B.15 CNC Milling Handbook

September 2024

B.15
MODELMAKING
WORKSHOP

Contents

Written By Teagan Dorsch

Using This Guide

This guide has been produced to support you as you explore making with the CNC Milling machine in the B.15 Workshop. The guide is divided into two parts: The first part outlines model considerations and file prep, while the second offers some design advice and further things to consider.

The guide will hopefully provide an overview of the CNC and how it is used in B.15 and we are always here to discuss any further questions with you.

Section Model by Lauritz Kobor

CNC Milling 101

The CNC Milling machine is a form of advanced digital fabrication - similar to the laser cutters, Cricut and 3D printers - that utilize digital files and modelling to control the making process. As with the other processes in B.15, it is just one possible way of working to help develop your model.

The CNC mill is a subtractive process that removes unwanted material from a 'stock' or block material through a rotating cutting tool.

When you come to B.15 for the first time wishing to CNC we will usually begin by discussing the type of work you are developing and why the CNC may or may not be the best choice of process.

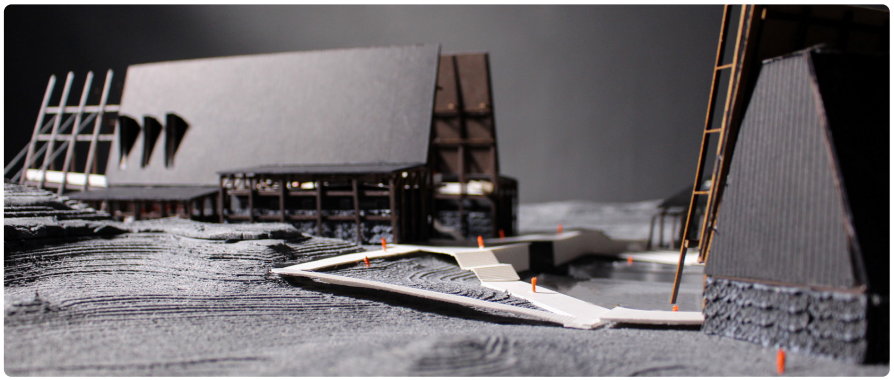
We will then look at your 3d models, sketches and ideas while discussing materials, limitations and the next steps for you while we prepare to CNC the file.

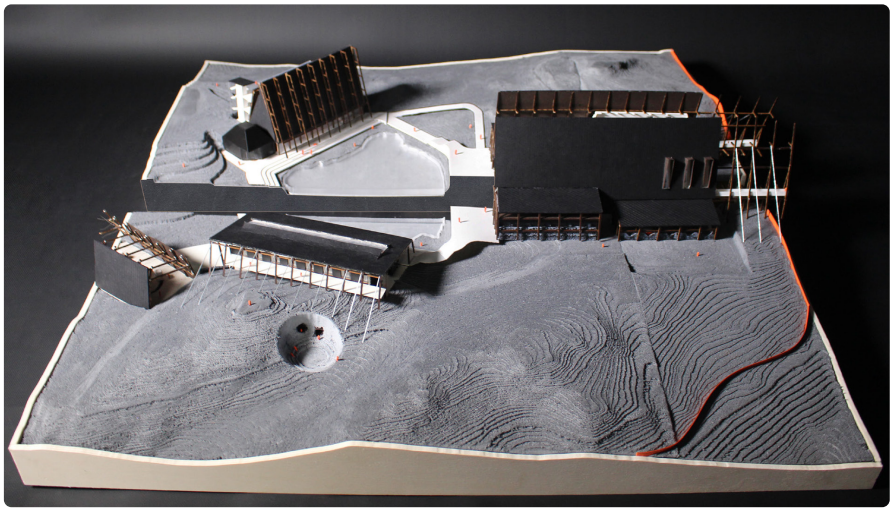
Quick Reference:

- Bed Size: 800x700x150mm
- Smallest Tool: 3mm
- Tool Length: 30mm
- Maximum vertical wall: 25mm
- No Undercuts

Initial Conversation

The initial conversations between student and technician are key to a successful CNC job. It help set out proper use of the CNC, aims with the model, an expected time line and next steps for you to take. Here are some key points we will discuss with you.



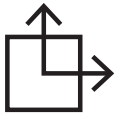


'Topo-licy: The Frontier that Topo-licy Built' by Alex Wallace, Tom Lee, and Sam Mason, MArch2 Infrastructure Space.

Concept

We will start by establishing the overall aims and concept of the model and whether the CNC would be a good option. It's not always the best process to use.

Size and Scale



Next, We will discuss the size and scale of the piece. It may be that the site being represented needs to be adjusted or split into several smaller parts to fit our CNC.

3D Modelling

We will then have a look over your 3d model or sketches and discuss the next steps for you. This might include changing, cleaning or adding to the 3d model prior to sending it to us.

Material Choice

We will then discuss the possible materials for your model and determine what might work best given your desired look and finish for the model.

Time and Cost

We will try to determine a time line for the model. It is important to remember that CNC can take several days to finish after receiving the file. Cost will be calculated based on the amount of new material used.

Material Options

A Sample board of these materials can be found in B.15.

MDF - This is a commonly used material for site models because it is cost-effective and takes finishes well.

Solid/PLY Wood - a variety of species of wood can be milled for specific grain patterns. Plywood is also a good choice if you are looking for layered lines within the model. However, depending on the species of wood/PLY this material can become expensive for larger models.

Grey Foam - This is a fast-milling material that can take shapes quickly. It is prone to compression and damage if it is handled a lot after milling.

Jesmonite - We can mill small blocks (A4) of Jesmonite AC100. This material mills details well but can have small air holes and be brittle.

Acrylic - We can mill small amounts of acrylic as well. Acrylic takes details well but it can be a brittle material and sometimes breaks easily. With time clear acrylic can be polished back nearly clear again after milling.

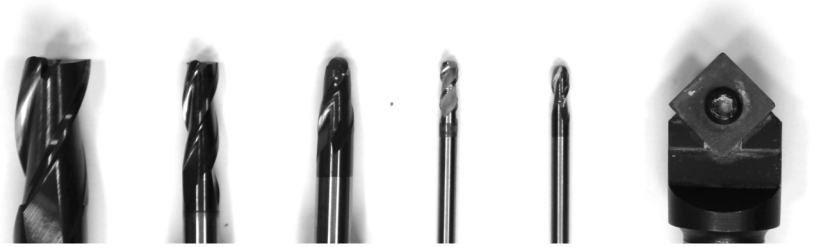
Velchromat - This is similar to MDF but it is denser and is coloured through the material. It takes details better than MDF but is more expensive.

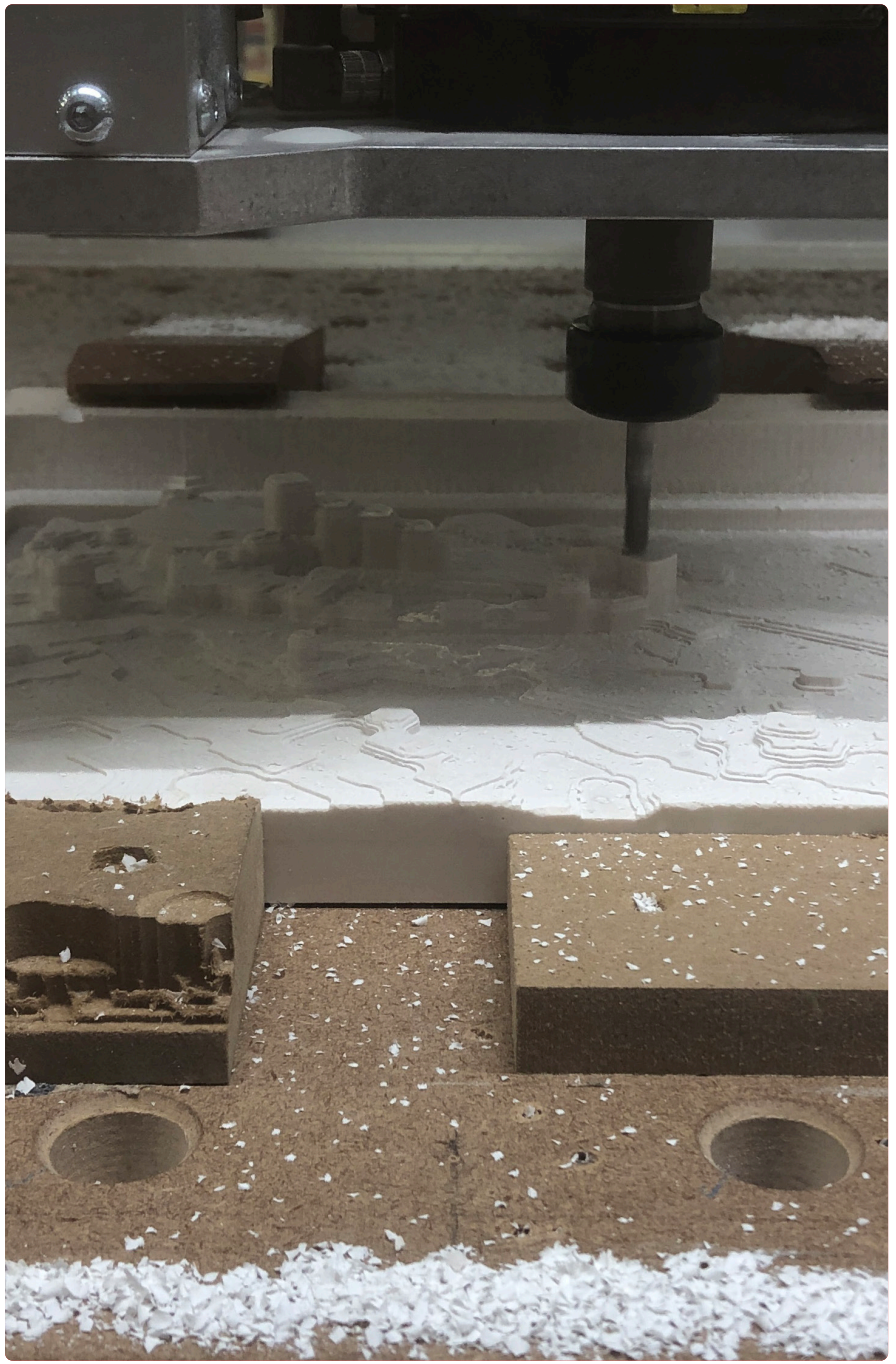
Tools

We have a range of milling bits in our workshop that can produce rough and fine models.

The smallest we can currently mill is with a 3mm diameter bit. This means that all internal corners will have a minimum radius of 3mm that will need to be removed during the post-processing of the model.

The largest 90-degree step-down our tools can handle is 30mm.





File Prep

There are a couple of key points to prepare your file for CNC'ing.

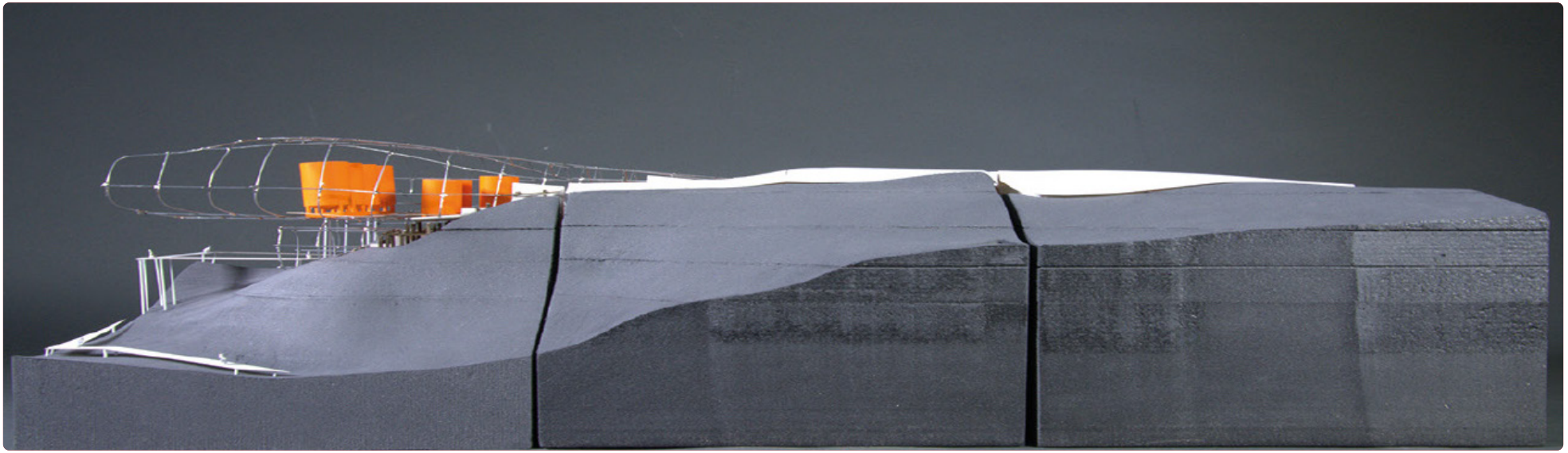
- Clean watertight model
- A digital model of the stock material
- .stl or .3dm file type
- A properly scaled file that is located at the world's origin
- Excess digital objects and layers deleted

After discussing and preparing your digital model for milling next you will need to model the stock material block. This digital stock material will match the physical blank material that is glued up. The aim of this is to improve material use efficiency, reducing the amount of material that needs to be removed and milling time. This will often result in blanks that are stepped rather than solid cubes.

There are two main file types accepted in B.15 for milling. Those are .stl object files- which are a series of meshes; and Rhino .3dm files - which can work between NURBS and Meshes. These files should only contain the scaled model to be milled and should not have other objects in it.

Regardless of the file type, it is ideal to have a closed 'watertight' model, which means that there are no missing faces or flipped surface normals. Files should also remove 'extra' information and unrelated models.

.3dm files offer more edibility and detailed selection in Fusion 360 and are the preferred file type where possible.



Section Model by Lauritz Kobor

File Advice

Rhino 3D Advice

Delete excess information and put the model on two layers - one for the model and one for the digital stock.

Bring the model to the origin - It is important for one of the model corners to be moved to the world origin point (0,0,0) or nearby in digital space.

Some useful Rhino commands to check your file:
Showedges - Use this to test the model for naked (unconnected edges) and non-manifold edges (edges with distorted normals or self-intersections)
MergeCoplanarfaces - Use this to merge faces in a mesh model to reduce the face count.

Mesh Files Advice

Mesh Files should be watertight (no missing polygons or holes in the model).

They should be located at or close to the world origin.

Extraneous digital models that are not to be cut should be deleted from the file to create a 'CNC' file of the model.

If possible simplify the polygons and retopologize the surface (rebuild the shape of the faces that make the model) to improve the usability of the file.

They can be made in any software as long as they are able to be exported as a .stl.

2D Contour Advice

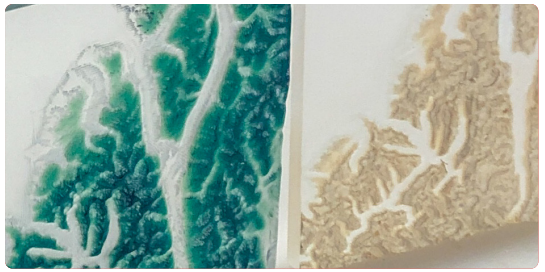
The CNC can also mill 2D Contours. This might be more similar to laser cutting but can be done at a larger scale out of thicker materials - with the trade-off of increased time to prepare the file. Milling 2D Contours allows for engraving details into the surface and milling profiles.

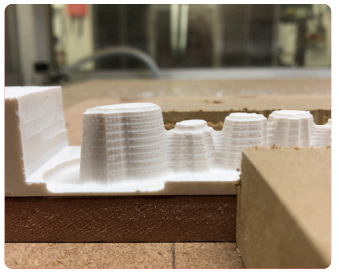
2D Contours can be made in Autocad, Illustrator, Rhino 3D, or Sketchup among others that can export a vector line.

Fusion 360 Advice

Once the files have been properly checked and finished they will be brought into Autodesk Fusion 360 where B.15 Staff will be programming the file for the CNC. Fusion 360 can make minor fixes to models that are not watertight but its main use is to program the toolpath that will incrementally mill down the stock material into the final model.

Fusion works by converting the digital file into a series of points that become Gcode for the CNC machine to know how to move through space to mill the model.





Post-Production

Following the CNC milling it is advisable to take some steps to finish the model. The CNC will only make the model as smooth as the limits of our tools and as time reasonably allows.

You may find that you want to sand the model to a smoother surface quality. This will remove ridges that are commonly left by the tool stepover in the machine.

Internal corners might need to be corrected to be made at their proper angle. This can often be done with a chisel.

You may also decide on the surface finish to be applied - this can be a type of oil/varnish, stain, paint, etc.

Careful steps in post-production will help the model look refined. This is the same as with all models you are producing - similar to sanding off the burn marks on a laser-cut model.

Detail Test by Wei Feng

Design Advice

Milling Limitations

Our CNC is a 3-axis machine (XYZ) meaning that while it can mill in 3 dimensions it is unable to make specific motions or mill specific models.

Size restriction - Our maximum size that we can mill is 800 x 700 x 150mm. This does not mean that this is the size that you should aim for in your model. It is a better practice to show what is important and use different models and processes for specific investigations. Think about what you are showing at the chosen scale, consider the boundary to the model and how the model will be viewed. Remember that not all models need a rectangular base.

Material Restrictions - Please see our material page for materials we currently mill. If you have a special material you are hoping to CNC we can discuss this in person and look over a sample of the material.

Motions - Our CNC is unable to accommodate milling undercuts. This is where the top of the model is wider than what is underneath the cut, such as overhangs. Models with these features can be achieved through a combination of different processes that can be discussed with you individually for your model.

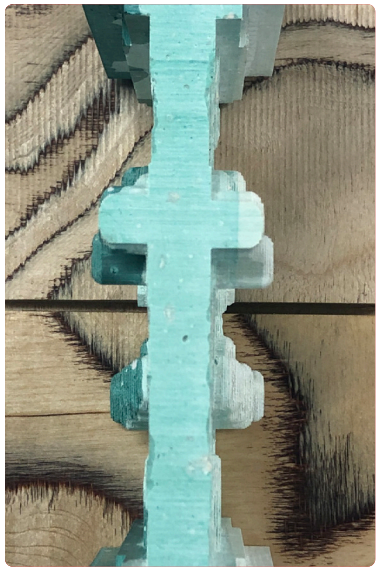
Advanced Milling Approaches

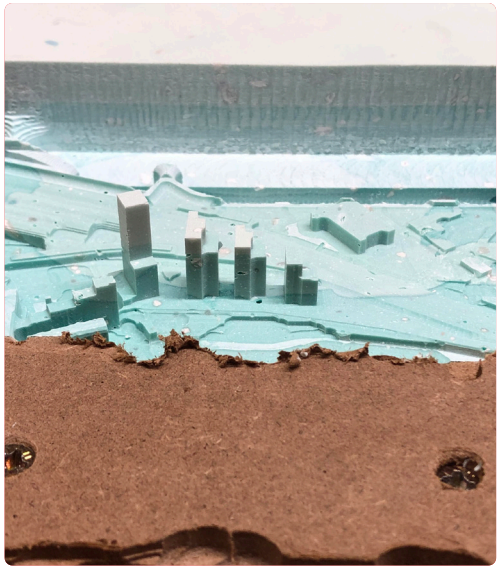
The CNC has plenty of room to experiment with your model-making practice as well.

We are currently improving our ability to mill both sides of the stock, also known as flip milling.

The CNC can also be used to make moulds for casting and positive and negative moulds to press sheet materials, Such as thin Aluminium, into forms.

There are plenty of other things the CNC can do with the right approach. It is all about testing and finding what is the best process for your model which can come from discussing your aims with us in B.15.

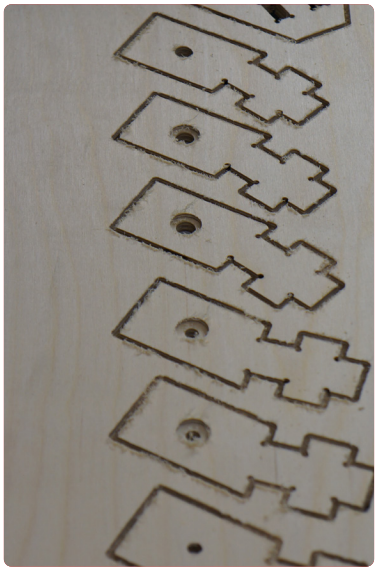




Milling Typologies

The following pages contain a sample of possible processes the CNC can help you to achieve. This is not an exhaustive list nor are these the only to produce this type of work. They are meant to help get you thinking about working with the CNC.

Profile / Component Milling - Components to a larger system can be milled as parts to be brought back together. This is often found in flat pack furniture systems.

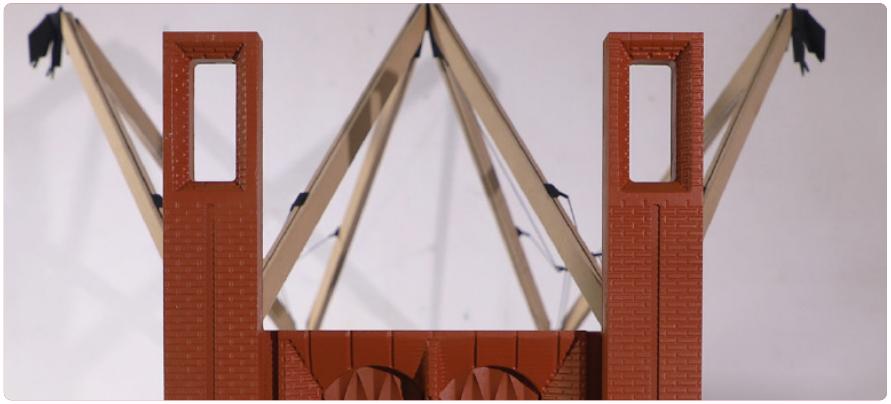


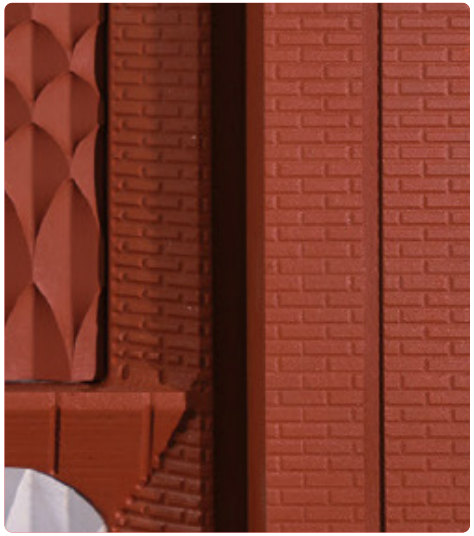
1:1 Component by Alexander Valakh and Lorena Chan

Stepped Contour / Landscape - Landscapes and site models can be milled to a variety of finishes from smooth to stepped. They take the digital model of the 3d terrain and reproduce that into the chosen material.

Site Model by Ardavan Shirzadi

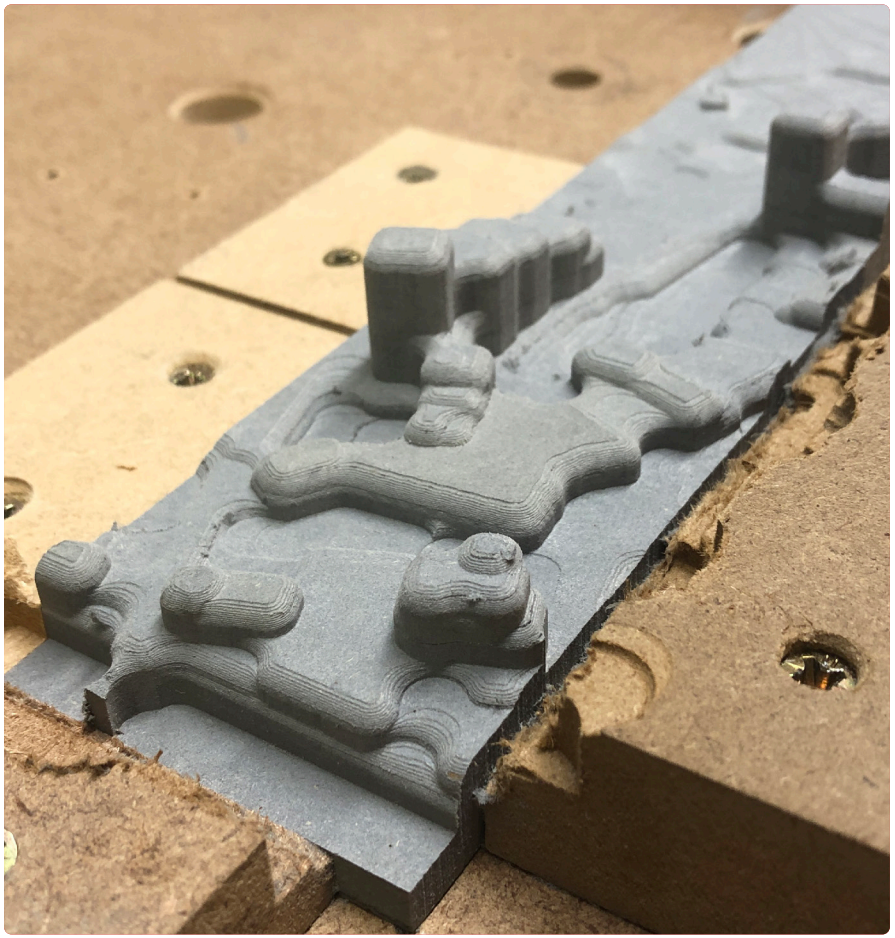
Detail Milling - We can use smaller tools and V-bits to engrave patterns and details into surfaces. This can be useful on larger scales where the LaserCutter might not be suitable.



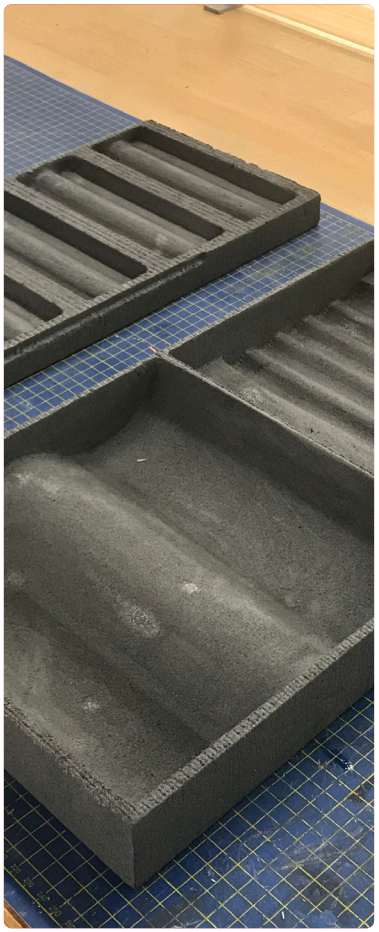


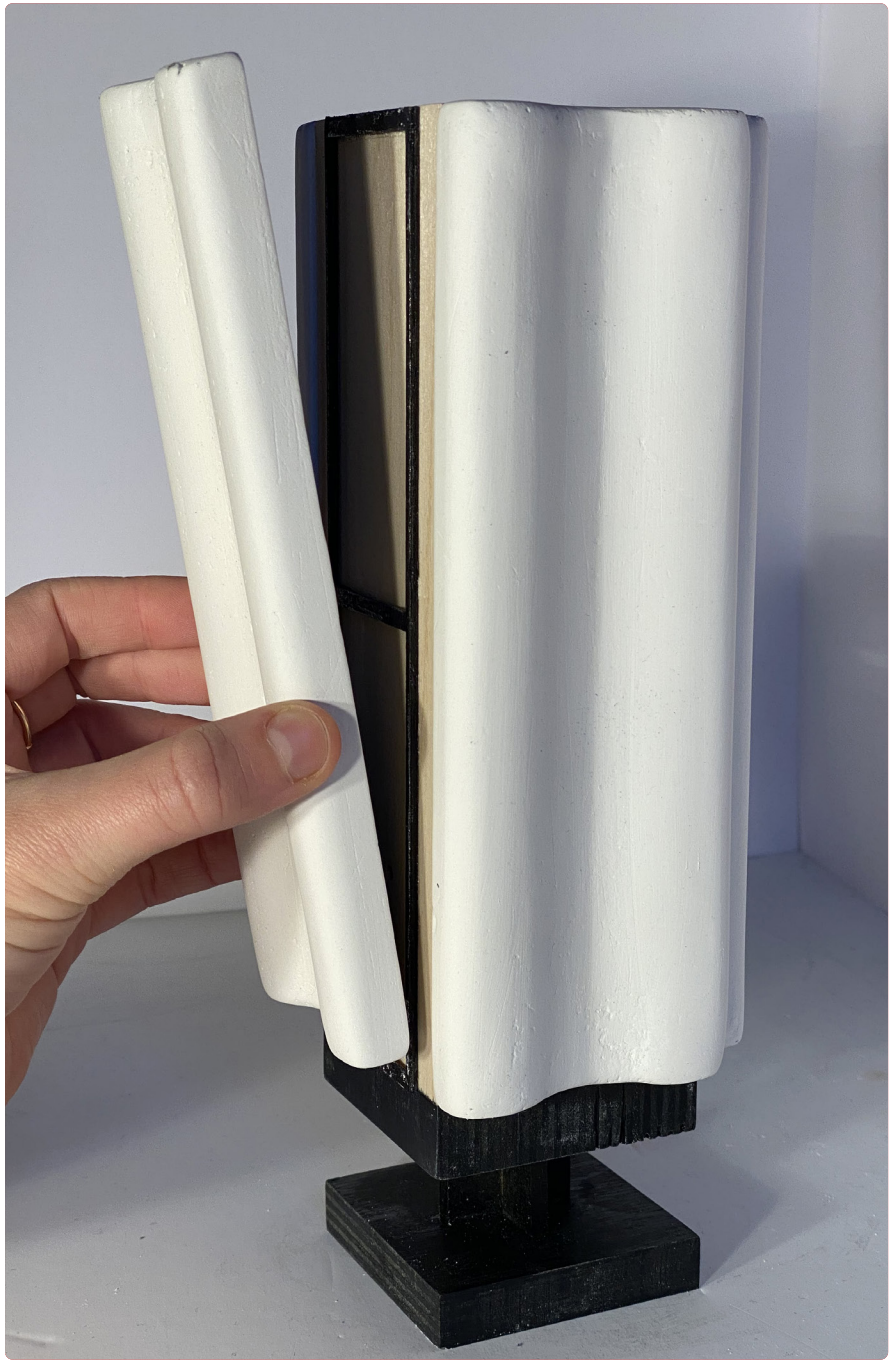
Section Model by Wei Feng

Massing - With careful modelling and consideration small massing studies can be carried out with the CNC. This could result in an insert into a larger model or a stand alone artefact.



Mould Making - By using a material that can be easily removed different types of moulds can be made. These could be for casting a master copy, casting jesmonite, for vacuum forming or for forming thin sheet material with a positive and negative mould





Detail Model by Hayley Sheldon

For further information relating to B.15, our services, other guides and more information about the workshop please check out our blog - which is regularly updated with the latest information.

Blog:

manchester.ac.uk/b15workshop

Sustainable Materials Guide:

Found Here

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