by John Armarego

3D PLASTIC PRINTING

This article features information on 3D plastic printers and how to use them to add scale detail using my 1/3 scale Sopwith Pup as a practical example.

The 3D Systems UP Plus 2 printer with all the supplied accessories. I have two of these along with other shed bots. There is nothing much better on a wet windy (non-flying) day to sit back with a nice cup of coffee listening to the shed bots working away making model aircraft parts.

This issue is a continuation of the previous article and provides information and background around how to use 3D plastic printers to develop scale detail for aeromodelling. Again I have used my 1/3rd scale Sopwith Pup as the example in this article. This aircraft was presented in my introductory article in a previous edition of Airborne.

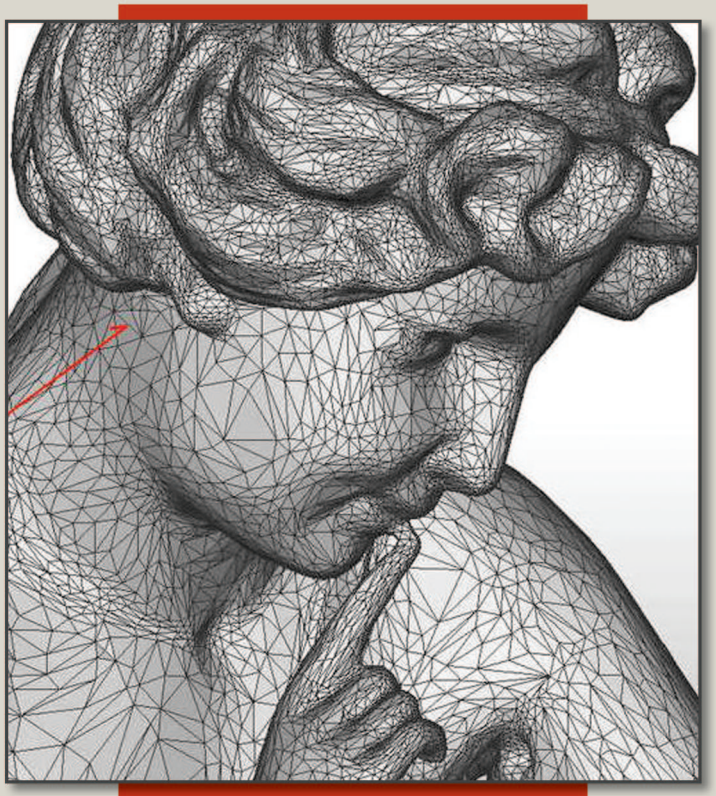
3D Plastic Printers

3D plastic printers have become cheap and readily available to the manufacturing industry and have become affordable for the home workshop over the last five to ten years. They have low running costs and are relatively easy to operate compared to other automated manufacturing techniques. The 3D plastic printers do not replace existing manufacturing processes but offer another option that has its own set of advantages and disadvantages.

3D plastic printers I'll be referring to here operate by extruding small molten ABS (Acrylonitrile butadiene styrene) plastic filaments layer-by-layer to form the desired shape of the part following a predefined file format. The main file format used for 3D printers is the STL (StereoLithography) file format.

STL files describe only the surface geometry of a three dimensional object. The object's three dimensional surface is represented mathematically by triangles, there are no texture or other common computer aided design (CAD) model attributes such as parametric features.

STL files mathematically represent the 3 dimensional model using triangles to define the surface.



STL files mathematically represent 3 dimensional models using triangles to define the surface.

The 3D printer I have had a lot of success with is the 3D Printing Systems UP PLUS 2, 3D Printer which currently retails for around AU $1300.00. All the plastic parts I have made for my 1/3rd scale Sopwith Pup have been made on the Up Plus printer. I have run this printer for hundreds of hours and made hundreds of parts. The consumables are the ABS filament that comes in 500g rolls and are available in many different colours. 500 grams of filament will make many parts and will cost you around $40.00 per roll. You can have the printer setup and ready to print your first part straight out of the box in around fifteen minutes.

Why Use 3D Printers?

3D printers have a solid role to play in assisting the scale model builder, along with the more contemporary range of other methods and techniques. The key is to understand the properties of the end product that they can make, and then how to best design your parts to utilise this manufacturing method for the correct fit for the proposed end product.

There are a lot of expectations built up around 3D printing — "It sounds so easy! I just have to unpack the box and turn it on, and I can start manufacturing any part I want". The reality is that they are no different from a document printer. If you need to write a bestselling novel it is not as easy as just pressing the print button and it is done.

So why spend the time and the investment in 3D printing technology?

- If you already have Computer Aided Design (CAD) and Computer Numeric Control (CNC) experience and expertise, then learning to use 3D plastic printing will be so, so simple to master
- It will allow you to make very detailed custom parts that will set your model apart
- You can design the parts so that other items or materials can be incorporated to add to the desired scale or functional effect
  Example: The Vickers gun I made for the Sopwith Pup was designed so that the flashing electronics and control that I made fitted inside the gun along with the bicycle head light LED to simulate the muzzle flash
- Once the design is done, or you have the STL file, making copies of the parts is very straight forward
- You can scale the part to almost any size you want
  Example: I have used the same STL file to make dummy parts for both my 1/3rd scale Sopwith Pup and my 1/5th scale Sopwith Pup
- Once you have generated a library of scale parts they can be easily modified for a range of other aircraft that you wish to make
  Example: I have made scale plastic dummy turnbuckles that can be used for just about any WW1 aircraft – the same also applies to the instrument I have made
- You can make fully functional parts, not just cosmetic parts for scale effect
  Example: The flying wire separators provide scale effect, and are also fully effective in stopping the flying wires from rubbing and wearing in flight as well as potentially generating receiver noise
- The 3D printed parts can be used as dies for forming aluminium sheet into complex shapes
- 3D printed parts can be used as the form to cover with thin aluminium sheet to make the final part
  Example: The ammunition guide on my Sopwith pup was 3D printed and then covered with litho plate to form the final scale part
- If there is room on the printer bed, you can easily print multiple examples of the same part at the same time

Properties & Functions ABS (Acrylonitrile Butadiene Btyrene)

The UP 3D printer can print several types of material and the main material I use is ABS. An important mechanical property of ABS is that it is tough and impact resistant.

Disadvantage: The ABS parts that come out of a 3D plastic printer are relatively strong but not as strong as a moulded ABS part.

Advantage: The ABS parts that comes out of a 3D plastic printer can be made with a range of filling options from solid to very sparse structures by changing the printing options. For flying model aircraft this is desirable because the 3D printed parts can be made very light. ABS can also be glued together with acetone, TETRA (simplyglues.com.au) or other plastic model glues.

PLA (Polylactic Acid)

PLA is another material that can be printed with the UP printers. PLA is manufactured from corn and is biodegradable.

Disadvantage: The parts made for PLA are fragile and will start breaking down in a few months.

Advantage: PLA can be used for investment casting which is sometimes referred to as lost wax casting. The part printed in PLA is used as the master for casting, the master is covered in casting sand in a sand casting box, molten metal can then be poured into the casting master. The molten metal vaporises the PLA and once cooled the metal takes on the physical form of the original PLA part.

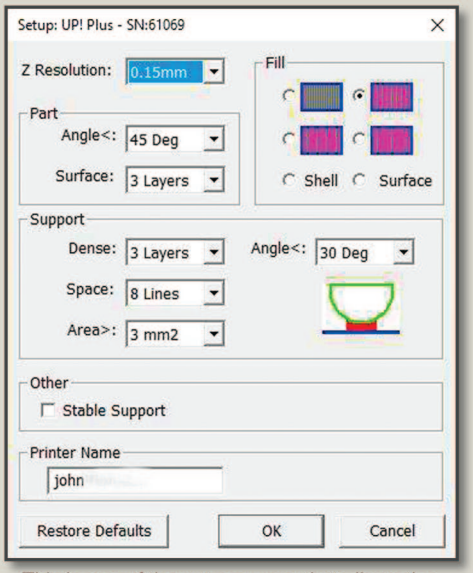
Support Material

You will hear the terminology 'Support Material' used frequently with 3D plastic printers. The support material is usually the same material as the part that is being printed. When a printer job is started, the printer lays down a bed of ABS to form a foundation for that part; this is support material. During the printing process if there is an overhang in the part due to its design, support material will be printed like a stalagmite (rises from the floor) to support the part material needed for the overhang section of the part. If this did not happen the printer would print the overhang material in free space and it would just full straight down into a mess.

There is some very intelligent software that comes with the UP printers that automatically generates support material for you. The support material is printed differently from the ABS laid down for your part. The support material can easily be pulled away from the part once completed. With more expensive 3D plastic printers, the support is often made of a different material and can be dissolved in a warm water detergent solution overnight.

Accuracy Or Resolution

On most 3D plastic printers you can set the print quality. The range is generally from low resolution of 0.4mm through to high resolution of around 0.1mm in 0.05mm increments. This is effectively the thickness of each layer of ABS that is laid down. The thinner the layer the higher the parts' resolution.



This is one of the setup menus that allows the operator to select the Z Resolution (layer height) as well as the density of plastic print along with other options for the support material.

Disadvantage: The highest resolution of 0.1mm is adequate for most aeromodelling application but is no way as accurate as some other manufacturing techniques. With the standard extrusion of molten ABS plastic as the deposition method, even the most expensive machines are not much better than this. This is effectively the limit of the viscosity at which molten ABS plastic can be extruded and heat bonded to each subsequent layer.

Advantage: The lower resolutions allow the printing time to be greatly reduced. Most of the parts I manufacture for my scale aircraft can take overnight to print. It is a relatively slow process even though it is referred to as rapid prototyping. You do not have to stay and watch the part being made, the machines are generally very safe to be left alone.

The resolution setting affects the layer thickness of the finished product and generates a stepped finish effect. This can be smoothed out by brushing the part with a solvent like acetone. If the part is to be painted this will also smooth out the finish.

Scaling

Once a part is loaded into the 3D printer it can be scaled. The scale factor can be chosen from the pull down menu or you can type in any value you like. A scale value of 2 will make the part twice as large and a scale value of 0.5 will make the part half the size. This function is very useful because you can draw the parts in any scale you like (I usually draw the parts in full size, i.e. one to one). This function allows you to select the desired scale, so if you need a 1/3rd scale Vickers gun then you print the parts with a scale factor of 0.33, if you want a quarter scale Vickers gun then you print the part to 0.25 scale.

How To Get The STL (StereoLithography) File

There are four main ways to get the STL file:

- Generate it yourself using a Computer Aided Design package (CAD)
- Use a 3D scanner
- Download 3D files you need from the internet
- Use a Photo-based application

1) Computer Aided Design Package (CAD)

You can learn how to use a Computer Aided Design (CAD) package. This is the best approach because once you have this skill you have it for life, and you can attempt to design just about any part you may want for scale detail in your next project. You can make parts and add detail to the level you want to go to.

This is however the hardest part. You not only have to learn how to use the CAD package, but you also have to know how to draw and design parts. Some of the modern CAD packages are very powerful and can take a long time to become proficient at. Some people find learning to draw using a modern CAD package very difficult, it really helps if you have a 3D brain. Luckily that is exactly what aero modellers seem to have, all that flying in three dimensions has developed the right brain for CAD.

*UP setup menu. The **Fit** icon fits the selected part to the available print area, **Move** allows you to move the part around the printer bed, **Rotate** lets you to rotate the object through all the axes, **Scale** scales the part to the desired size, and **Place** automatically places the part in the bed centre.*

Thanks to the rapid prototyping and 3D printing revolution, there are now a whole range of different applications for creating 3D models. Gone are the days where you'd require an engineering degree, or have to be a CAD CAM expert to create even a basic model. Some applications are dead easy to use and some have a steep learning curve. The more complex the packages the more powerful they are (you won't need all the functions available for 3D plastic printing). 'SolidWorks' is at the highest end moving down to very useful packages like AutoCAD Lite; there is now a vast range of free or very affordable packages that are also very good.

2) 3D Scanning

Sounds great but it's much more difficult than you would think. You can only effectively get the outer surface of a part (they cannot scan the inside of items). You also generally lose any size reference when you're scanning a part. The surface can generate reflections causing the surface file to have many artefacts in it which need to be removed. The scanned file can be very large and is very difficult to edit and modify if you need to.

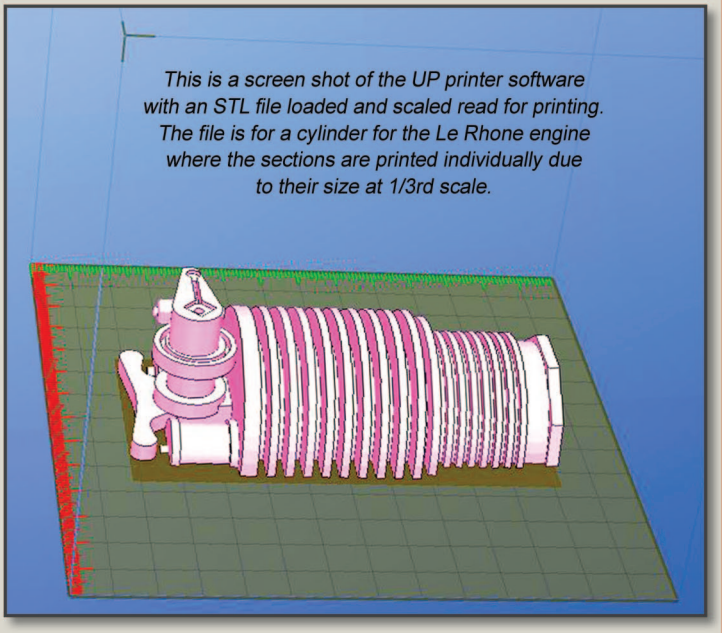
3) Downloading 3D Files

Many 3D model libraries are available on the internet. These instantly seem to get populated with the same 3D files that are on all the other sites. Many of them are made for animation/rendering and are flat surfaces with images projected onto them. These cannot be printed. Unless you are very lucky you will not find the scale parts you require for you current project. I am generating my own specific model aircraft libraries for scale parts as I construct each new aircraft that I want to build.

4) Photo-Based Applications

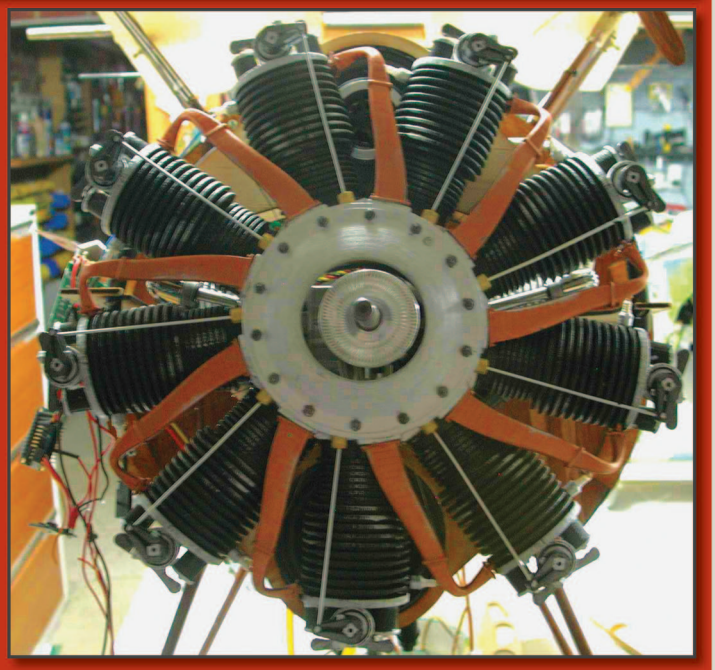
These generally give poor results like 3D scanning, although the applications for generating STL file of faces seem to work very well. These are ideal for making up scale pilot heads.

Making A Part

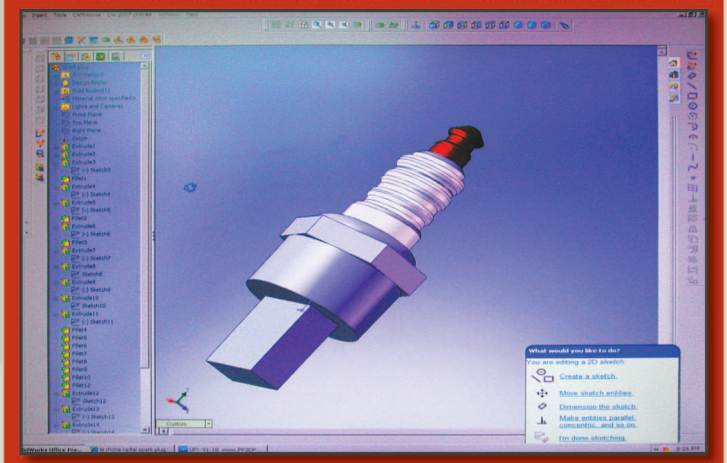


Printing a part with a 3D Plastic printer is relatively straight forward; this is the main advantage of 3D printing. Once the printer is set up the main steps are:

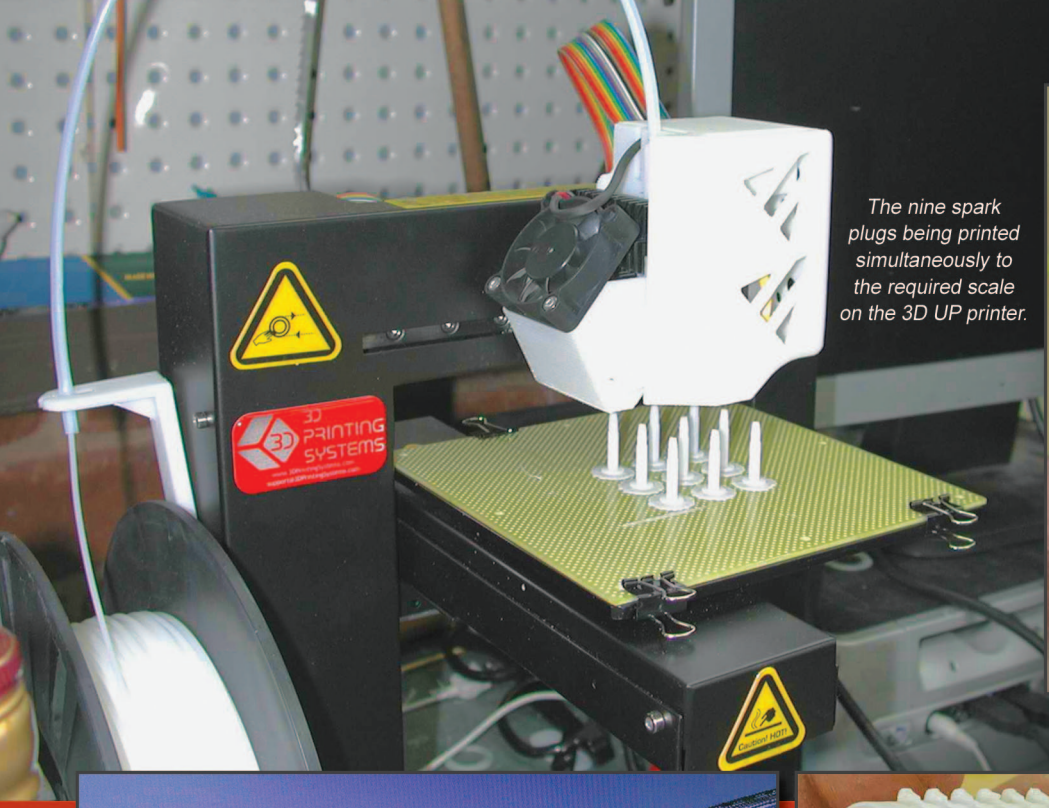
- Load the design file into the printer
- Set the orientation of the part to be printed with respect to the printing bed
- Set the size you want the finished part to be (scale)
- Make sure the part fits within the size limits of the machine you have (parts can be designed to be printed in multiple separate sections and joined later
- Initialise the printer
- Let the printing extrusion head and (usually) the printer bed reach operating temperature
- Start printing (while printing, the machine can be left unattended)
- When printing is finished the printer can be set to cool down and switch off
- Remove the part from the printer bed
- Peel away the support material



Completed 3D printed Le Rhone 9 cylinder dummy engine. Saito 57cc four stroke petrol boxer twin cylinder engine sits behind the dummy engine.

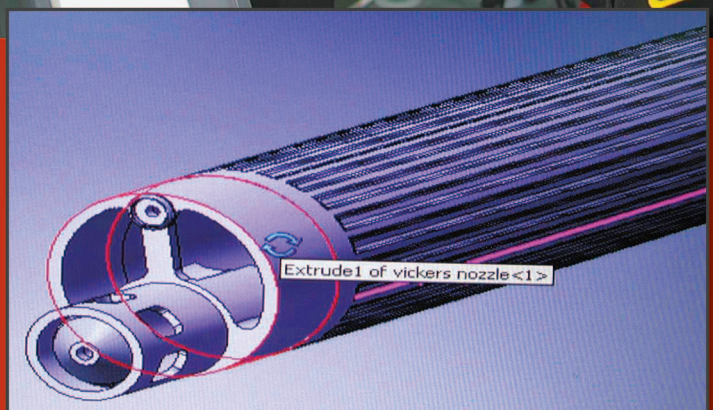


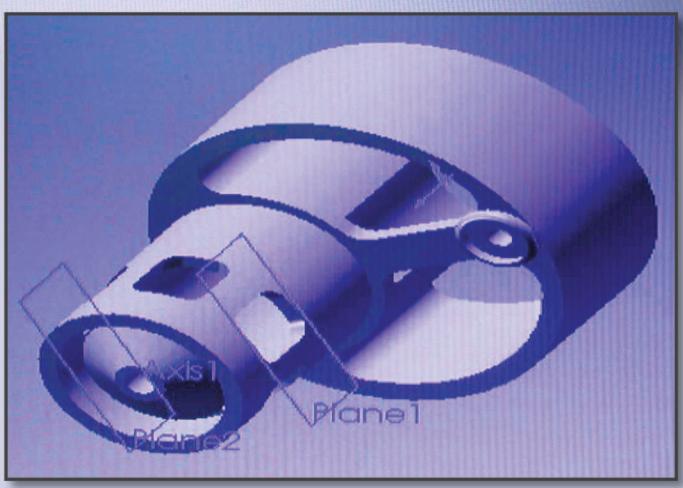
Spark plug drawn up in full scale using a Computer Aided Design (CAD) package. The CAD design file can be exported into the required STL file required by the 3D UP printer software.



The nine spark plugs being printed simultaneously to the required scale on the 3D UP printer.

Completed ABS muzzle for the 1/3 scale Vickers machine gun.

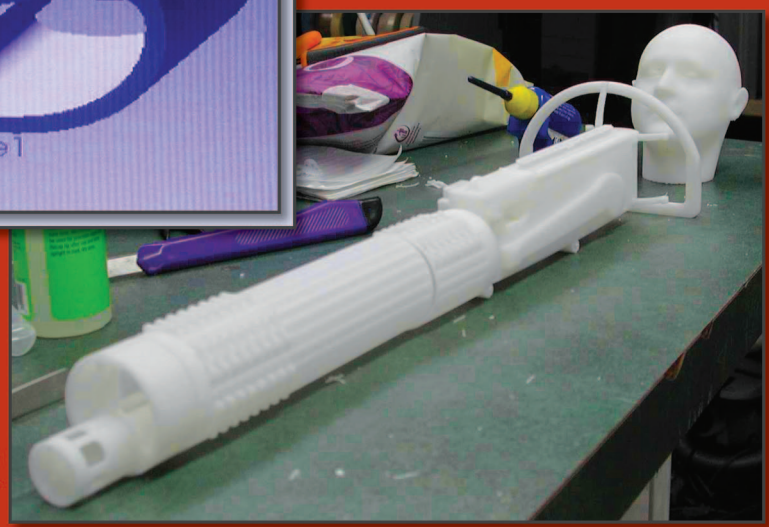




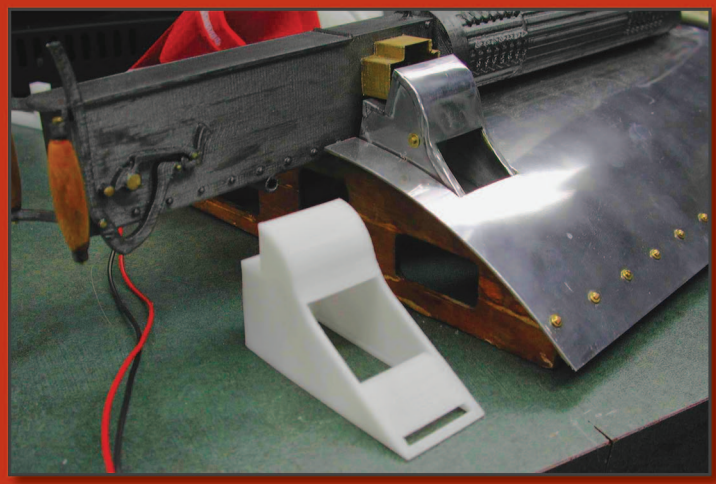
Vickers machine gun drawn up full scale using a Computer Aided Design (CAD) package. The design is sectioned to enable the gun to be printed in sections because of its size. The sectioned CAD design file can be exported into the required STL file required by the 3D UP printer software.

An example of where the end result is simply just amazing with the UP 3D printer. This is the barrel of the Vickers machine gun with the cooling louvers. The finish and the detail of such a delicate part is incredible. When you match the design with the printer's strengths and capability the end result is almost impossible to match with other manufacturing techniques.

Painting and assembly of the 1/3rd scale Vickers machine gun.



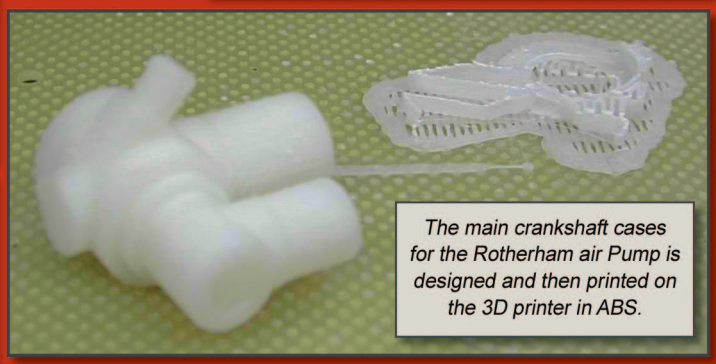
Printing of the Vickers machine gun completed awaiting internal electronics for muzzle flash, painting and assembly.



3D printed ABS structure awaiting covering with the aluminium Lithographic plate to provide scale realism.

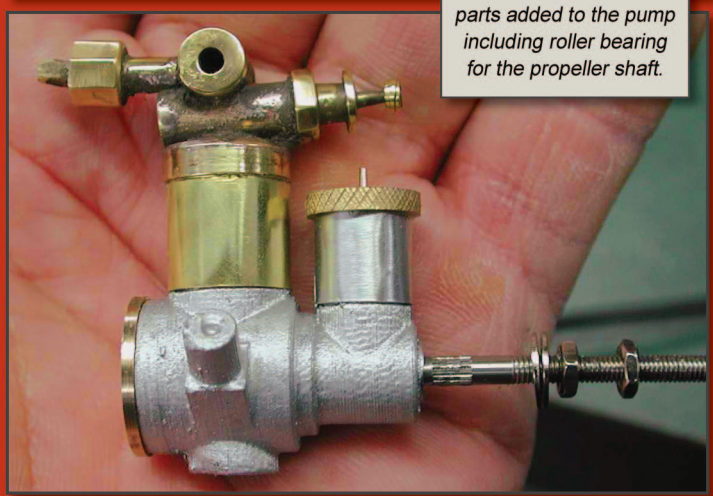
Copies of my CNC machined scale turnbuckles. The same design file lets me to make the part by printing it in ABS plastic or making it out of steel. The dummy turnbuckles are to reduce weight in a non-structural scale application.

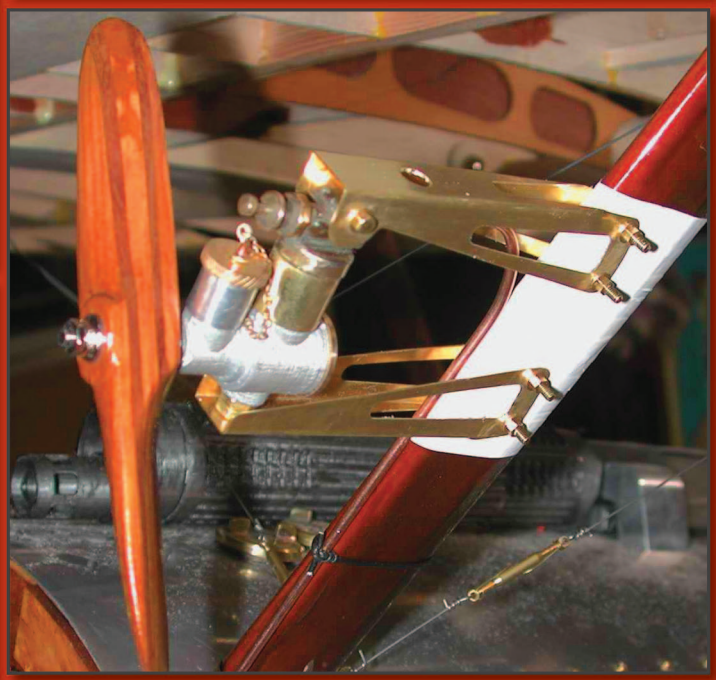
Completed 3D ABS part covered in an aluminium lithographic plate and polished awaiting fitment to the aircraft.



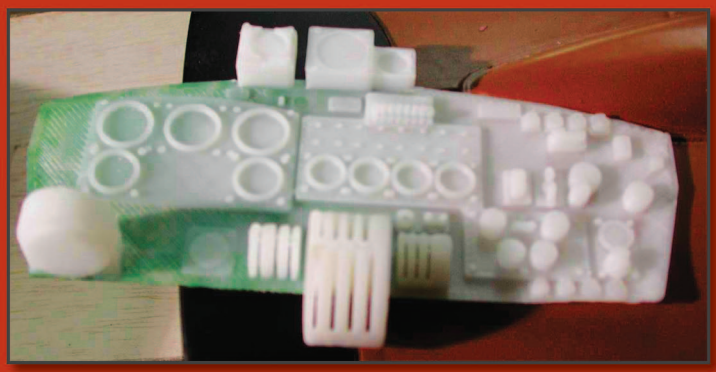
The main crankshaft cases for the Rotherham air Pump is designed and then printed on the 3D printer in ABS.

Additional machined parts added to the pump including roller bearing for the propeller shaft.



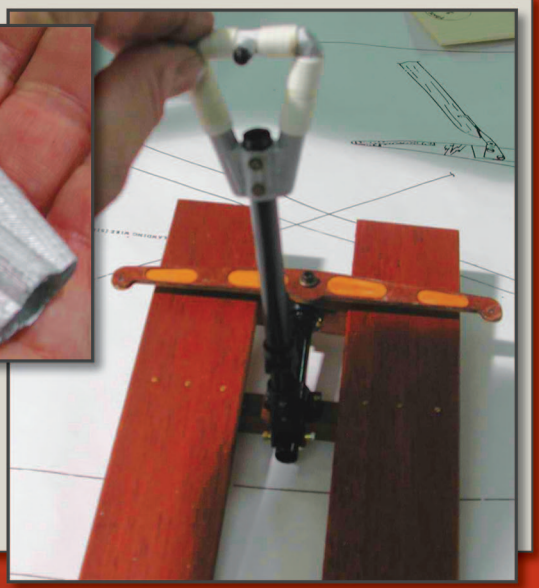


Completed and mounted Rotherham Pump.
The pump is used to pressurise the main fuel tank on the full sized aircraft.
The propeller activates the pump to 1.5 to 2.5 psi pressure.



Above and Right: Something different.
Lancaster instrument panel drawn up and printed on the 3D printer.

Functioning control column and handle drawn up using CAD and printed on the 3D plastic printer.



As presented in previous issue of Airborne, the cockpit features many 3D printed parts.

Using photo-based applications you can take photos of people's faces and generate STL files from multiple photos. Results are outstanding and heads can be printed in any scale required. You can also mess with the face parameters and generate very interesting results.

If you have specific questions about any of the Scale Matters articles you can email me aeromodeller@outlook.com and I'll do my best to answer any questions.

You may also find some interesting "build information" at www.nitrodude.forumer.com

The web site for the National Aeromodelling and Aviators' Society (NAAS) can be found at www.naas.org.au or on their Facebook site at www.facebook.com/naasact/

Until then, happy building and plenty of flying.