Objective: To develop a sustainable, cost-efficient, environmentally friendly, pressure-resistant, thermally insulated, buoyant, and structurally sound model of a shelter/home that can be scaled to fit the needs of impoverished and homeless families that are threatened by natural disaster extremities.

This will be done using curvilinear architecture (cylinders) to ensure the model's buoyancy, strength, pressure-resilience, and cost-efficiency. We made use of the Fibonacci Sequence, a ratio that occurs in every biological (and sometimes man-made) component of nature to design our prototype. We used the ratio/sequence to make use of Luban, a software that performs algorithmic partitioning on 3D models, which is generated using the Fibonacci ratio of each predicted piece when partitioning a curvilinear model.

However, the model's pressure-resilience, thermal insulation, chemical-resistance, strength, environmentally friendly, and hydrophobic properties come from our model's material, PETG. PETG (Glycol Modified Polyethylene Terephthalate) is amorphous, making it safely recyclable. Glycol is also naturally very strong, and when combined into a copolymer, it gives the material thermal stability, durability, and basic chemical resistance, as PETG tends to behave like reinforced plastic (PETG is a modified version of plastic/PET). Testing and calculations reveal crystalline structure can withstand 10,000 lbs per sq inch at a decrease $8 per sq ft of construction cost.

December 2nd, 2021

We printed out a few test prints and determined a leveling problem in the x-axis rail. The manufacturer sent us a replacement and it just arrived today. It will be installed and we will reprint the sample to make sure the issue is resolved. The first piece is being printed as a test.

December 11th, 2021

The first piece **part_22** is officially printed (pictured below). The next piece is approximately 7% completed. Piece 2 is completed (**part_32**)

December 12th, 2021

Both **part_1** and **part_43** failed because of temperature and extruder issues experienced using PETG and PLA(instead of PVA). New extruders will be arriving next Friday. So far, we have one part completed: **part_32**.

December 15th, 2021

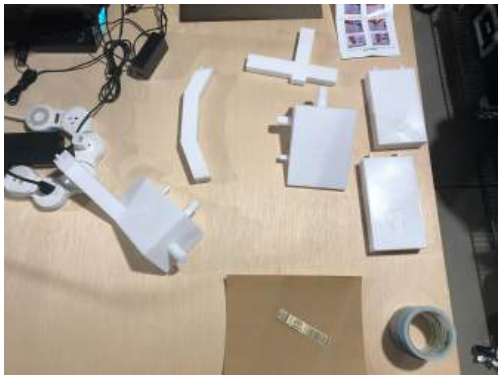
Update: **part_1** and **part_2** are also completed. We have three pieces(including part 1, 2, and 32) completed in total and #4(**part_3**) is on the way.

December 16th, 2021

#4,**part_3**, completed printing. Part_4(#5 in terms of all components)is currently printing

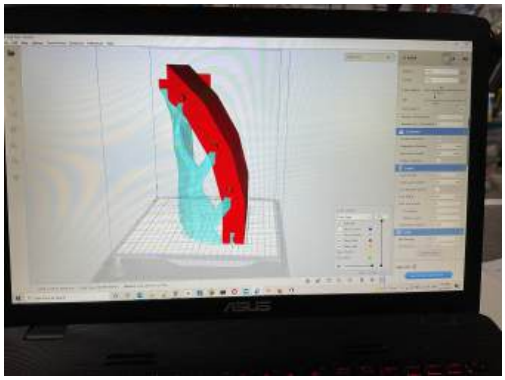
December 18th, 2021

6 parts have been printed (Parts 1, 2, 3, 4, 5, 32). We are printing part_6 and part_11.

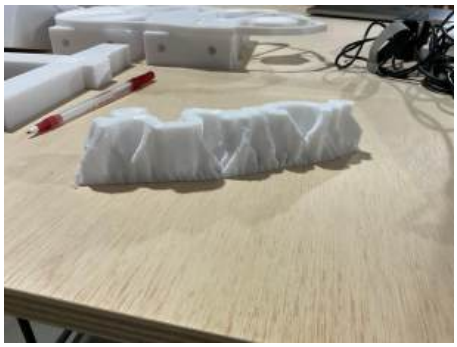


December 21st, 2021

We are now able to print using a new organic support called “Tree”. It is able to print out support according to the shape of a particular piece.



Tree support (shown in slicer software)



Sample Tree support

December 22th, 2021

A total of eleven pieces have been printed.

Our twelfth and thirteenth pieces are printing (**part_26 and part_15**)

December 24th, 2021

We glued **part_9** and **part_15** together

We have a part of a cylinder completed! So far we have 13 pieces printed.

#14 will be done printing in about 1.5 hours. And the fifteenth and sixteenth are well on their way.

December 25th, 2021

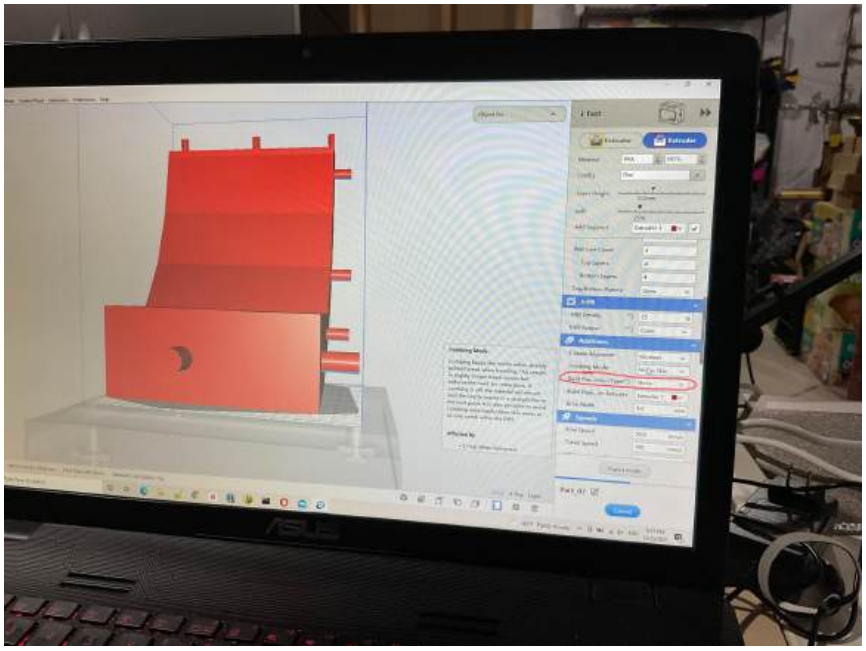
Inserted carbon fiber rods

Because of the low temperatures of the extruder on the i-fast (240 Cº), the support wasn't adhering to the part that was printing. From now on, I'm printing with nozzle temperatures at 250 Cº to fix this issue.

Since we couldn't print a piece because it couldn't even fit on the i-fast (our largest printer), we eliminated the thermal borders in the .Gcode file and that fixed the issue.

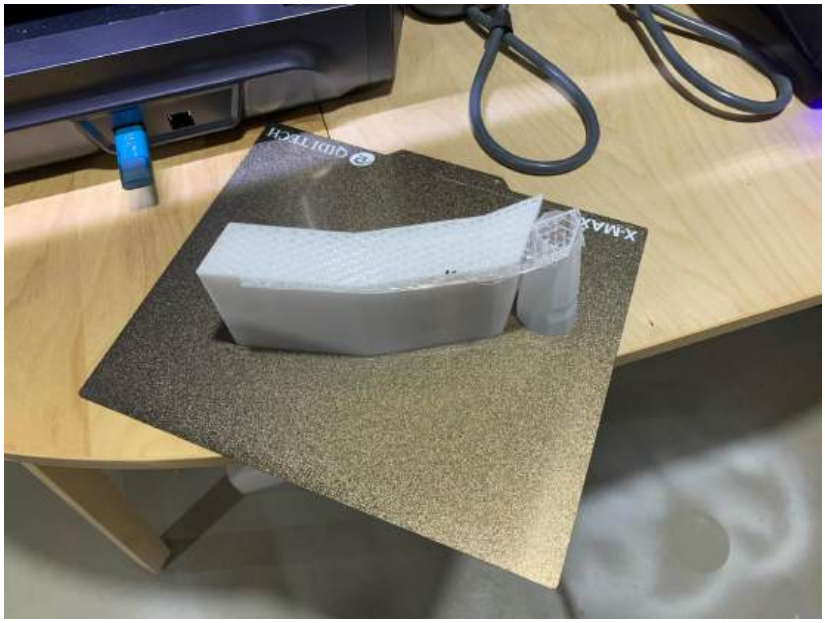
In the Build Plate Adhesion Type option, the "none" option should be selected instead of "skirt". "Skirt" would not have allowed us to print past the recommended thermal borders and warned us not to print so near the edge otherwise the model wouldn't stick entirely as more heat is concentrated near the center of the plate than near the edges of the plate. The "none" option would ignore these borders and still allow us to print such a large piece. We're only crossing the thermal border by about half a millimeter so hopefully, no major issues will arise.

The gray outline is gone because we have turned on the "none" option. This means that the slicer software is not aware of the thermal borders anymore and we can print.

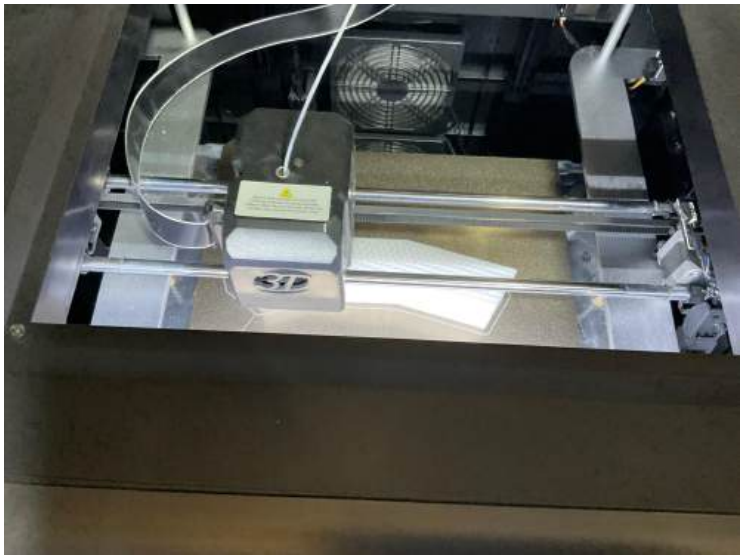


December 27, 2021

An accident occured. We don't know how it happened because we didn't see it happen but there was a loud sound in the basement like something was jumping off-track. By the time Josette (Eliza_5342) reached the basement, the sound was gone and everything was still printing or so she thought. Observing just a few moments longer, she saw this. It seems like something occurred and the extruder came off track on the X-Max but then self-corrected and repositioned itself in the wrong spot.

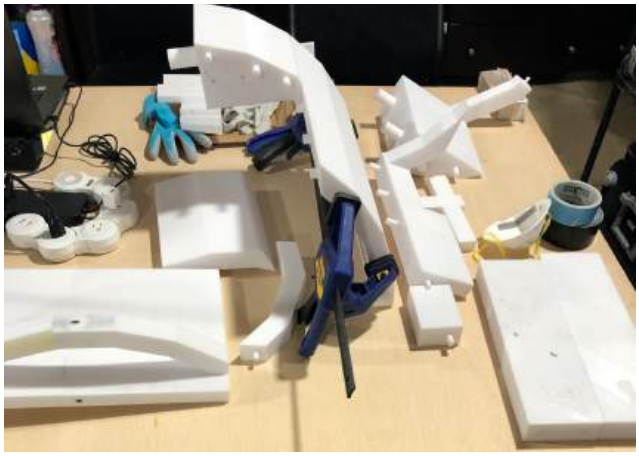


Reprinting failed piece:



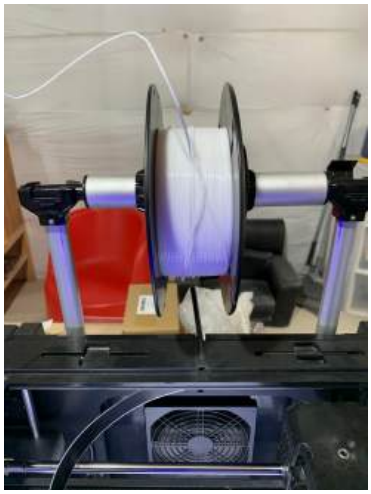
December 29th, 2021

We have seventeen pieces in total and part of our left cylinder is formed!



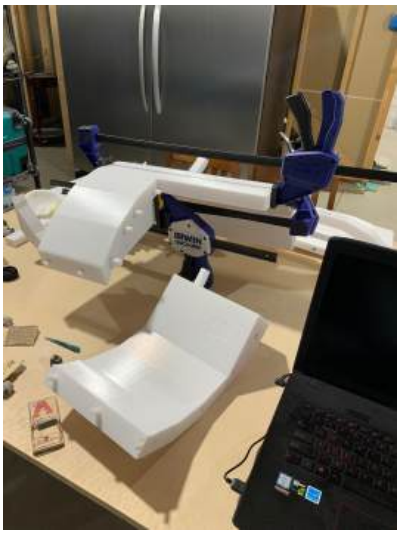
January 1st, 2021

Sometime this morning, the filament got tangled for **part_21** on the X-Plus. We weren't aware of what was going on and weren't awake to witness this accident resulting in us losing 55 hours of print time.

The superstructure is coming together(see pictures attached below). The pieces seem to fit perfectly so we could get to gluing soon.





January 2nd, 2021

We have a total of 20 pieces printed currently.
By Tuesday, we'll have 22 super structure pieces.

Because we have 14 "super structure" pieces left to print and each one takes 70+ hours, we have to assemble the pieces along the way to save time. Some of the pieces are already fitting together.

January 3rd, 2022

Pieces that have been glued together so far (pictured below):

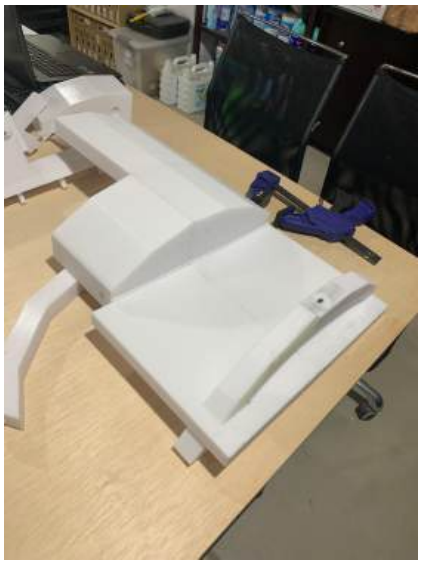
We did a little bit of research for formulas and found a .PDF explaining how to compute the distributed capacity of a cylindrical structure (Radial Force). To solve for Radial Force: P= RF/πDL, solve in terms of RF, RF=P(πDL) (P= pounds per square inch, we will use the machines in the TSA lab to find this and plug it into this equation, RF=Radial Force, L=length of cylinder, D=diameter or height of cylinder) -See article for further details and context.

http://blockwise.com/wp-content/uploads/2020/08/R862-HoopForce-RadialForce-Pressure-Derivation.pdf

How to calculate the flexural strength of the patio shade using Four-Point Test Flexural Strength Calculation: $\sigma = FL / wd^2$ (σ=flexural strength, F=maximum force applied, L=length of object, w=width of object, d=depth of object).

https://sciencing.com/calculate-flexural-strength-5179141.html

January 4th, 2022



Partial roof is pictured above. We're planning on connecting the patio after a couple more pieces adjacent to it are printed to assure alignment.

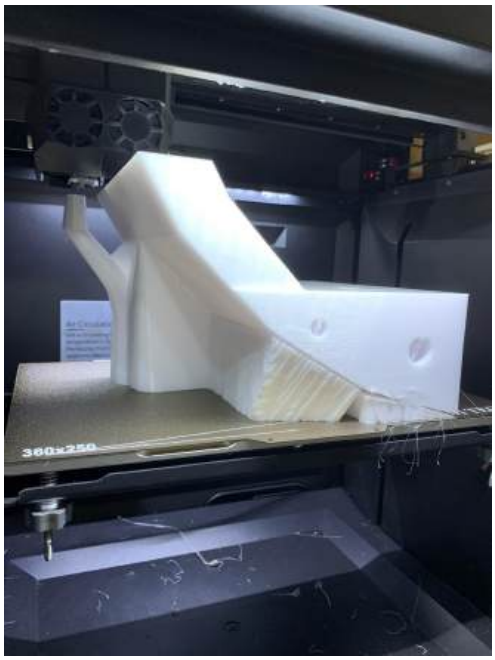
We have two major sections that will go together once the glue dries.

Part_21 will be done in 10.5 hours

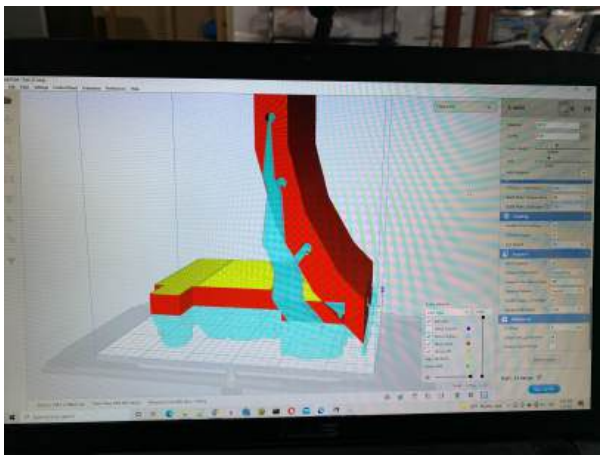
Part_18 will be done in 18 hours.

Part_7 still has 58 hours to go

January 5th, 2022



Progress of **Part_7** pictured above.

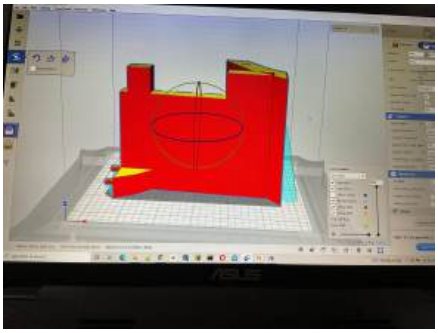


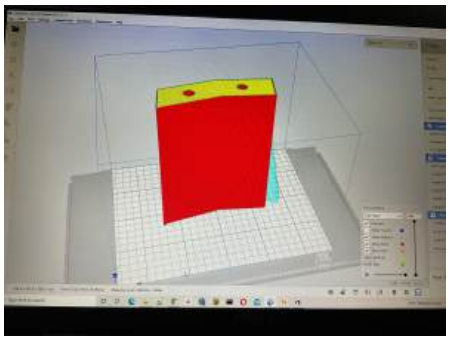
#37 above is taking 125 hours and that's only because we positioned the component upside-down to minimize the support needed.

We have 22 pieces completed so far and 3 are currently printing.

We have a major part of the cylindrical structure completed (pictured below):

January 8th, 2022





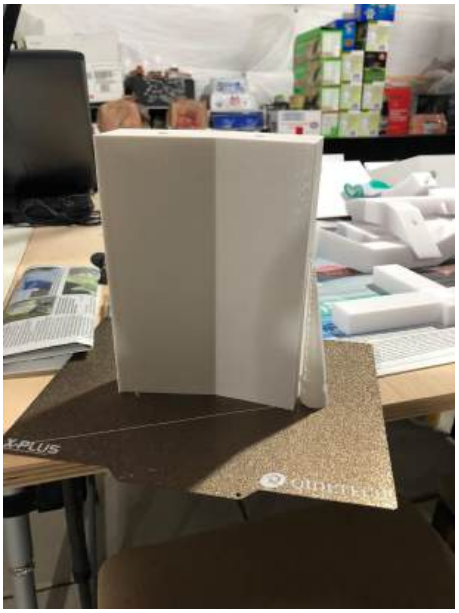
Part 37 has been cut into two parts using NetFabb.

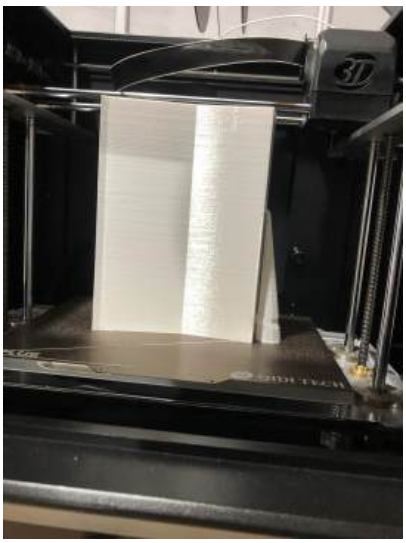
January 9th, 2022

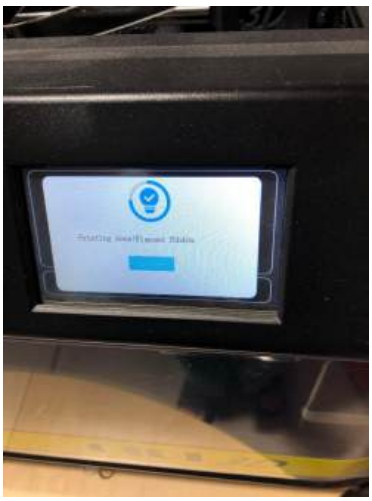
More sections are coming together

January 10th, 2022

Part_37 (cut 1) has completed printing just this morning.







We officially have 27 pieces printed in total.

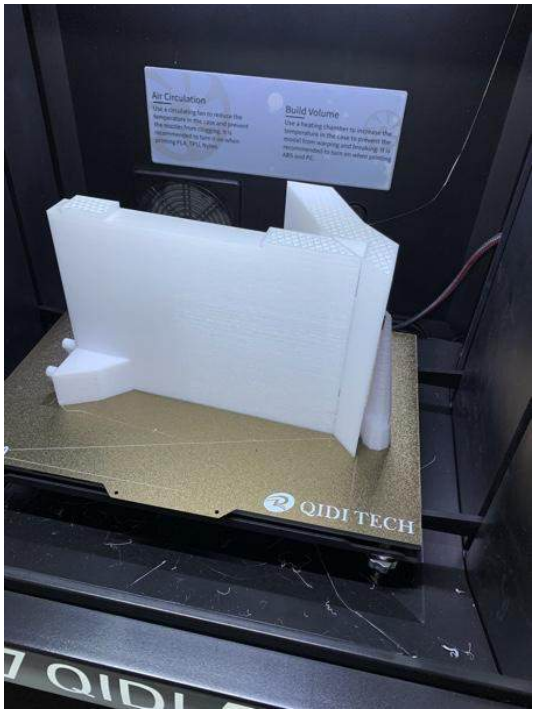
We have **part_20** printing on the X-Max and there is about 53 hours left to print.

This part is digitally perfect and contains no warpage at all.

Part_37 (cut 2) i s printing and there is about 19-20 hours left

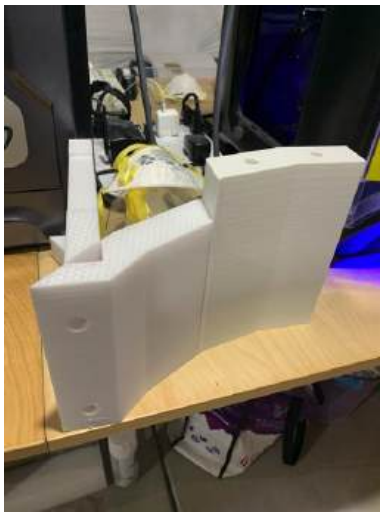
Also no warpage; we have successfully mastered this skill.

Letting the x-plus cool until the next piece is put on the printer, **part_36 (cut 1)**



Part_37 was lost. In the process of loading a new filament, we tried to turn off the sensor as she usually does, but this time, just the act of turning off the sensor caused a hardware malfunction and rebooted the system. All saved images that the system should have made along the way were also wiped out.

Had it worked, these two pieces would have melded together perfectly.



Reprinting right now:

January 11, 2022

I glued the 2 sections of the floor together.

We lost 63 hours today. All we can do now is accelerate the integration of the components. Since glue takes 24 hours to cure. We just saved 24 hours by not putting it off till the end. By the time the last component rolls off of the printer, we'll be 95% done assembling the model.

Part_37 failed last night again at 3 am.
The nozzle got clogged. We reinstalled the new one that Qidi sent. Luckily as we did, the new one was redesigned. It looks like it distributes temperature more evenly. It looks. sturdier. Everything is back on track and printing again.

January 13, 2022

All 3 printers will be working on the 30th and 31st pieces by tomorrow morning and complete by Monday morning.

The 29th piece will be completed tomorrow morning.

More of the cylindrical structure is completed

X-plus X-max I-fast

January 14, 2022

Update: **Part_31** is now printing on the X-Max.

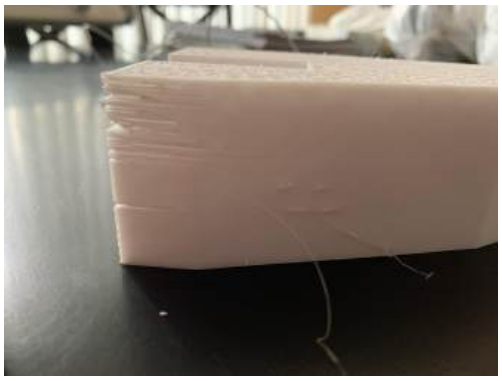
January 16, 2022

Update: more of the cylinder is coming together

January 17, 2022


The patio roof is coming together

January 18, 2022



#59 failed. Extruder was too close to the plate.
Mishika (Bhatiam) re-leveled the plate on the iFast. #59 is reprinting. She also reduced the temperature on the X-Plus and X-Max by 5 degrees to reduce the surface burn marks.

We just put 22 on the X-Plus. The X-Plus will just be used for the non-large pieces from this point on.

Josette (Eliza_5342) and Mishika (Bhatiam) have calculated the maximum strength of our cylinder.

Here's the formula again for background:

To solve for Radial Force: P= RF/πDL, solve in terms of RF, RF=P(πDL) (P= pounds per square inch, we will use the machines in the TSA lab to find this and plug it into this equation, RF=Radial Force, L=length of cylinder, D=diameter or height of cylinder)

Radial Force = P * 3.14159 * D * L = 586 lbs/square inch * 3.14159 * 24 inches * 24 inches = 1,060,399.72224 lbs

This means the cylinder of our home can hold over 1 million and sixty thousand pounds (approximately 530 tons) of mud landing on it before it collapses.
24 inches = 2 feet = diameter of house

For the full scale house (9 feet tall), the number would be 586 lbs/square inch * 4.5 (9/2=4.5, 4.5 times the strength, bigger model) * 3.14159 * 108 inches * 108 inches = 96,628,924.68912 lbs

This means that the breaking point of our full scale house is 48 thousand tons of mud.

For perspective, the U.S. M1 tank (https://en.m.wikipedia.org/wiki/M1_Abrams) is only 68 tons compared to our 530 tons.

530/68=7.79411

Compared to conventional roofs which are designed to hold up to only 10 feet of snow or 20 pounds per square foot (https://experthomereport.com/how-much-weight-can-my-roof-hold/), a 9 ft by 9 ft conventional roof, which is the length and width of our prototype at full scale, would have a maximum capacity of 9 * 9 * 20 = 1,620 pounds

This means our plastic cylindrical house is over 59,000 times stronger than most houses in the world.

96,628,924.68912/1,620=59,647.48437

Here's the final strength of our model: 1060761.63341 pounds
It didn't change much with the 0.2

And here's the final number for the full scale model with the 0.2 difference: 96661903.8443

Torsion(for the floor):

Modulus of Rigidity:

G=(F/A)/Delta X/ L

G=Modulus of Rigidity
F=Force which acts
A=Area=26.063*6.69291=174.43731
Delta X=transverse displacement (what's the minimum amount of twisting required to break it?)=1mm = 0.03937 inches

(586.2*1.375/174.43731)/(0.0393701/26.063)=3058.91224

$T=(JT/l)*G\varphi$
T=Torsion
JT=Force which acts
l=length
G=Modulus of Rigidity
φ=Angle of twist

(586.2*1.375/26.063)*3058.91224*1=101471.84918

Notes: 1.375 is the thickness of the floor or 1 ⅜ inches

Torsion(for the ceiling):

Area of square: (113*110)*4= 49720mm
Area of Rectangle: 178*830=147740 mm

Modulus of Rigidity:

G=(F/A)/Delta X/ L

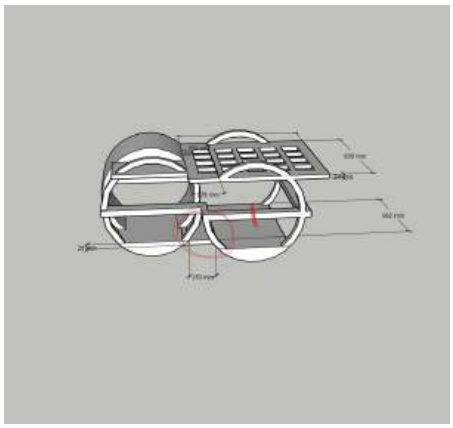
G=Modulus of Rigidity
F=Force which acts
A=Area=178*830=147740mm=5816.53543 inches
Delta X=transverse displacement (what's the minimum amount of twisting required to break it?)=1mm = 0.03937 inches

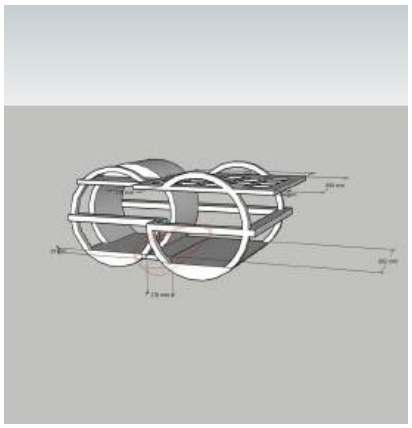
(586.2/5816.53543)/(0.03937/32.6772)=83.649020075

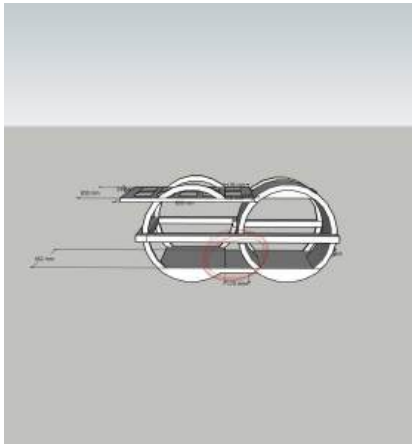
T=(JT/l)*Gφ
T=Torsion
JT=Force which acts
l=length
G=Modulus of Rigidity
φ=Angle of twist

(586.2/32.6772)*83.64902*1=1500.58926

Torsion(for the back railing):







Modulus of Rigidity:

G=(F/A)/Delta X/ L

G=Modulus of Rigidity
F=Force which acts
A=Area=568*109=61912mm=2437.4803 inches
Delta X=transverse displacement (what's the minimum amount of twisting required to break it?)=1mm = 0.03937 inches

(586.2*1.5/2437.4803)/(0.03937/22.3622)=204.90147

T=(JT/l)*Gφ
T=Torsion
JT=Force which acts
l=length
G=Modulus of Rigidity
φ=Angle of twist

(586.2/22.3622)*204.90147*1=5371.26229

5371.26229+1500.58926+101471.84918=108343.70073

Flexural strength

Note: The bridging point of the floor section and the narrow section of the ceiling section is more narrow than the railing which is longer and wider which is why we use the 3 point flexural strength test. We use the 4 point flexural strength test for the railing (there are two points of stress representing more than one point of stress to larger objects). 3 point has only one point of stress (in this case the ceiling and the floor sections are too narrow to have two points of stress).

Flexural strength (floor):

σ = 3FL / 2wd^2

(3(586.2*26.063))/2*6.69291*1.14173^2=199,941.6573

Flexural strength (ceiling):

σ = 3FL / 2wd^2

(3(586.2*32.6772))/2*7.00787*0.944882^2=179,772.43367

Flexural strength (railing):

σ = FL / wd^2

(586.2*22.3622)/4.29134*1.53543^2=7201.57454

199941.6573+179772.43367+7201.57454= **386,915.66551**

Notes: 100 initial plate, 80 for all subsequent plate and 234 for the extruder.

January 20, 2022

Update: more of it is coming together. We have a total of 35 pieces and 3 are printing right now.

January 21, 2022

Part_23 has completed printing. Now, we have 36 pieces in total.

It came off the X-Plus with no burn marks on top unlike previously when the fan hadn't yet been installed.

January 22, 2022

Part_39 fell off the i-fast and onto the floor. We recalibrated the plate and it is currently reprinting now.

I-fast, 7% X-Plus, **part_42** X-max, **part_52**

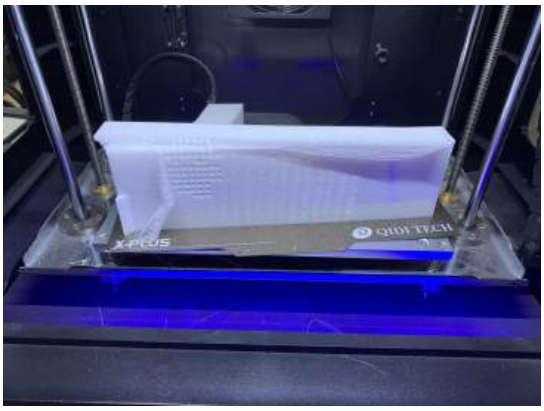


January 23, 2022

Now it looks like this:


Piece update: about 40 printed, 23 to go, 3 printing

January 26, 2022

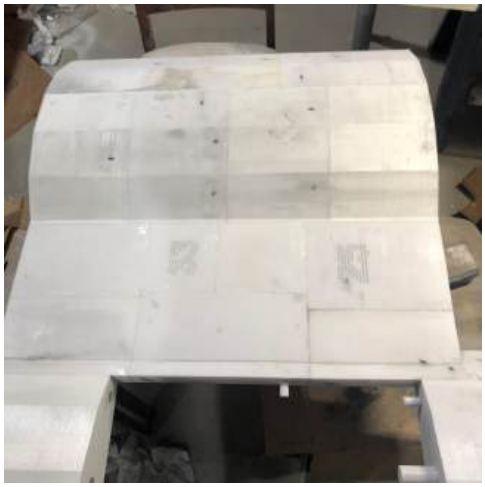


January 27, 2022

We have about 17-18 pieces left to print and by the end of the week, there will be about 14 or less.

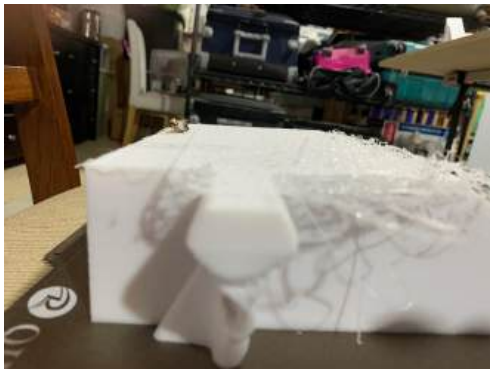
January 29, 2022

We have fourteen pieces left and three are printing.



January 31, 2022

Update: we have 12 pieces left to print



A Super structure print failed. A clump of PETG fell on the print, catching onto the extruder as it glided over it, dragging the plate.

February 1, 2022

There are 9 more pieces left to print.

February 2, 2022

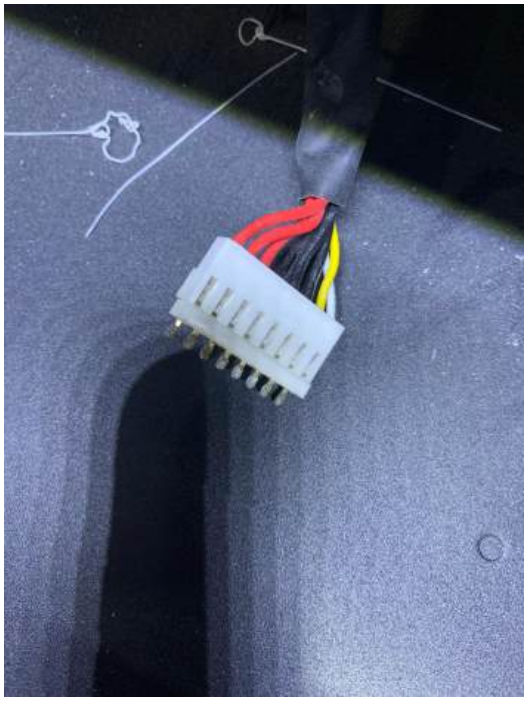
February 5, 2022

There are 4 more pieces to print.

February 6, 2022

The extruder got caught on a piece of debris and started printing in a single clump.

It then got stuck on another piece of debris and the force was so strong that it got yanked and ejected off the print bed, the door flying open.



February 7, 2022

There are currently 2 pieces left, printing. The X-max is out of commission and only the X-plus and I-fast are being used.

February 8, 2022

We are printing the last piece, on the I-fast.


There were many clamps needed. It took up all the clamps in the basement for just this row of the patio roof because there are many components that could shift and warp as a result of not being clamped properly.

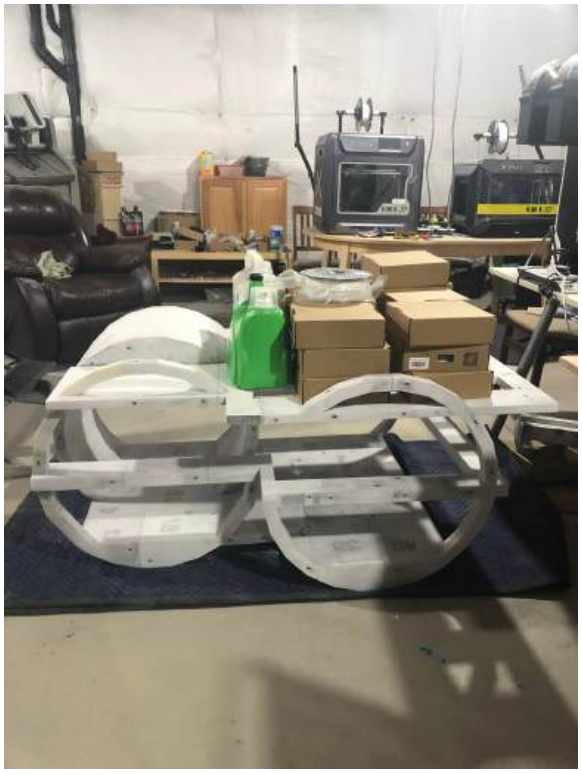
February 9, 2022

Last piece is completed. Note: most setbacks were due to our own learning process. This design prototype, when scaled, results in around $8 per sq foot in costs.

February 14, 2022

From this view, it looks amazing. It's astonishing that this whole structure seems like it's only being held up by toothpicks.

We are ready for painting! Proof of unibody construction, first try. Can lift at any angle and without cracking/breaking.



February 20, 2022

The model is partially painted.

February 21, 2022

February 21, 2022

February 23, 2022

March 1, 2022

Painting is completed.