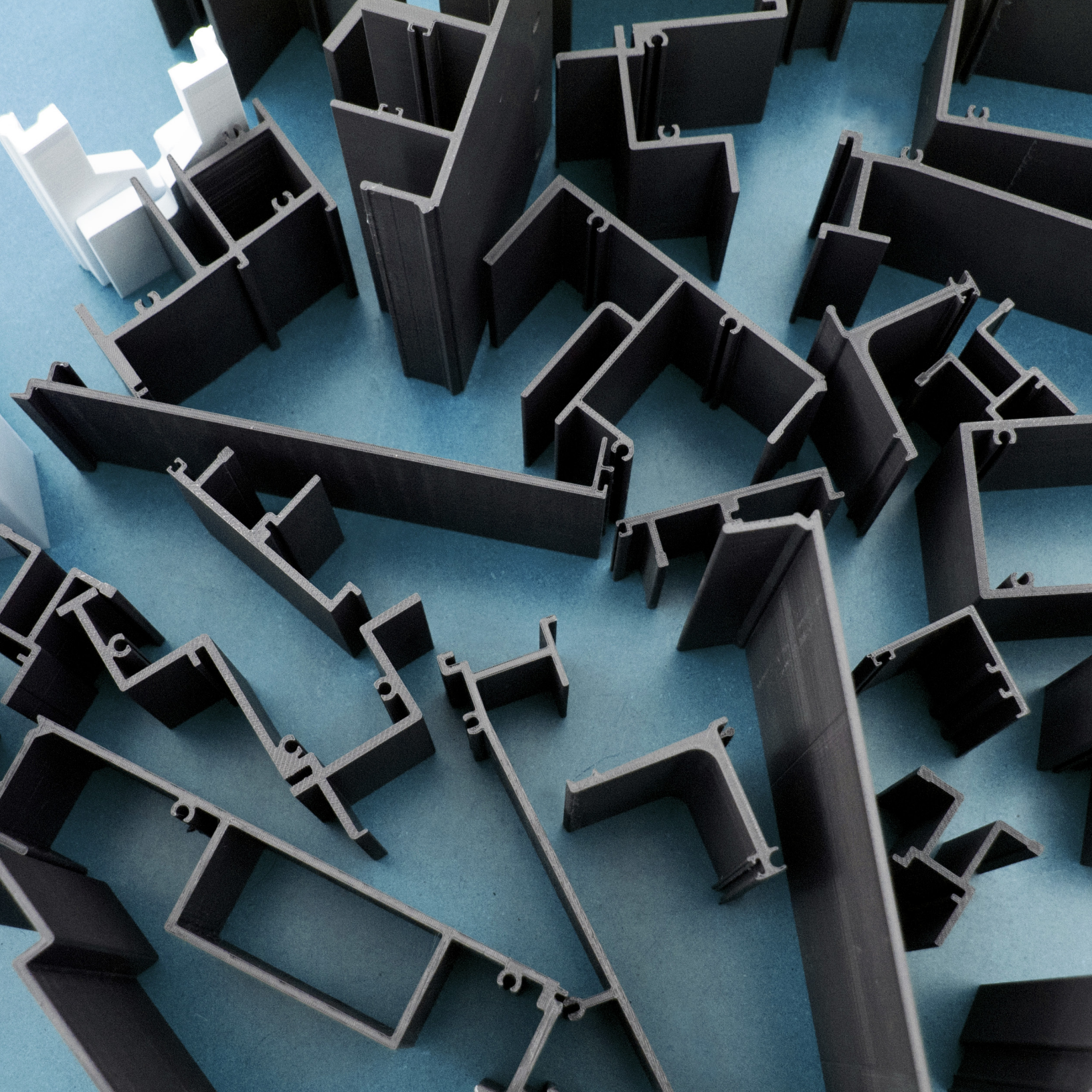




3D PROTOTYPING

NATHAN LUCERO

Physical models are excellent communication tools for both design and architecture. The Studios have many ways to build model parts, and we are always developing new techniques – but we do not create models just because we have the ability. Every model the Studios build has a goal to accomplish. Whether that goal is to test a concept, communicate a form, show scale, or provide an impressive visual, the goal must be clear so that it may be successfully met. Models require a significant investment of time, energy and skill, so we want to get the most out of them. The Studios now have a portfolio of models from the last three years; each one has a story, and each has taught us how to improve our craft.

THE RATIONALE: REASONS FOR USING A MODEL

The core duty of any model is to communicate a design and/or process. The Studios use models for details that have a high priority or significance because models have proven far more effective than two-dimensional images. We have found that models receive more attention and curiosity than any other material we bring to a presentation or meeting. Models are also used in-house to communicate designs as well as to demonstrate processes. These models may not be presentation-level models because they provide a specific physical function.

Beyond communicating a design, the Studios also use models as calling cards. Giving a model to a client can leave a lasting impression. We would never leave any printed work without a logo on it so we do the same with our models. We place the Studios' logo and name on models even if we do not anticipate leaving it with a client or architect. The Studios have also incorporated client or project logos into our models.

THE PROCESS

BEFORE WE BUILD

The design of the model is driven by the goals the Studio want to accomplish with the model. The goals must be clear before we start fabrication. We do this in order to focus our efforts. We would rather have fewer. This also saves time and resources.



With all of the Studios' capabilities and limitations in mind, we design and create our models. Our tools and software may vary based on what tool is best for what we are trying to accomplish. Our designers are very familiar with the capabilities and limitations of our machines. The Studios also outsource work when needed. The Studios' primary tool is our 3D printer, so this article will mainly address this method.

3D PRINTER

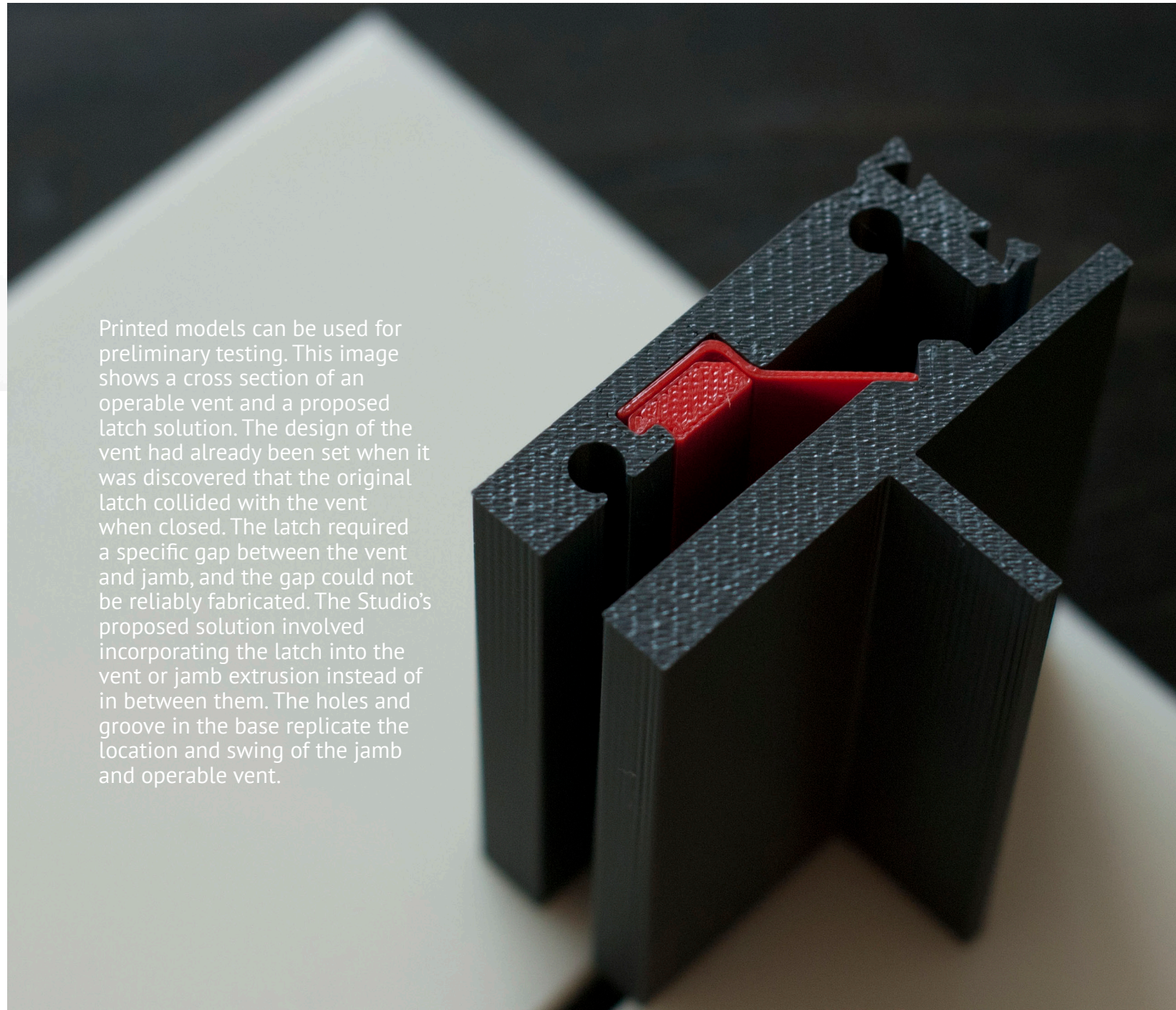
Our machines use stereo-lithograph, also known as Standard Tessellation Language (STL) files to create parts. It does not matter which program we use to make the STL file, as long as the file is from a valid, closed, polysurface or a solid. The program allows us to orientate the part, specify the density of inside cavities, and select the amount of support. The software rarely allows us to print something that will collapse during the print, although it has happened. The program will also allow us to completely surround parts with support if we see fit to do so. Once the part has been set to the right orientation, and the correct physical properties have been set,

the program then takes the part and slices it horizontally every 250 micrometers along its height. These slices become the layers in the print. Each slice generates a path for the print-head to follow. The program also calculates the amount of the support material needed for the part. The program slices the support and generates a separate path for the support. Now the printer has two paths to follow. The plastic and support are printed side by side on the same layers. The program generates a print file for the machine, and the machine has a print queue, much like a paper printer.

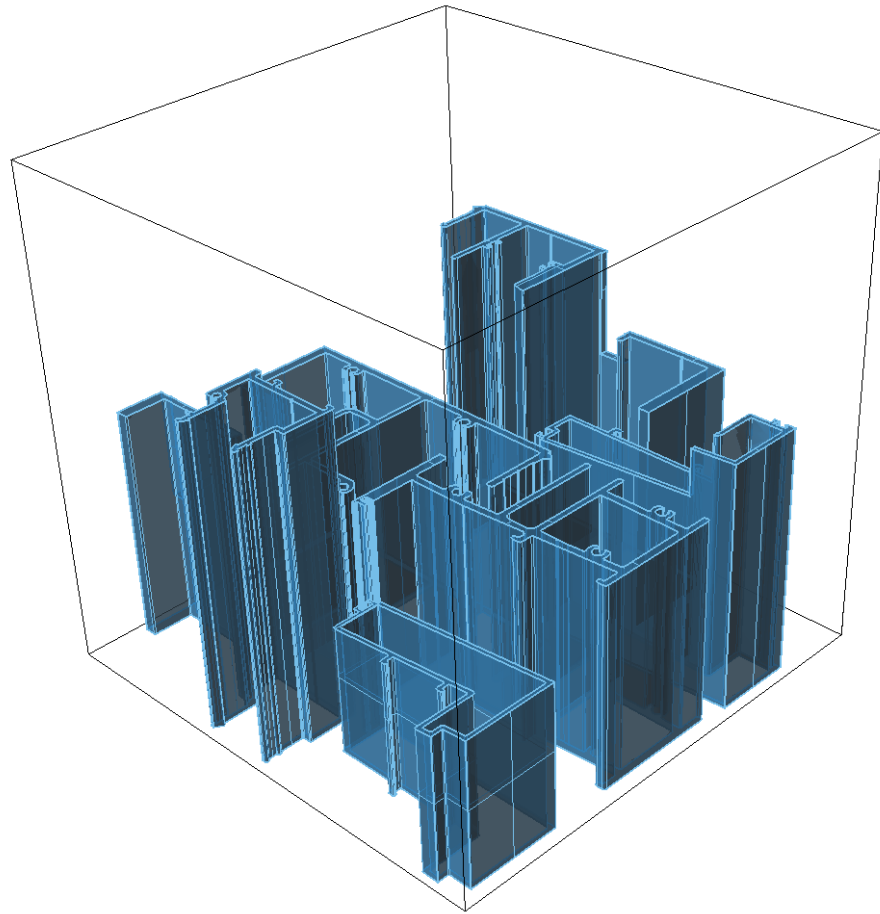
Like an ink-jet printer, the Studio's 3D printer has cartridges. These cartridges hold spools of plastic and support material instead of ink. There are two large ports at the front of the machine that receive the cartridges. The machine pulls the material from the cartridges and feeds it into the printhead. In the printhead the material is heated to 150° C (300° F) and is then pushed out as a strand of plastic. The strand of hot plastic is 250 micrometers thick and will adhere to the previous layer of plastic. When plastic is printed onto the support material, the bond is not as



FIGURE 1 + 2
Many of the model making techniques the Studios use have come from our designers' professional and academic experience prior to joining Enclos. Our designers have worked in a variety of fields such as consumer product design, industrial design, exhibit and stage design, architectural model fabrication, aerospace engineering and yacht manufacturing.



Printed models can be used for preliminary testing. This image shows a cross section of an operable vent and a proposed latch solution. The design of the vent had already been set when it was discovered that the original latch collided with the vent when closed. The latch required a specific gap between the vent and jamb, and the gap could not be reliably fabricated. The Studio's proposed solution involved incorporating the latch into the vent or jamb extrusion instead of in between them. The holes and groove in the base replicate the location and swing of the jamb and operable vent.



strong and it is possible to pull apart the two materials. If the support does not come loose, there is a solvent that can dissolve the support.

The machine resembles a very high-tech freezer in size and appearance. The front of the machine has a door at the top that opens into the main cavity. Inside the printer there is a metal shelf or “bed” that moves vertically. The metal bed had a series of grooves and two twist locks that secure a specific kind of plastic tray. The part is printed on the tray. The machine prints a platform of support on the tray. If the plastic printed directly onto the tray, the part would permanently bond to the tray. The support creates a layer of support that the parts can break from. The support also creates structure under parts of the model that are not supported below when built from the bottom up. An example would be an arch. An arch printed from the bottom up is two different parts at the base and need to be supported in the middle until they are connected at the top.

The printhead moves along the X and Y plane and the bed moves up and down along the Z axis. One layer of the model and support is printed onto the bed by the print head, the bed drops 250 micrometers, and the printhead prints a new layer on top of the previous layer.

When a part is complete, the bed drops, and the printhead moves to the back of the machine. The machine will then start to cool itself and go into standby mode. The tray is unlock and removed from the bed removing the parts with it.

POST-PRINTING

In some instances, parts are printed without the need of support. This happens a lot with die patterns or any other part that is extruded. Extruded parts are typically straight enough to support themselves when being printed. When this happens, the part can be taken off the

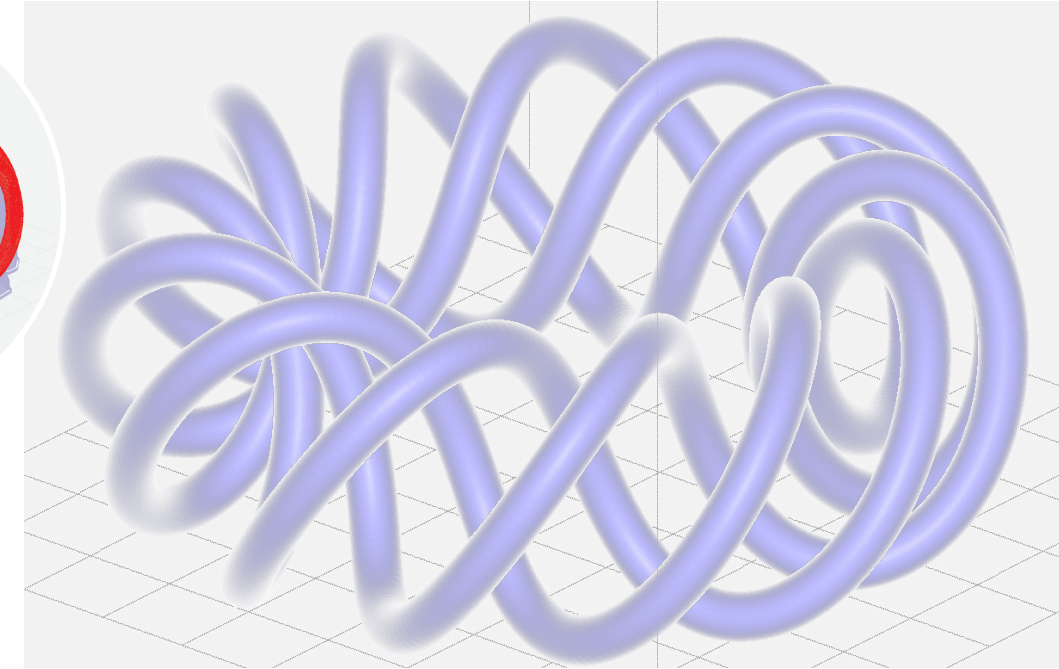
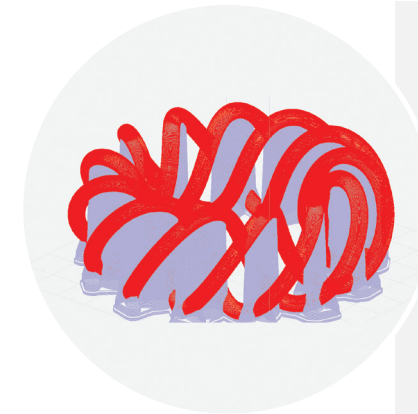


FIGURE 3
An example of a digital model created in Rhinoceros 5D, ready for 3D printing.



FIGURE 4
The Studio's machines use stereo-lithograph, also known as Standard Tessellation Language (STL) files, to create parts.



FIGURE 5
Photograph from the Studio's 2012 holiday greeting card, which incorporated a 3D printed wreath and snowflakes made from white ABS plastic. The decorative red ribbon is the only non-3D printed element.



support bed and used immediately. Parts that require some support material need to have the support cleaned from them. Sometimes the support can be broken off by hand or with a small tool. If the part is too fragile, or if we are unable to reach the support with a tool, the part is then soaked in a solvent bath. The bath dissolves the support but does not damage the plastic part. The dissolving and cleaning process is straightforward, but if executed incorrectly, can leave parts dirty.

If we know a part is going to require support, we always print the part solid. You can print large parts so they are mostly hollow on the inside, but this creates a problem when you soak the part. The outside of the part is not completely sealed off, so some water from the solvent tank makes it into the part. If a model is solid, the water with the solvent only gets so far. If the part is hollow, water and solvent can enter the cavity and become trapped. This is problematic because the solvent can leak out of the part and leave residue. To avoid this we print solid objects, dissolve supports in the solvent bath, and then run it through an extensive soaking process.

THE CLEANING PROCESS

Models sit in a metal tub that holds a solvent solution. The solvent comes dry in a plastic container and closely resembles dish washing detergent. The solvent is poured into water in the tub. The metal tub can be heated and produce an ultrasonic pulse that aids in breaking up supports. The parts are placed into the tub for however long it takes to free all of the support from the part.

When the part is removed from the tub, it is rinsed with fresh water at a sink. After that, the part is soaked in a clean water tub with a submersible pump for 12 to 24 hours. This process pulls all of the solvent out of the part. The longer a part sits in the solvent, the further it gets into the part and the longer it takes to clean it.

The part is then rinsed a final time and left to dry for an additional 12-24 hours. As one can see, this process increases the time needed to create a model. This is an acceptable trade-in for a part that is clean and will not leach out residue. We try to prioritize parts that need more time. We can also print parts that don't need support while parts that do need support are being cleaned.

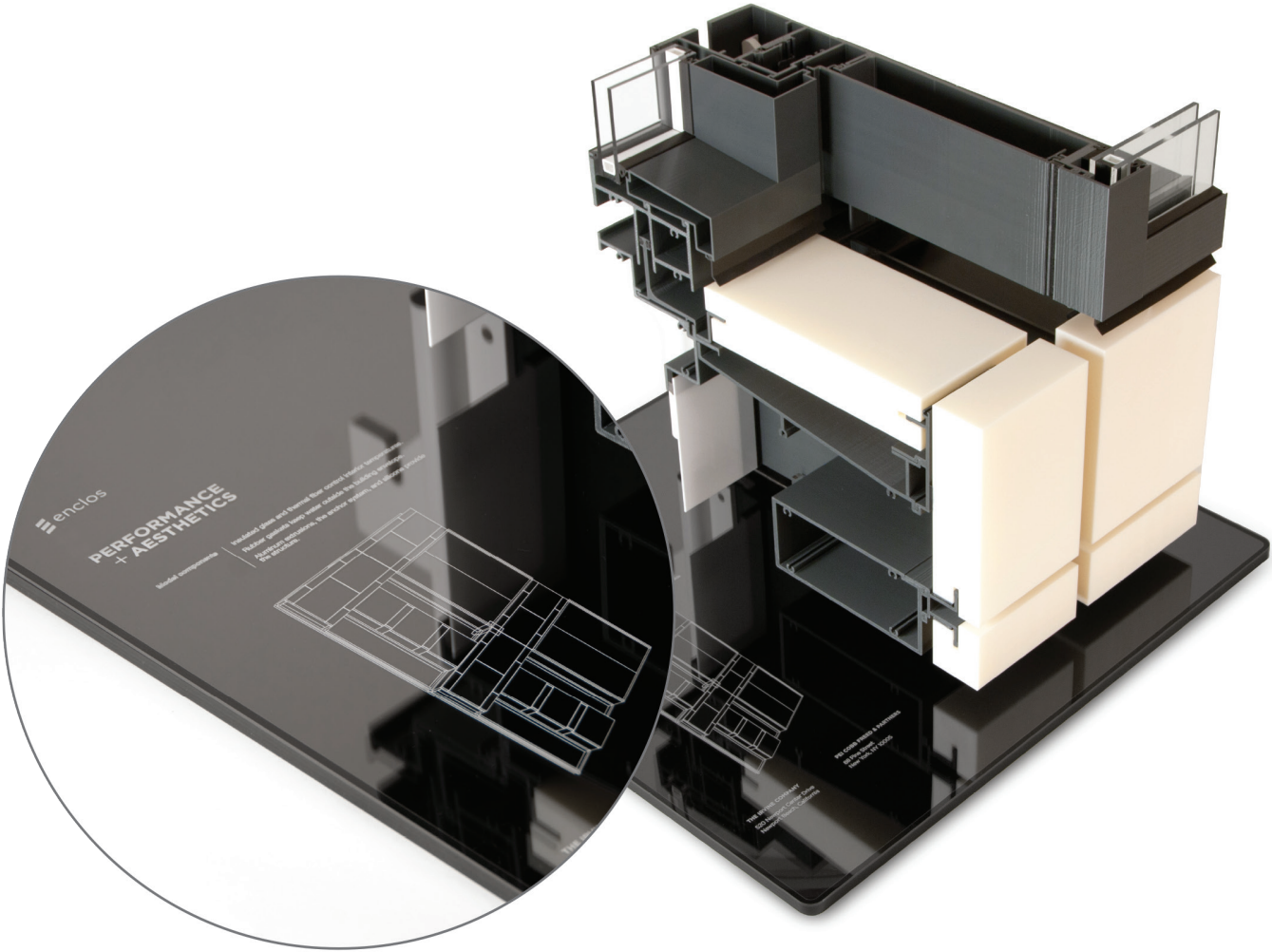
ASSEMBLY

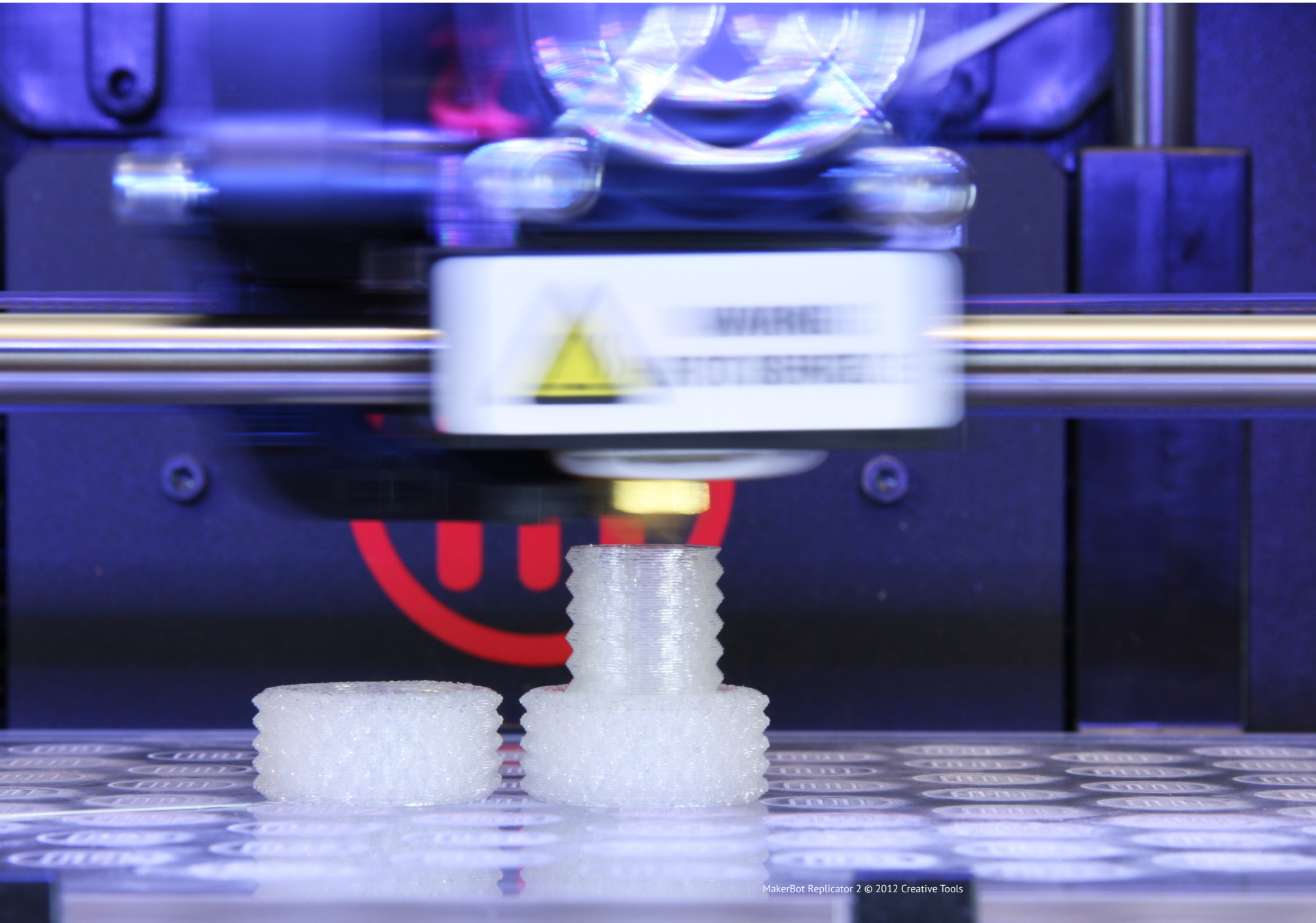
At this point we have a collection of parts that are clean and ready to be assembled. In most cases we prefer to use as many mechanical solutions as possible. We will try to find the same fasteners that are specified in the design and use them in the model. We also try to print physical features into our parts that guide in assembly.

The material used in the 3D printer is acrylonitrile butadiene styrene (ABS) plastic. It is a thermoplastic, which means it can be reshaped using only heat. This makes it ideal for printing because the machine only needs to add heat, instead of a chemical, to bond the plastic. In the Studios' first year using this material, we found that most glues and adhesives did not bond well with the plastic. In most cases glue was hard to use and would leave a mess. In worse cases, the glue would fail altogether. With a little bit of research, we found that other designers using ABS plastic were using acetone to "weld" parts together. Acetone essentially melts ABS plastic. To test this we purchased a small detail brush and some nail polish remover. We clamped two ABS plastic parts and brushed acetone between them. The acetone melted the surfaces between the two parts and then evaporated. Within 15 minutes the two parts were "welded" together and there was little to no mess from the acetone on the parts.

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FIGURE 6
This model's base used laser cutting to incorporate the Enclos logo, project name and details, and a two-dimensional reference drawing. When building a full-scale model, the Studios incorporate actual gaskets and parts. Not only does this add an additional level of realism and detail, but in some cases actually helps to build the model. In this image, the A-B clips are helping to keep the jambs together and the gaskets are helping to keep the faux-IGU in place.





MakerBot Replicator 2 © 2012 Creative Tools

FUTURE CAPABILITIES

The range of materials available for 3D parts has increased and the size and cost of the printing machines has decreased. Three-dimensional desktop printers are becoming more and more common. The Studios are always reviewing new machines that come to market to see if their capabilities could be used in the Studios. It will soon be common to see 3D printers next to paper printers and plotters. Right now 3D printing is the Studios' main tool for making parts, but we will soon incorporate other processes and materials as well.

Small volume, or one-off pieces, are becoming more accessible as the prototyping industry advances. Laser cutting machines have been around for a long time and we have a lot of experience working with them. These machines are coming down in cost and the software that operates them has become easier to use. Machined parts have always been expensive and time consuming, but similar to 3D printing machines, CNC milling machines have been making advancements as well. It is now possible to get a machined part from 3D files in days rather than weeks, often incorporating a variety of materials.

We are excited about implementing different processes and materials if it helps create a more effective model. No matter how sophisticated our models become, the Studios are grounded by the fact that our models aid in communicating and designing curtainwall and various facade structures.

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FIGURE 7
MakerBot Replicator 2 in action.