Molded Fiberglass Chair

Will Maggs & Chip Bruchez

Preface
Will Maggs and Chip Bruchez graduated from Philadelphia University in May of 2012 with a B.S. in Industrial Design.

They would like to extend a special thanks to...

The Maggs &
The Bruchez Family

Hy Zelkowitz
Gotz Unger
Charlie Rozier &
Orly Zeewy

Will Rhoda
Kris Pepper &
Eliot Coven

Joel Erland &
Kate Kaman

"Art resides in the quality of doing, the process is not magic..."

-Charles Eames

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I. Introduction

Furniture Design Class
Will had taken a furniture design course in his spring semester of his Sophomore year as a student of Philadelphia University's Industrial Design program. He decided that he wanted to create unique and engaging furniture.

His process invovled carving a chair by hand from a blue modeling foam. He proceeded to wrap the blue foam in fiberglass fabric and finish it by hand. This process is very difficult, as fiberglass is an extremely hard material and requires a lot of effort to finish.

After literally thousands of hours of sanding, the chair's surface was reaching the desired finish, although lumps and imperfections in its shape kept it from being complete and symmetrical.

Will realized at this point that the process he had undergone was not a practical way to produce furniture under a budget that would create chairs at a reasonable cost.

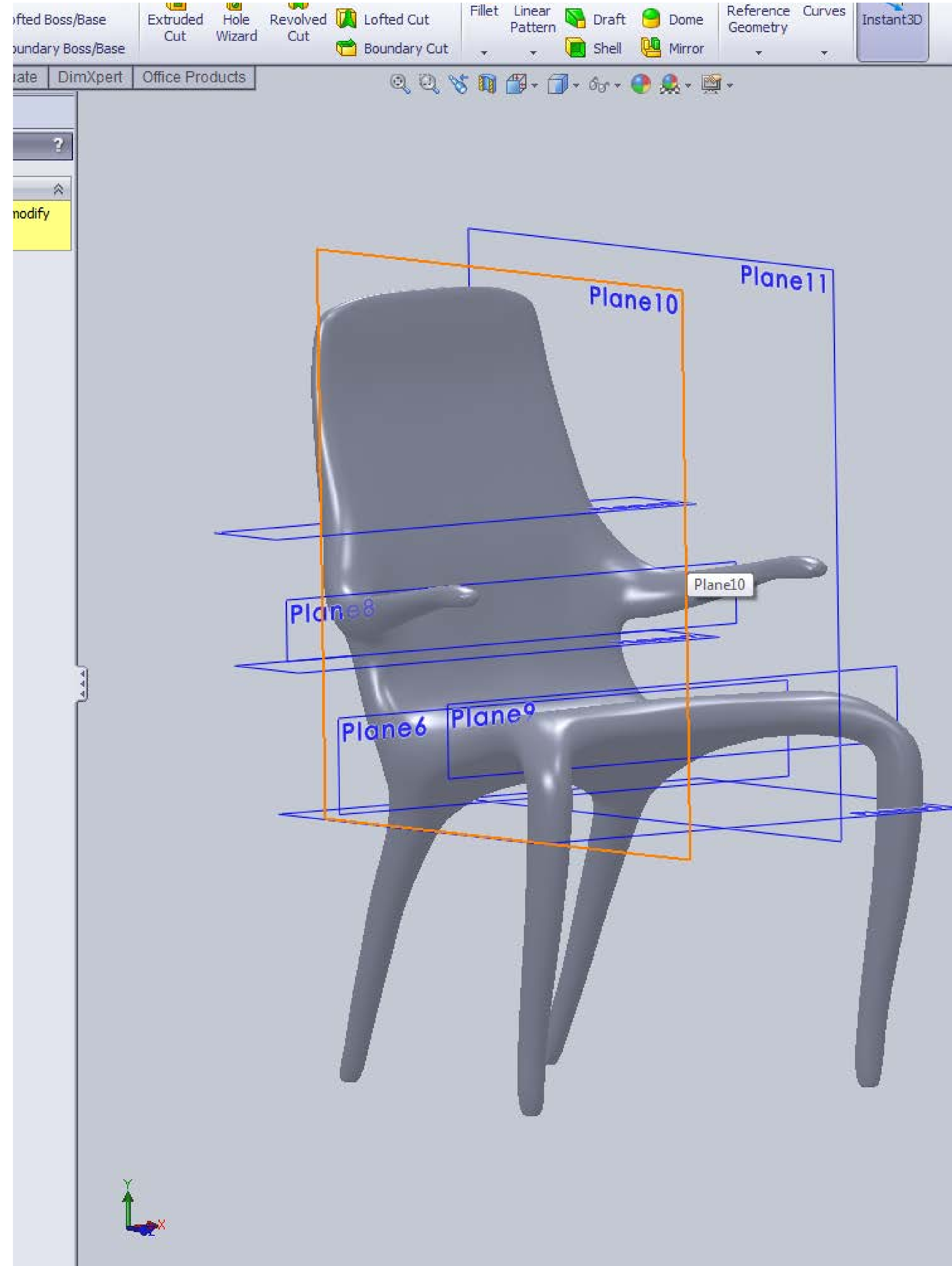
"Will realized at this point that the process he had undergone was not a practical way to produce furniture..."

Next Steps
From this point, Will decided to look into having his chair scanned in 3d. After shopping around, he shipped the chair away and received a 3d model in CAD that could potentially be CNC routed after all of the lumps were worked out and the symmetry issues resolved.

At the same time, he wanted to look into reproducting the prototype with a mold. He met with two sculptors about their ability to pull a mold off of such a complicated form. They agreed that they would be capable of doing it. However, after looking into rapid prototyping the chair, Will realized that it was too expensive for his budget.

Meeting with the sculptors opened other doors, as Will interned for them for over two years, gaining a large knowledge of mold making and fabrication. They also had promised Will that since his internship was not paid monetarily, they would offer up shop space, time, and their knowledge on work of his own in the future.

"they would offer up shop space, time, and their knowledge on work of his own..."



II. Project Preparation

Premise
During the senior year of Philadelphia University's Industrial Design program, the students are required to do a capstone (thesis) project, or a summation of what they have learned during their college career and a step towards what they would like to be doing professionally after gradutaion.

Thesis Proposal
Will and Chip decided to team up for their thesis project and continued to persue creating unique furniture. One of the main goals was to make something that was reproducable. After Will explained what he learned from his first furniture project to Chip, they began discussing what a successful project would entail.

It was decided that a mold was necessary to reduce the amount of time spent making each chair. So they proceeded to look into all of the currently existing processes for molding parts.

"We decided that a mold was necessary to reduce the amount of time spent making each chair."

Comparison of Molding Processes

	Cost (Overhead)	Cost (Per Part)	Disadvantages
Injection Molding	$$$	$	Requires uniform wall thickness
Gas Assisted Injection	$$$$	$	Most expensive part of the process is mold flow analysis
Rotational Molding	$$	$	Does not work on tight radii or corners and yields low quality finishes
Investment Casting	$	$$$	Exremely heavy final parts
CNC Routing	$	$$$	High cost per part
Fibreglass Layup	$	$$$	Requires having an opening in the final part to lay fiberglass into the mold
Compression Molding	$$$	$	Requires uniform wall thickness

III. Our Process

Realization
After researching the various ways of molding, we decided fiberglass was the best material to make our chairs out of.

Ideally, fiberglass is very thin due to its excellent strength to weight ratio. It is considerably lighter, and more than twice as strong as steel.

The most traditional fiberglass manufacturing technique, glass lay up, gives a uniform finish on the exterior of the part, and a uniform wall thickness. However, it requires a large hole on one side of the part so the fiberglass can be applied by hand to the inside of the mold. A good example of a part manufactured using glass layup is a boat hull. The undesireable finish on the inside of the hull is masked with flooring, wood working, and upholstery.

Compression molding, which is also fairly common in fiberglass manufacturing, allows for slight variation in wall thickness of the part as well as a uniform finish on the entire part. In compression molding, a two part aluminum mold is slammed together, with the fiberglass inside of it, compressing the fibers and resin together. However, this process also has its limitations. Compression molding tends to yield fairly simple parts. A good example of a well made compression molded product is the Eames Shell Chair.

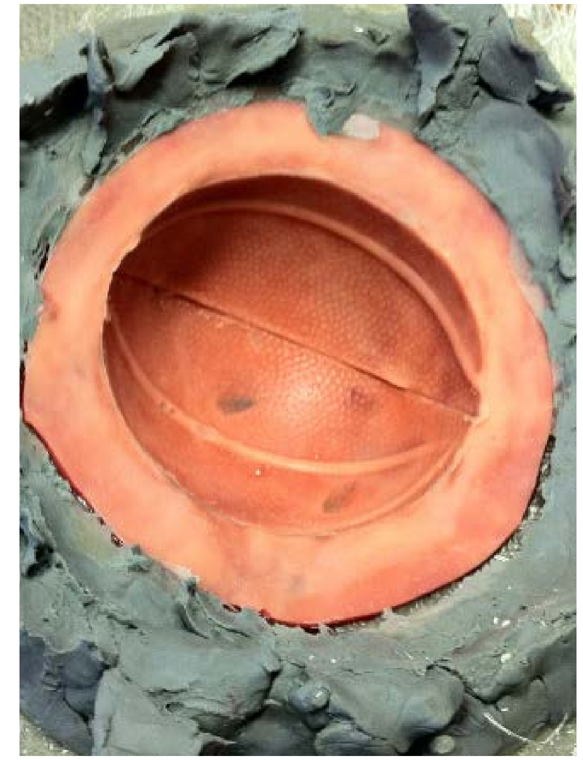
Discovery
Weeks went by as we thought deeply about how to proceed in developing unique furniture. In order to acheive a hard shell, the idea of a filler material or bladder seemed to be the best solution. But how does the inner material ensure that the fiberglass surrounding hits the walls of the mold?

We really wanted to look into creating a bladder, but decided that making complex forms, getting them to fit inside a mold, and getting the bladder back out of the mold after would be a very difficult task.

Eventually, we came up with the ideal solution. We would create a mold, pour an expanding flexible foam into the mold, and then wrap that nerf like material in faberglass and fit it back into the mold. Since the foam is flexible, it will compress enough to host a fiberglass jacket and then also have enough pressure to force the fiberglass to the walls of the mold consistently.

That day we wanted to do a very quick run through of our proposed process and we proceeded to purchase a foam basketball to start a test. After a week's worth of mold making, we were ready to wrap the original part in fiberglass. Once it had hardened, we opened the mold to a hard fiberglass shell that replicated the initial ball and was rock hard. The only problem with this test was that we used a low quality part to pull the mold and couldn't prove that we could get a glossy or high quality finish.

"The flexible foam will have enough pressure to force the fiberglass to the walls of the mold."



IV. Test Pattern Making

Blue Foam & Fiberglass
The next portion of the process we had to figure out was how we were going to create the part that we would pull a mold off of. Our first idea was to cut a shape out of a blue insulation foam and wrap it in fiberglass.

We carved out a shape that somewhat resembled the leg of a chair. We wrapped this part in fiberglass fabric, which was very thick and difficult to lay on without heavy seams.

After it had hardened, we proceeded to sand it, but sanding fiberglass is very difficult and proved to be far too time consuming. We used a hydraulic orbital sander and even that did not work nearly well enough in forming the fiberglass. We needed an alternative method, as doing all of this sanding on a large part would consume all of our time.

Yellow Polyurethane Foam
Blue insulation foam was very low cost, which was a part of the initial decision to use it. However, it does not finish very quickly and is also very brittle. Yellow polyurethane foam is a much finer material and carves more similarly to wood. Although it takes a bit more time to carve the yellow modeling foam than the blue insulation foam, it would be much easier and cleaner to finish.

So we wanted to create our next master test part out of a yellow modeling foam and decided on a tear drop shape as being a good representation of the form we were looking for. It had a very tight curve as well as large flatter surfaces.

"Yellow polyurethane foam is a much finer material and carves more similarly to wood."

Finishing the Yellow Foam
Finishing a part can be accomplished in many different ways. We started by applying a thin coat of plaster to fill all of the holes in the yellow polyurethane foam. Plaster is a softer material. The idea is to move from a softer, more easily sandable material to ones that are harder and will give a finer finish.

After the plaster was sanded to as smooth a finish as we could get it, we covered the part in a glazing spot putty. Glazing spot putty is what is used on cars to fill scratches and minor dings. Hours were spent between sanding and applying more spot putty until we decided to spray the part with red paint.

The red spray paint helped us clearly identify troubles with the surface, like lumps or wholes in the finish. From the red paint, we could sand away the lumps and then continue to add glazing spot putty where it was needed to fill any remaining holes.

The final coating we used to finish the part was a sandable primer. The sandable primer is ideal for filling any small holes and sealing the part off. In the far bottom right image, you can clearly see where there was plaster (cream in color), glazing spot putty (dark red), the paint (bright red), and the sandable primer (gray).

"The red spray paint helped us clearly identify troubles with the surface, like lumps or wholes in the finish."





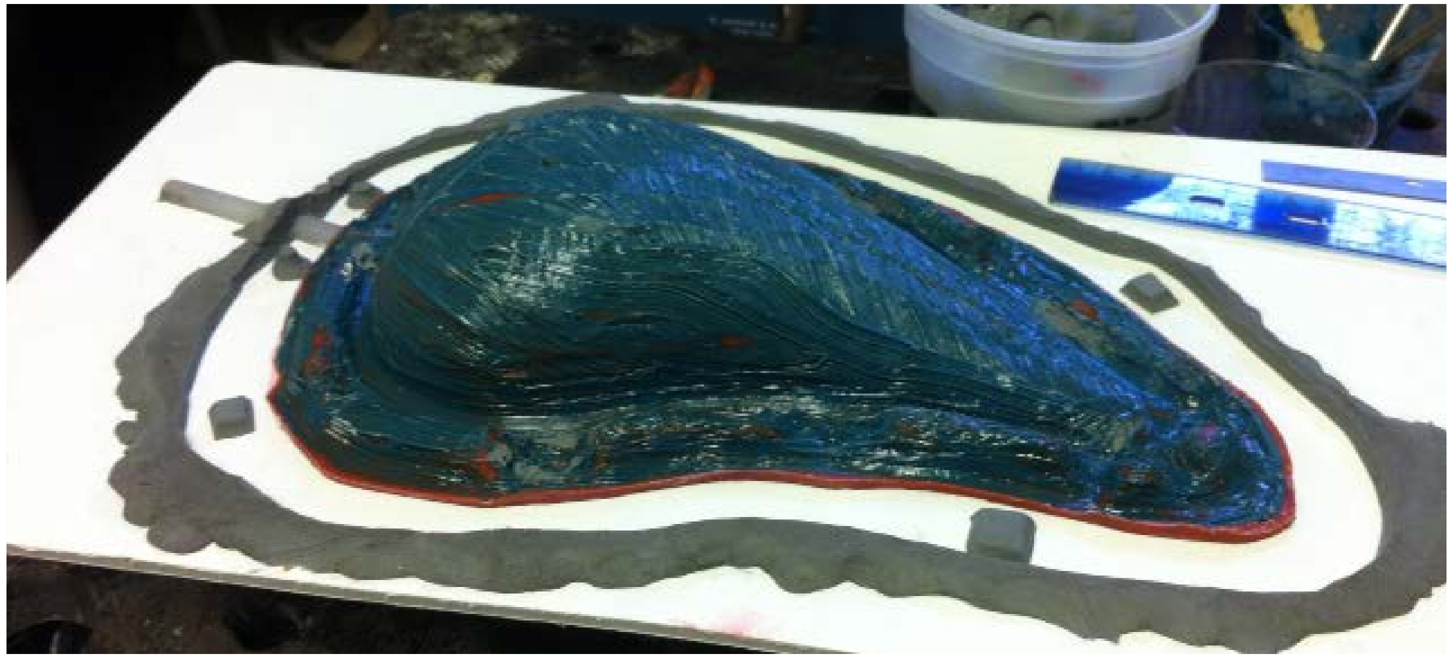

V. Test Mold

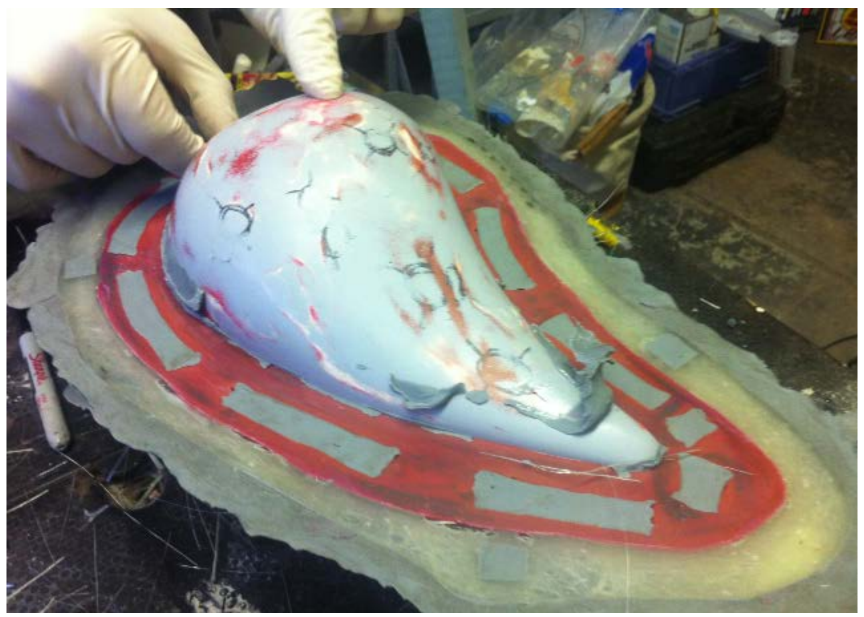
Silicon & Fiberglass Glove Mold
When creating a mold, you need to ensure that the part you are putting into the mold and then the parts after that you will pull from the mold can easiily be released. For our molding process, we wanted to use a silicon glove mold. This is accomplished by having a silicon mold that is reinforced by a fiberglass backing.

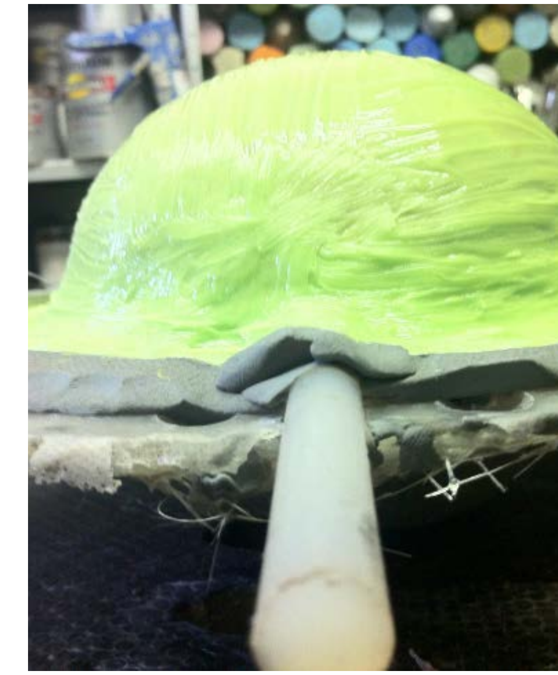
Silicon allows for more freedom when creating the mold. Since it is flexible, you don't have to worry about the part getting stuck when releasing it. The silicon also picks up the details of the part very nicely. One of the down sides of using the silicon, however, is that it takes quite a while to cure. The process for applying the silicon is mixing two liquids and brushing them onto our part. We needed three layers on each half and each layer takes approximately six hours to cure.

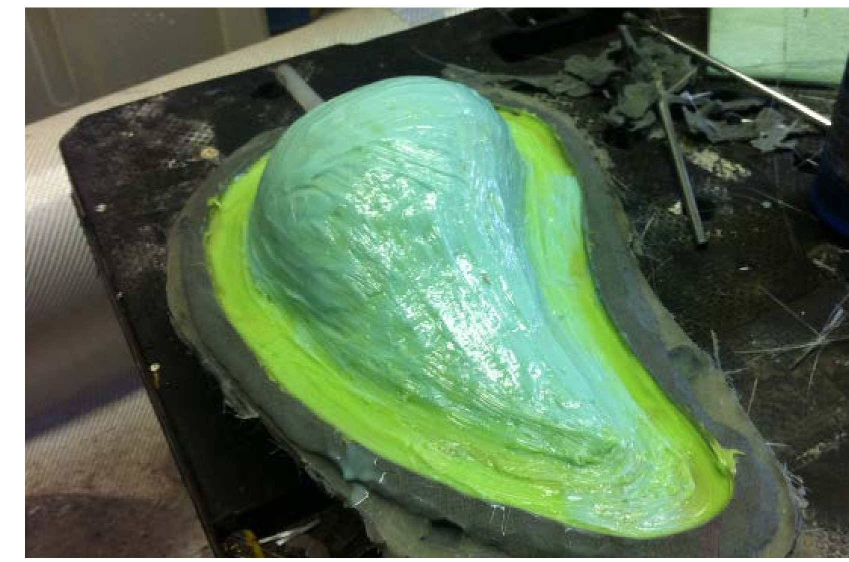
After the silicon is hardened, we prepped our mold space for the fiberglass "glove" and added a fiberglass shell to each silicon half.

"For our molding process, we wanted to use a silicon glove mold."









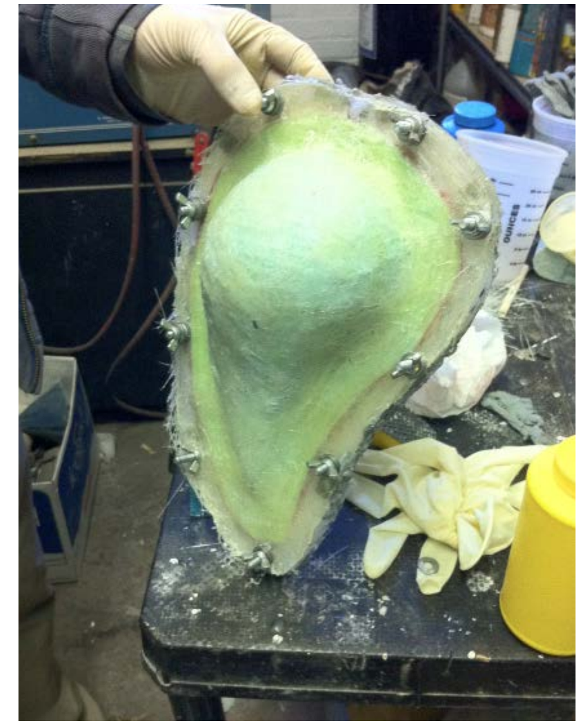
Expanding Flexible Foam
Once we had a completed mold, we were ready to pour our expanding flexible foam into the mold. Before we could pour the foam, however, we drilled holes around the perimeter of the mold, allowing for us to bolt it shut when we were ready to enclose it.

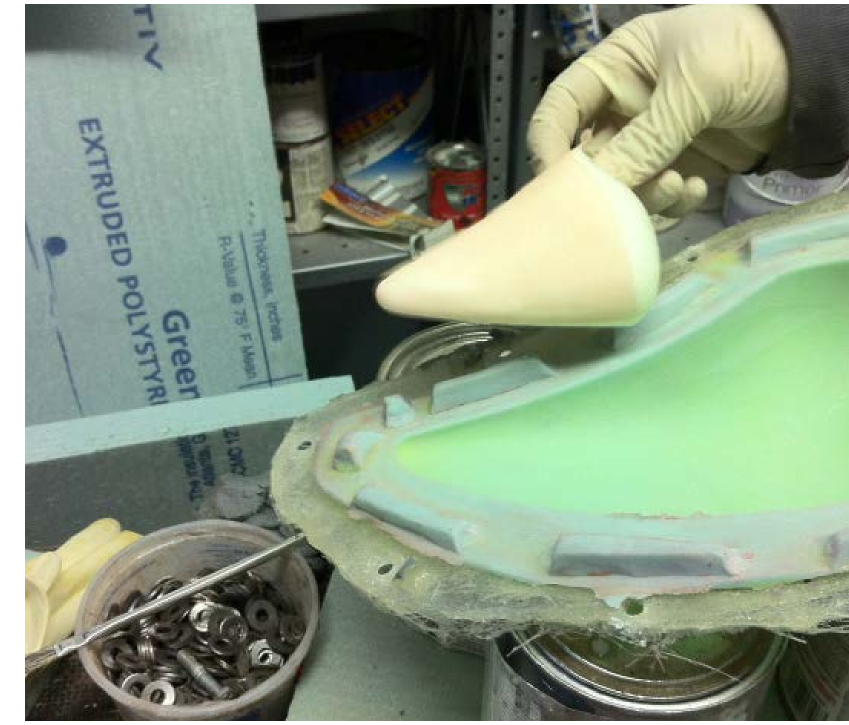
When we initially came up with the idea for using a flexible foam, we didn't know exactly the density of what we were looking for. We drove to Smooth On Inc.'s headquarters about an hour and a half out of Philly and picked up a variety of samples. We decided on a medium density foam that expands six times the amount of liquid that is poured and mixed.

The expanding foam is very tough to work with. We accounted for having to pour foam into our mold and there is an opening the size of a gluestick. The first batch we mixed and tried to pour in started expanding very rapidly and wouldn't pour through our spout. After Parts I & II are mixed there are 25 before you must quickly pour. The foam expands and becomes too thick to pour after 50 seconds. We ended up only filling the bottom of our mold (as seen in the top right image).

We learned that we would have to mix the two parts very quickly, and then pour them into the open mold, immediately enclosing it and bolting it shut.

Unfortunately, the release agent we used on our silicon warped our mold, and we were left with a silicon mold piece that was unusable, which in turn, produced a foam piece that was unusable.





Remaking the Second Mold Half
We wanted to recreate the second half of the mold, not only because it was slightly warped, but because the fiberglass shell and the silicon weren't fitting snugly. If there is any movement and flexibility when our parts are in the mold, we won't be able to pull consistent pieces.

This time around, after we did our layers of silicon, we used a gel coat before adding the fiberglass backing. Gel coat is a hard shell like material that would be ideal for fitting snugly to our silicon mold, prior to adding fiberglass. The gel coat is the glossy white coating shown in the images.

After the gel coat, we applied matte fiberglass instead of the usual woven sheets we had been using prior, since the gel coat and matte combined was strong enough without the need for the thicker woven fabric.

"This time around, we used a gel coat before adding the fiberglass backing."

Test Foam Preparation

The first step to our process is to pour the expanding flexible foam. From our prior experiments with the foam, we learned that it was difficult to pour it through our spout, so we poured it into one half of the mold and quickly endclosed it.

Unfortunately, we didn't pour quite enough and had to fill the rest of the mold. We then used a plastic zip lock bag with a spout, kind of as if we were pouring icing. This worked well and the foam expanded through the opening, which is not a problem as the foam cuts very easily.

"...so we poured the expanding foam into one half of the mold and quickly enclosed it."

"...it proved our process by exactly replicating the desired shape with a hard, glossy fiberglass shell."

Pulling Parts from the Test Mold

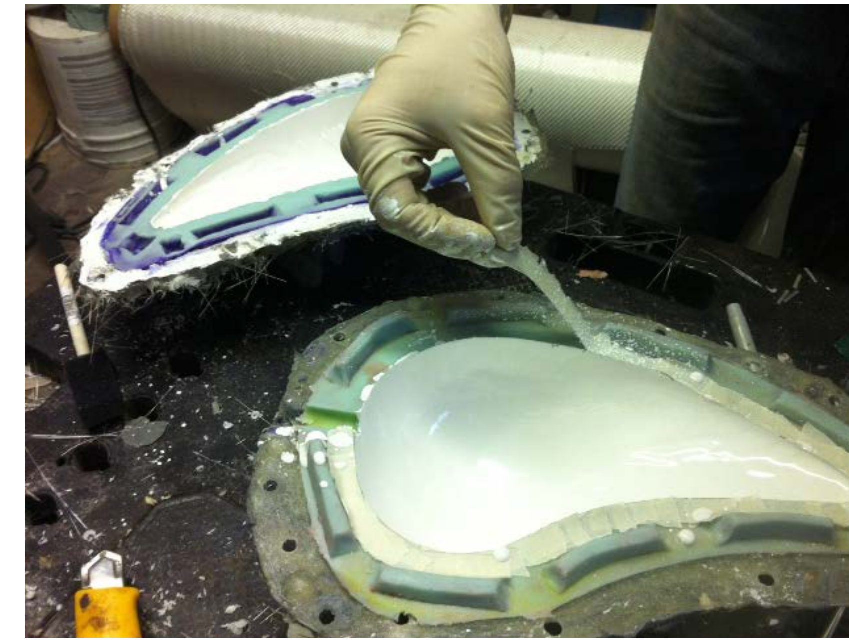
Now we had our foam "plug," which we needed to wrap in fiberglass and put back into the mold. Fiberglass, however, would not give a clean finish, as the material we are using is a woven fabric texture that would be visible.

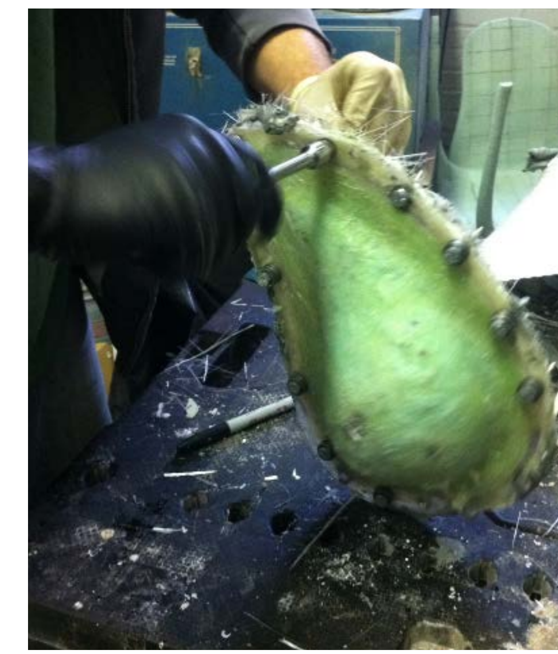
To get a high gloss shell around the fiberglass, gel coat is applied to the mold prior to putting the foam part inside with the fiberglass. Gel coat, ideally, is sprayed, but we didn't have the means to spray it so we brushed it into the mold, using tape to prevent the gel coat from going outside of our tear drop shape.

We put the foam plug into the mold with the fiberglass fabric and cut a few shapes to fit nicely. Once we were ready, we applied resin to the fiberglass and forced the foam, which was now wrapped in fiberglass, back into the mold. We bolted it shut and had to wait twenty four hours for the gel coat and fiberglass to harden.

Unfortunately, gel coat needs a temperature of approximately 70° to cure entirely within a twenty four hour period. We had a hard time regulating the temperature in the spray room we were working in, during the winter months, and when we opened the mold and pulled the part out, it wasn't entirely cured. The resin also bulged out at the seams of the mold and created a hard seam, which we could easily cut off. The part we pulled out had some fingerprints from us handling it before the gel coat was entirely cured but it proved our process by exactly replicating the desired shape with a hard, glossy fiberglass shell.

The only other downside to our process at this point was that since we used silicon for our mold, which is flexible, the pressure of the foam pushing out created some lumps in our final part. We realized at this point that a silicon glove mold was not suitable, and that we'd need to use a fiberglass mold.

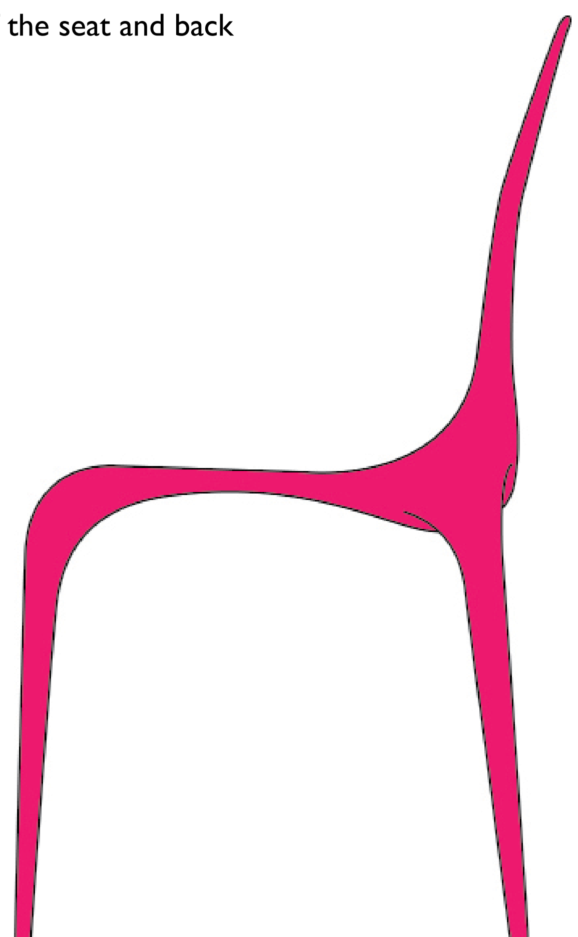


VI. Designing the Chair

'Sits-like' Model
It was necessary to determine how this chair would feel when you sit in it, with out committing the time or money to making the real thing. So, in a couple of hours one afternoon, we used some scrap material and built our sits-like model.

Once this is built, the proportions and curves of the back and seat can easily be adjusted. To adjust these curves we used 1" x 10" strips of cardboard to build up the chair where necessary. These changes are then carefully measured, and added to the side view which we are working with to create the final piece.

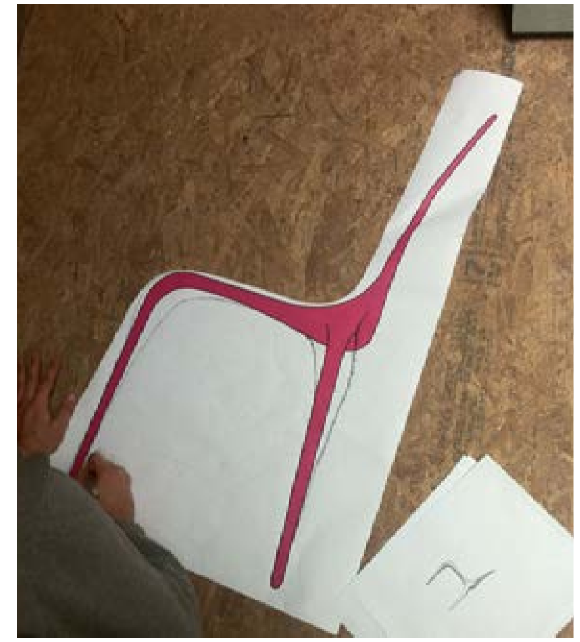
This was a cheap way to ensure that we had a general idea of how the seat would feel. In this stage, we also determined width of the seat, width of the back, and height of the seat and back from the floor.

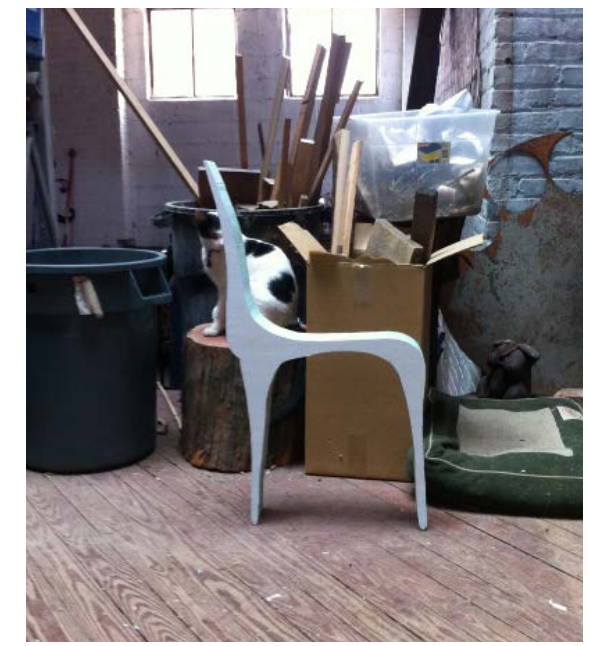


'Looks-Like' Model #1
The next step was to make a fast, cheap model of how this chair would actually look in 3D, in full scale. We decided to use blue insulation foam as our material. First we cut out the side view 8 times and glued them together, creating a fin model. Next, we began sculpting. This was the first real exploration of form for this project because we had great difficulty doing any perspective drawings of the details.

Prior to creating this model, we discussed the concept of having a sweeping, elegant plane held up by the back legs. We wanted it to look almost as if the back legs were an afterthought - a growth or adaptation the chair made to support its sweeping front legs, seat and back.

"...the back legs were an afterthought - a growth or adaptation the chair made to support its sweeping front legs, seat and back."







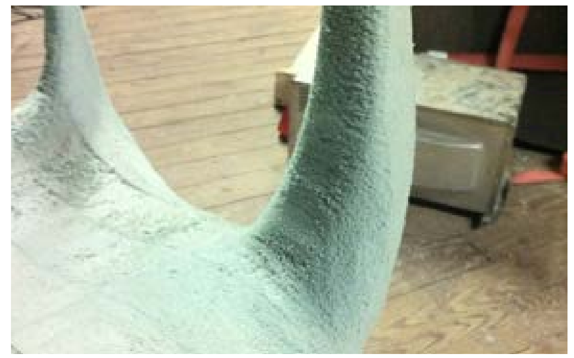












Philadelphia

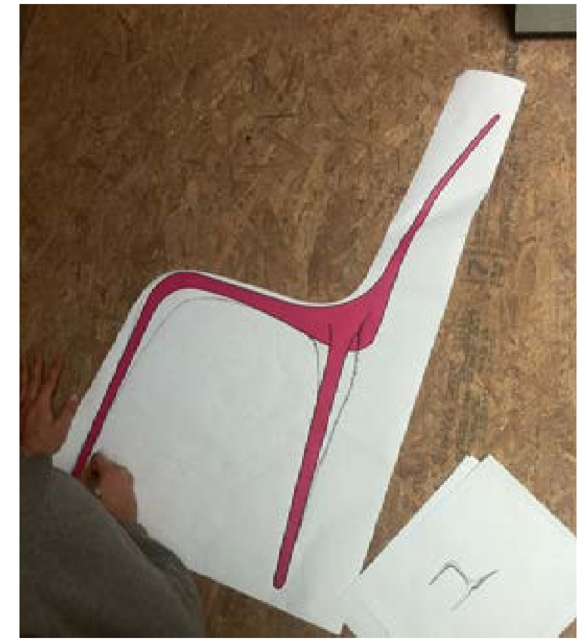


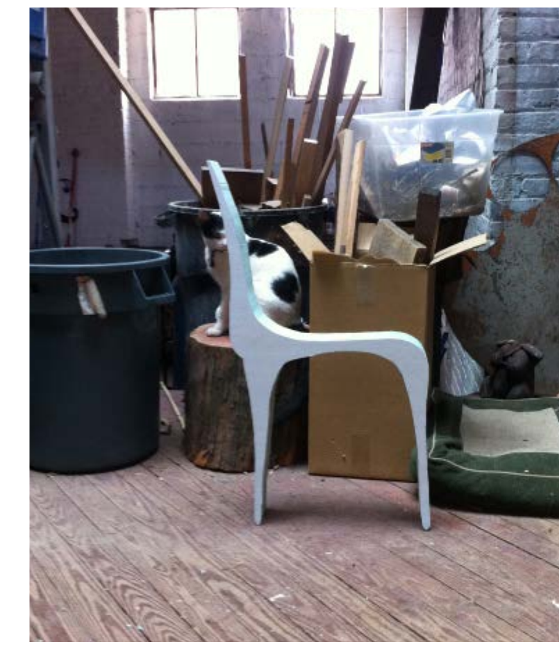
Philadelphia

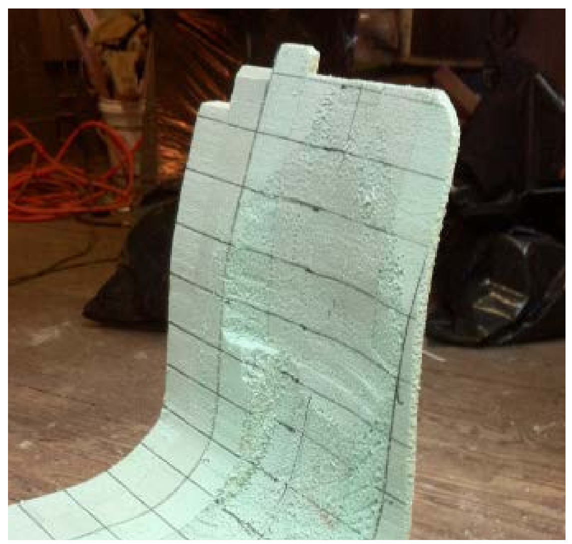

'Looks-Like' Model #2
The second time around, we wanted to make some changes to the overall form of the chair by refining and adding some features. Most notably, we made a contour on the inside of the back of the seat, where your back rests. We also brought the back legs back about two more inches, as we were concerned about people leaning back in the chair and falling and began using templates to increase the accuracy of our symmetry.

In our first model, the back was a flat plane, and we decided that curving it would make your back nest better in it. We also added two inches to the overall width of the chair, refined some of the chamfers, and altered the way that the back legs meet the chair slightly. This made for a smoother transition from the back legs to the seat of the chair, while still giving the appearance of holding up the seat, as was discussed in the original model.

"We began using templates to increase the accuracy of our symmetry."








Dow
ULINE
ULINE




ULINE
ECONOMY
AIR BUBBLE
ULINE





HUSKY

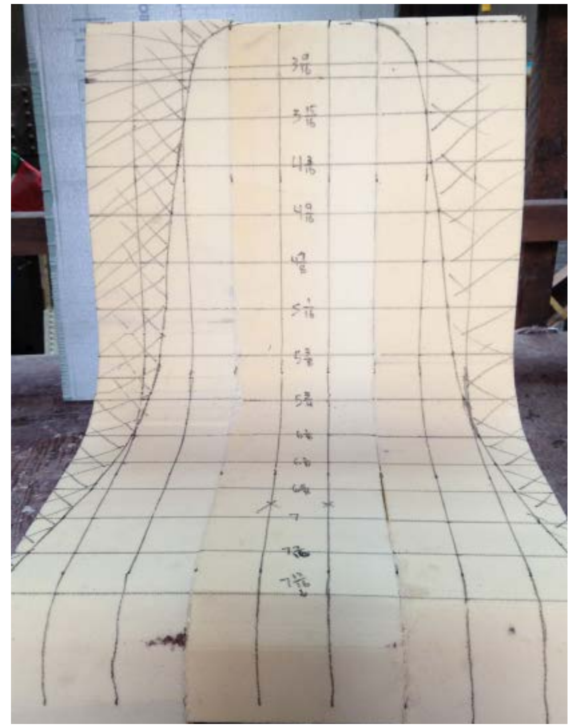
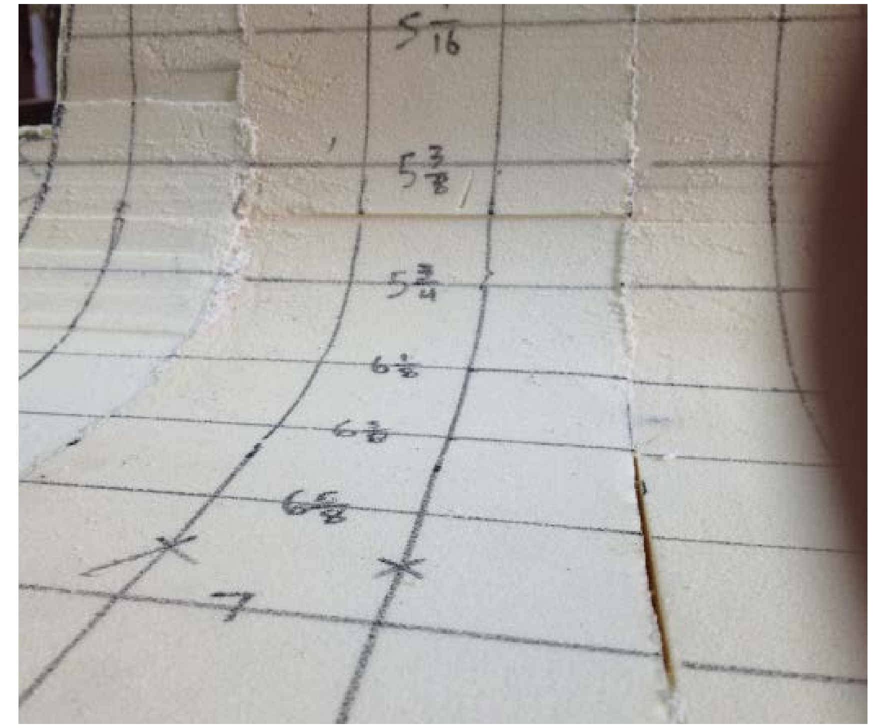

HUSKY

VII. Building the Final Chair

Sculplting the Final Model
Our final model took considerably longer than our first two models for several reasons. We used a more dense, higher grade modeling foam to achieve a higher quality in our part. Symmetry was also very important on this model because we wanted the part to be of a high enough quality that we can pull a mold off of it.

We used rulers and a grid system to transfer measurements from our second looks like model to our final chair, carved slowly, and made a variety of templates.

"We wanted the part to be of a high enough quality that we can pull a mold off of it."

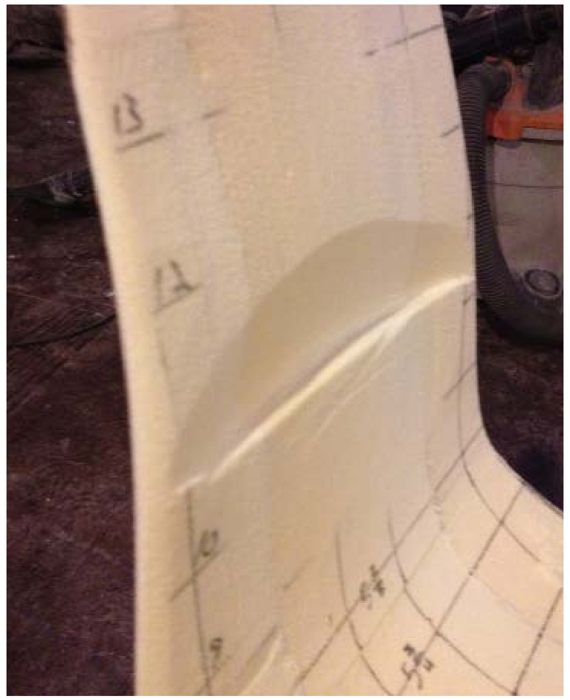
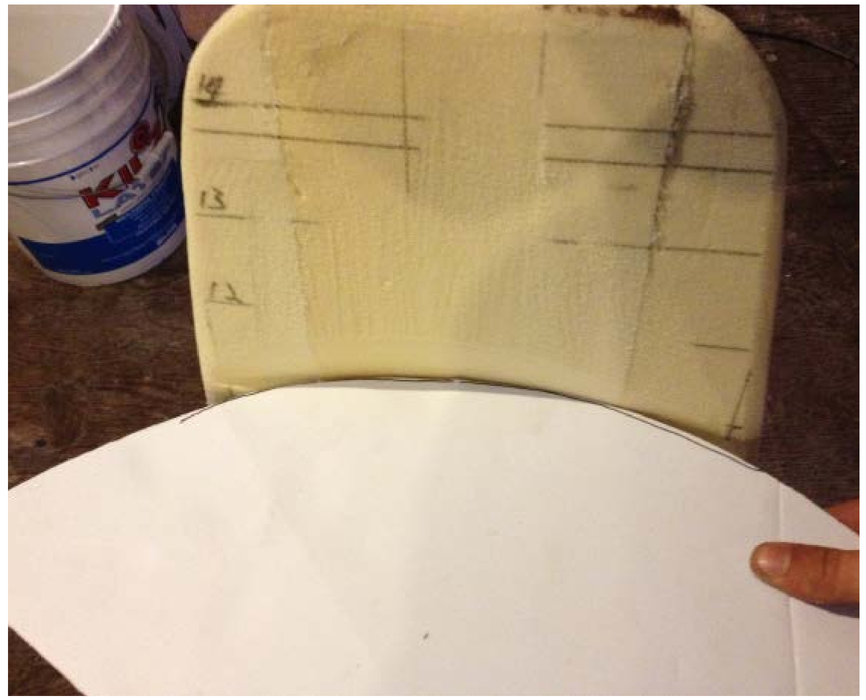


















PhilaU







The Seams
Once we had shaped it as best we could with rasps and sand paper, we noticed that anywhere there were glue seams, there was a noticeable lump. This was because the glue is harder and more dense than the foam we were carving.

We decided that we needed to dremel out the seams on the entire part and fill the holes with plaster. This would allow for more consistent sanding and create a more perfect part.

"This would allow for more consistent sanding and create a more perfect part."

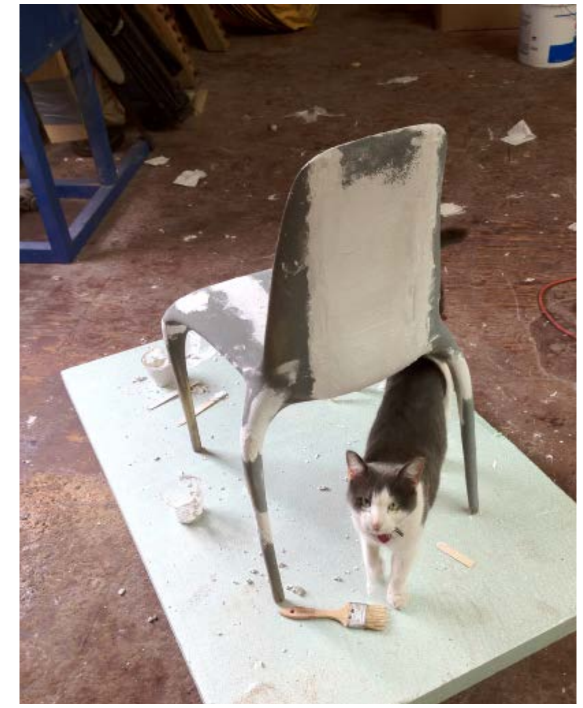
Finishing and Detailing
This stage was the most time and labor intensive part of our entire project. Once we had finished sculpting the chair, we needed to fill the surface. The modeling foam we were working with was very pourous, so to achieve a high gloss finish, we needed to spend a lot of time filling the "pores" with various types of plaster, spot putty, and primer. This part of the process took close to four weeks.

The one side, where the curve of the back and seat meat, was noticeably smaller than the other. We had to load plaster on this edge and rescuplt it carefully to match the other side.

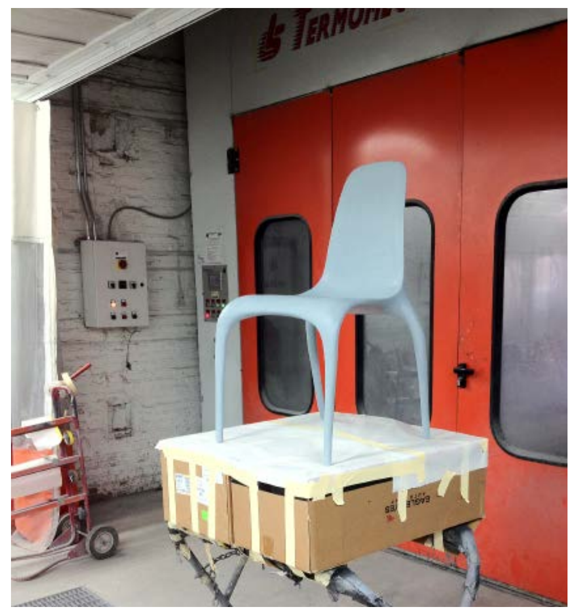
Where the feet of the chair meet the ground had also become an issue. We hadn't considered how to finish them and they were all different and uneven. Again, we globbed plaster onto the ends and cafefully sculpted them. Once we had a consistent flow for the legs, we rolled the legs over sandpaper on a flat surface until they all met the ground evenly.

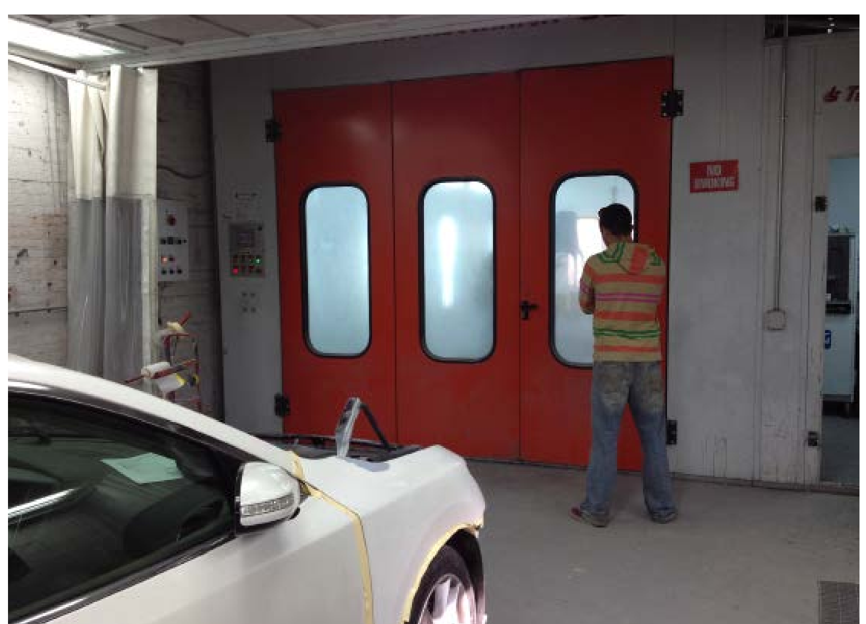
Once we got it to as good of a finish as we could, we wanted to have it painted with a hard and durable paint. We took it to a small, local autobody shop and had a professional paint it with a high gloss white car paint.

"We rolled the legs over sandpaper on a flat surface until they all met the ground evenly."










Final Chair
When we picked the chair up from the autobody shop after having left it there over night, we were awestruck. It looked better than we could have planned.

Unfortunately, our timeline for our senior thesis project ran a little short. We had proved our process with a test part and had created what we thought was a beautiful chair. We were unable to marry the design and the process, however.

As you are reading this, the chair is being developed further and steps are being made to put this chair into production. The process will not remain stagnant either. Further ideas for good use of the developed process are surfacing daily and will manifest themselves.

"We had proved our process with a test part and had created what we though was a beautiful chair."


CHEERS!

"When you grow up you tend to get told that the world is the way it is and you're life is just to live inside the world. Try not to bash into the walls too much. Try to have a nice family, have fun, save a little money.

"That's a very limited life. Life can be much broader once you discover one simple fact:

"Everything around you that you call life was made up by people that were no smarter than you... and you can change it, you can influence it, you can build your own things that other people can use.

"Once you learn that, you'll never be the same again."

-Steve Jobs


skinny
skinny