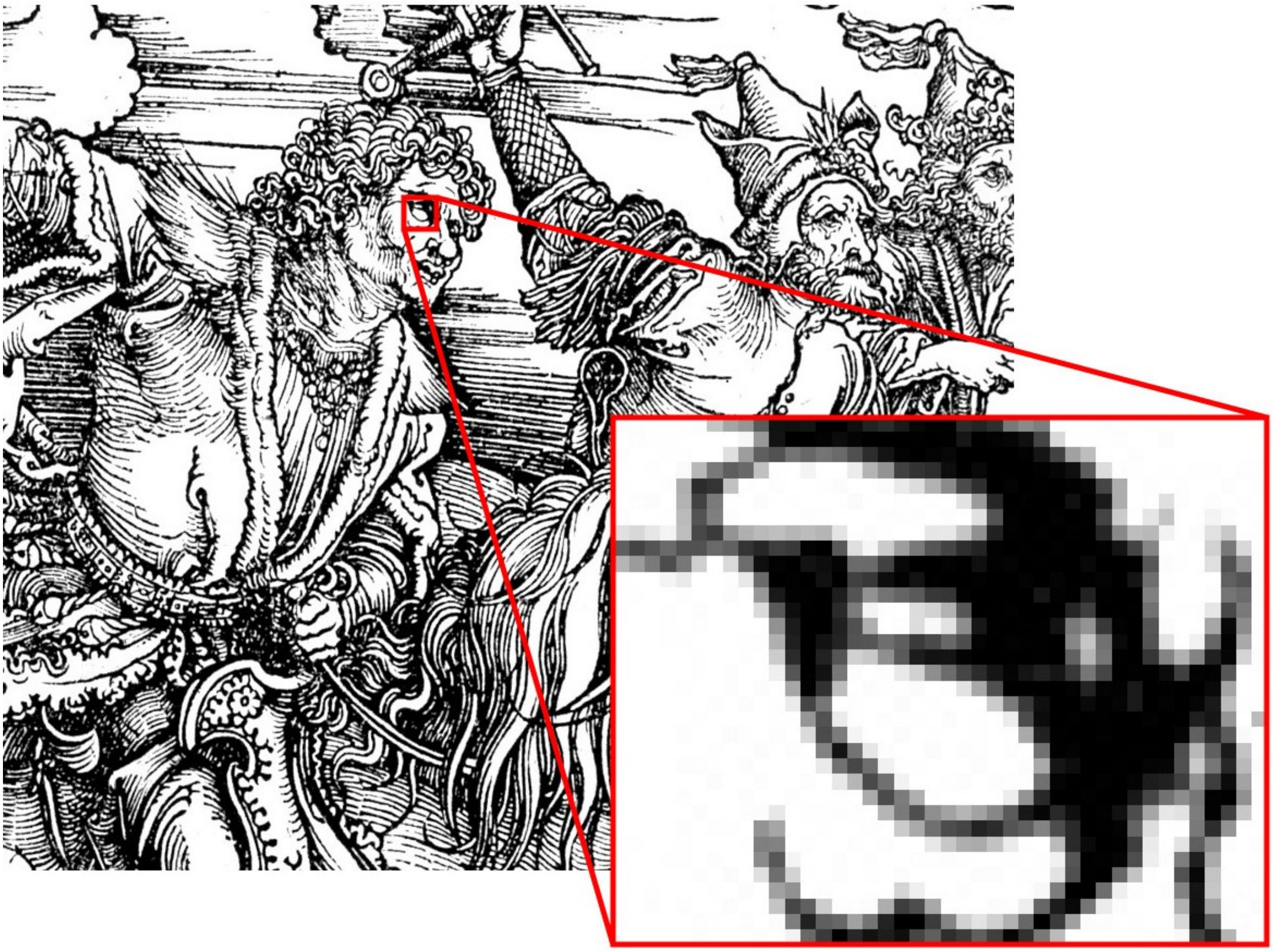
This introduction focusses on the basic requirements to convert a sketch into a format that can operate the laser cutter/engraver.

The Epilog laser is sent an image like a document or image is sent to a printer. How does it interpret an image? This depends on the image format, whether the image is represented as a **vector** or **raster** file.

Digital image format basics: raster and vector images

There are two different ways of representing visual data in a digital format. The most common is raster format where the image is stored as pixels, tiny squares of colour on your screen or print. Each one of these pixels has information about it's position and colour. The colour is often defined as RGB, or red, green, blue. The three colours red, green and blue can create any colour in the visible light spectrum when used together. The RGB value of a pixel simply defines the amount of red, green and blue used to make the colour of the pixel.

This format is the one produced by digital cameras, flat bed scanners and is the output of computer monitors. If you expand a raster image, or “zoom in” you will see that the picture is made from small squares of colour.

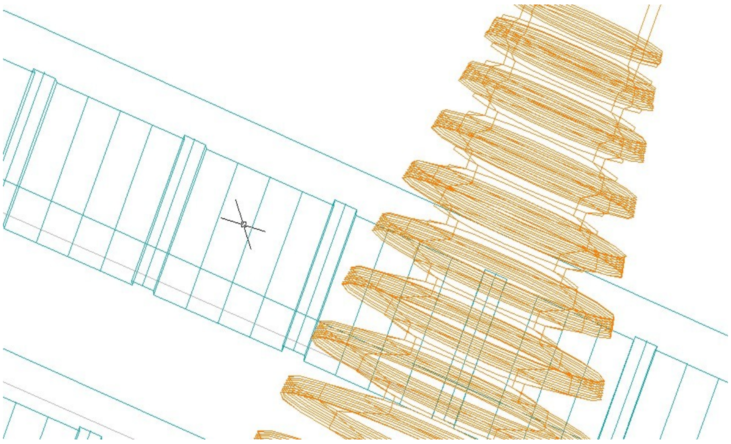


There are many programs that manipulate raster images, Microsoft Paint, Adobe ® Photoshop [http] and The Gimp [http] are well known. Raster images have a number of common file formats such as Windows bitmap (*.bmp), compressed raster formats include Joint Photographic Expert Group (*.jpg), Tagged Image File Format (*.tiff), Graphics Interchange Format(*.gif), Portable Networks Graphics (*.png).

Vector images store graphical information as lines or vectors (there are many different terms for the same thing, e.g. paths, traces, polylines, splines). Most lines come in a few easy definitions like circles, arcs, ellipses and rays. Anything else is covered by splines which are vectors that can contain complex curves, the maths behind their definition is usually the Bezier spline. In a vector image the areas defined by vectors at the borders can be “filled” with a colour or pattern, much like painting by numbers.
Images that do not have clear boundaries between colours (e.g. a photo of a sunset or candy floss) do not translate well into vector images. More about this later.
Because a vector image is defined by the geometry of it's vectors and not a fixed grid of dots, the scale of detail is unimportant. If a raster image is enlarged, it becomes possible to see the pixels that make up the image, if a vector image is enlarged, the lines and curves that make up the image are recalculated to be enlarged. There is no loss of definition. Text fonts are a common example of this as the alphabetical letters are defined with vectors.

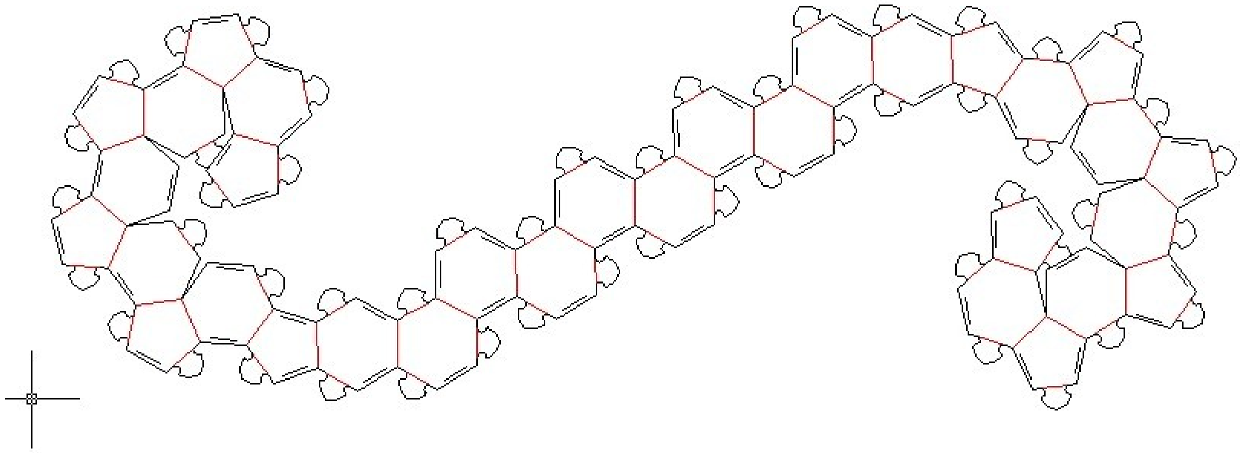
If a font is enlarged,

the text does not become pixellated. This makes vectors ideal for engineering and architectural design drawings. To draw a bolt on a cruise ship using a raster image, it would be necessary to have a picture as physically big as the ship to show the bolt in any detail. It would take an enormous amount of computer memory to store such an image.



With a vector drawing of the ship, the drawing of the bolt and the entire ship's hull are stored as a collection of lines and curves, the difference in physical length of any vector has little effect on computer memory. This geometrical definition of an image does not rely on the resolution of pixels, the precision definition makes the vector image suitable for controlling manufacturing machines. The vector drawing programs used for architecture and engineering are termed CAD or Computer Aided Design, when CAD vector drawings are used to drive a machine, this is Computer Aided Manufacture. There are vector drawing programs used for graphics such as Adobe Illustrator, CorelDraw, Xara Extreme. These programs tend to have better facility for fills and shading than simple CAD programs such as AutoCAD or progeCAD. When it comes to geometrical patterns (such as ½ drops) and precise alignment, it can sometimes be easier to use a CAD program.

Why are raster and vector images relevant to using a laser cutter? The Epilog laser is capable of working with both raster and vector images. It interprets raster images as individual pixels and shoots a beam of laser light with a brightness corresponding to the brightness of the pixel. This is ideal for engraving photographic images. When it becomes necessary to cut through materials, it is better that the laser beam continuously follows the path of the cut outline rather than cutting individual pixels that make up an outline in a raster image. If the image is a vector image, the laser beam moves along the individual vector.
The Epilog laser is an example of Computer Aided Manufacturing as it uses an image file to control the machine.



This leads on to the practical question: what is the easiest way of putting a design in a vector format? This depends on the design. If the design involves straight lines and exact geometries, it is probably easiest to draw the design using a vector image program.
If the design is based around an illustration or has more fluid curves it is possible to get a raster image and vectorise it.

Vectorising a drawing using Adobe Photoshop (r) and Adobe Illustrator (r)
There is an automated procedure for tracing the edges of a raster image with vectors. The success of these techniques depend on the clarity of the boundaries in the original image.

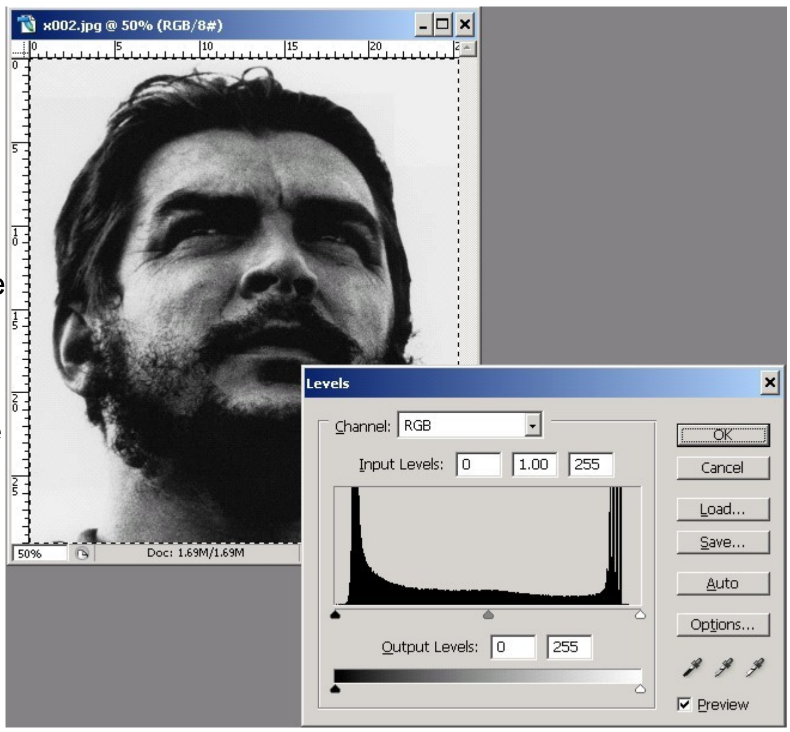
First open, or scan in the source image into Adobe Photoshop for cleaning up the image.
`File → Open` (Ctrl+O)
`File → Import →` [Scanner or camera TWAIN driver]

For most images, the vector information can come from a grey scale or black and white image.
`Image → Mode → Grayscale`

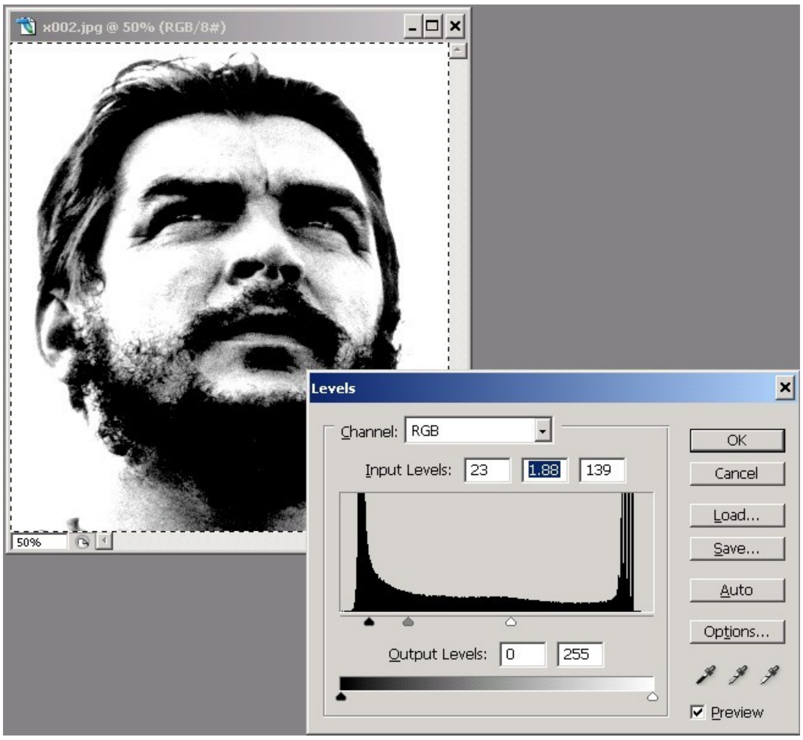
One technique to enhance the contrast of an image is to change the levels

`Image → Adjustment → Levels` (Ctrl+L)

Images that work well will have a generous difference between the levels of black and the levels of white. Adjust the pointers below the graph to clip the variations of black and white in the picture. Note that the graph can be misleading as the height of the black graph indicates the proportion of grey scale colour present, the greyscale colour represented corresponds to the position on the horizontal axis. You may find that in obtaining one



clear boundary, you lose other detail. This is a case of making artistic decisions.



One process which may sharpen local detail is a “High Pass Filter”

Finally, you may find speckles on the image, there are noise filters in Photoshop that weed out any spots under a certain size

Save the raster image as something Adobe Illustrator can read (the default file format *.psd works just fine) and open the file from within Adobe Illustrator.

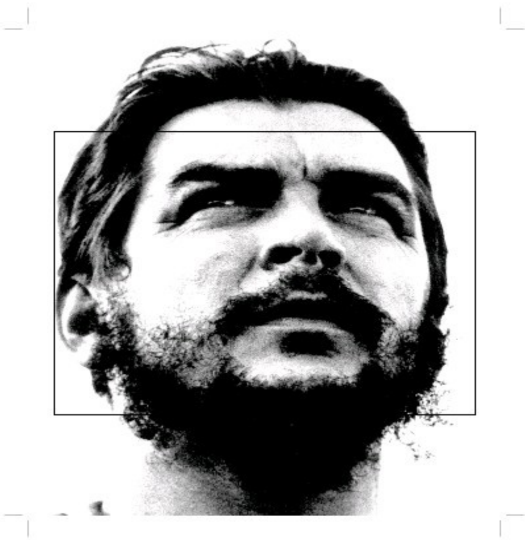
`File → Save As..`
(Shift+Ctrl+S)

NB: *It appears that Adobe Photoshop CS2 and Adobe Illustrator CS2 crash readily when running simultaneously on an iMac with OSX as we have in the MAGICbox. Sometimes it is easier to just run one program at a time.*

`File → Open` (Ctrl+O)

If you find the image larger than the “Artboard” in the background (the black square outline defining the document size), adjust it to fit or it will clip the vector output.

`File → Document Setup..` (Alt+Ctrl+P)



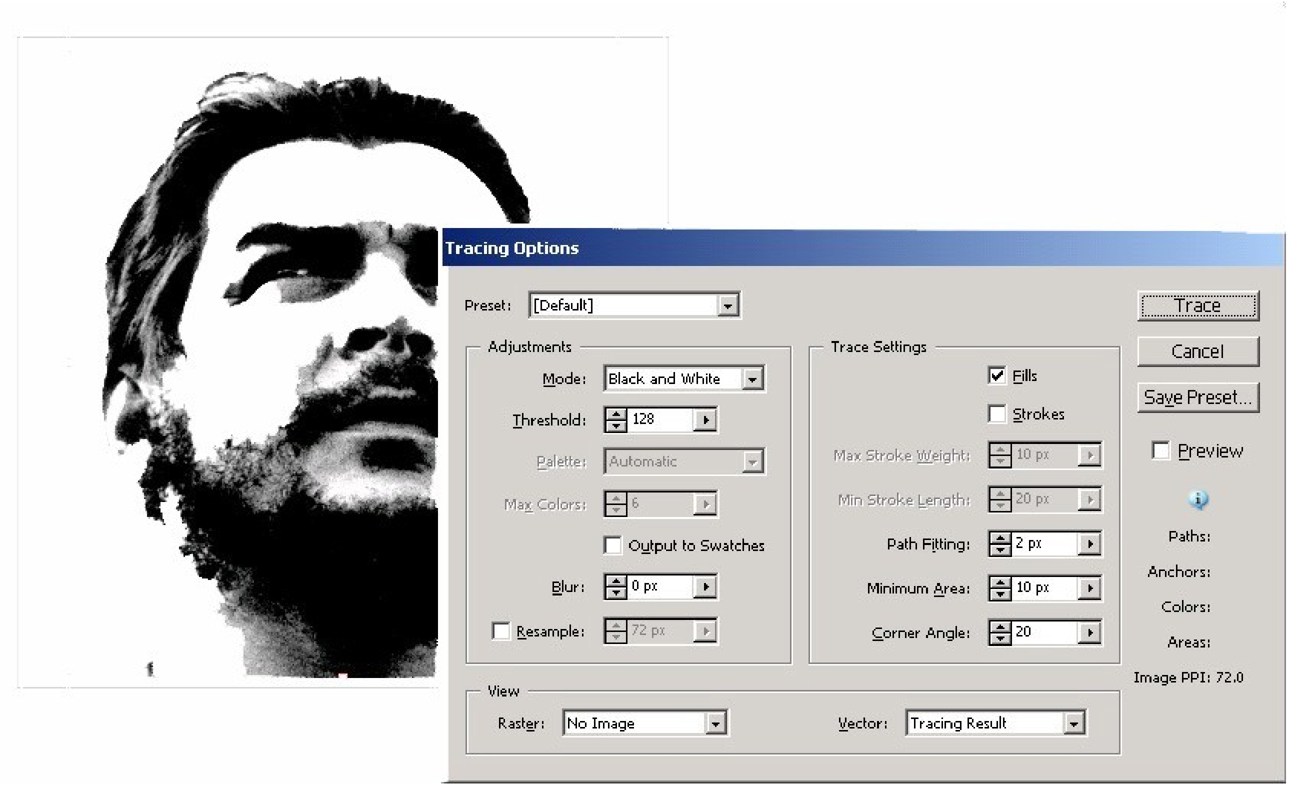
Select the whole image

`Select → All` (Ctrl+A)

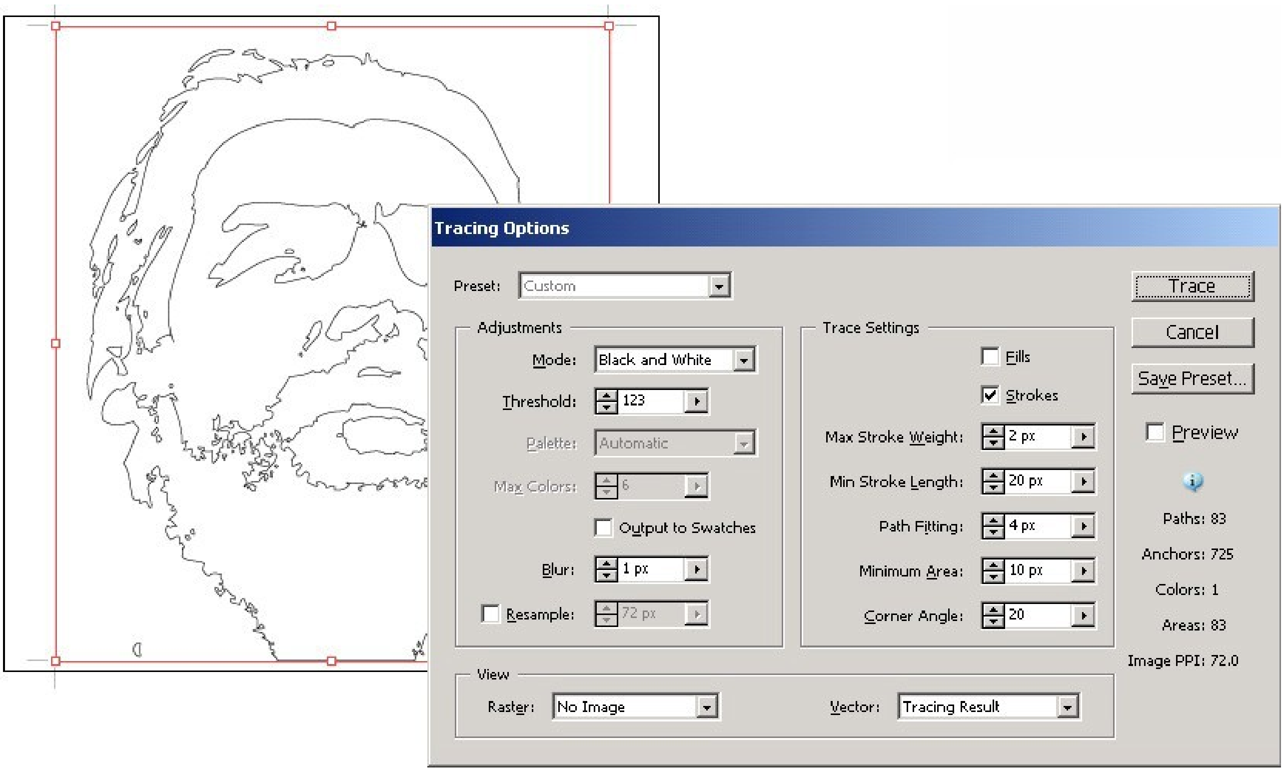
Open the vectorisation dialogue box

`Object → Live Trace → Tracing Options`

The Tracing option window gives good control over the vectorisation process, though the number of independent variables can seem intimidating. The first control to note is the “Preset” which gives a pre-set setting based on the type of image to be vectorised. This works well as an initial guess.

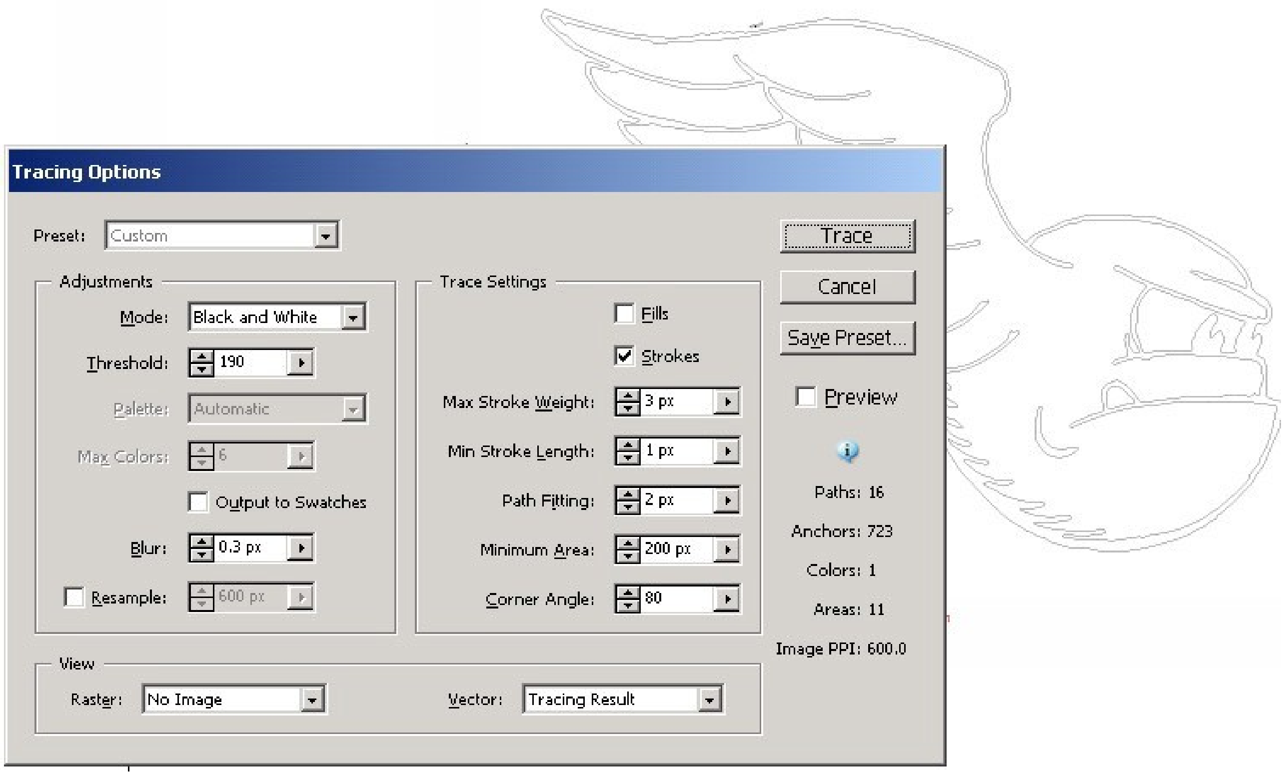


Note that the laser does not do anything about fills unless it is treating them as a raster area. To get a better picture of what the laser will cut, disable the “fill” check-box.

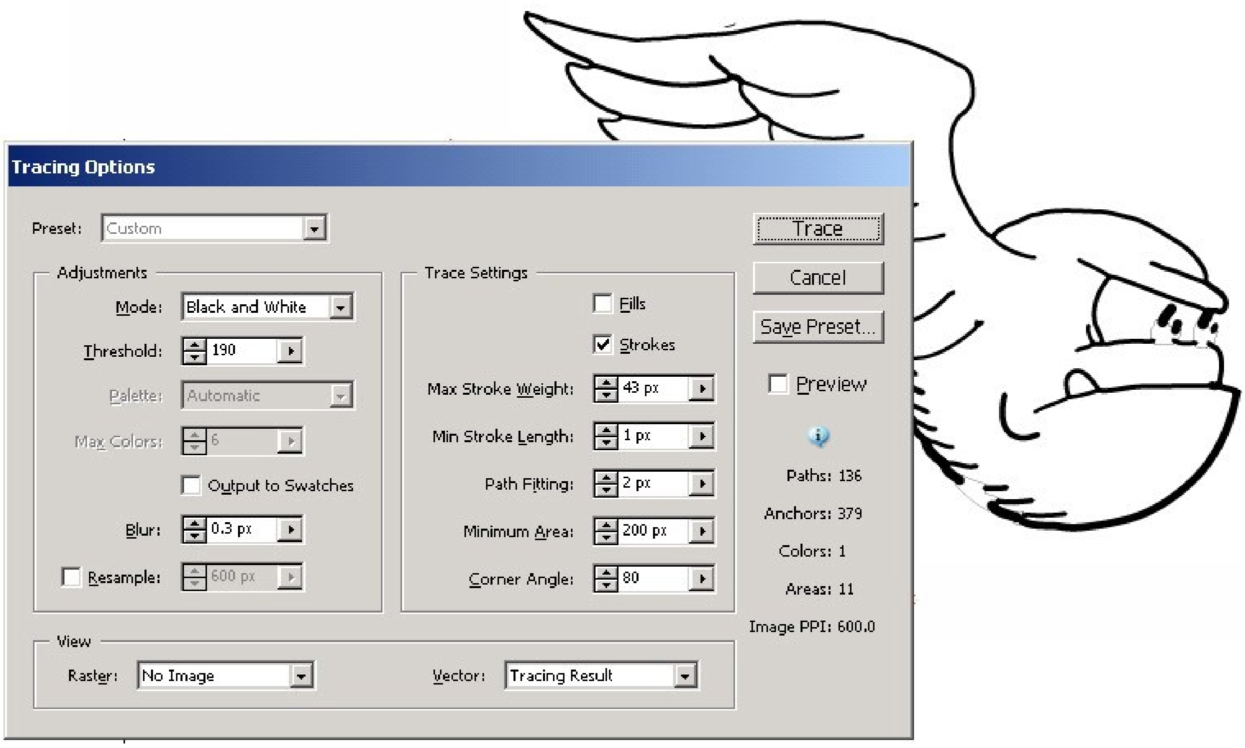


How thick is the actual laser cut or kerf? The manufacturer states 0.25 mm, 0.5 mm is a closer figure. This is only the case on perfectly flat material. If the beam is out of focus, the cut gets wider (and less effective). More on this later.

You will notice that on images with drawing lines or outlines, consideration must be given to whether the individual lines should be represented as individual vectors or as long filled areas.



To adjust this parameter, move the “Max Stroke Weight” slider. The value indicates the minimum width of a line in pixels to count as a filled area.



The default behaviour of Illustrator is to present lines judged as single vectors as thick lines. Hence the motley proliferation of thick and thin lines.

The next slider to make a notable difference to the vectorised output is “Path Fitting”. This value defines how faithfully the vector at a colour boundary follows the contrasting pixels. The larger this value is, the smoother the vector line becomes as it does not have to follow the contour of every pixel.

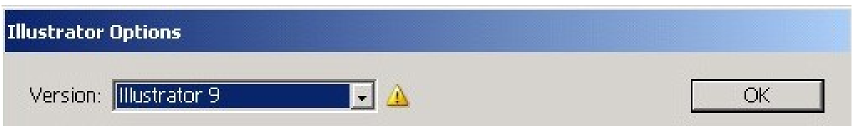
Remember that it is possible to superimpose vector images from different vectorisations of the same original image. Detail lost in one image can be superimposed on another.

It is quite common to find that on many images it is necessary to retrace steps and readjust the image in Photoshop to get the desired result.

If the vectors have to be further edited, manipulated or deleted, then select Live Paint.

`Object → Live Paint → Make` (Alt+Ctrl+X)

Once the vectorisation is finished, the vector file may be saved as a native Illustrator file (*.ai). This format is well interpreted by the CorelDraw 12 program that drives the Epilog laser.
When saving the file, select a Version 9 legacy format as opposed to the default CS2 format, otherwise the CorelDraw 12 program will not translate the format. This option is available on the second window that opens during saving.



Note: Files in the lab are transferred between machines on USB memory. If you attempt to open a file with a dot-underscore preceding your file name, this will create an error as the these files are an artifice of the OSX operating system (e.g ._example.ai). You should find your file elsewhere in the same directory. Further unusual behaviour involving USB memory may occur if there is a U3 virtual partition on the device, this will cause the Windows 2000 operating system to reboot on the computer driving the laser.

The Epilog Laser (www.epiloglaser.com) is supplied with a CorelDraw driver and a rudimentary AutoCAD driver. As there is the potential to damage the machine using the AutoCAD driver, only the CorelDraw method will be covered here. [There is also a Unix CUPS driver, but to be honest there are few decent Linux vector packages, Inkscape, Xara Xtreme, Blender and GCAD are some examples.]

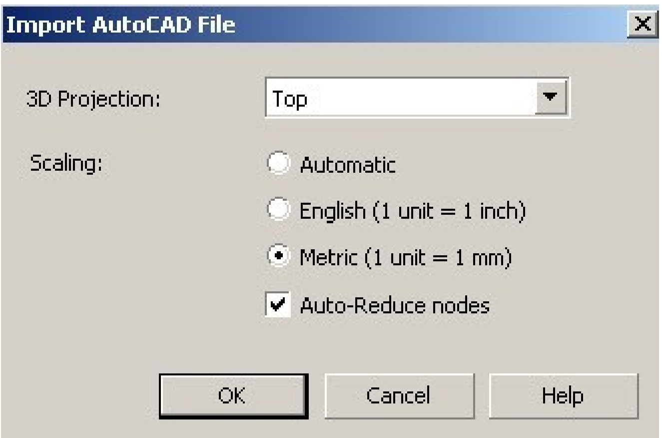
Open the file from within CorelDraw

`File → Open    (Ctrl+O)`

Note: do not check the “preview” box while opening Illustrator *.ai files as this causes

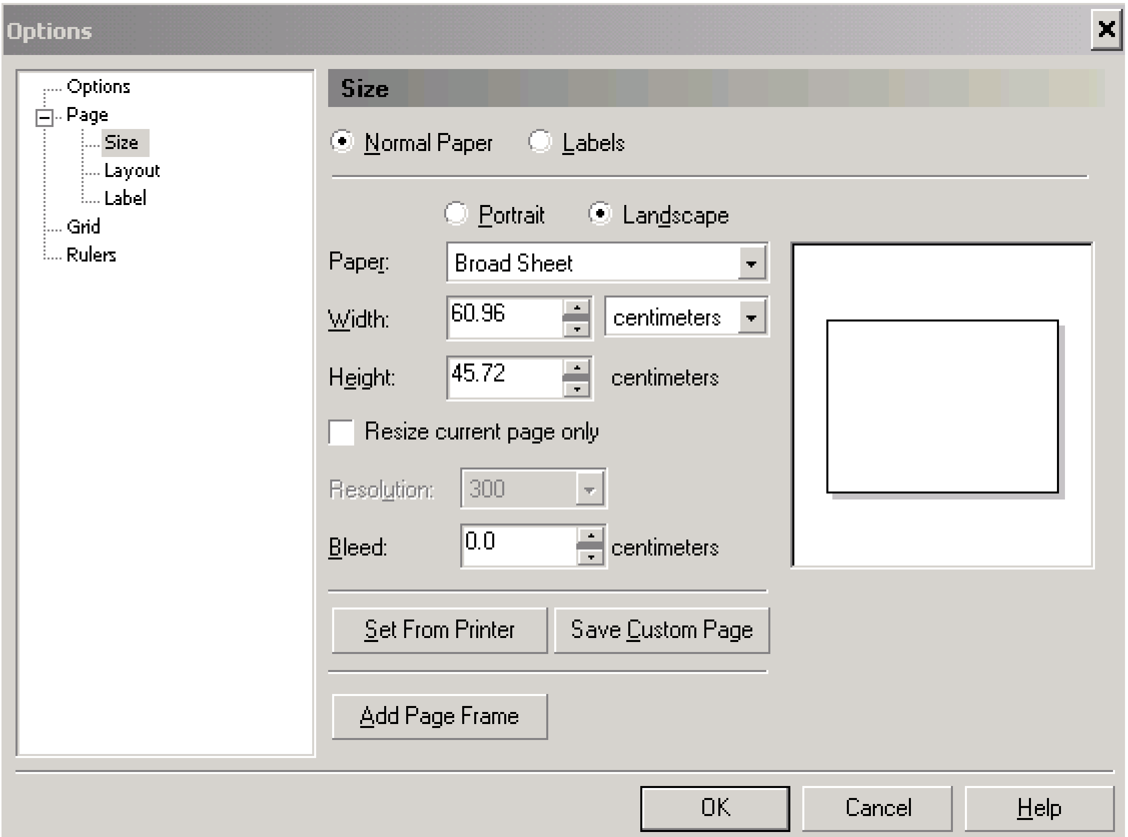
CorelDraw to crash.
If your drawing is not visible it may be necessary to zoom out (generally possible using mouse thumbwheel).

When opening Drawing eXchange Files (*.dxf – a CAD standard), *.dwg files from CAD applications, ensure that the formats are not too new, pre 2004 generally works. There is also a dialogue box that appears. Ensure that "**`Auto-Reduce Nodes`**" is checked, otherwise Corel will import duplicate instances of the same vectors. Use a specified scale such as metric or imperial for best results. Remember that units are arbitrary and that scale is a construct for the convenience of architects. When you lay out designs for a laser-cutter, they must be physically smaller than the laser-cutter bed.



There are two important layout considerations when using CorelDraw to drive the Epilog Laser.

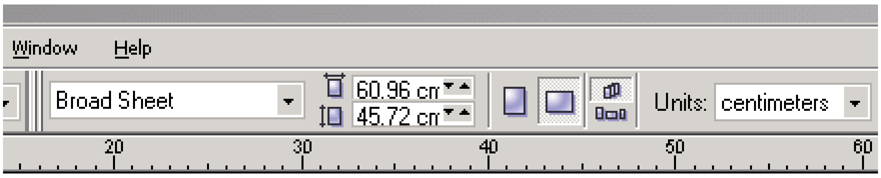
The background "paperspace" or "`artboard`" as it's know in Illustrator **MUST** be set to **`Broadsheet Landscape`** (24" x 18")



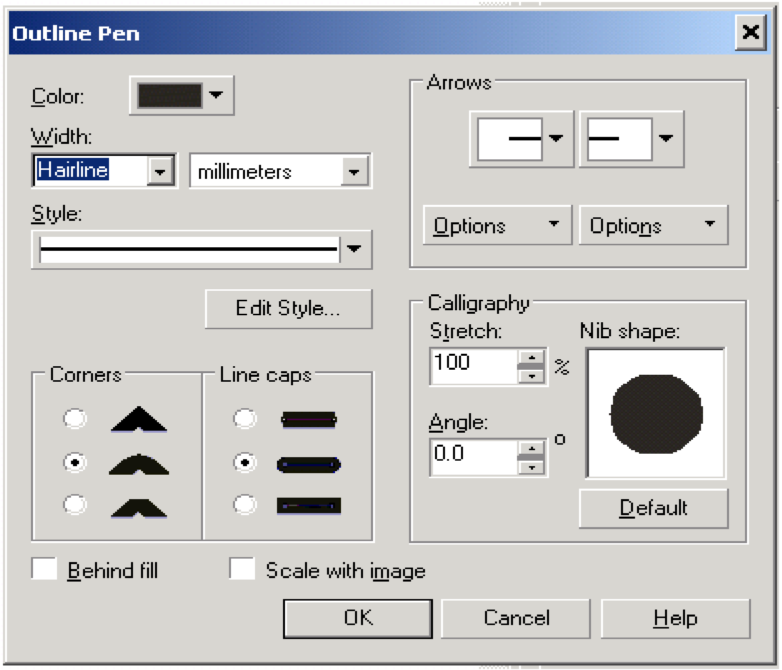
`Layout → Page Options`

Alternatively there is generally a toolbar available to do the same thing.

The other consideration is that the width of the vectors must be set to the minimum finite width, in the case of CorelDraw, this is given as “**`hairline`**”. The most reliable means of altering the vector properties is to select the vectors and change their properties via a nib icon button in the lower right hand corner of the window.



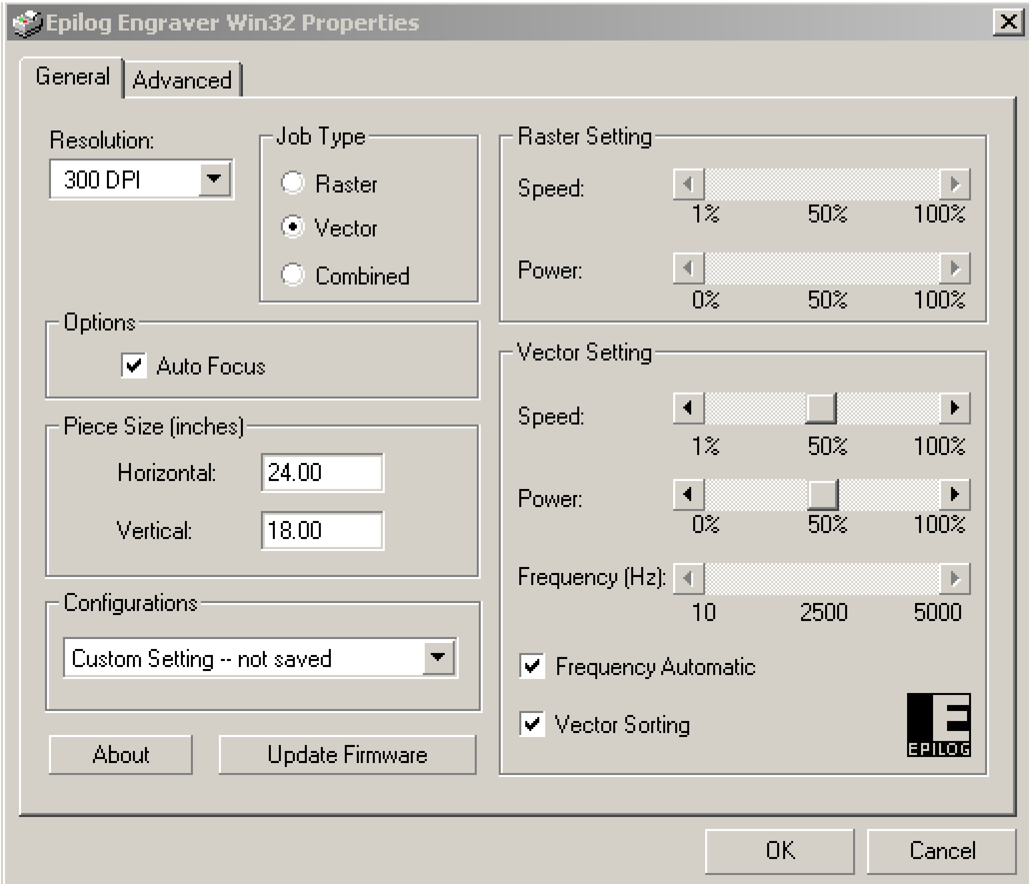
This should bring up a dialogue window in which the line width can be set. If the linewidth is set to a value greater than “**`hairline`**”, the lines are treated in a raster fashion. If the linewidth is set to zero, the vectors are ignored.



Vectors outside the Broadsheet background are ignored.

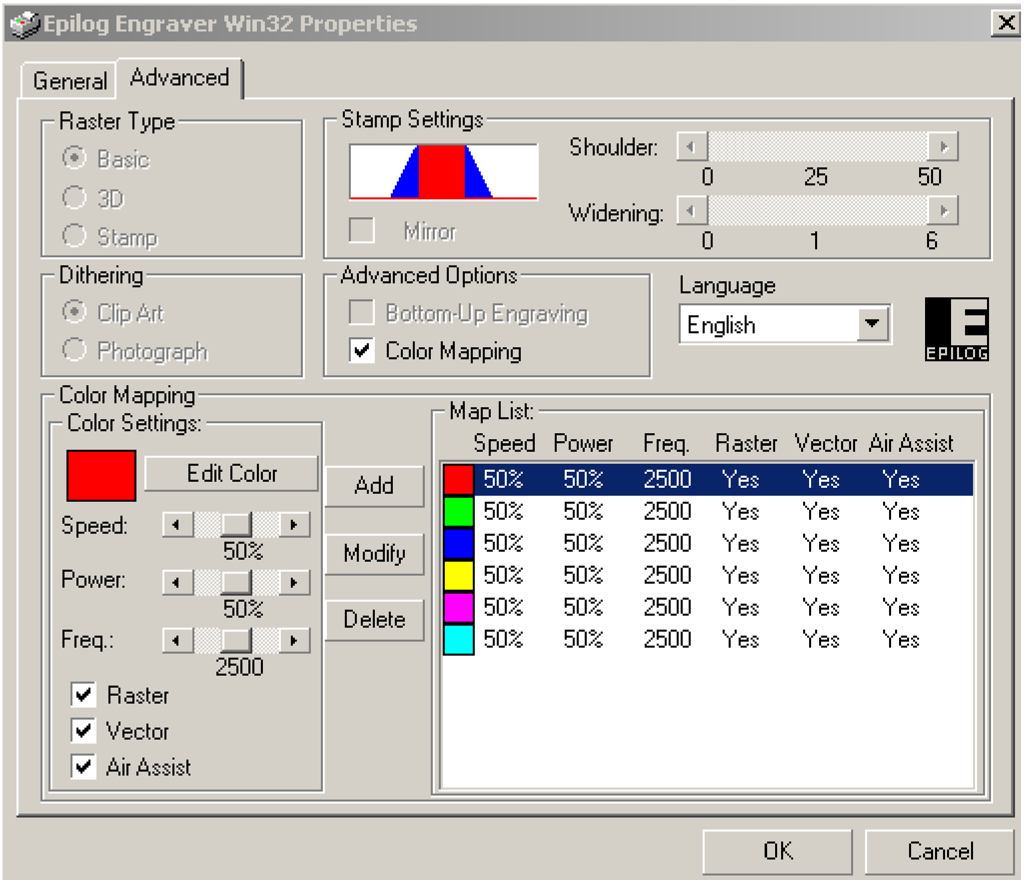
Once the image is ready to laser cut, the laser settings are accessed through the print driver interface. The main parameters to consider are the speed at which the beam moves and the power intensity of the beam. As the laser outputs 35 watts of light, the power is adjusted by pulsing the beam for periods of varying duration.

It can be difficult to estimate in advance the power required to cut a material of a specified thickness as each material behaves differently. The most practical means to establish the settings is to experiment with a test piece.



Ideally, the power given should just burn through the material and the speed should be the fastest possible in order to minimise time.
To give an example, if a material is not cut to sufficient depth with a setting of 100% speed and 100% power, then if the speed of travel of the laser beam is reduced, the time the laser beam has to cut through the material is increased. If, on the other hand, it seems that the laser beam is burning too deeply into the material then the power of the laser can be reduced.
There are samples in the MAGICbox laboratory of materials that have been cut with different speeds and powers that may give some guidance. When you find the ideal settings for your material, make a note of them.

“Advanced” Epilog driver parameters; setting different multiple parameters



The “**Advanced**” tab gives access to parameters that are used less frequently. The most common usage assigns different laser energy values to different coloured vectors. This can be useful if one wishes to perform cuts and engraved work on the same workpiece.
Please use very standard RGB

colour values in preparation (e.g. 254,0,0)as CorelDraw may sometimes create a visually identical colour to the one intended for the driver without actually sending the correct values. Tick the “**`Color Mapping`**” box to use this feature. Note that the values are not actually changed until one presses the “**`Modify`**” button. Any vector with a colour not specified in this box will be cut with the vector settings in the “**`General`**” window.

SAFETY CONSIDERATIONS FOR USING THE EPILOG LASER

The Epilog Laser presents a fire hazard as it uses a 35 watt laser to cut or engrave material. As such, it cannot be left unsupervised when in operation. If everything goes wrong and fire breaks out, the correct type of CO_2 fire extinguisher is situated next to the machine. A fire extinguisher of this size lasts less than a minute in continious use. You are under no obligation to put the fire out: do not endanger yourself. Leave the area and ensure that a member of staff or security is immediately informed. You may be relieved to know that spontaneous uncontrollable fire is a highly unlikely situation.

The Epilog Laser requires a compressed air supply of 1 to 2 bar and fume extraction. The compressed air is delivered from a compressor next to the laser, there is one electrical mains switch (see photo) and a knob to meter the air supply.

Turn the knob in a clockwise direction and watch the needle on the dial directly below. If there is more than 2 bar of pressure, this can cause damage to the internal air supply valve in the laser (this can be heard as a piercing whistle). It is best to turn the air supply on before performing any vector laser cut, it is not so important during raster engraving (the manufacturers claim). If the air supply is turned on during a cut, the static pressure may be greater than that displayed on the dial causing damage to the laser air valve when the job finishes.
The function of the compressed air is to blow fumes and vapours away from the laser optics, preventing a build up of dirt. The second purpose is to extinguish any flames that may arise as the material is cut.

The fume extractor is a beige metal box with a fume hose going in from the back of the laser and another going out the window. Check that the hose is still routed out the window.

The extractor has an illuminated ON/OFF switch next to the power lead. Turn it on when the laser in use; otherwise the room fills with smoke. The extractor has a number of lights at the front indicating whether the filter is blocked. If it shows a red light on the front, the filter is blocked, do not use the laser.

The laser itself has an ON/OFF switch next to it's power lead. Allow the machine a minute to boot up.

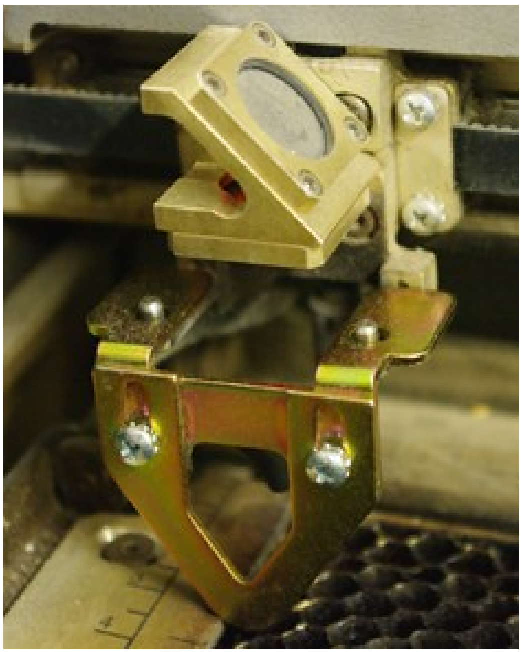
Once all three machines are running, jobs can be sent to the laser from the Corel driver interface. Press “Print”. A flashing light indicates data transfer on the laser control panel. The file name should appear on the display alongside a number indicating which job it is. Several jobs can be sent to the laser , the desired job can be selected with the UP and DOWN keys. There is a green button marked “GO” that initiates a laser job. The red STOP button will pause the job and the RESET button will terminate the job. Note that the STOP button will only pause a job after the current vector being cut has finished. To interrupt the laser beam, lift the lid of the machine. The safety cutout will cause the main beam to turn off though the X and Y axes will continue to move.

The beam emitted by the laser is reflected through three mirrors, it is then focussed on the surface of the material to be cut.
This is the same as focussing the sun's rays through a magnifying glass to the smallest bright dot.
The thickness of the material to be cut affects the focal point, the entire laser-cutting bed is

moved up and down to compensate. The default behaviour is for the laser to automatically detect the thickness of the material being cut and adjust the laser to compensate. As the laser only takes a focus at the beginning of a job, it means laser cutting only works on flat materials.
The second consequence is that the beam goes out of focus past the focal point, the laser energy is spread over a wider area and is less effective; this places a limitation on the effective thickness of material that can be cut. 8mm in wood is a good bet.

If the laser bed is raised too high for the thickness of the material to be cut, it must be manually lowered to avoid the laser travelling head striking the material. The bed is adjusted up and down by pressing the “**FOCUS**” button and then using the “**UP**” and “**DOWN**” buttons to raise and lower the bed (there can be a delay in the action). Once the bed has been given generous clearance, pressing the “**JOB**” button returns to the original state where the “**UP**” and “**DOWN**” keys select between jobs.

Sometimes the autofocus does not work. With thin material this can happen because the laser doesn't think there is anything on the bed. Then the laser has to be manually focussed. In this case, the “`autofocus`” check-box within the print driver must be disabled when the job is sent.
There is a metal trunnion-shaped manual-focussing-depth-setter thingy that is hooked on the laser travelling head. It is magnetic and engages with two pins. Adjust the height of the bed as described above. The rounded apex of the triangle/trunnion on the manual-focussing-depth-setter should be almost touching the surface of the material to be cut. Once the depth has been set, remove the manual-focus thingy, press the “**JOB**” button to return to your file and proceed as normal.



If by chance the bed is raised so high as to jam the autofocus plunger beneath it and the machine refuses to lower the bed, immediately turn the machine off and inform the facilitator.

Finally, there are three spring loaded bars that hold the bed grille in position, they have rulers printed on them. If the bed is raised while these bars are pulled up, the Y-axis gantry can jam leading to machine damage. Never run the machine while these bars are vertical.

With any luck the laser should do what is expected. If it is cutting a raster job, the laser head will oscillate left-to-right as it burns each pixel. The order in which it cuts the vectors is the order in which they are defined in the file. There is little pretence of efficiency in this driver.
Normally the material will be cool to the touch once the job has finished and the workpiece can be immediately removed.

DANGEROUS MATERIALS

Polyvinyl-chloride, PVC or vinyl releases chlorine gas when vaporised by a laser. This strips the coating off the laser optics and may cause the death of the operator if inhaled. If you don't know what you are cutting, get assistance. Don't take risks.

Polycarbonate releases phosgene gas. Again, a serious health risk. Polycarbonate is sold as Lexan, is found in machine guards, riot shields and CDs

Fluoropolymers, found in high temperature seals and high temperature rubber products may release fluorine gas, yet another toxic gas.

Circuit board plastic, PCB, contains chlorine.

PTFE - an acronym for Polytetrafluoroethylene or "non-stick", the -fluoro- means fluorine gas.

Symalit® PVDF 1000 (Polyvinylidene Fluoride)

Care must be taken when cutting corrugated cardboard as air can fuel a fire on the underside. Do not attempt to cut stacks of sheet material for the same reason.

Some handy hints and tips
The CO_2 laser in the machine is tempermental when cold. The first cut of the day might not work. In this case, wait until the laser starts up then press "**STOP**" followed by "**RESET**" and "**GO**" to run the job again. Don't move the material on the bed.

The job may not have cut entirely through in all places. In this case, the easiest thing to do is to run the job again. The chances are, you have taken the workpiece out to discover this. The trick is to get it aligned in it's original position again. It is a good idea to align the workpiece at the machine bed corner (top left hand side), pushing it right up against the rulers at the sides of the bed grille.
Another technique for aligning the workpiece is to turn on the reference laser point at the front control panel, "**RED DOT**" and run the job with the safety cover open. This allows you to check the alignment of the beam and, if necessary, pause the job and re-align the piece without cutting it.

The bed grille is quite delicate, it is easy to warp it. As the surface of the workpiece has to be flat, a warped and dimpled bed will not provide good support. Avoid poking the bed, get assistance straightening it if necessary.

The Epilog laser has a print buffer of about 10Mb, when this is full, it does not display an obvious error message. Instead the laser will refuse to update the job and a nonspecific print failure message may be displayed in CorelDraw. If you check the print buffer, you will find the print job spooled there. To clear the Epilog laser print buffer, turn the laser off and on again. Any jobs that have been spooled (queued) should be flushed to the Epilog laser print buffer.

Common materials suitable for laser cutting
Please ensure whatever material you use is stored flat and not rolled

Paper, card, corrugated cardboard..
Note that Fabriano rag paper does not char or scorch

Leather, suede, etc (check for PVC plastic coating)

Glass

Wood, plywood, fibreboard, pasteboard

Anodised aluminium (note that the laser marks the anodised surface but does not cut the metal.

Rubber, linoleum (battleship printing grade)

Stainless steel with Cerdec coating

Acrylic, cast or extruded. Perspex ®
Acrylic cuts particularly well on the laser and exhibits little or no local melting. Cast acrylic has a frosted effect when engraved and costs slightly more than extruded acrylic which has a glossy surface when engraved.

ABS (acrylonitrile butadiene styrene)
ABS comes in black or white, with one side smooth, and the other side textured. The thickness of ABS can vary by up to 10% within the same sheet. ABS is opaque to infrared light (IR), so it can be used for IR-sensing applications.
ABS is easy to machine and is not brittle (it will bend quite a bit before it cracks). ABS parts will not crack or break easily, even if you drop them. Lego and mobile phones are made from ABS. ABS is less rigid than acrylic, and is somewhat soft. ABS can be glued with a specialist adhesive. Laser-cut ABS parts tend to smell, so you might have to air them out for a few days and wipe dust and residue from the edges. Do not attempt to clean ABS parts in your dishwasher (the parts become discoloured).

PETG (polyethylene terephthalate glycol)
More flexible than acrylic

Plastic Foams

- EPDM foam
- Neoprene/EPDM blend foam
- Polyurethane foam
- Silicone foam
- Jiffy®
- Plastazote® Low Density Polyethylene foams (including grades: LD15, LD24, LD33, LD45, LD60, LD70)
- Plastazote® High Density Polyethylene foams (including grades: HD30, HD60, HD80, HD110, HD130)
- Plastazote® High/Low Density Blend Polyethylene foams (including grades: HL34, HL47, HL79)
- Plastazote®Low Density Polyethylene - Metallocene Resin foams (including MP15, MP24, MP33, MP45)
- Evazote®
- Zotefoams®

Ketron® Peek® (Polyetheretherketone)
Expensive, engineering plastic.

Polypropylene PPE

Fluted Polypropylene Sheet - (also referred to as Correx sheet or board)
Polypropylene Copolymer (Propylex)
Polypropylene Homopolymer (PPH)

High Density Polyethylene (HDPE/PE300)
Has a tendency to melt

Nylon
(Untested)

Styrene

Acetal Homopolymer (Ertacetal H, Delrin®) (POM, acetal)
Delrin is a very tough, slippery material that resists warping and deforming well. You cannot glue anything to Delrin, more expensive than acrylic, ABS, or PETG. Gears are often made from Delrin.

Kevlar fibre sheet (takes a high power)
Carbon Fibre

Useful links

Essential bedtime reading
http://www.epiloglaser.com/mini_helix_manual.pdf
http://en.wikipedia.org/wiki/Image_file_format

Free and GPL image software
http://www.gimpshop.com/
http://www.inkscape.org/
http://www.xaraxtreme.org/
http://www.gimp.org/
http://www.tamasoft.co.jp/pepakura-en/
http://www.progesoft.com/?page=smart2008
http://plasticbugs.com/?page_id=294
http://pfrostie.freeservers.com/cad-tastrafy/
http://www.becausewecan.org/Sketchup_to_CNC_via_OpenSource_Free_CAM_plugin

http://www.cad-schroer.com/index.php?screen=1.1&ziel=Products-MEDUSA-M4Personal&land=com

Alternative services
http://www.customlasercutting.com/
http://www.csm.arts.ac.uk/37056.htm
http://www.cncworkshop.co.uk/
http://www.zapfab.com/Default.aspx
http://www.quickparts.com/english_Quickparts_1.aspx?Page=/index.aspx
http://www.atlaser.co.uk/prototyp.htm

Materials suppliers
http://www.theplasticshop.co.uk/
http://e-magnetsuk.com/magnets/flexible_rubber_magnets/

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