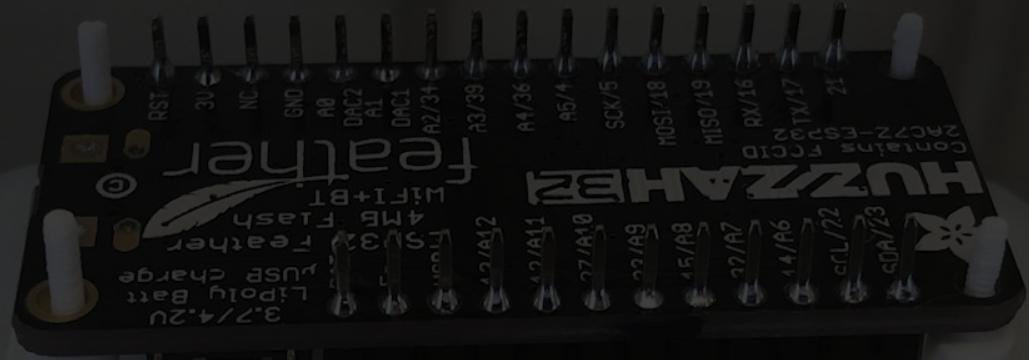


PROTOTYPING FORM 1: 3D MODELING + PRINTING

CSE 599 Prototyping Interactive Systems | Lecture 7 | Oct 17

Jon Froehlich • Liang He (TA)





LEARNING GOALS

PROTOTYPING WITH CAD MODELING + 3D PRINTING

How **CAD tools + 3D printing** can be used to **rapidly prototype form**

An introduction to two primary 3D printing methods: **SLA** and **FDM**

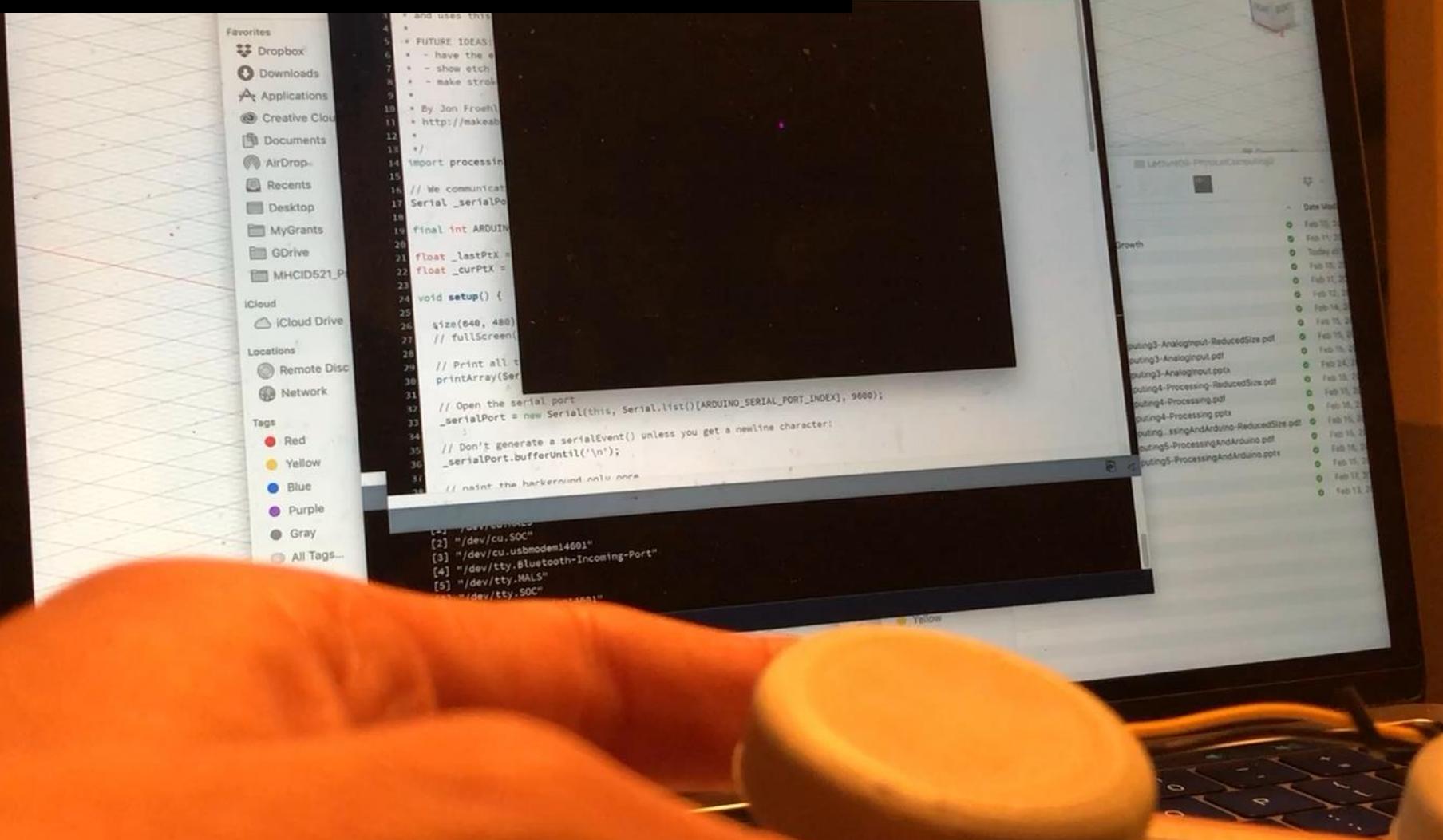
The **3D printing pipeline**

Modeling designs in **Fusion 360**

What is **slicing** and **what do we use it for**

3D PRINTING

PROTOTYPING GAME CONTROLLERS



Design and video by Jon Froehlich

The image shows a laptop screen with several windows open, likely running on a Mac OS X system. The main window is titled "ArduinoEtchASketch" and displays the following code:

```
/*
 * This example
 * and uses this
 *
 * FUTURE IDEAS:
 * - have the e
 * - show etch
 * - make strok
 *
 * By Jon Froehl
 * http://makeah
 */
import processing.serial.*;

// We communicate
Serial _serialPort;

final int ARDUINOPORT = 0;

float _lastPtx = 0;
float _curPtx = 0;

void setup() {
    size(640, 480);
    // fullscreen();
    // Print all t
    printArray(Serial.list());
    // Open the serial port
    _serialPort = new Serial(this, Serial.list()[ARDUINO_SERIAL_PORT_INDEX], 9600);
}

// Don't generate a serialEvent() unless you get a newline character
_serialPort.bufferUntil('\n');

// paint the background only once

```

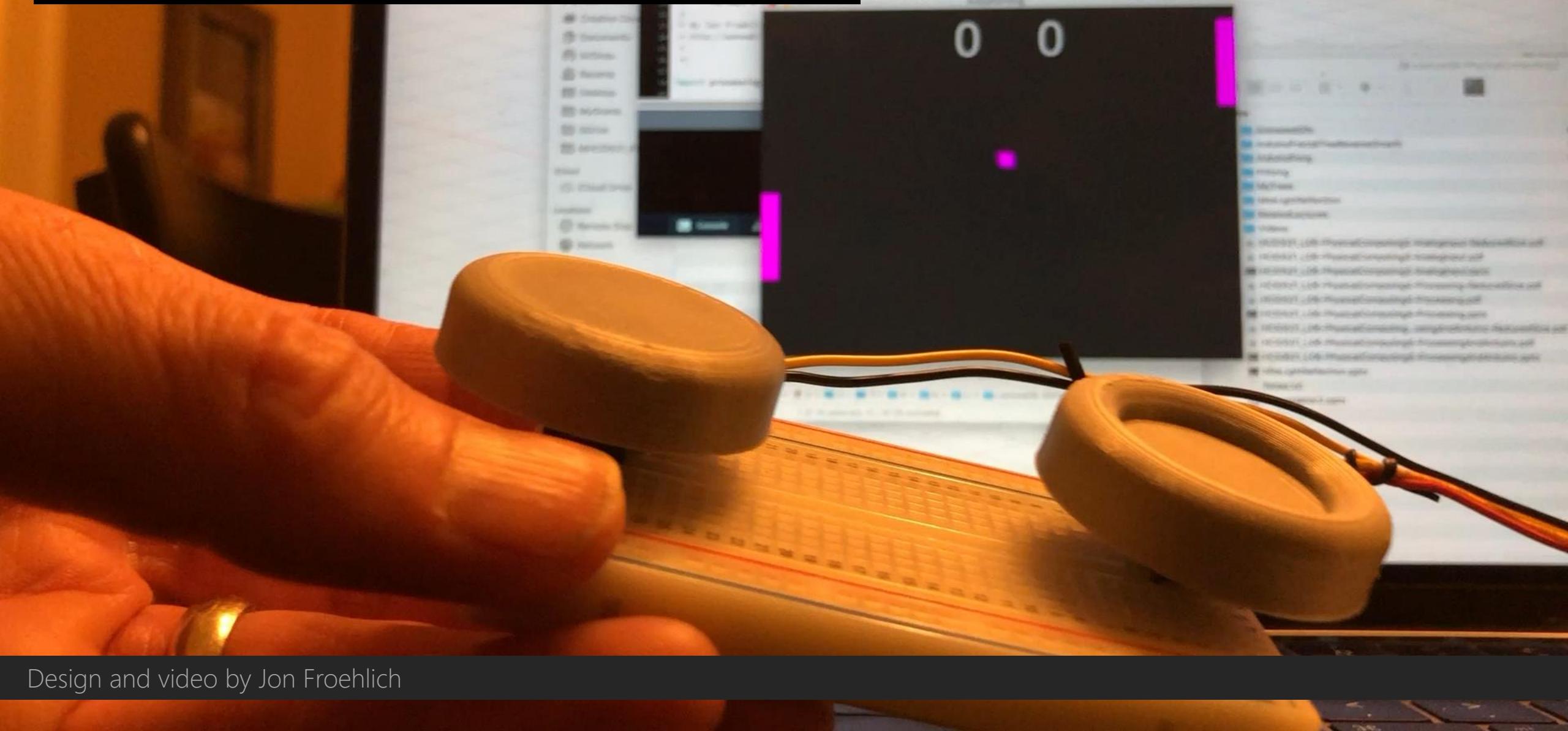
Below the code, a terminal window shows the output of the command `Serial.list()`:

```
[0] "/dev/cu.SOC"
[1] "/dev/cu.usbmodem14601"
[2] "/dev/cu.usbmodem14601"
[3] "/dev/cu.usbmodem14601"
[4] "/dev/tty.Bluetooth-Incoming-Port"
[5] "/dev/tty.MALS"
[6] "/dev/tty.SOC"
```

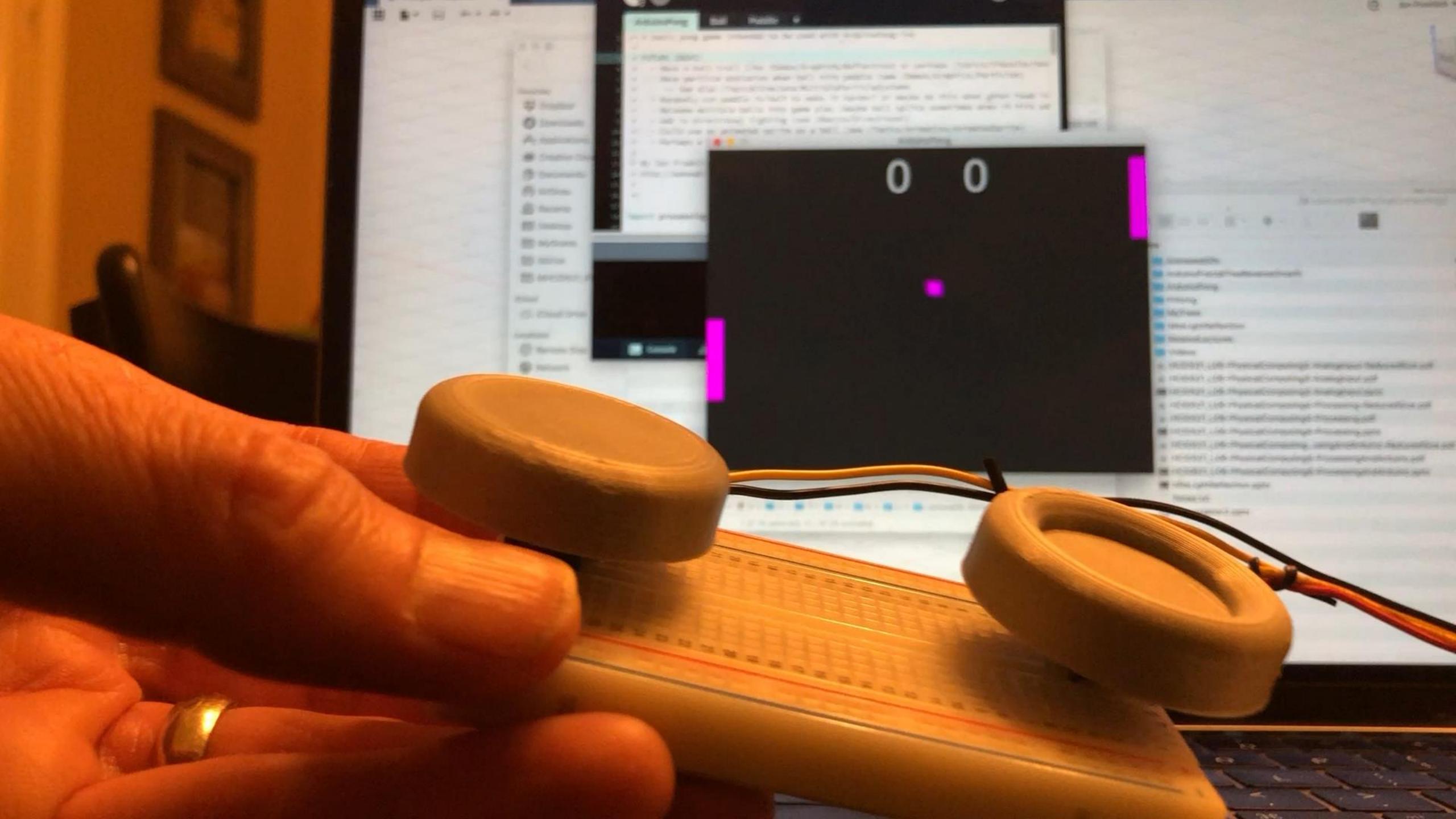
Other windows visible include "Trimpot_Simple v5" (another Arduino sketch), "ArduinoPong | Processing 3.6.3" (a Pong game), and a file browser showing a folder structure for "ProcessingAndArduino".

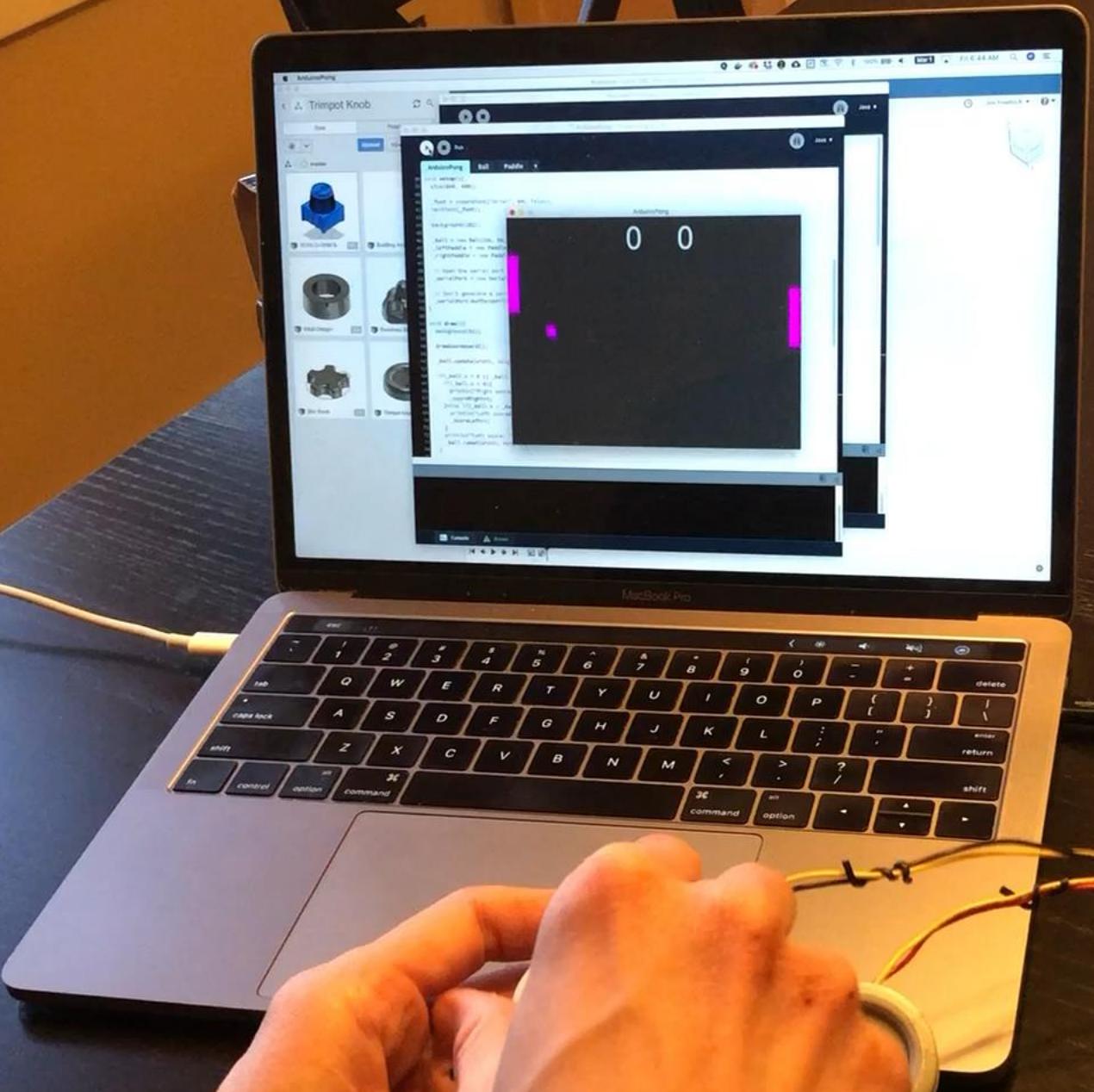
3D PRINTING

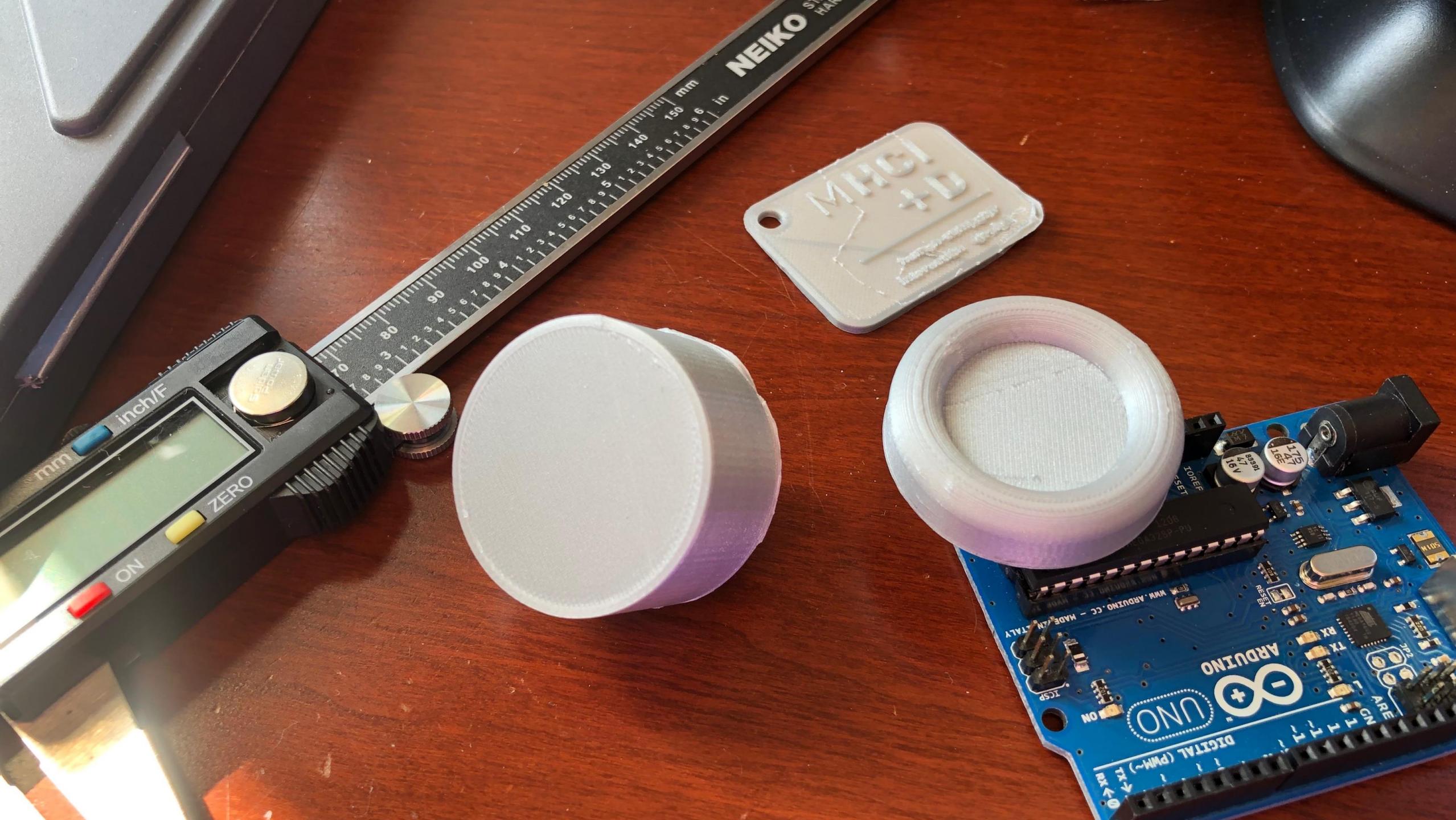
PROTOTYPING GAME CONTROLLERS



Design and video by Jon Froehlich







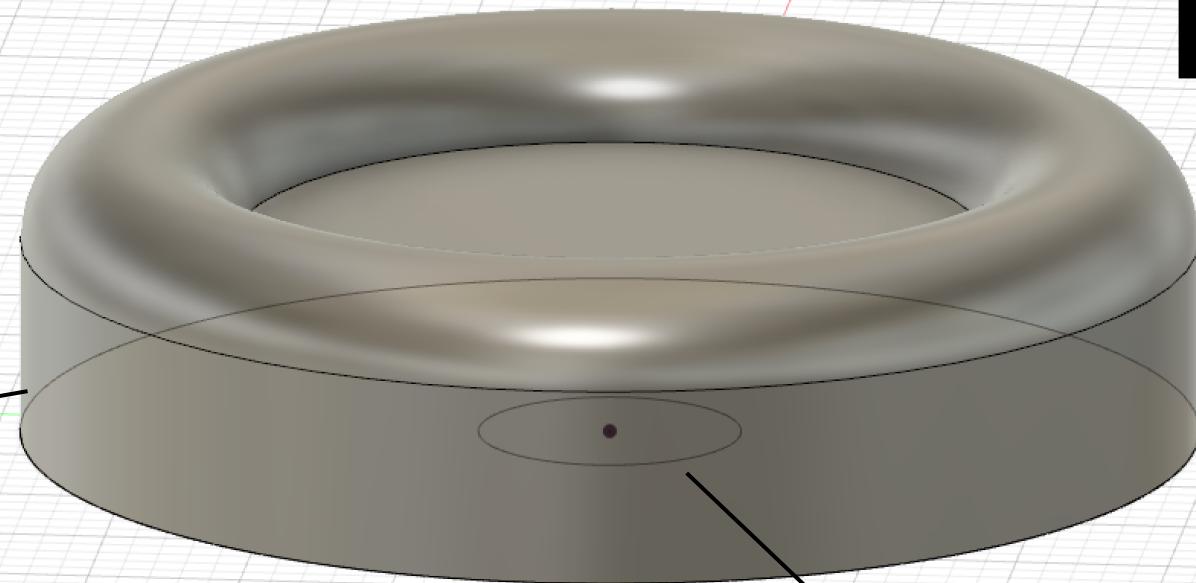
3D PRINTING

LIVE DEMO: CREATE TRIMPOT-BASED CONTROLLER

Trimpot Knob Simple v5

- Document Settings
- Named Views
- Origin
- Bodies
- Sketches

Knob height: 10-15mm

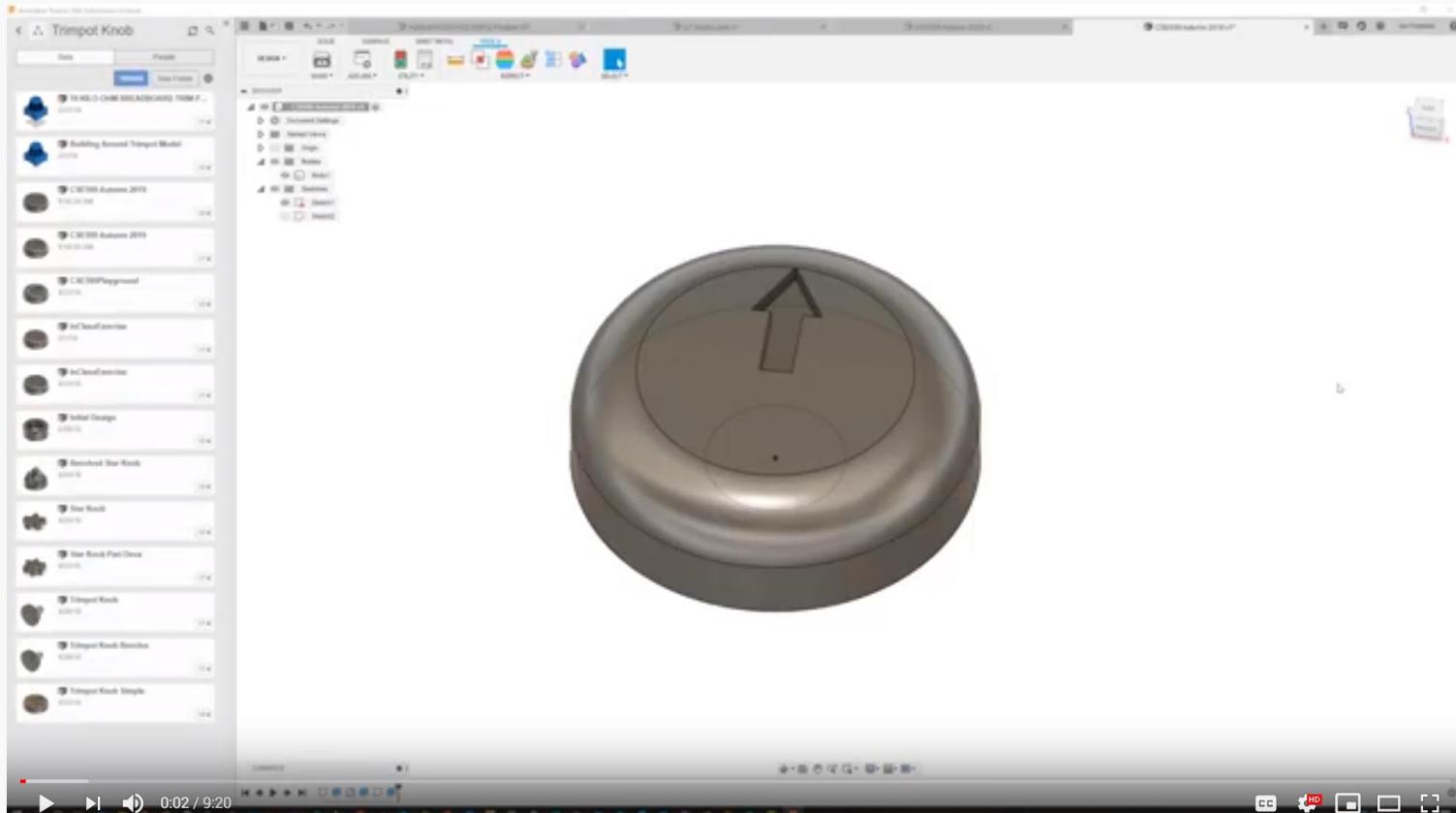


Knob diameter:
30-35mm

Hole for trimpot:
diameter: ~8.6mm
height: 5.6mm

3D PRINTING

VIDEO RECORDING: CREATE TRIMPOT-BASED CONTROLLER



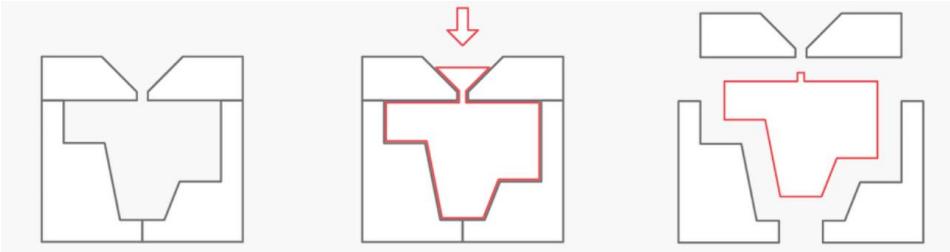
Rapidly Prototyping an Input Knob Using Fusion 360

6 views • Oct 17, 2019

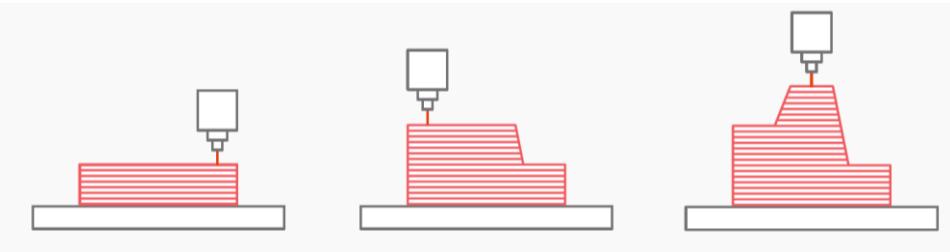
0 like 0 dislike SHARE SAVE

Source: https://youtu.be/bF1hreNH_E0

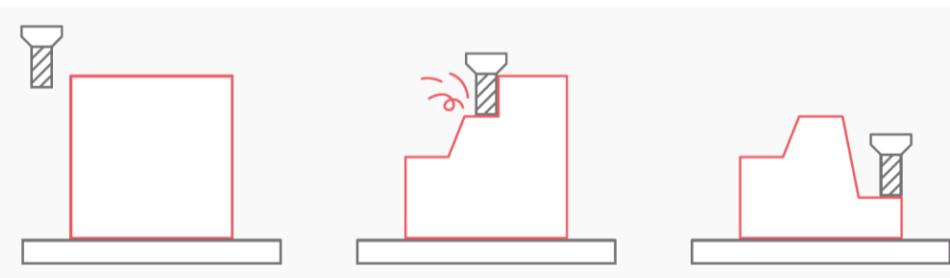
MANUFACTURING TECHNIQUES



Formative manufacturing: best suited for high-volume production of the same part, requiring a large initial investment in tooling (molds) but then being able to produce parts quickly and at a very low unit price.

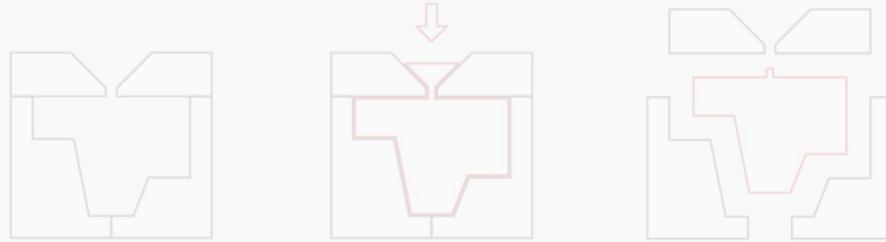


Additive manufacturing: best suited for low-volume, complex designs that other methods are unable to produce or when a unique, one-off rapid prototype is required.

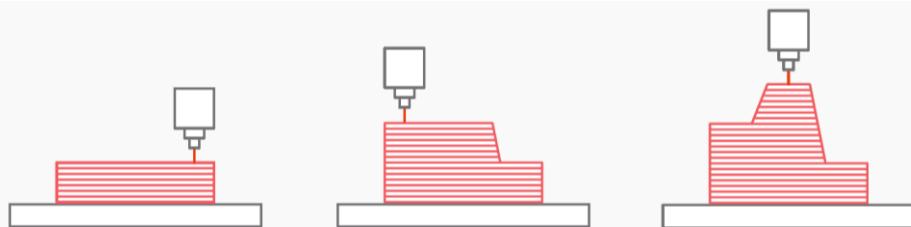


Subtractive manufacturing: lies in between formative and additive, being best suited for parts with relatively simple geometries, produced at low-to-mid volumes, and where materials like wood or metal are necessary

MANUFACTURING TECHNIQUES



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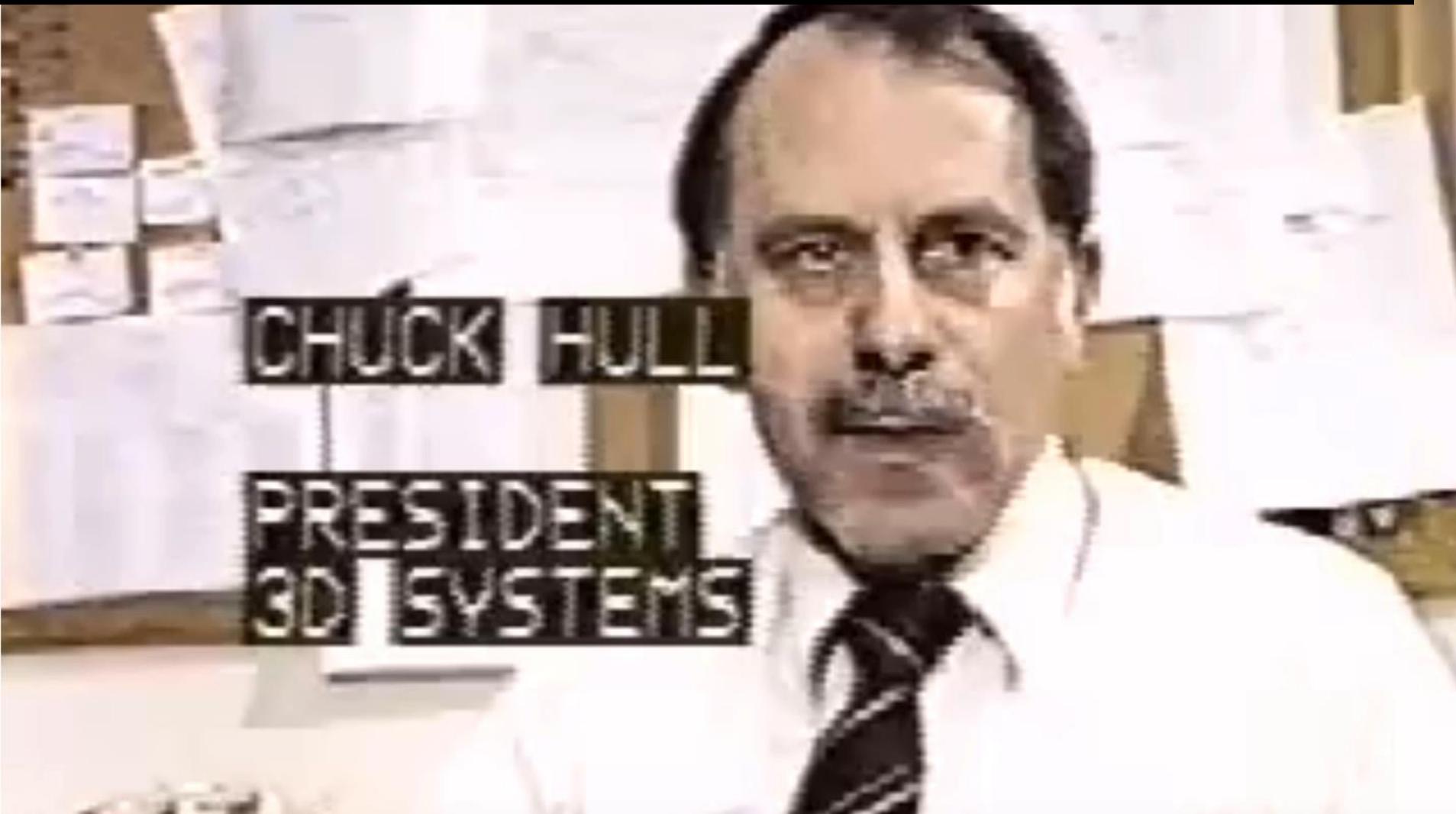
1987

The first commercial 3D printer
SLA-1 printer by 3D Systems Inc.
Invented by Charles Hull



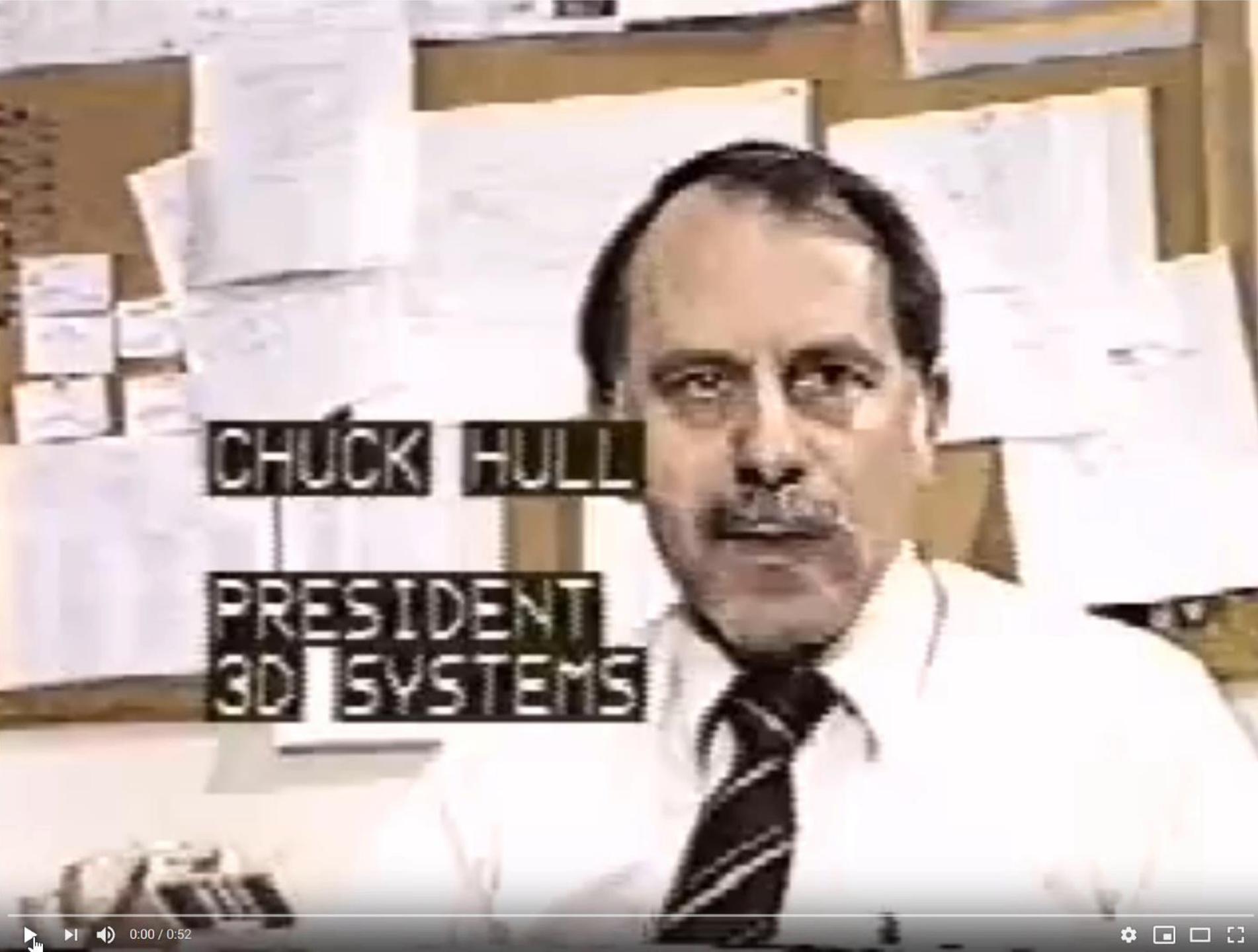
WHAT'S SLA?

INVENTOR CHUCK HULL EXPLAINS STEREOLITHOGRAPHY



Source: <https://youtu.be/eyUPSYynywM>

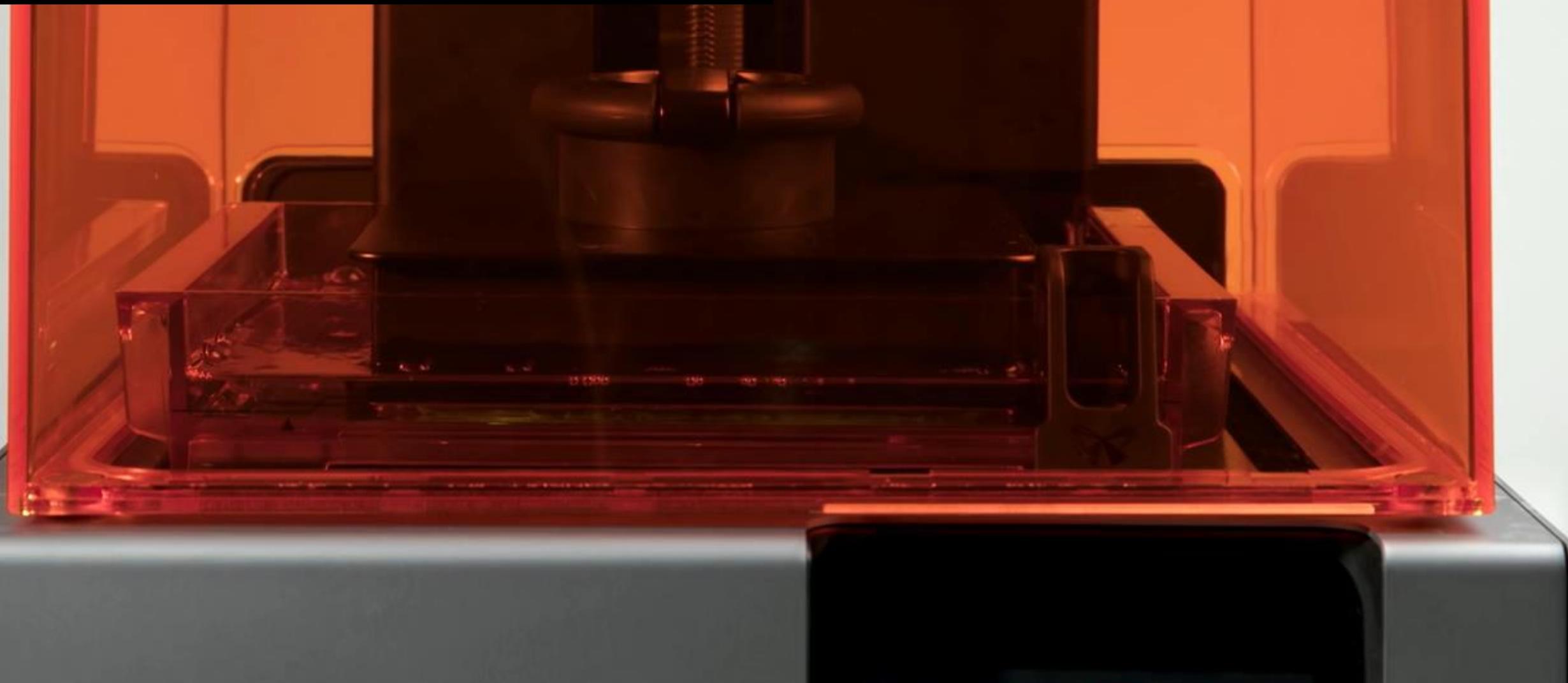




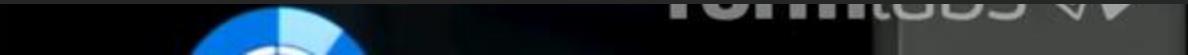
CHUCK HULL
PRESIDENT
3D SYSTEMS

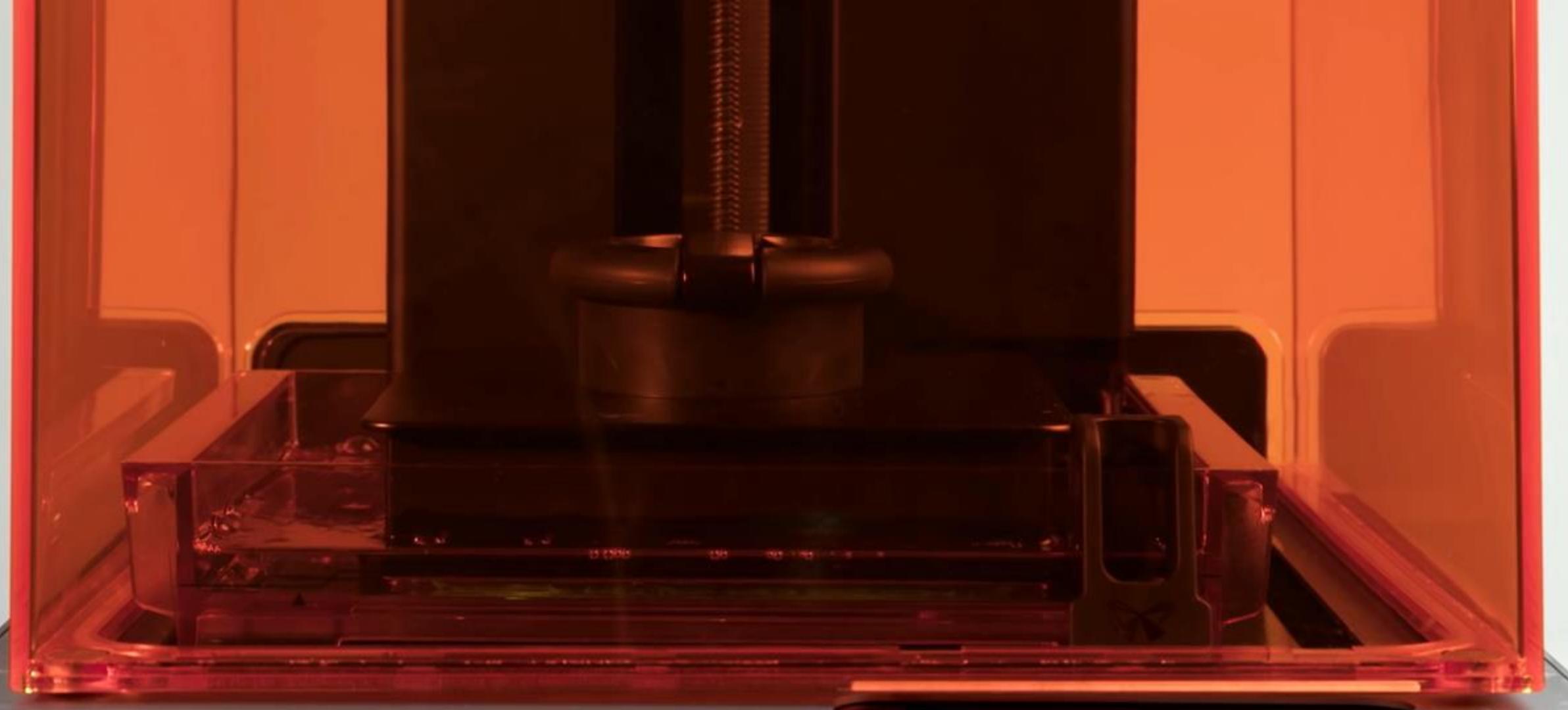
WHAT'S SLA?

WHAT IS STEREOLITHOGRAPHY?



Source: <https://youtu.be/8a2xNaAkvLo>





▲ LAYER 29 / 1474

TIME REMAINING

formlabs

THE GOOD

SLA creates **precise & smooth** models

Great for **creating molds** for casting

THE BAD

SLA is **expensive** (both printers & resin)

Resin is **sticky & messy**

Prints **require post-processing** by bathing in isopropyl alcohol

1992

The first commercial FDM printer
3D Modeler by Stratasys, Inc.
Invented by Scott & Lisa Crump



1992

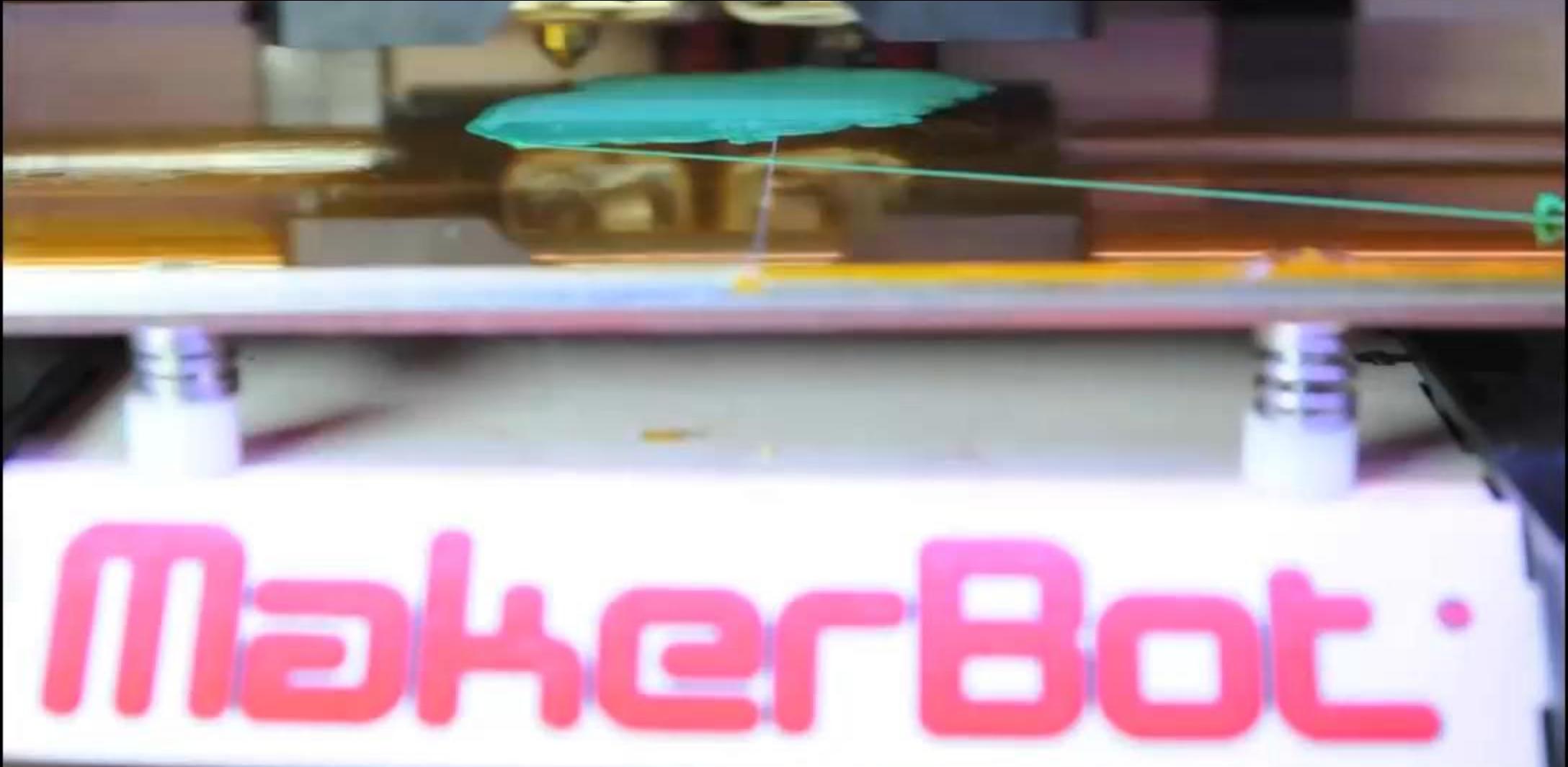
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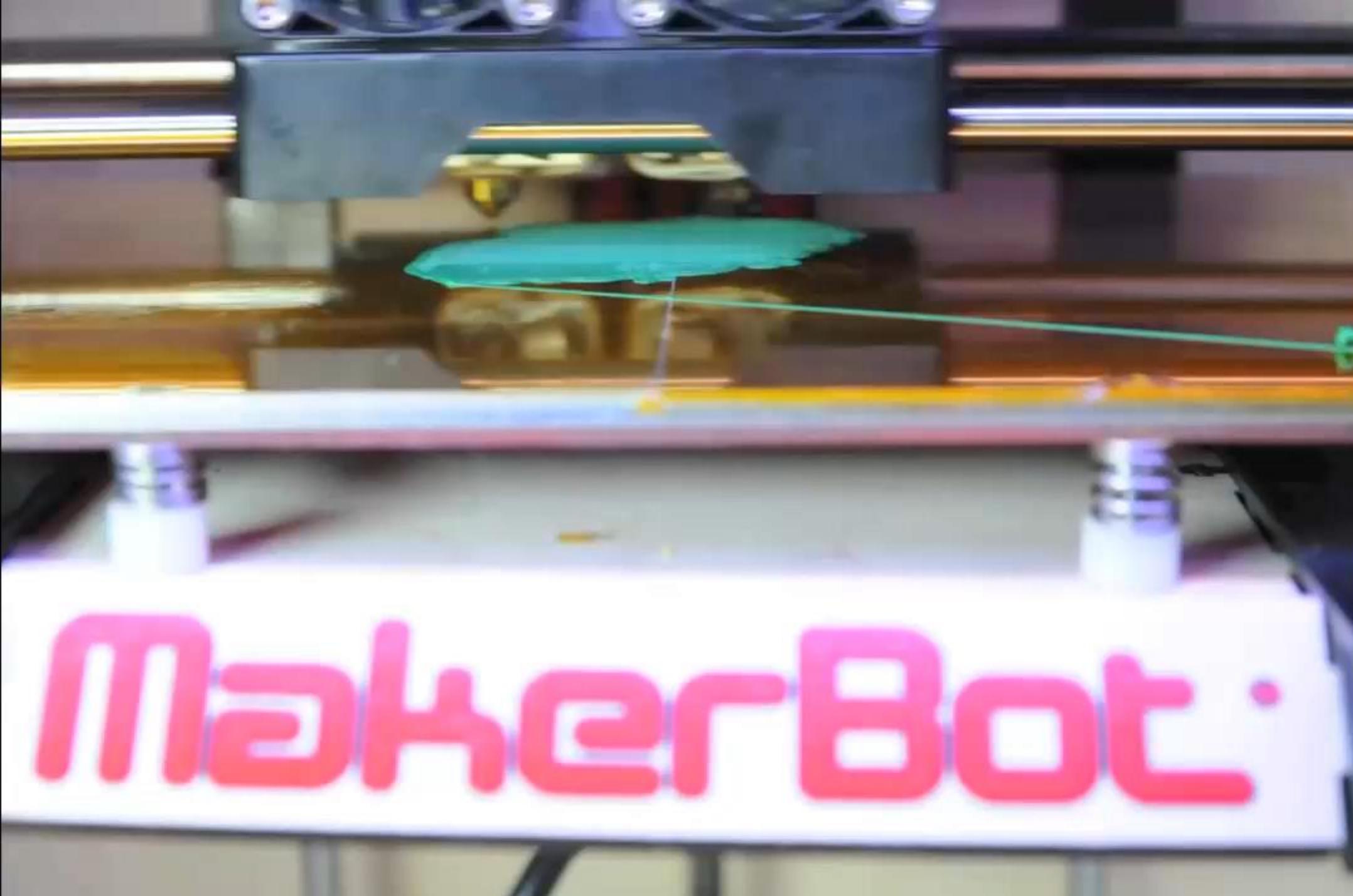
"The idea for the technology came to Crump in 1988 when he decided to make a **toy frog for his young daughter using a glue gun loaded with a mixture of polyethylene and candle wax**. He thought of creating the shape layer by layer and of a way to automate the process. In April 1992, Stratasys sold its first product, the 3D Modeler."

FUSED DEPOSITION MODELING

3D PRINTING ON A MAKERBOT REPLICATOR

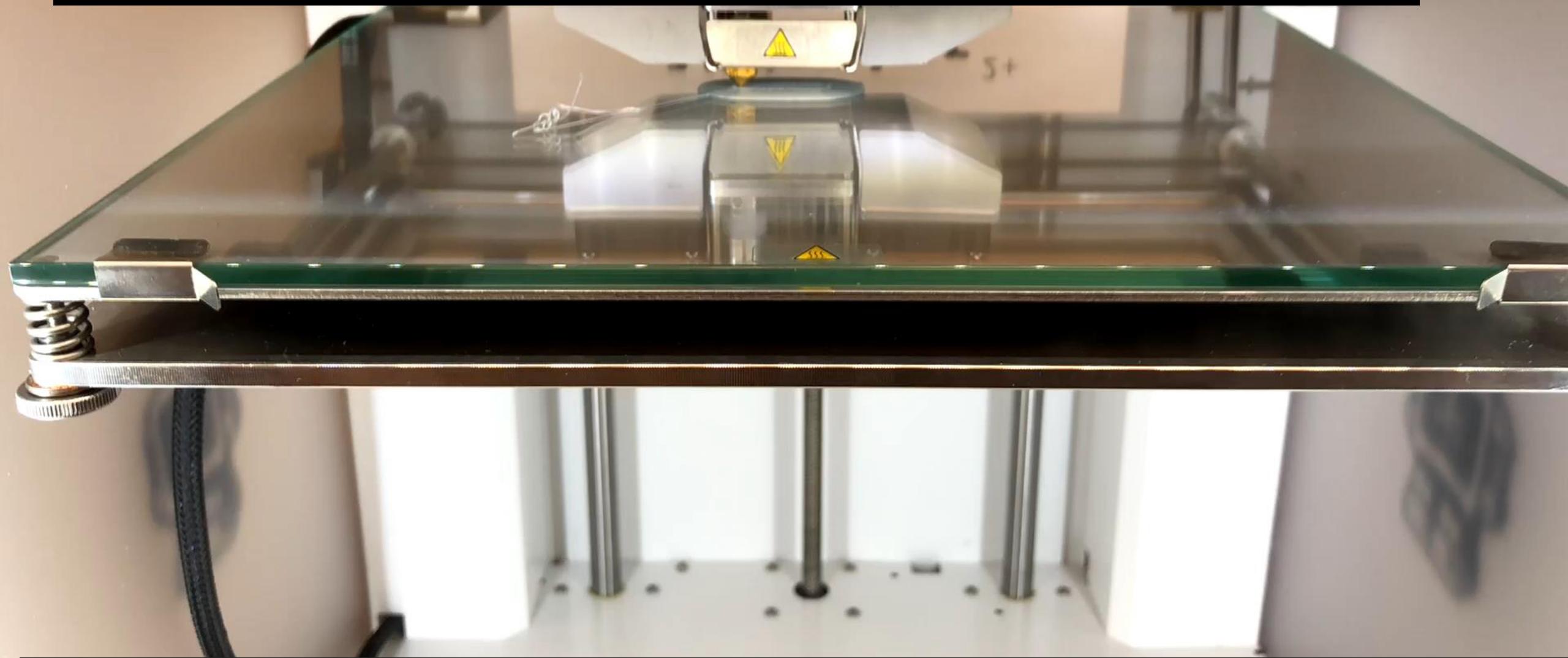


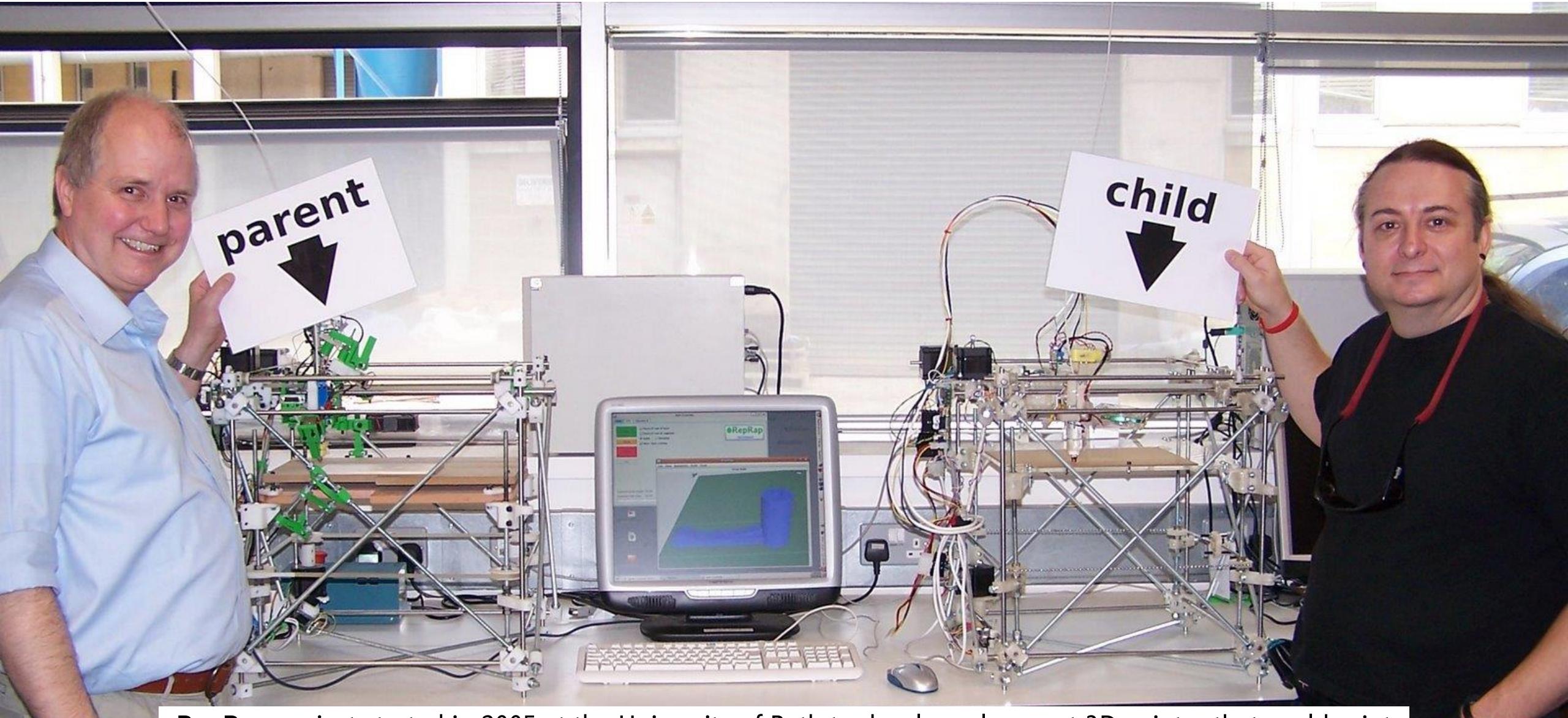
Source: https://youtu.be/8_vloWVgf0o; Edited by Jon Froehlich



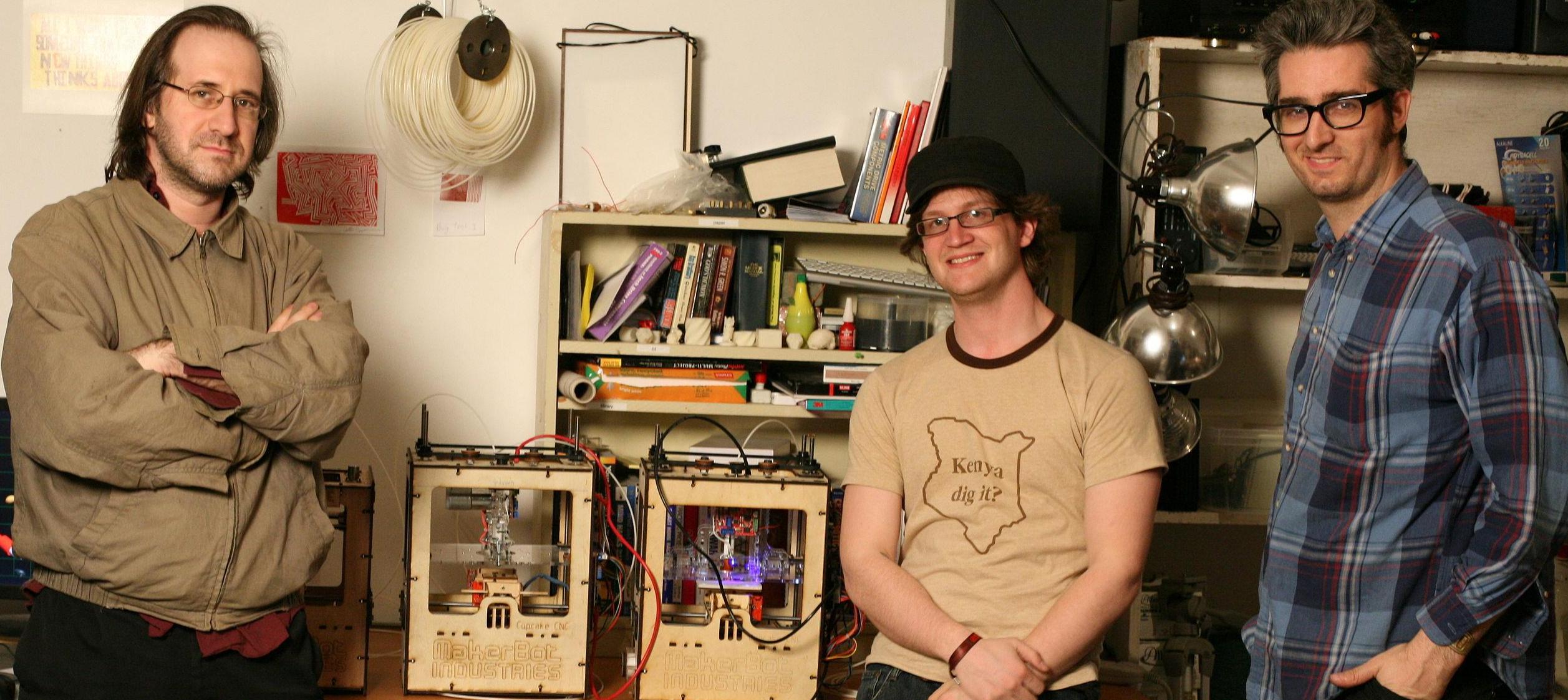
FUSED DEPOSITION MODELING

3D PRINTING A MILLENNIUM FALCON ON AN ULTIMAKER 2+





RepRap project started in 2005 at the University of Bath to develop a low-cost 3D-printer that could print most of its components. RepRap stands for **replicating rapid prototype**.



MakerBot founded in **2009** by Adam Mayer, Zach "Hoeken" Smith, and Bre Pettis to build on **RepRap project**.

How expiring patents are ushering in the next generation of 3D printing



Filemon Schoffer May 15, 2016

Comment

The year 2016 is quickly shaping up to be one of the hottest years on record for 3D printing innovations. Although there is still a lot of hype surrounding 3D printing and how it may or may not be the next industrial revolution, one thing is for certain: the cost of printing will continue to drop while the quality of 3D prints continues to rise.

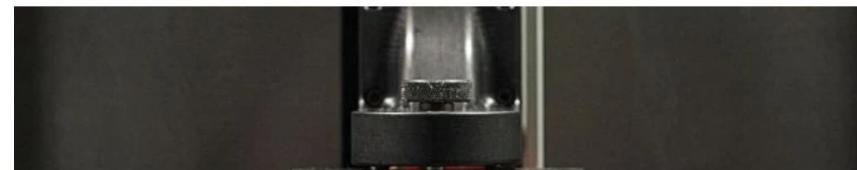
This development can be traced to advanced 3D printing technologies becoming accessible due to the expiration of key patents on pre-existing industrial printing processes.

These expiring patents — many of which were issued just before the turn of the century and are reaching the end of their lifespan — are releasing the monopolistic control over processes that have long been held by the original pioneers of the 3D printing industry.

For example, when the Fused Deposition Modeling (FDM) printing process patent expired in 2009, prices for FDM printers dropped from over \$10,000 to less than \$1,000, and a new crop of consumer-friendly 3D printer manufacturers, like MakerBot and Ultimaker, paved the way for accessible 3D printing.

The next generation of additive manufacturing technologies are making their way down from the industrial market to desktops of consumers and retailers much like FDM did. Among these include patents for three specific 3D printing technologies: liquid-based, powder-based and metal-based printing processes.

Liquid-Based Technology



Filemon Schoffer

Contributor

Filemon Schoffer is the head of community at [3D Hubs](#).

More posts by this contributor

- [3D printing technologies explained](#)
 - [Metal 3D printing takes flight](#)
-

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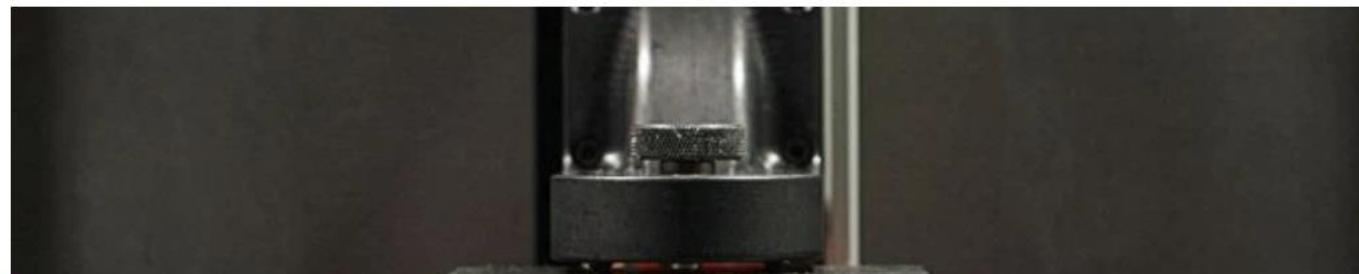
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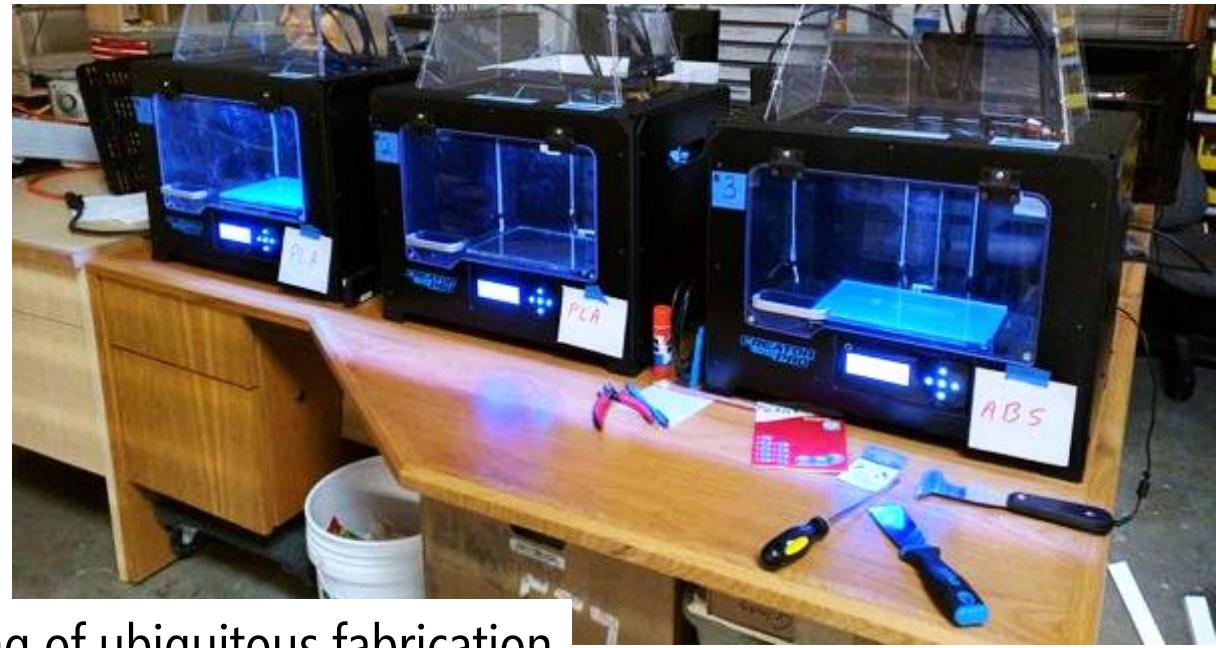
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Liquid-Based Technology





2009 marked the beginning of ubiquitous fabrication



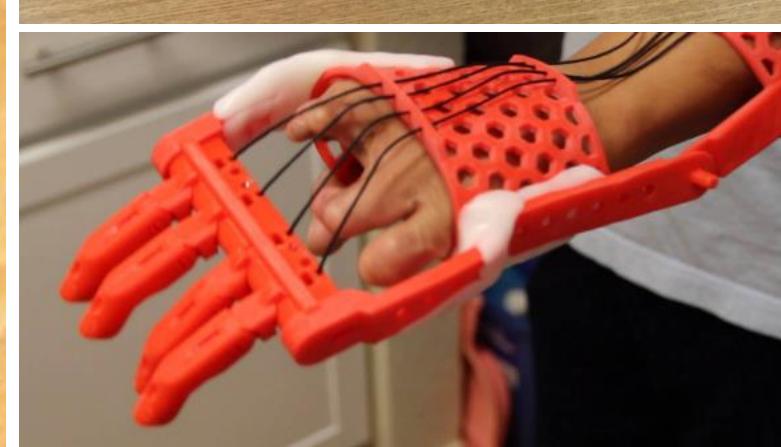
By 2012
We reached the peak
of the "hype cycle"



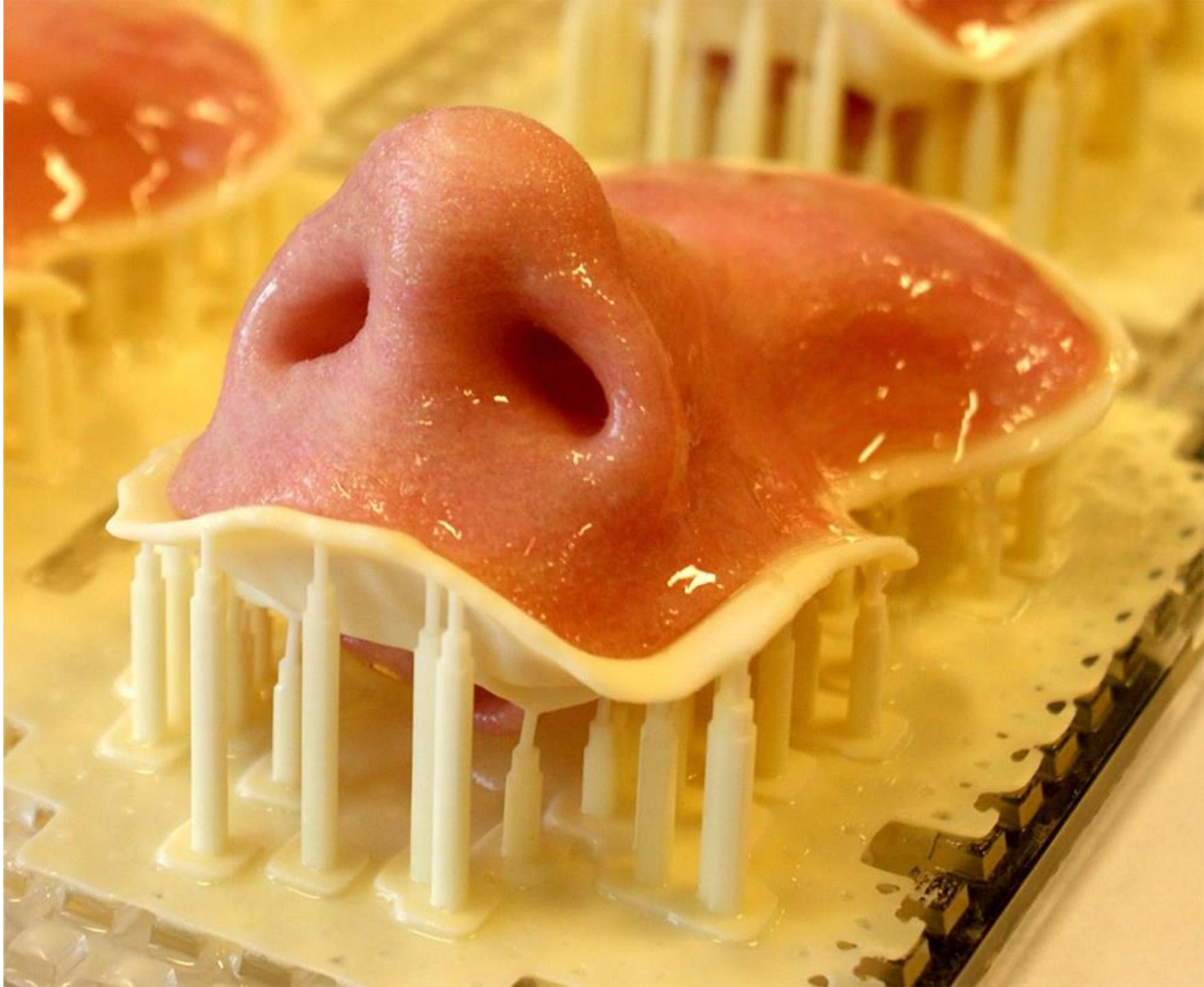
FDM 3D PRINTING
FASHION



FDM 3D PRINTING PROSTHETICS



FDM 3D PRINTING BIOLOGY





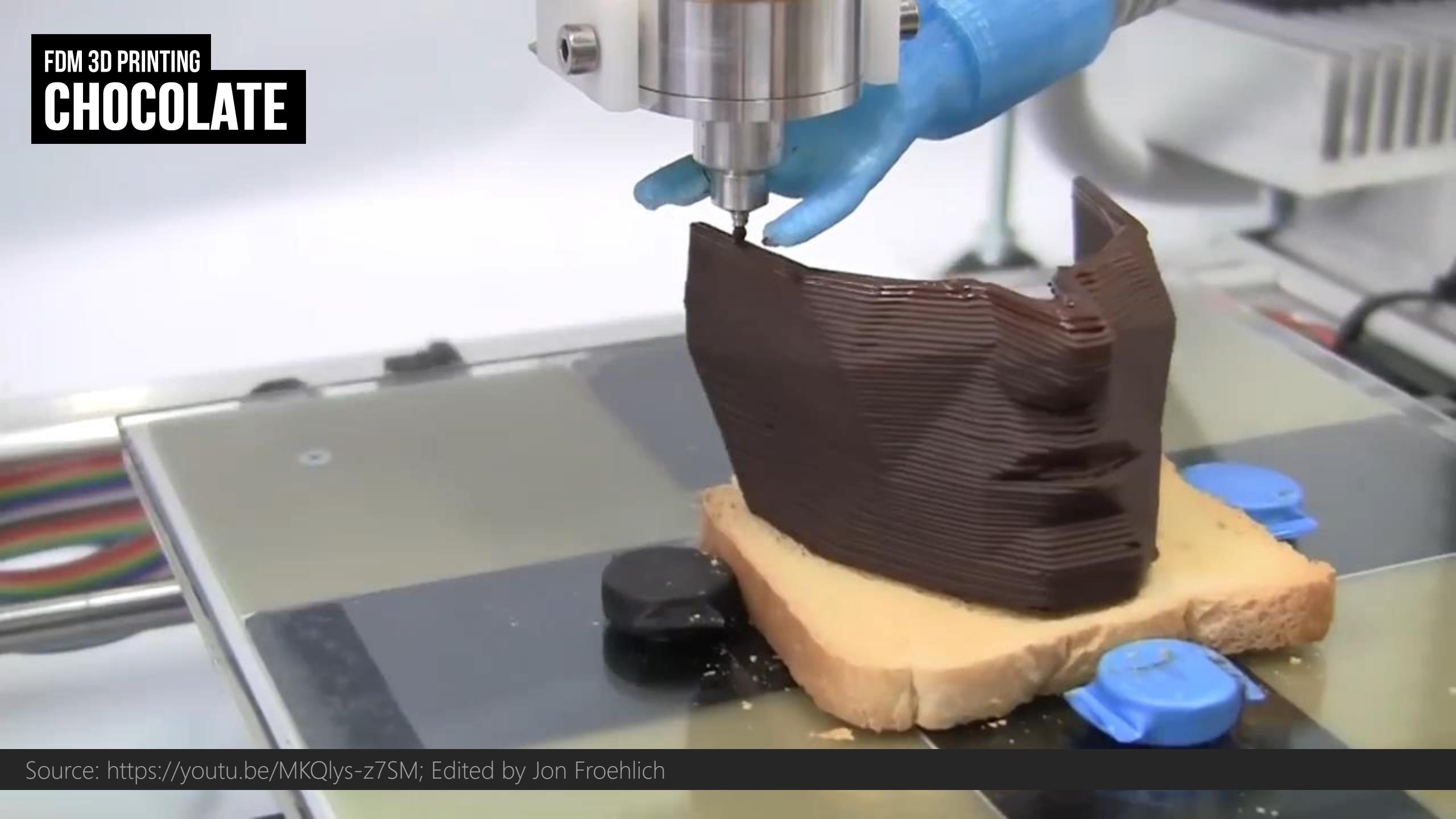
Source: <https://youtu.be/GUdnrtnjT5Q>; Company: Apis Cor

FDM 3D PRINTING CARS



Source: <https://youtu.be/iT9A0pBBL2A>; Company: Local Motors

FDM 3D PRINTING
CHOCOLATE



Source: <https://youtu.be/MKQlys-z7SM>; Edited by Jon Froehlich

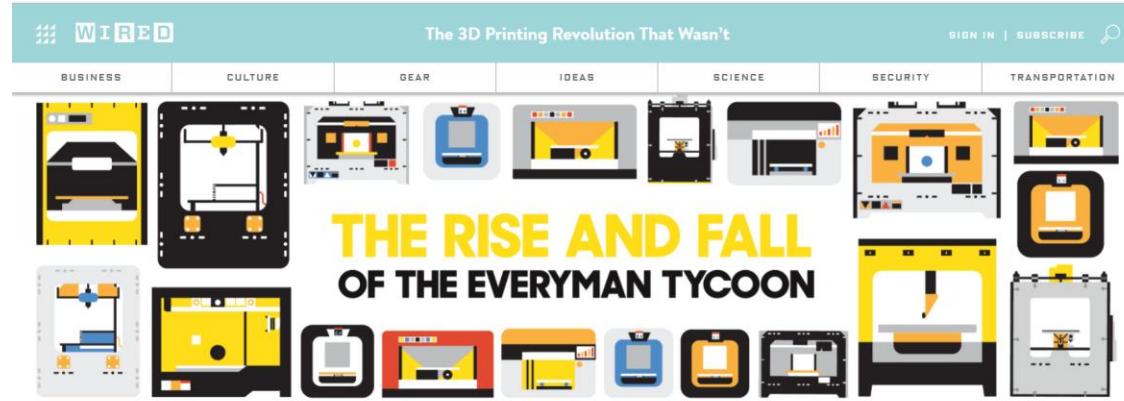
FDM 3D PRINTING

PANCAKES!



Source: <https://youtu.be/6rEHNGPibb0>; Company: Pancake Bot

By 2016
The peak was over & a
more realistic attitude set in



ANDREW ZALESKI

BACKCHANNEL 12.01.16 12:00 AM

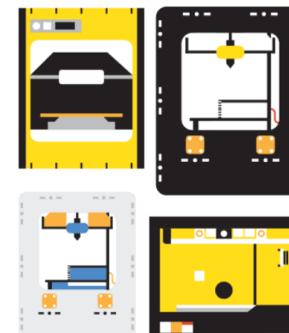
THE 3D PRINTING REVOLUTION THAT WASN'T

SHARE



MAKERBOT MADE A BOLD BET THAT 3D PRINTERS WOULD BECOME AS COMMON AS MICROWAVES. JUST ONE PROBLEM: NO ONE ELSE SHARED THAT DREAM.

It was October 2009 when Bre Pettis — his unmistakable sideburns and dark-rimmed rectangular glasses framing his face — took the stage at Ignite NYC, threw his hand in the air, and shouted “Hooray!” two times. A PowerPoint slide lit up behind him, revealing a photo of a hollow wood box crisscrossed with wiring. Bouncing up and down, his profuse mop of graying hair flopping about, Pettis began: “I’m going to talk about MakerBot and the future and an industrial revolution that we’re beginning — that’s begun.” A former art teacher, Pettis had emerged as a key character in the growing maker movement of the late 2000s, a worldwide community of tinkerers who holed away in makeshift workshops and hackerspaces, equally at home with tools like old-school lathes and contemporary laser cutters. Pettis had begun his ascent in 2006, producing weekly videos for *MAKE* magazine—the maker movement’s Bible—that featured him navigating goofy



SHARE



Brooklyn, lay off even more workers, and move all manufacturing to a contractor in China, even as the company celebrated the sale of its 100,000th 3D printer. Analysis of those same annual reports published by Stratasys shows that MakerBot sold a paltry 1,421 printers through the first three months of 2016.

"In 2014, MakerBot was convinced there was a consumer market ripe and ready. In 2015, we realized the consumer market is not where we thought it was," Jaglom told me the day MakerBot announced it was closing its Brooklyn factory.

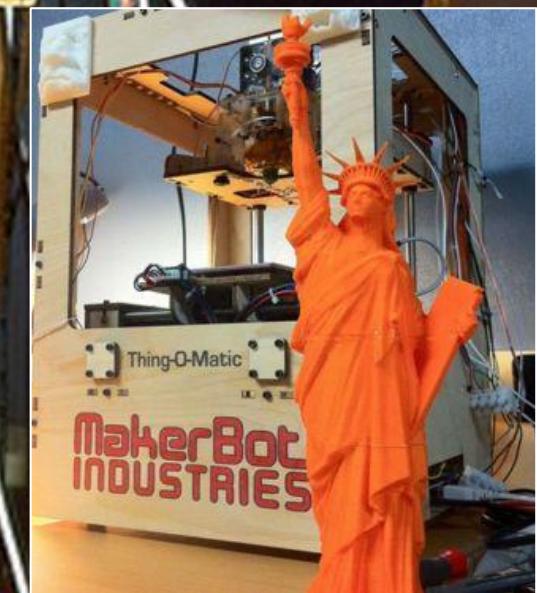
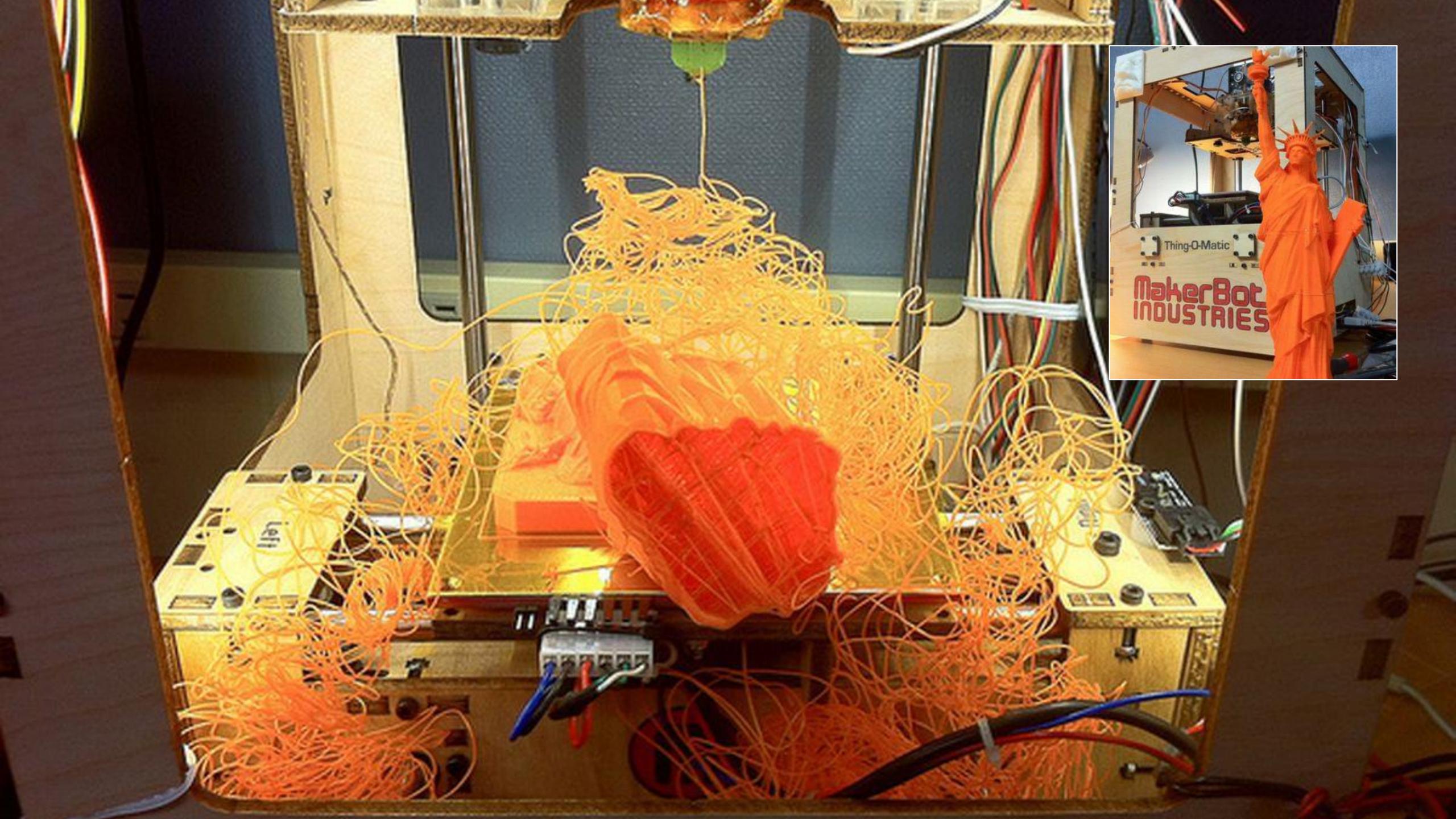
Here's the thing about 3D printing: It's not as revolutionary as it was made out to be, at least not yet. Big companies, like General Electric and Ford, experiment with 3D printing and even use it to produce some parts. GE this year even spent \$1.4 billion to acquire two 3D printing companies. But 3D printing technology still isn't reliable enough, fast enough, or cheap enough to supplant injection molding or traditional, subtractive manufacturing processes.

It's also not a simple process. If you want to print out original pieces, you need to know how to do 3D design, which admittedly has become much simpler thanks to online software like TinkerCAD. But an extruder head might become jammed during printing. The print bed might warp. The finished print might be crooked, which means you have to re-orient the part for printing. "There's a ton of work involved. It's not a thing where you can push a button and get what you were imagining," says Rockhold.

During the heady days of 3D printing, these weren't questions that were ignored so much as problems to be solved at a later date. What's happening now is what Jaglom calls the "de-hyping" of the industry, as the public perception of 3D printing finally catches up to reality. Stratasys' stock price took a tumble, from an all-time high of \$136 in January 2014 to \$25 in October 2015, when MakerBot announced its second round of layoffs.

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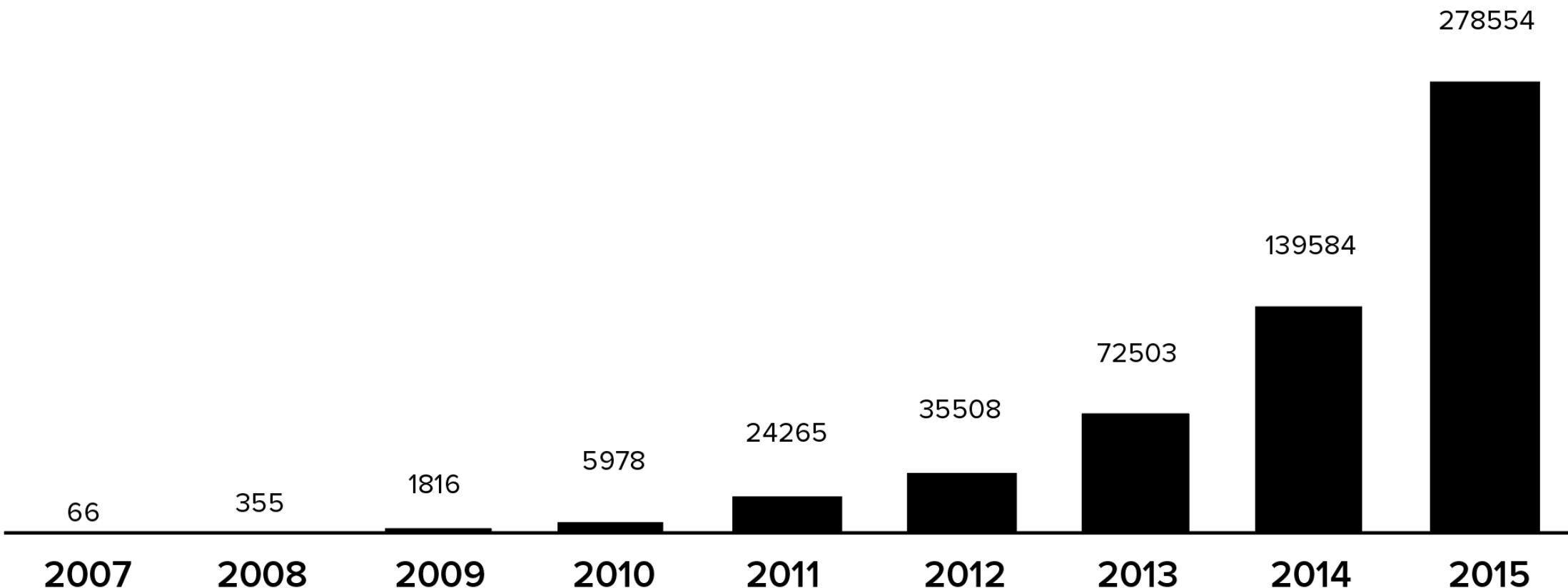


With the right skillset, **3D modeling + printing** can be a powerful (and fast) form prototyping method

BACKGROUND

CONSUMER-GRADE 3D PRINTERS SOLD IN 2015

Printers all < \$5000 sold globally per year



BACKGROUND

WHY 3D PRINT?

Speed. Designers can build, print, solicit feedback, & iterate on ideas quickly. 3D-printing allows the designer and other stakeholders to get a tangible, physical experience of a design.

Iteration. Digital models can be easily tweaked & reprinted.

Cost. Cost at low-volumes (*i.e.*, one-offs) is quite competitive compared to alternatives. Injection molding, for example, requires expensive mold-making equipment and each mold is expensive to produce. 3D-printers themselves are far cheaper than formative and subtractive machines.

Personalization. Certain industries (*e.g.*, dental, prosthetics) can use high-grade 3D-printers to quickly produce personalized devices for each patient (user)

Complex geometries. 3D-printers can create physical forms with complex geometries that would be impossible or very difficult using other manufacturing processes.

WHY 3D PRINT?

MAKE THINGS NOT POSSIBLE WITH OTHER APPROACHES



Source: <https://youtu.be/qBHg1xhANxU>; Edited by Jon Froehlich



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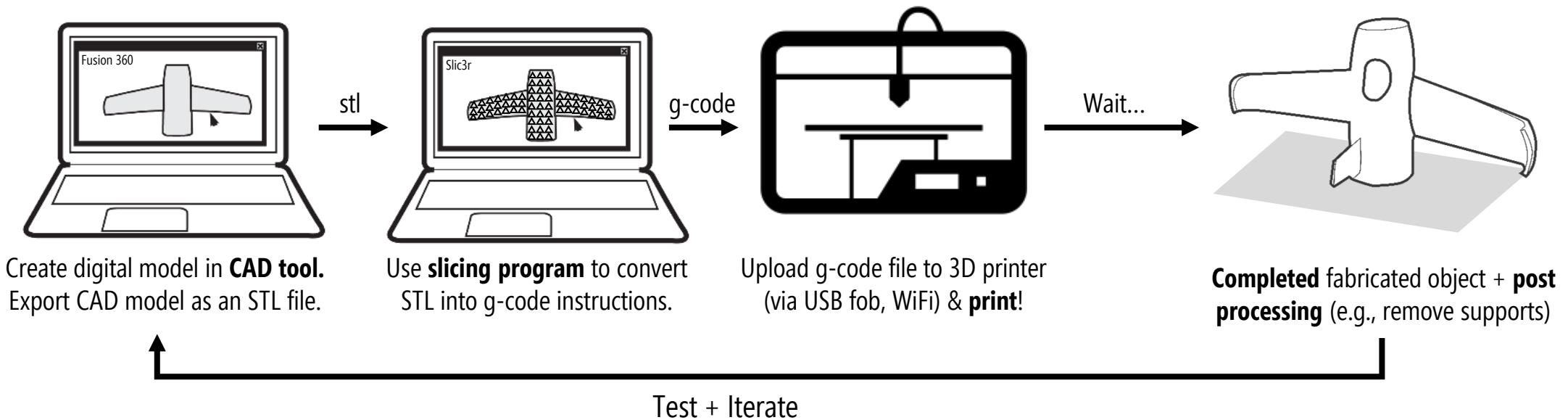
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Ease of access. Unlike injection molding or even subtractive processes like CNC mills or laser cutters, 3D-printers are relatively cheap to buy and operate. Many public libraries and other community spaces provide access as well.

Sustainability. Subtractive methods remove significant amounts of material that is not used, resulting in high waste volumes. 3D-printable ABS plastic can be recycled & PLA is compostable. Check with local recycling/compost centers.

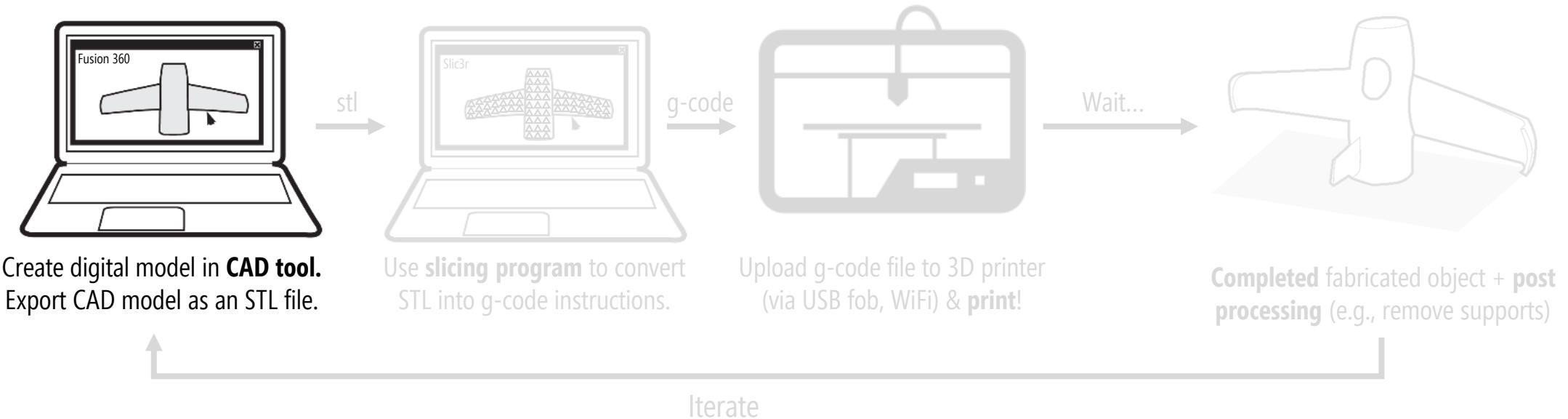
3D-PRINTING PROCESS

6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING



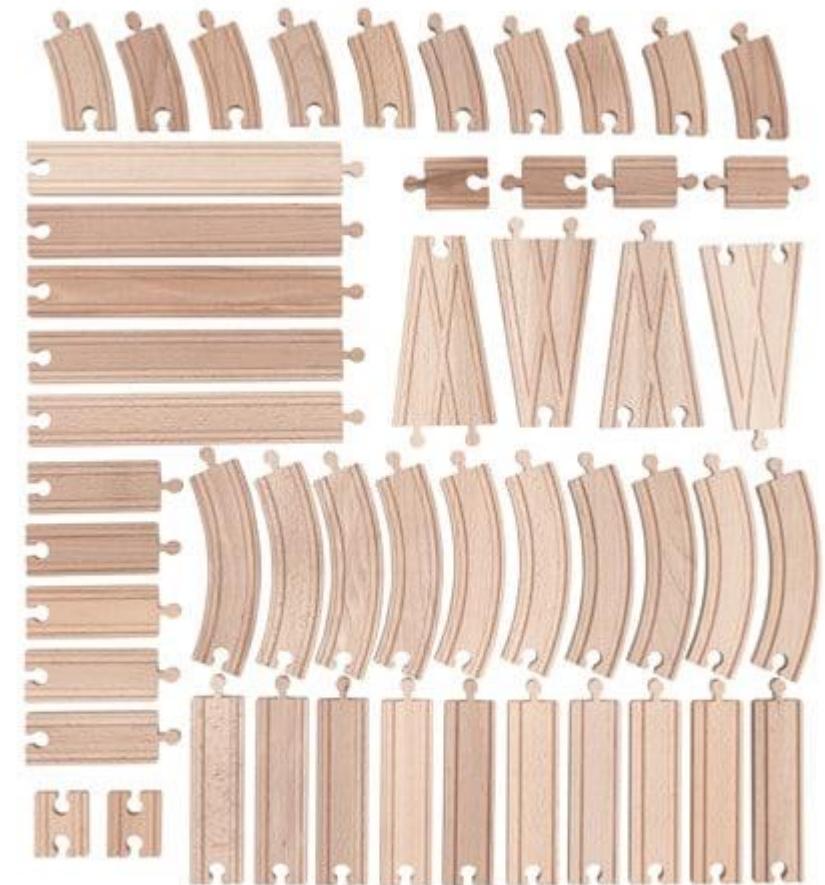
3D-PRINTING PROCESS

1. CREATE DIGITAL MODEL IN CAD TOOL



3D-PRINTING PROCESS

EXAMPLE: TRAIN TRACKS



STEP 0: MEASUREMENT

MEASURING!





GBM1218
www.alvinco.com

D:\Dropbox\3DPrinting\JonTrainTracks\Notes.txt - Notepad++

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

Notes.txt

```
1 Ikea Straight Train Track
2 Width: 39.29mm
3 Total Length: 160mm
4 Total length minus connector: 145mm (or more like 145.15mm on caliper)
5 Depth: 12.03mm
6
7 For the track trough itself:
8 Track starts at: 4.37mm into the width
9 Track is: 5.90mm wide
10 From bottom to beginning of trough: 9mm
11 Trough depth: 3mm
12
13 The connector:
14 Straight part is 5.25mm wide
15 Is 6mm long
16 Circle is 11.14mm in diameter (5.57 in radius)
17
18 Ikea Curved Train Track
19 Width: 40mm
20
21 Female connector
22 6.46 width inner chamber
23 12.56 diameter (6.28mm)
24 4.17 inner length
```

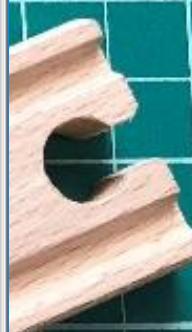
Normal text file

length : 1,138 lines : 35

Ln : 34 Col : 42 Sel : 0 | 0

Windows (CR LF) UTF-8

IN



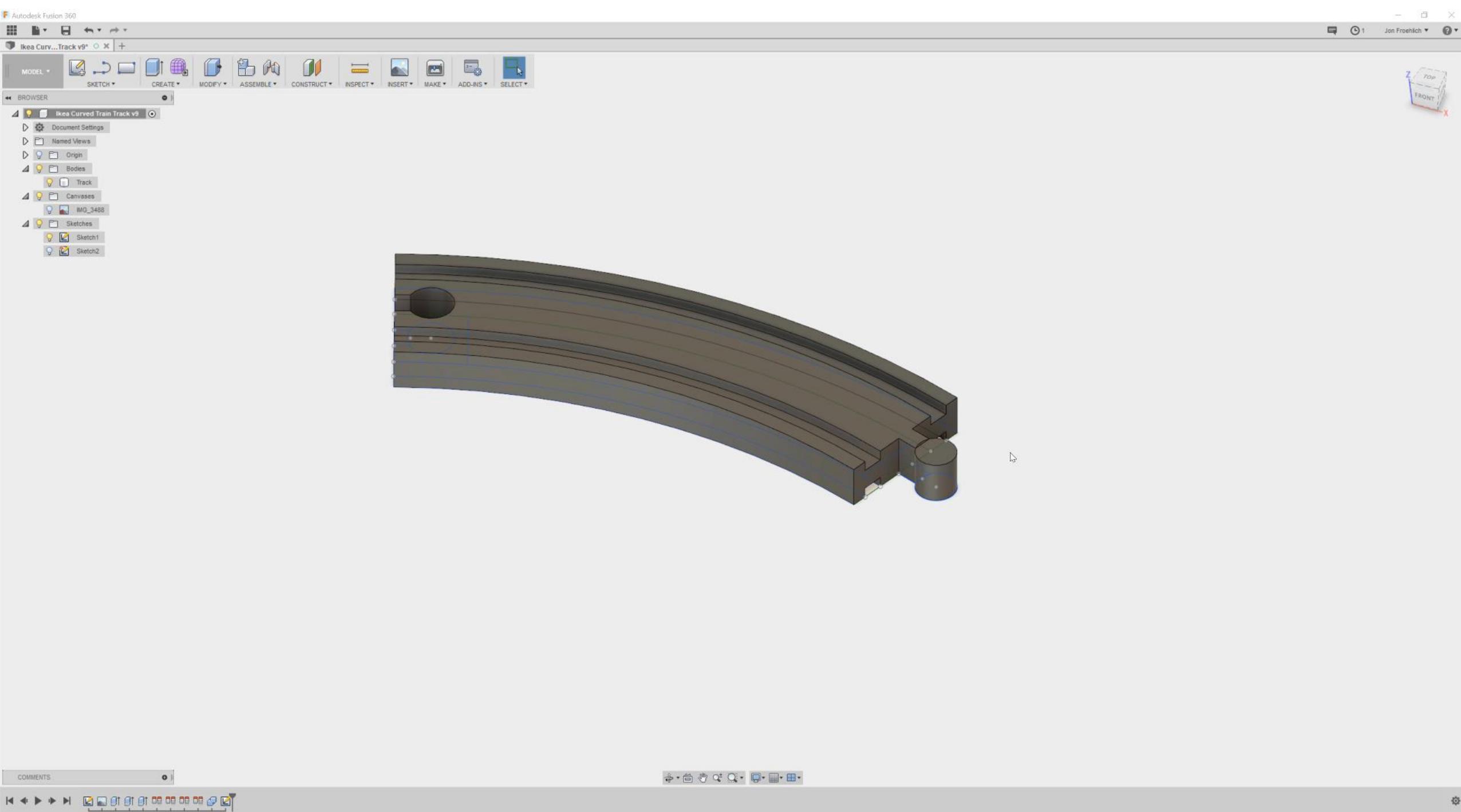
45°



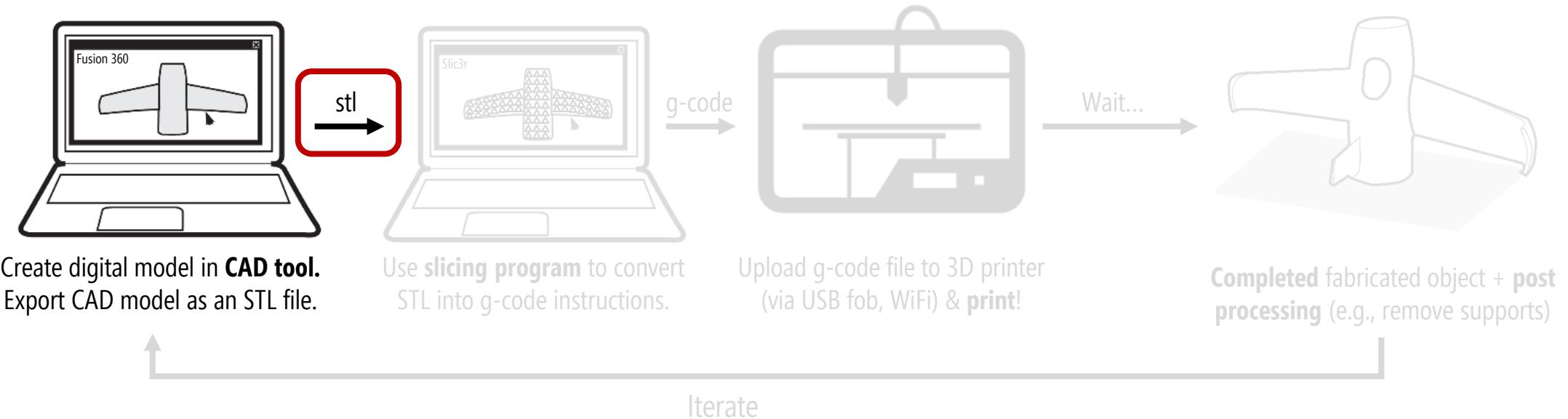
STEP 1: CAD MODELING

CREATING CUSTOM TRAIN TRACKS

Source: Jon Froehlich



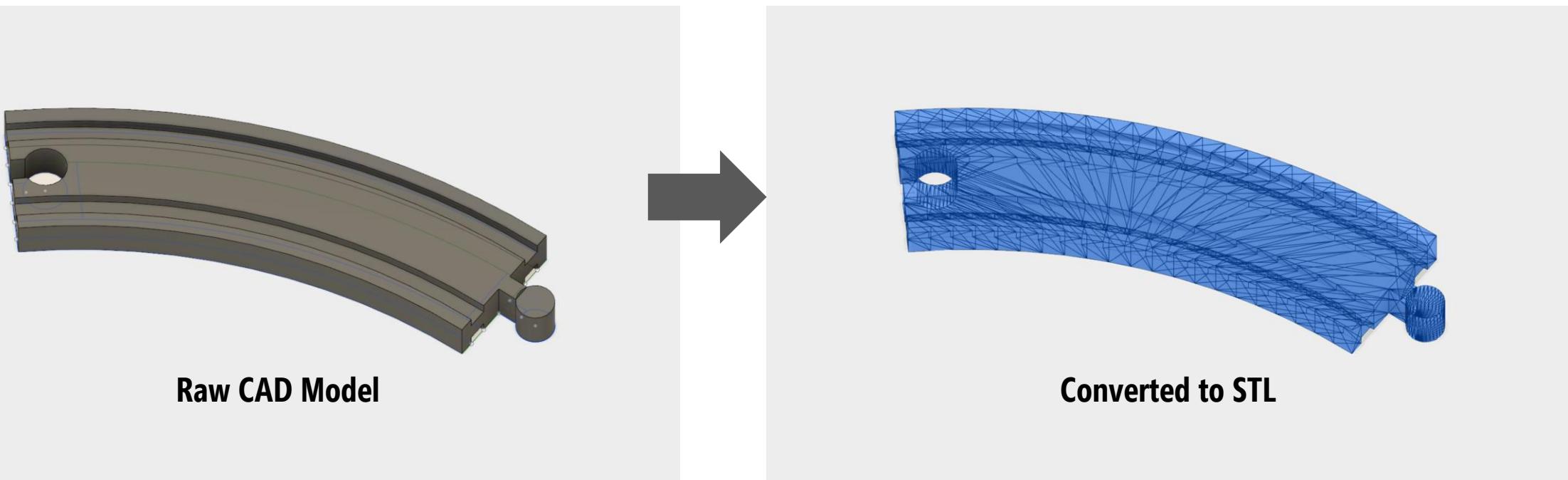
2. EXPORT CAD MODEL AS STL



STEP 2: EXPORT TO STL FILE

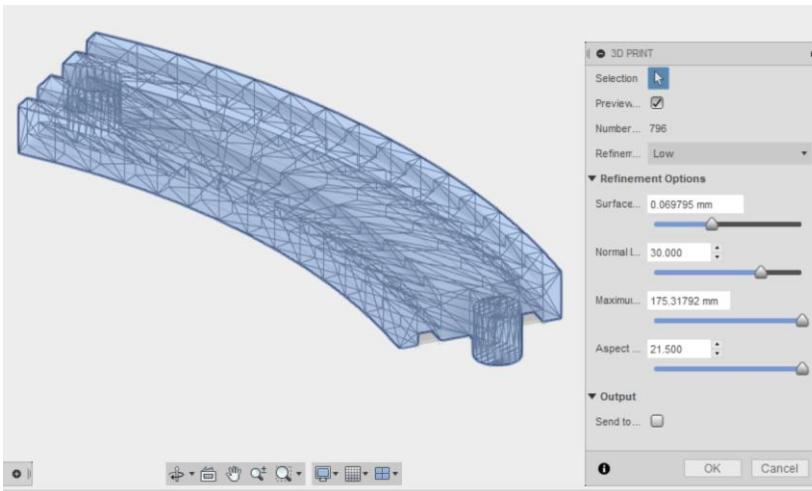
EXPORT CAD MODEL AS STL (TRIANGLE MESH)

The STL (Standard Triangle Language) is the industry standard file type for 3D printing. It uses linked triangles to represent the geometry of the solid model (aka a triangle mesh). All modern CAD tools allow you to export their native file format into STL.



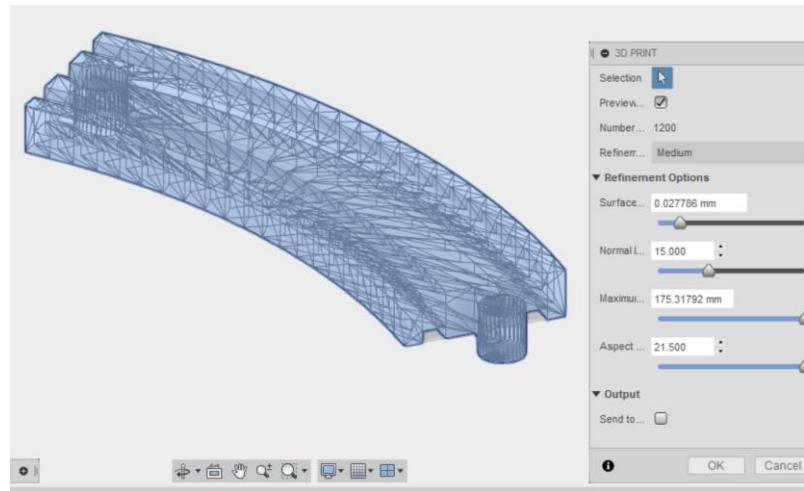
STEP 2: EXPORT TO STL FILE

CONFIGURING EXPORT RESOLUTION (# OF TRIANGLES)



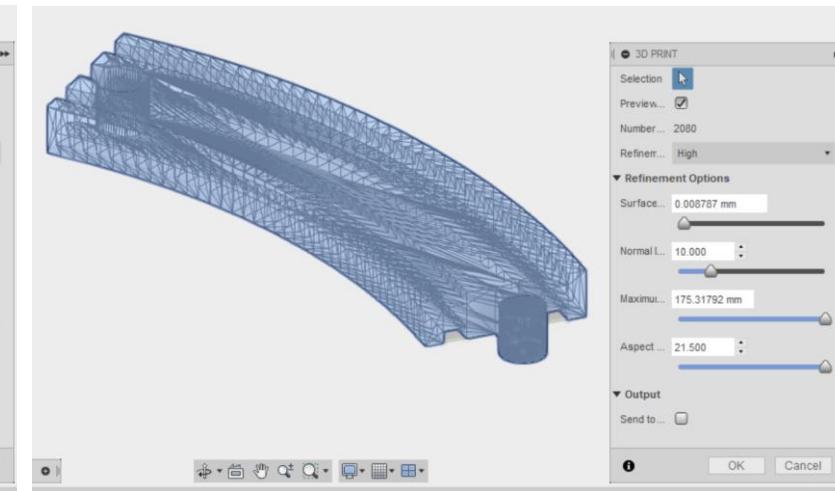
Export Quality: Low

Number of triangles: 796



Export Quality: Medium

Number of triangles: 1200



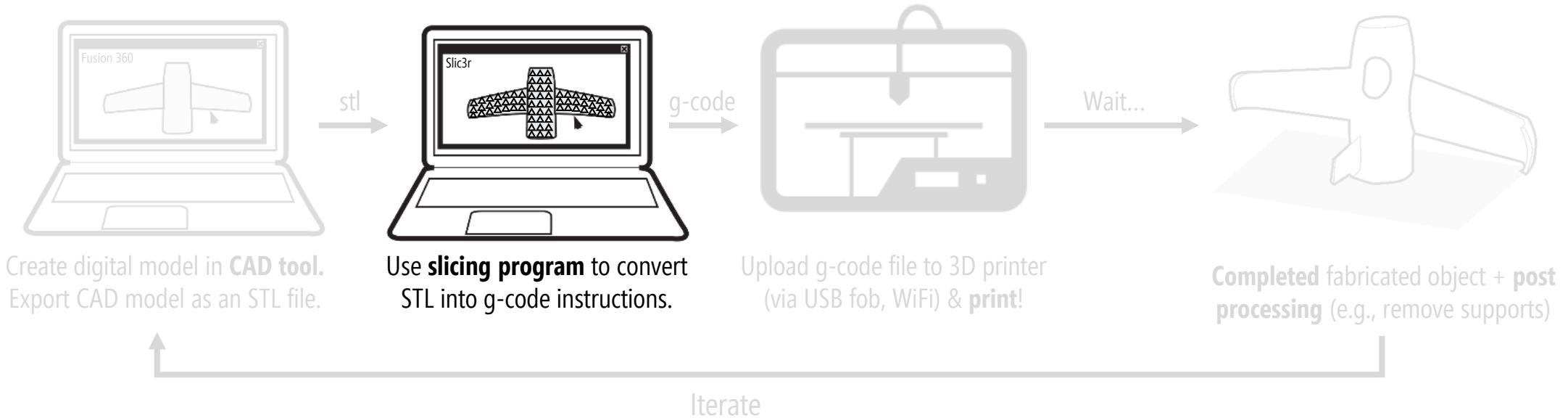
Export Quality: High

Number of triangles: 2080

Number of triangles

Typically the default export quality is fine. If you export at too low of resolution, the model will have visible triangles on its surface when printed. Increasing the resolution too much (*e.g.*, beyond capabilities of printer) will just lead to file bloat and print difficulties.

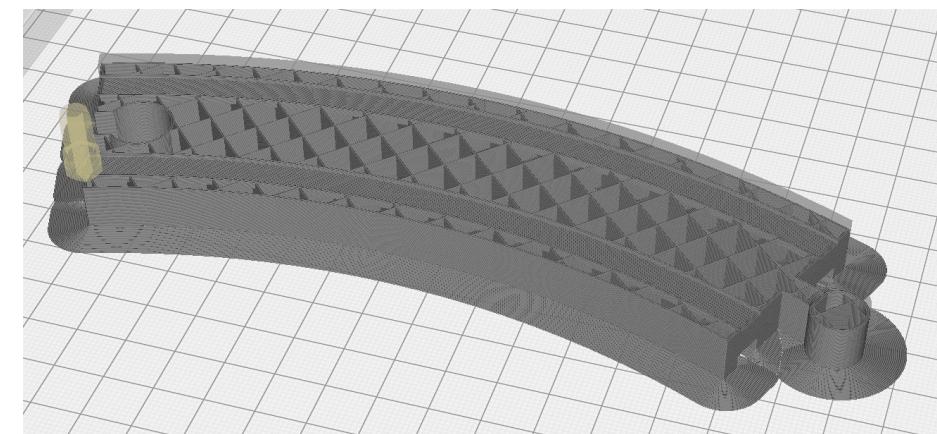
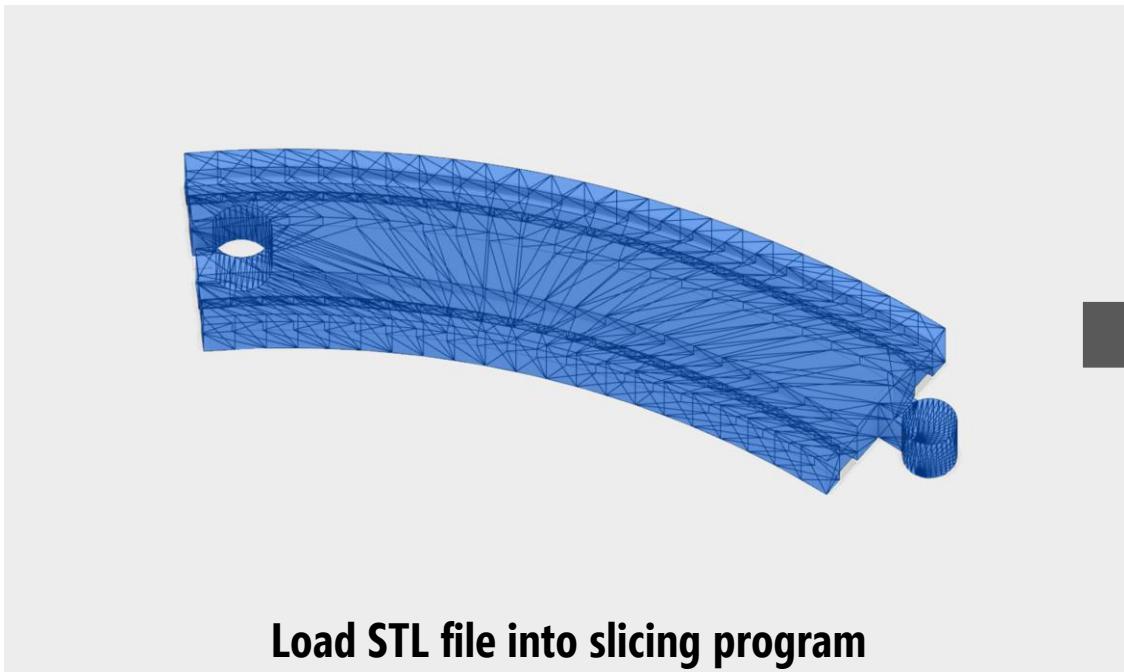
3. USE SLICING PROGRAM TO CONVERT STL TO G-CODE



STEP 3: SLICING & GENERATING G-CODE

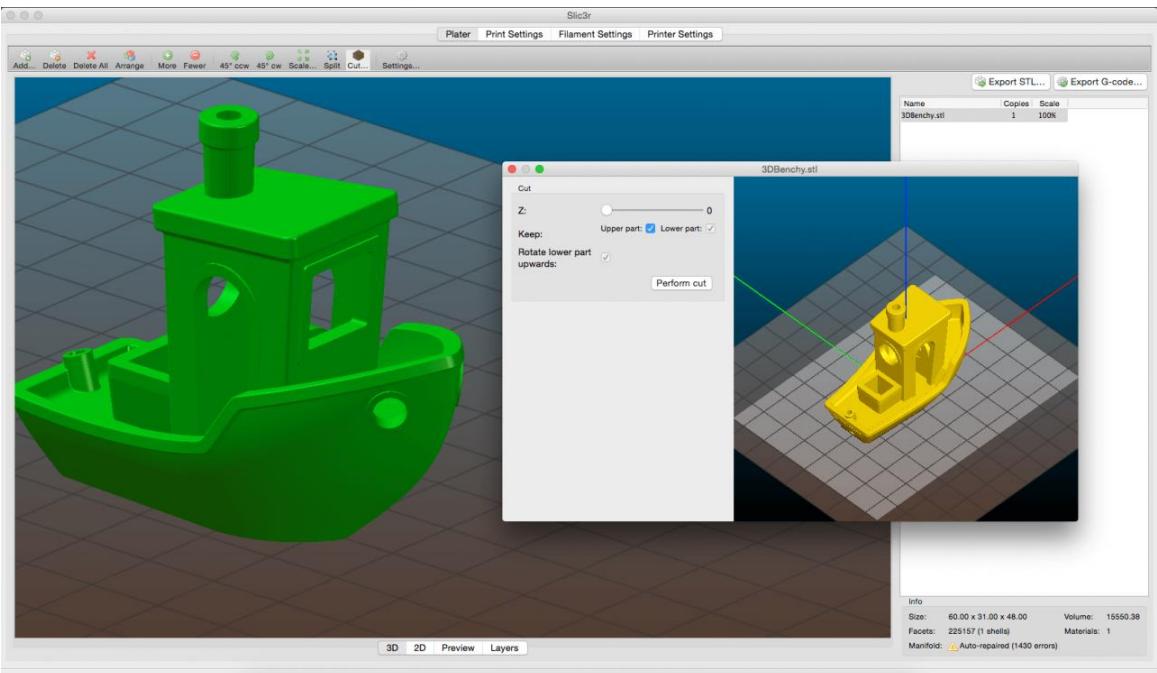
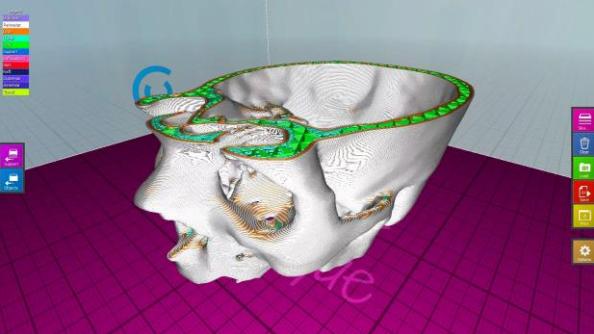
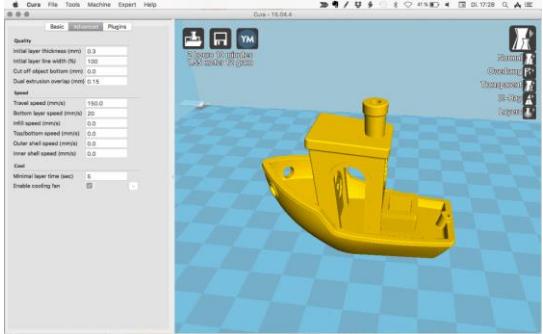
SLICERS CONVERT STLS INTO PRINTER INSTRUCTIONS

While STL is an industry standard file type for geometrical models, this needs to be converted into printing instructions your 3D printer can understand (g-code). Slicers cut the model into horizontal slices (layers), generate toolpaths to fill them, and calculate the amount of material to be extruded.



Slicer will create g-code (toolpath) instructions for printer

STEP 3: SLICING & GENERATING G-CODE SLICER PROGRAMS



Software	User	Price	OS
3DPrinterOS	Beginners, Advanced Users	Freemium	Browser, Windows, Mac
Astroprint	Beginners, Advanced Users	Freemium	Browser, Raspberry Pi, pcDuino
CraftWare	Beginners, Advanced Users	Free	Windows, Mac, Linux
Cura	Beginners, Advanced Users	Free	Windows, Mac, Linux
IceSL	Advanced Users	Free	Windows, Linux
ideaMaker	Beginners, Advanced Users	Free	Windows, Mac, Linux
KISSlicer	Beginners, Advanced Users	Free/\$35	Windows, Mac, Linux, Raspberry Pie
MakerBot Print	Beginners	Free	Windows, Mac
MatterControl	Beginners, Advanced Users	Free	Windows, Mac, Linux
Netfabb Standard	Intermediate Users, Advanced Users	\$1,000 to \$4,300 (annual subscription)	Windows
OctoPrint	Intermediate Users, Advanced Users	Free	Raspberry Pi, Windows, Mac, Linux
Repetier	Intermediate Users, Advanced Users	Free	Windows, Mac, Linux
SelfCAD	Beginner, Advanced Users	Free trial, \$9.99/month	Browser
Simplify3D	Beginners, Advanced Users	\$150	Windows, Mac
Slic3r	Advanced Users, Professional Users	Free	Windows, Mac, Linux
SliceCrafter	Advanced Users	Free	Browser
Tinkerine Suite	Beginners	Free	Windows, Mac
Z-Suite	Beginners	Free	Windows, Mac

STEP 3: SLICING & GENERATING G-CODE

ULTIMAKER CURA

The image shows a 3D model of a '3D PRINTER TEST' block in Ultimaker Cura. The model includes several overhang test features of different angles (10°, 15°, 20°, 30°, 40°, 50°, 60°, 70°, 75°) and a large 'ultimaker 3' logo. The software interface includes a toolbar at the top, a 'Solid view' dropdown, and a printer selection for 'Ultimaker 3'. On the right, the 'Print Setup' panel is open, showing settings for 'Extruder 1' (selected), 'Material' (PLA), 'Print core' (AA 0.4), and a 'Check compatibility' link. It also includes sliders for 'Layer Height' (0.15), 'Print Speed' (Slower to Faster), and 'Infill' (10%), and checkboxes for 'Enable gradual' infill, 'Generate Support', and 'Build Plate Adhesion'. A note at the bottom right suggests reading the 'Ultimaker Troubleshooting Guides'.

ultimaker³

3D PRINTER TEST

OVERHANG TEST

10° 15° 20° 30° 40° 50° 60° 70° 75°

ultimaker 3

Solid view

Ultimaker 3

Extruder 1

Extruder 2

Material PLA

Print core AA 0.4

Check compatibility

Print Setup Recommended Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 10% Enable gradual

Generate Support

Build Plate Adhesion

Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

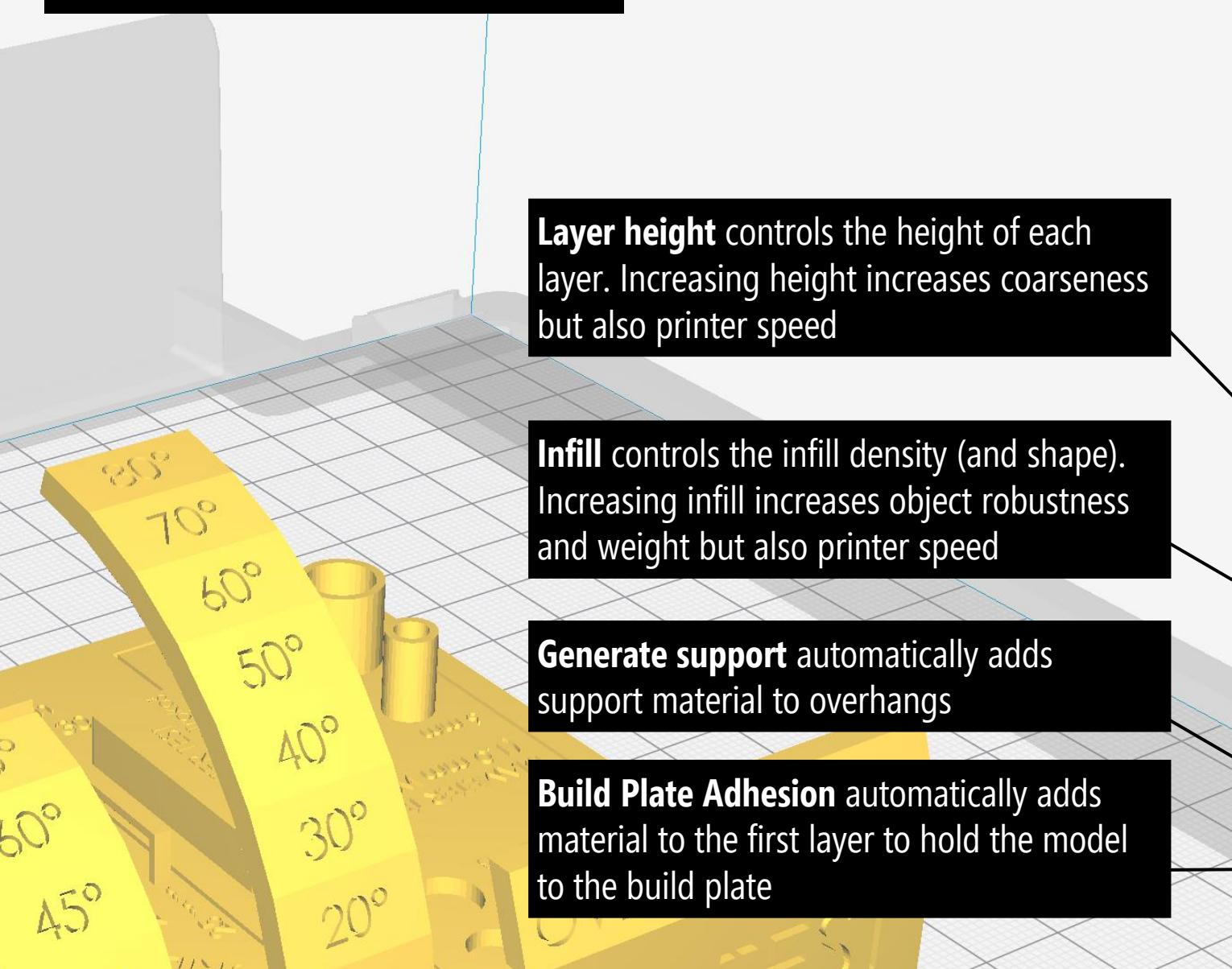
Ready to Save to File

STEP 3: SLICING & GENERATING G-CODE

ULTIMAKER CURA



Solid view ▾



Layer height controls the height of each layer. Increasing height increases coarseness but also printer speed

Infill controls the infill density (and shape). Increasing infill increases object robustness and weight but also printer speed

Generate support automatically adds support material to overhangs

Build Plate Adhesion automatically adds material to the first layer to hold the model to the build plate

Ultimaker 3

Extruder 1

Extruder 2

Material

PLA

Print core

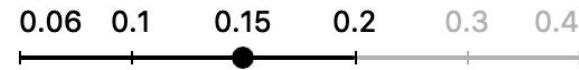
AA 0.4

[Check compatibility](#)

Print Setup

Recommended

Custom



Slower Faster



Enable gradual



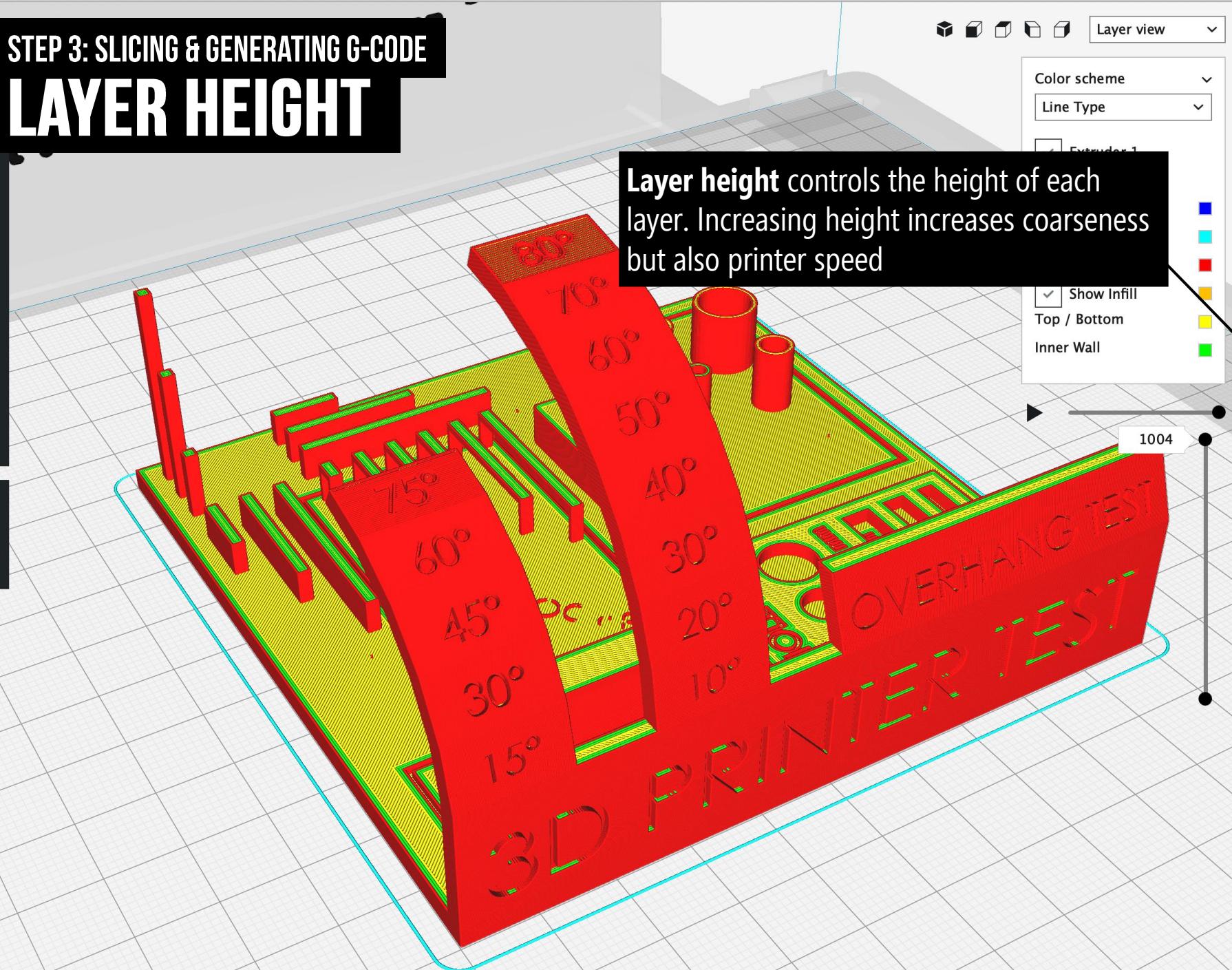
Generate Support



Build Plate Adhesion

STEP 3: SLICING & GENERATING G-CODE

LAYER HEIGHT



Ultimaker Cura

Layer view

Ultimaker 3

Extruder 1

Extruder 2

Material

PLA

Print core

AA 0.4

[Check compatibility](#)

Print Setup

Recommended

Custom

Layer Height

0.06

0.1

0.15

0.2

0.3

0.4

Slower

Faster

Infill

10%

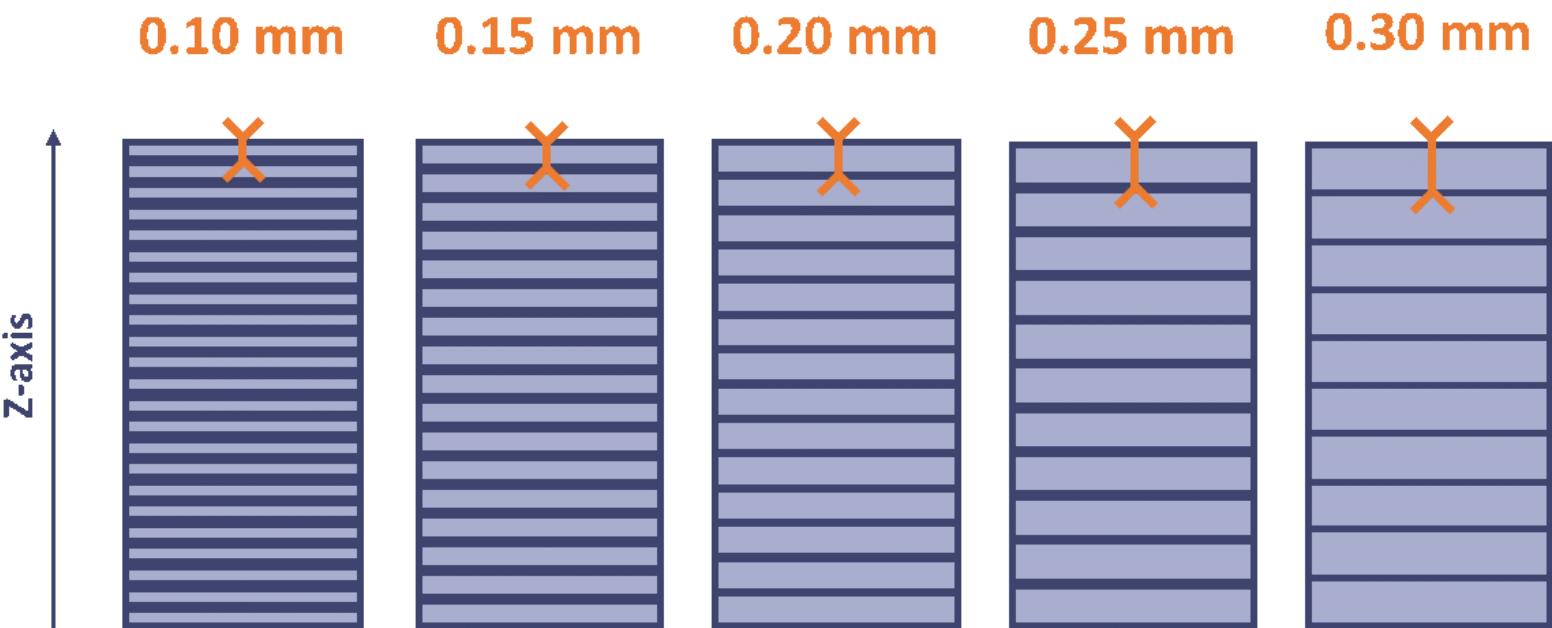
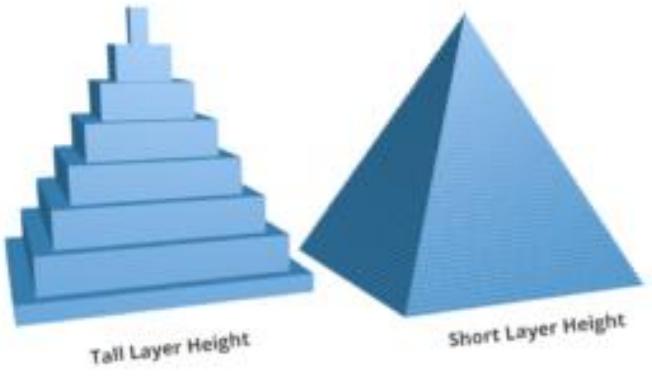
Enable gradual

Generate Support

Build Plate Adhesion

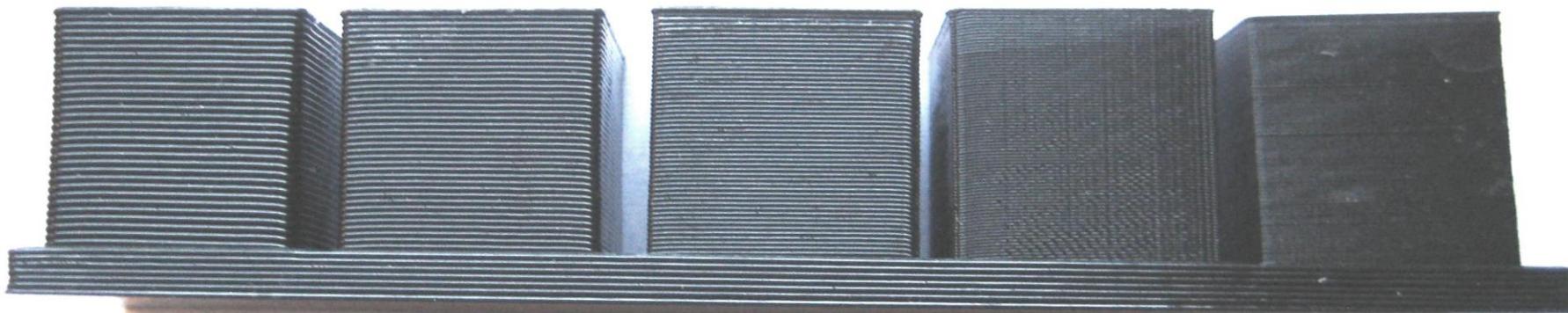
Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File



Layer Heights

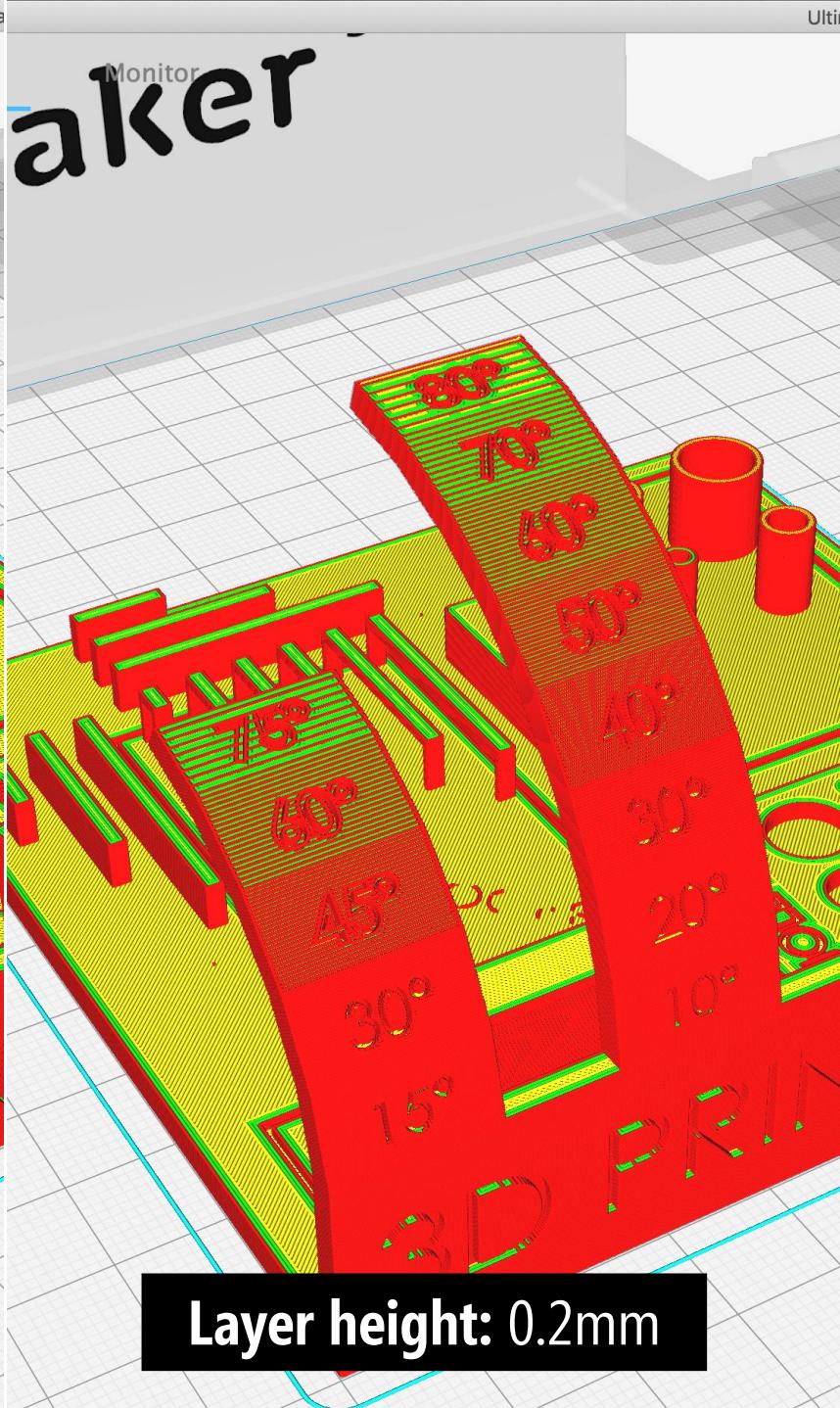
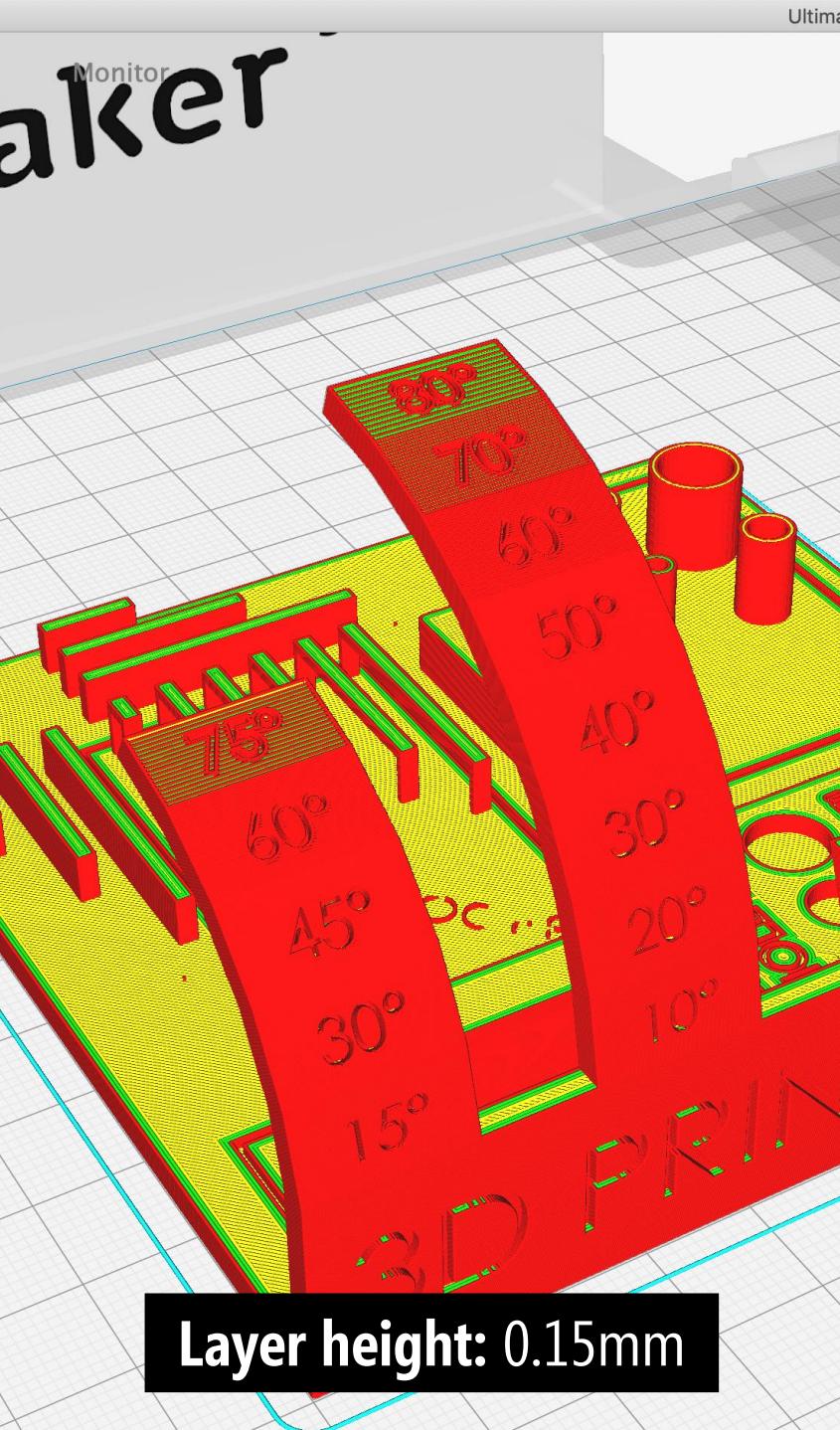
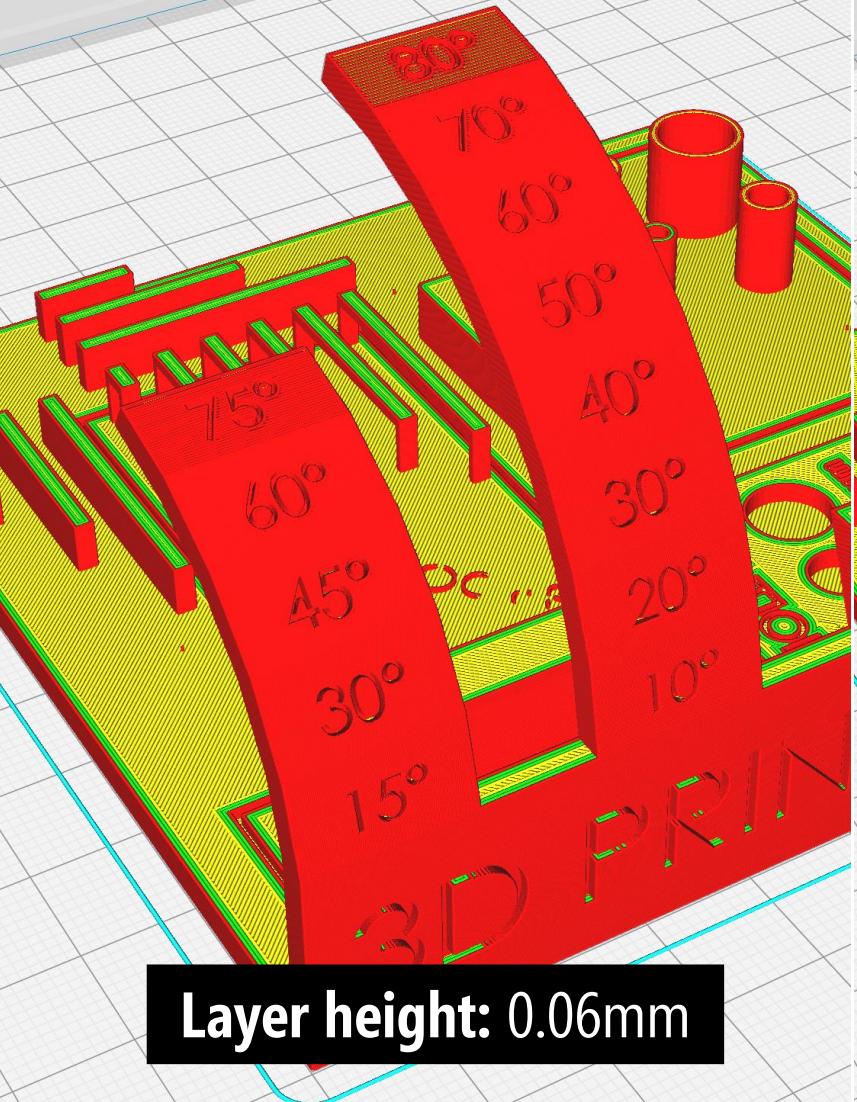
0.8 mm 0.6 mm 0.45 mm 0.3 mm 0.1mm



Ultima

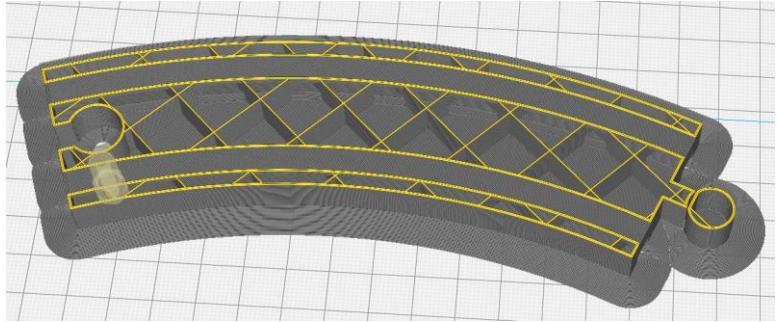
Monitor

STEP 3: SLICING & GENERATING G-CODE LAYER HEIGHT



STEP 3: SLICING & GENERATING G-CODE

SETTING INFILL



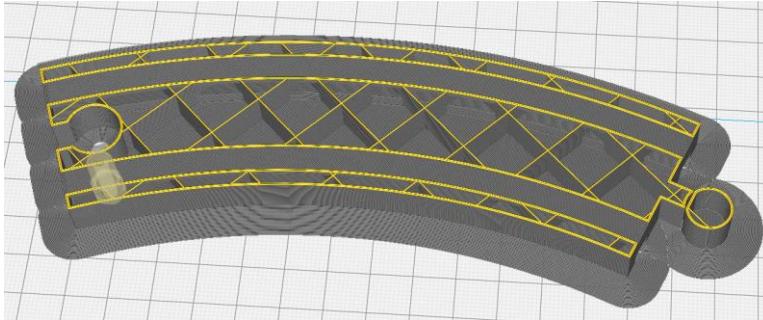
Infill Density: 5%

Estimated print time: 2h 53min

Estimated filament: 2.92 m / ~23g

STEP 3: SLICING & GENERATING G-CODE

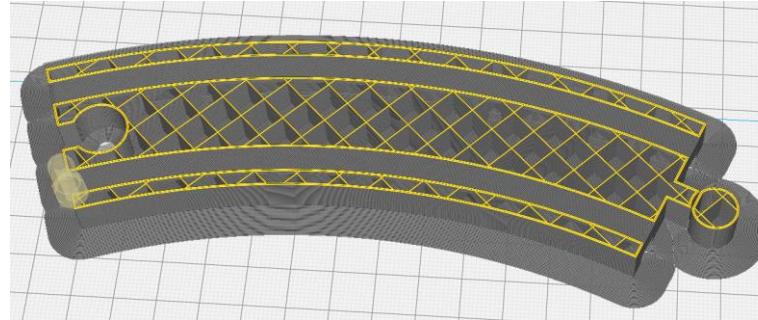
SETTING INFILL



Infill Density: 5%

Estimated print time: 2h 53min

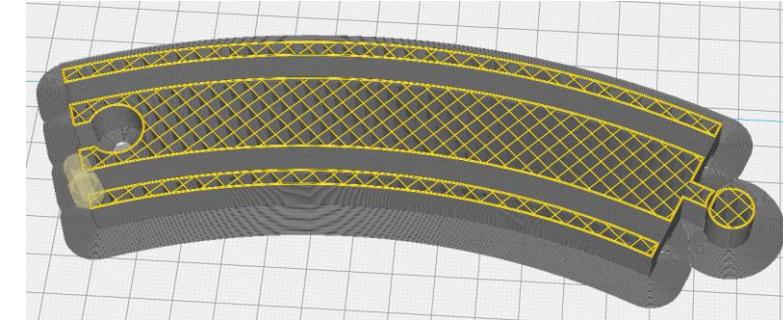
Estimated filament: 2.92 m / ~23g



Infill Density: 10%

Estimated print time: 3h 06min

Estimated filament: 3.28 m / ~26g



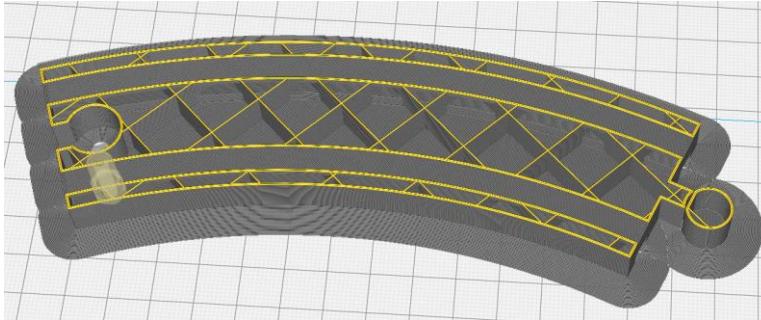
Infill Density: 25%

Estimated print time: 3h 35min

Estimated filament: 3.99 m / ~32g

STEP 3: SLICING & GENERATING G-CODE

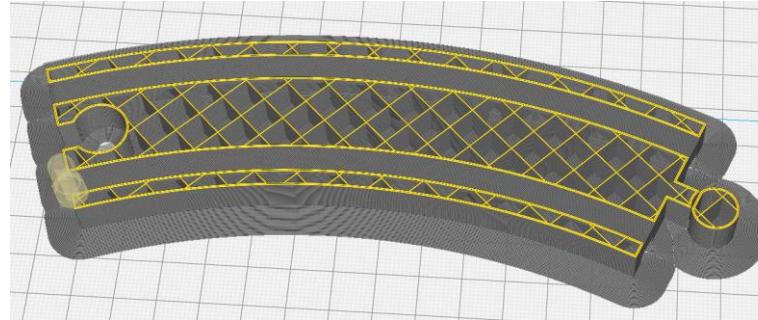
SETTING INFILL



Infill Density: 5%

Estimated print time: 2h 53min

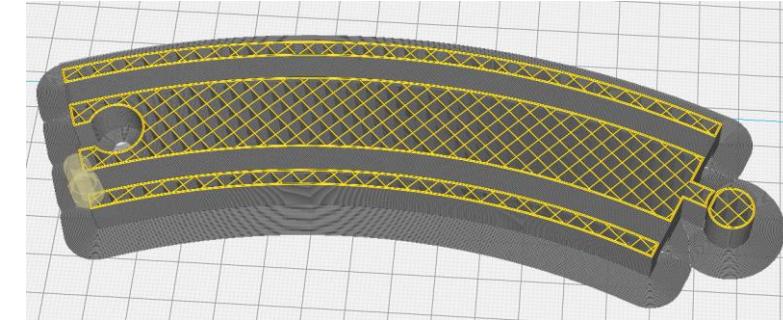
Estimated filament: 2.92 m / ~23g



Infill Density: 10%

Estimated print time: 3h 06min

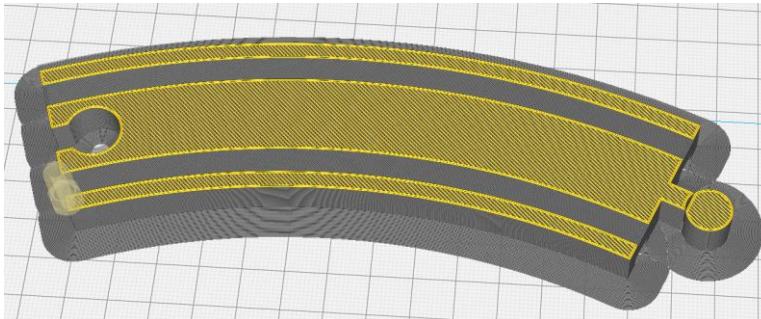
Estimated filament: 3.28 m / ~26g



Infill Density: 25%

Estimated print time: 3h 35min

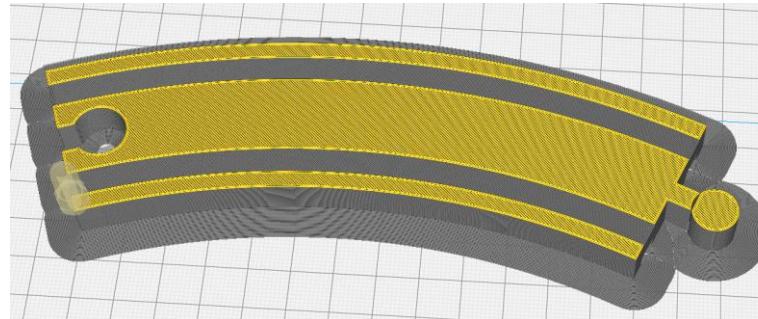
Estimated filament: 3.99 m / ~32g



Infill Density: 50%

Estimated print time: 4h 58min

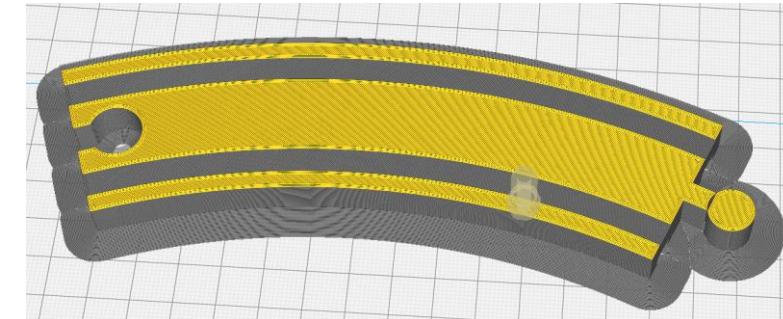
Estimated filament: 6.13 m / ~48g



Infill Density: 70%

Estimated print time: 4h 58min

Estimated filament: 6.13 m / ~48g



Infill Density: 100%

Estimated print time: 10h 53min

Estimated filament: 9.65 m / ~76g

INFILL PERCENT



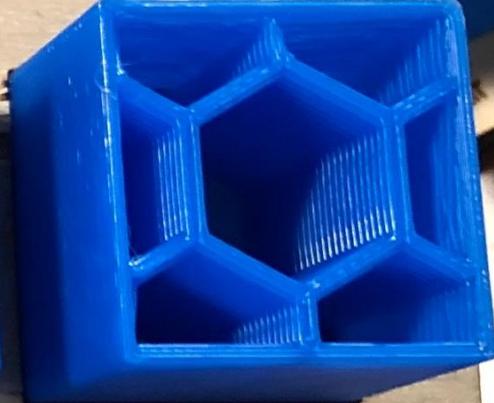
5%



10%



15%



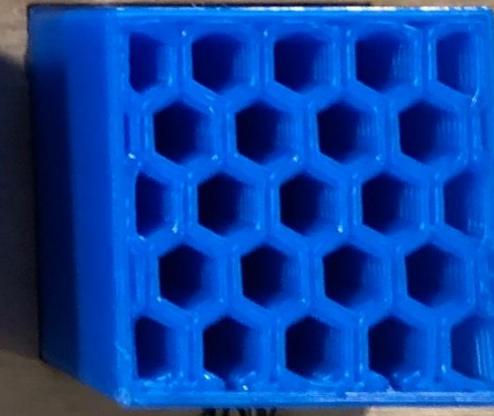
20%



25%



30%



40%



INFILL PATTERNS



Rectilinear



Wiggle



Triangular



Full Honeycomb

Ultimaker Cura

STEP 3: SLICING & GENERATING G-CODE

GENERATING SUPPORTS

Color scheme

Line Type

Extruder 1

Extruder 2

Show Travels

Show Helpers

Show Shell

Show Infill

Top / Bottom

Inner Wall

Layer view

Extruder 1

Extruder 2

Material

Print core

Check compatibility

Print Setup

Recommended

Custom

Layer Height

0.06 0.1 0.15 0.2 0.3 0.4

Print Speed

Slower Faster

Infill

10%

Enable gradual

Generate Support

Build Plate Adhesion

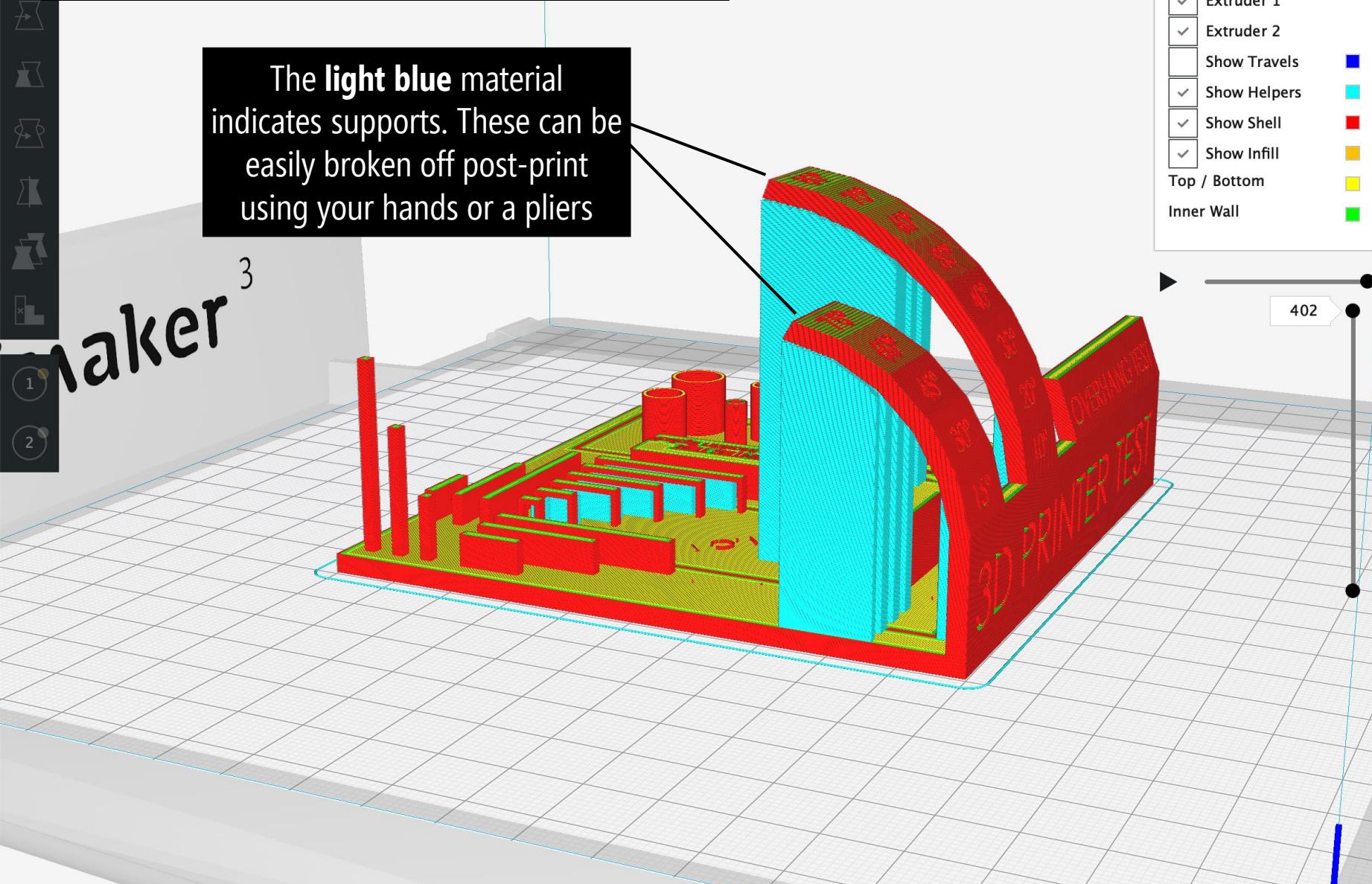
Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

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Ready to Save to File

STEP 3: SLICING & GENERATING G-CODE

GENERATING SUPPORTS



The **light blue** material indicates supports. These can be easily broken off post-print using your hands or a pliers

Ultimaker 3

Layer view

Color scheme

Line Type

Extruder 1

Extruder 2

Show Travels

Show Helpers

Show Shell

Show Infill

Top / Bottom

Inner Wall

Material PLA

Print core AA 0.4

Check compatibility

Extruder 1

Extruder 2

Print Setup

Recommended

Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 10% Enable gradual

Generate Support

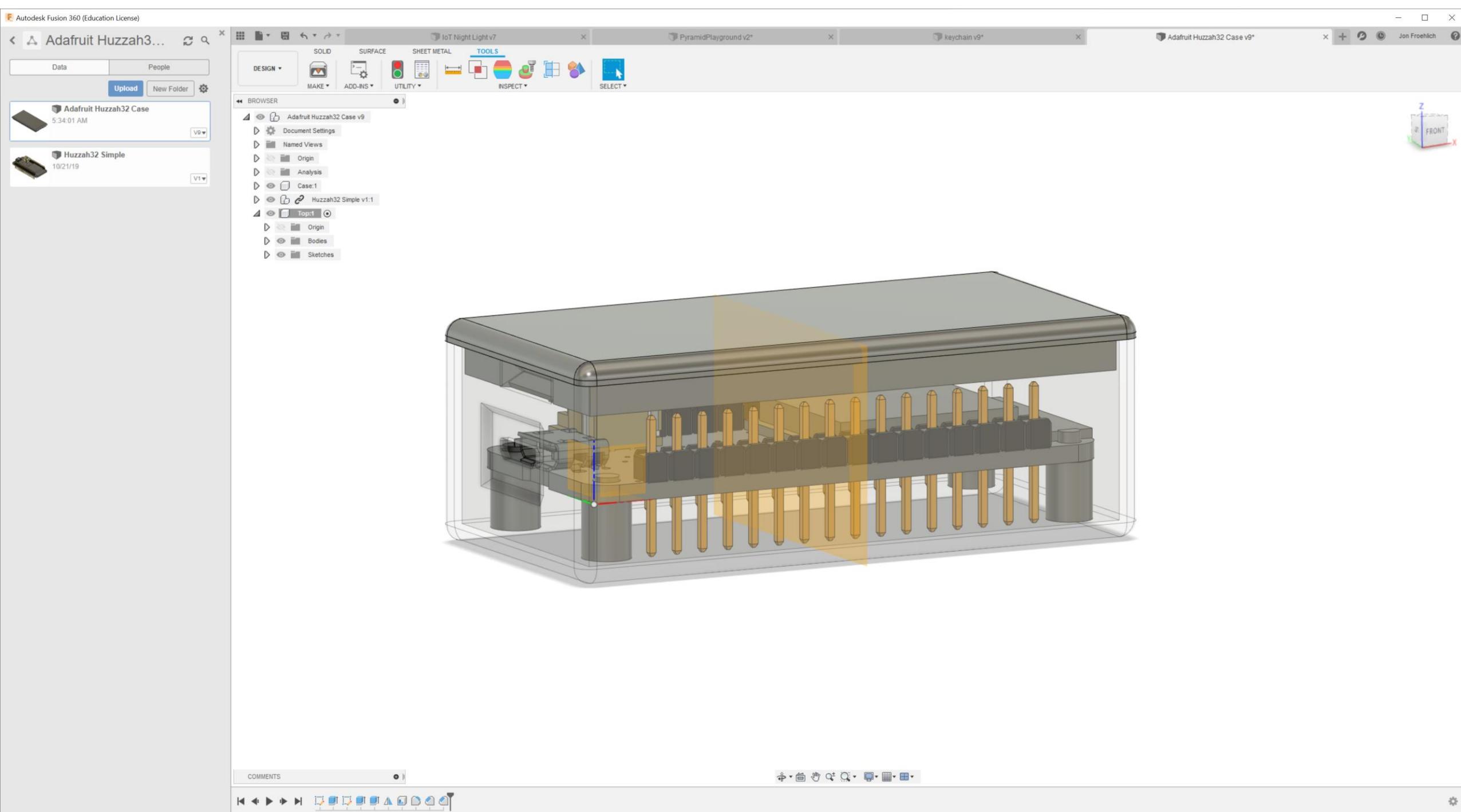
Extruder 1

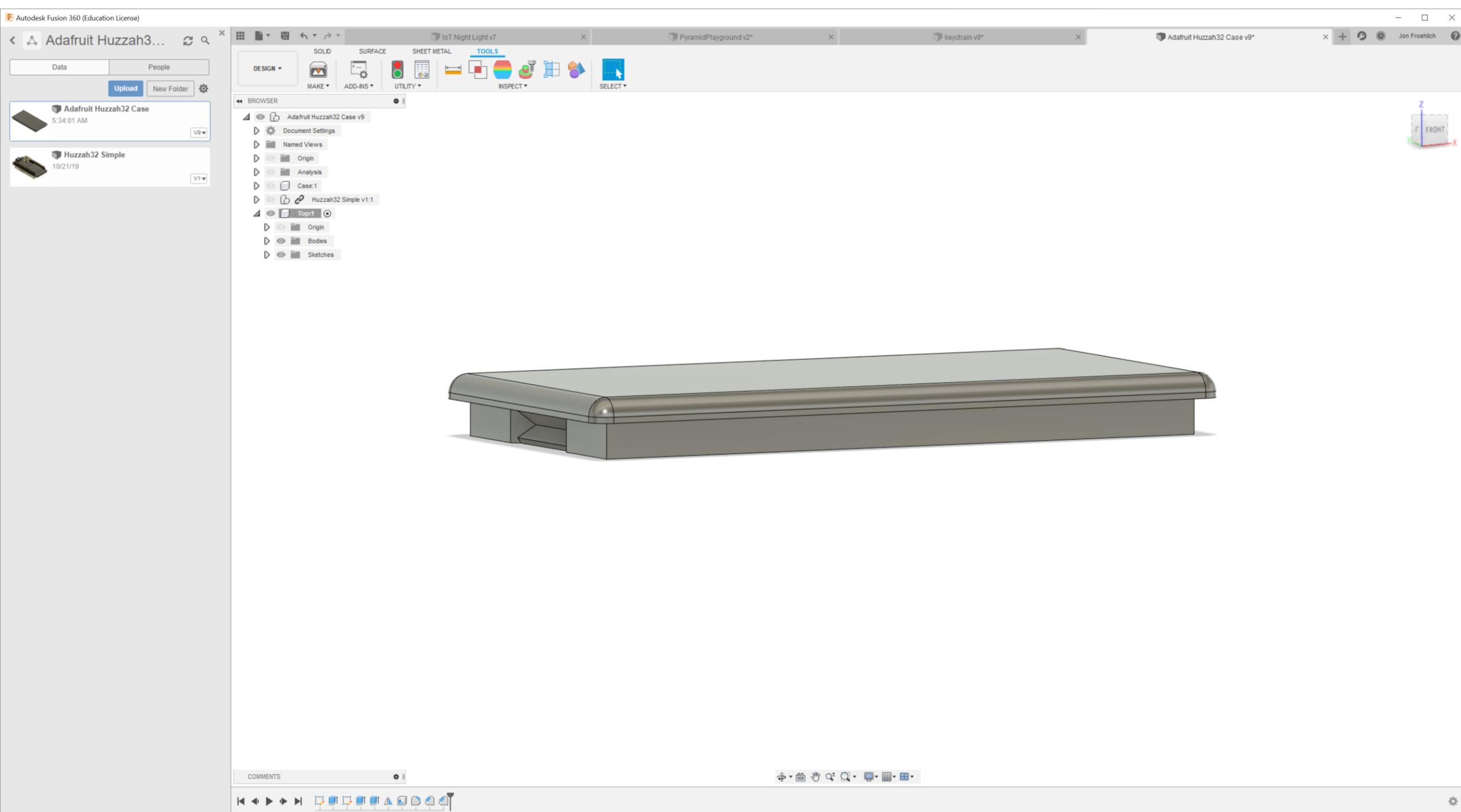
Build Plate Adhesion

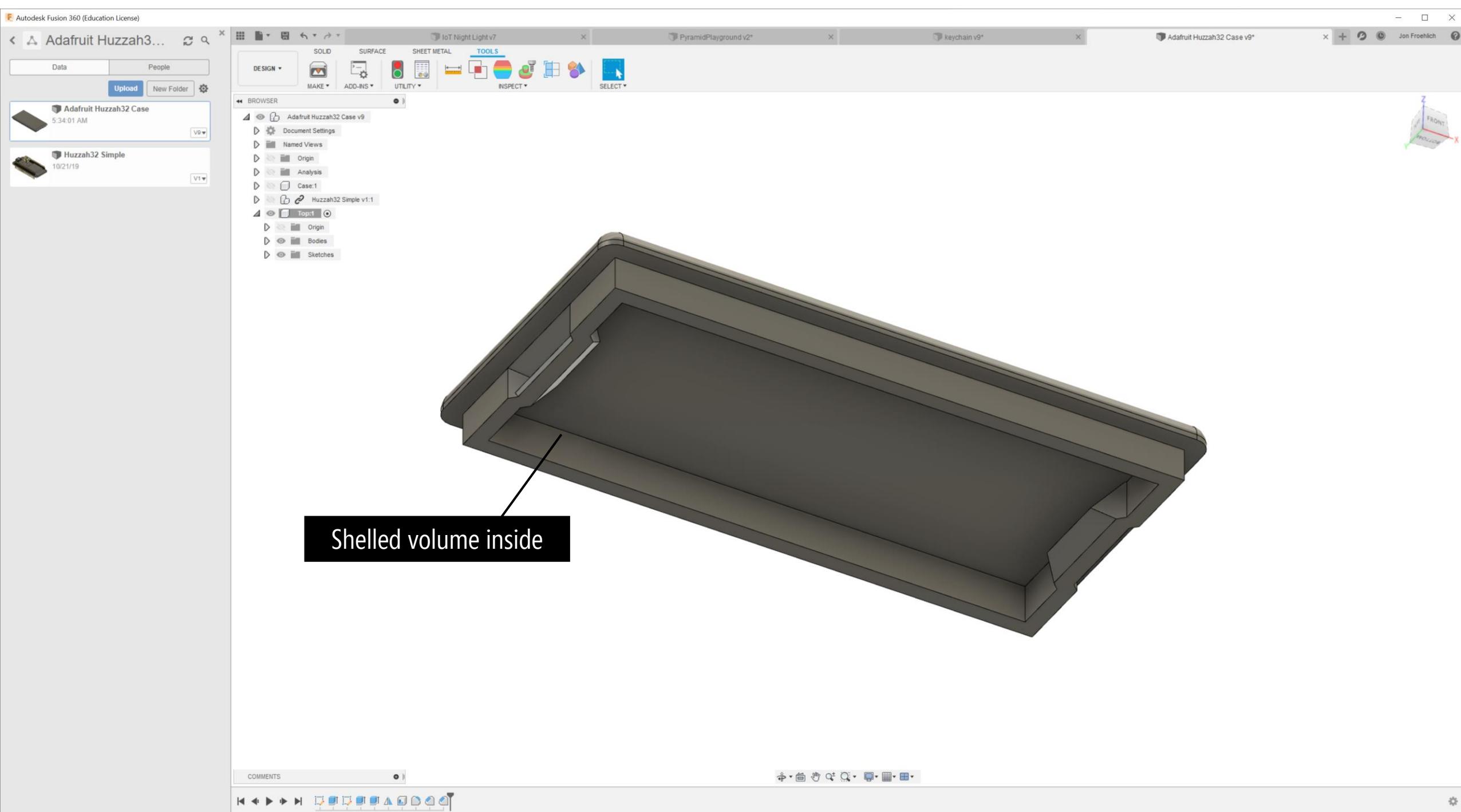
Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

Once you produce the STL, you will want to **reorient the model in the slicer** to reduce the need for support material. Here's an example.









Ultimaker 2+

Generic PLA
0.4 mm

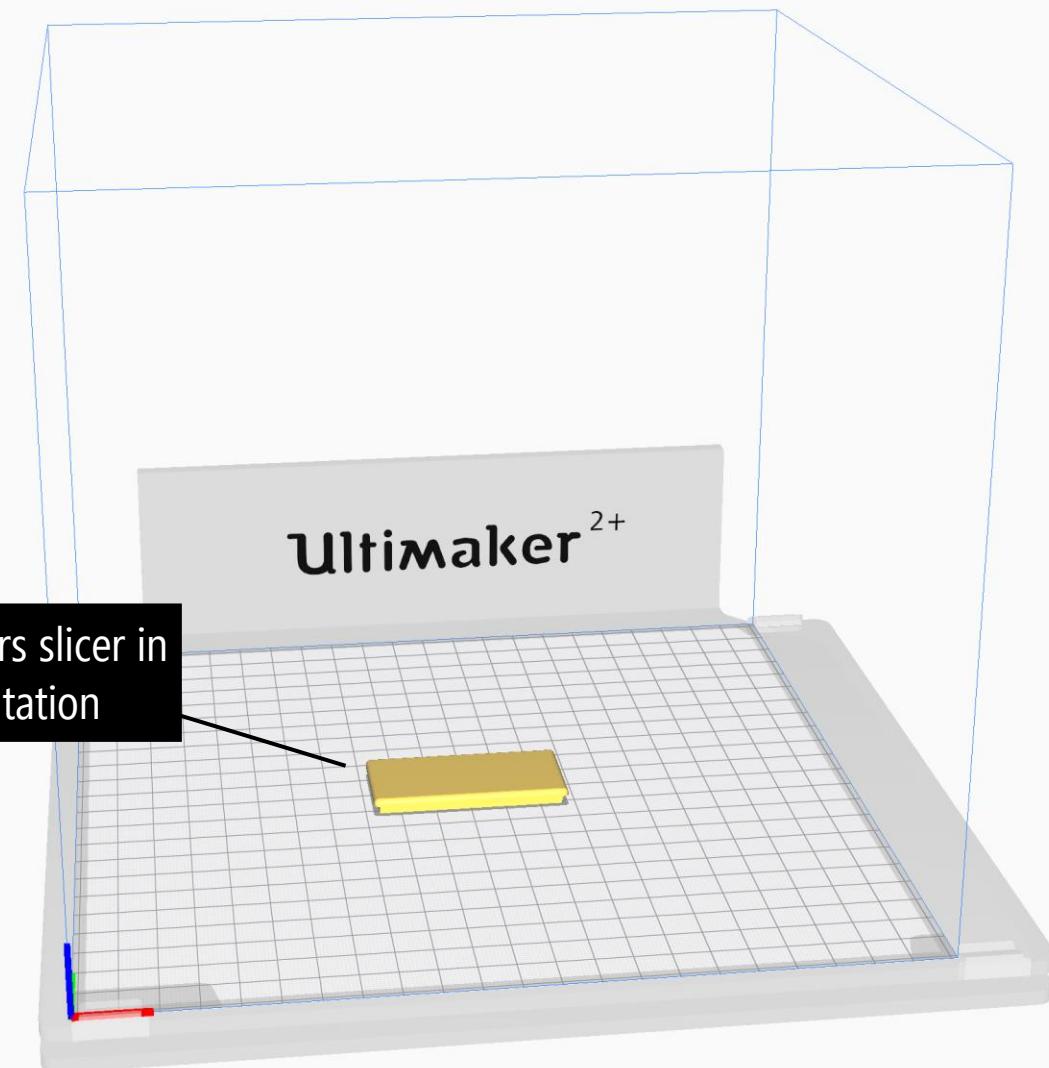
PREPARE

PREVIEW

MONITOR

Marketplace

Sign in

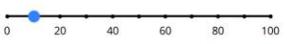


Print settings

Layer Height



Infill (%)



Support



Adhesion



Custom >



Object list

UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8

55.8 x 27.9 x 5.0 mm



Slice

Ultimaker Cura
File Edit View Settings Extensions Preferences Help

cura.
Ultimaker 2+ Generic PLA 0.4 mm

PREPARE PREVIEW MONITOR Marketplace Sign in

Fine 0.1mm 10% On Off

Print settings

- Layer Height: 0.06 - 0.15 - 0.2 - 0.3 - 0.4 - 0.6
- Infill (%): 0 - 20 - 40 - 60 - 80 - 100 (Gradual infill)
- Support:
- Adhesion:

Custom >

By default, enters slicer in "built" orientation

Object list: UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8
55.8 x 27.9 x 5.0 mm

1 hour 24 minutes 5g · 0.64m Preview Save to Removable... ▾

Ultimaker Cura
File Edit View Settings Extensions Preferences Help

PREPARE PREVIEW MONITOR

cura.
Ultimaker 2+ Generic PLA 0.4 mm

Fine 0.1mm 10% On Off

Print settings

- Layer Height: 0.06, 0.1, 0.15, 0.2, 0.3, 0.4, 0.6
- Infill (%): 0, 20, 40, 60, 80, 100 (Gradual infill)
- Support:
- Adhesion:

Custom >

But the problem is that the inside of the case presents a massive overhang

Object list
UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8
55.8 x 27.9 x 5.0 mm

1 hour 24 minutes
5g · 0.64m
Preview Save to Removable... ▾

PREPARE

PREVIEW

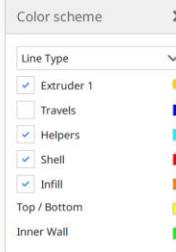
MONITOR

Marketplace Sign in

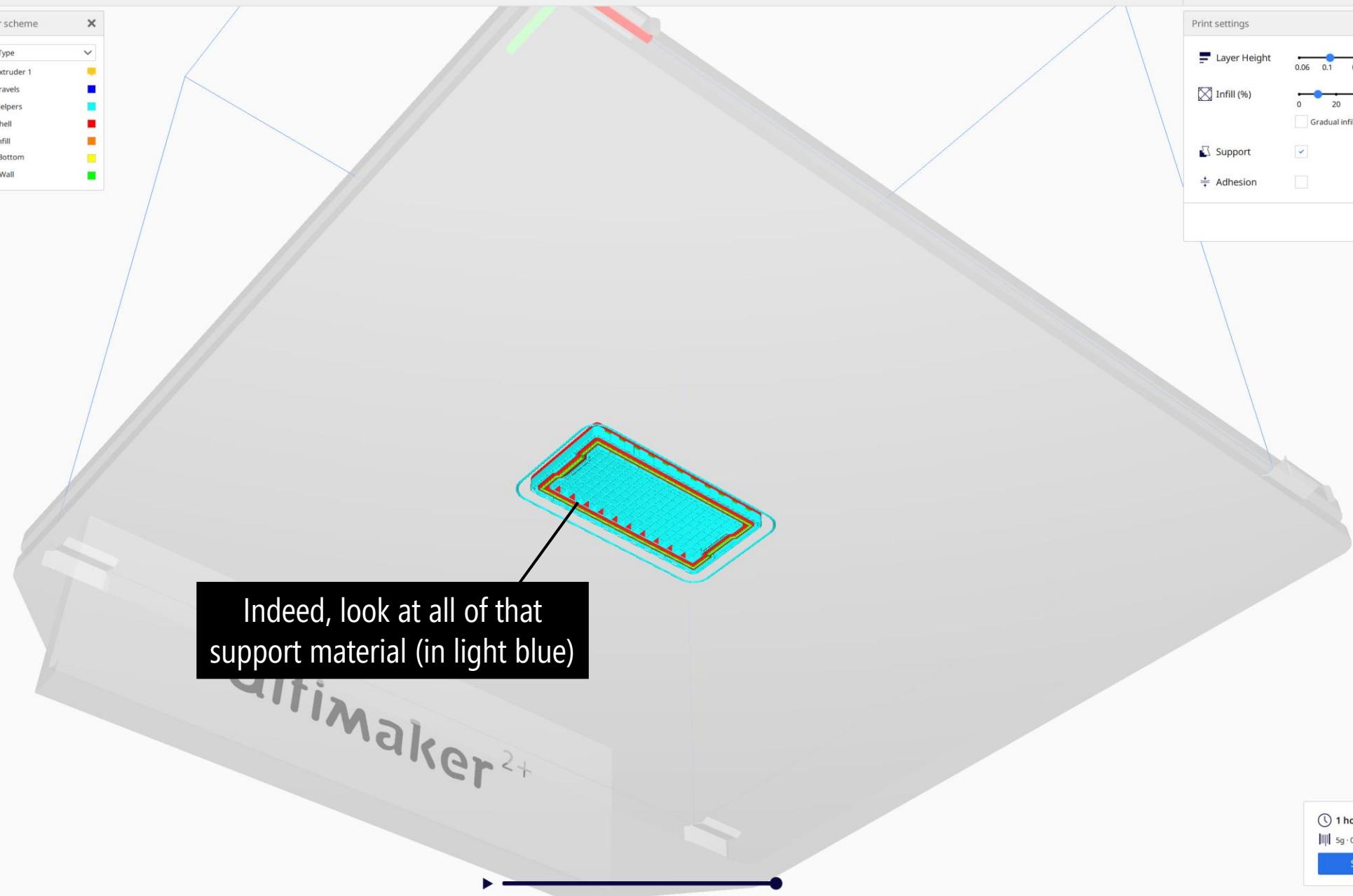
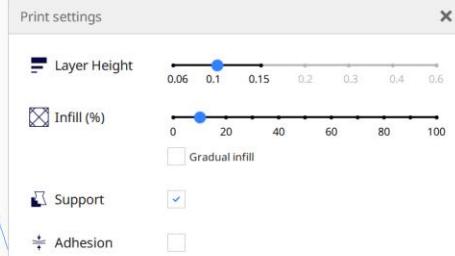
CURA.

View type Layer view

Color scheme Line Type



Fine 0.1mm 10% On Off



Object list

UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8

55.8 x 27.9 x 5.0 mm



1 hour 24 minutes

5g · 0.64m

Save to Removable Drive

Ultimaker Cura
File Edit View Settings Extensions Preferences Help

PREPARE PREVIEW MONITOR

View type Layer view Color scheme Line Type

Color scheme Line Type

- Extruder 1
- Travels
- Helpers
- Shell
- Infill
- Top / Bottom
- Inner Wall

Fine 0.1mm 10% Off Off

Print settings

- Layer Height 0.06 0.1 0.15 0.2 0.3 0.4 0.5 0.6
- Infill (%) 0 20 40 60 80 100
- Support
- Adhesion

Custom >

Select face to align to the build plate

Snap Rotation

48

Use the slicer to reorient the model in an orientation that minimizes support

Object list
UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8
55.8 x 27.9 x 5.0 mm

1 hour 9 minutes
4g · 0.50m
Save to Removable Drive

The image shows a 3D model of a 'ultimaker 2+' logo on a build plate. The model has support structures and is oriented at an angle. Three colored circles (red, blue, green) are overlaid on the model, indicating different print paths or layers. A callout box on the left points to the 'Color scheme' and 'Line Type' settings, which are used to define the different types of lines in the print. Another callout box points to the 'Print settings' panel, which includes options for layer height (set to 0.1mm), infill percentage (set to 10%), and support structures. A large text box on the left side of the interface provides instructions: 'Use the slicer to reorient the model in an orientation that minimizes support'.

Ultimaker Cura
File Edit View Settings Extensions Preferences Help

cura.
Ultimaker 2+ Generic PLA 0.4 mm PREPARE PREVIEW MONITOR Marketplace Sign in

Now we have flipped the model upside down!

Object list UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8 55.8 x 27.9 x 5.0 mm

1 hour 2 minutes 4g · 0.50m Preview Save to Removable... ▾

The image shows a 3D printing software interface for Ultimaker Cura. On the left, there's a vertical toolbar with icons for various file operations. The main workspace displays a 3D model of a rectangular base with the text "ultimaker 2+" printed on it. The model is currently positioned upside down on a build plate, indicated by a callout box with the text "Now we have flipped the model upside down!". The build plate has a grid pattern. To the right of the workspace are several control panels: one for "Print settings" showing options for Layer Height (set to 0.1), Infill (% - set to 20), Support (unchecked), and Adhesion (unchecked); another for "Marketplace" and "Sign in"; and a status bar at the bottom showing a print duration of "1 hour 2 minutes" and a material usage of "4g · 0.50m". The top menu bar includes File, Edit, View, Settings, Extensions, Preferences, and Help.

Ultimaker Cura
File Edit View Settings Extensions Preferences Help

PREPARE PREVIEW MONITOR

View type Layer view Color scheme Line Type

Color scheme

Line Type

- Extruder 1 (Yellow)
- Travels (Blue)
- Helpers (Cyan)
- Shell (Red)
- Infill (Orange)
- Top / Bottom (Yellow)
- Inner Wall (Green)

Fine 0.1mm 10% Off Off

Print settings

- Layer Height (0.06 to 0.6)
- Infill (%) (0 to 100) Gradual infill
- Support
- Adhesion

Custom >

48

ultimaker²⁺

Object list

UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8

55.8 x 27.9 x 5.0 mm

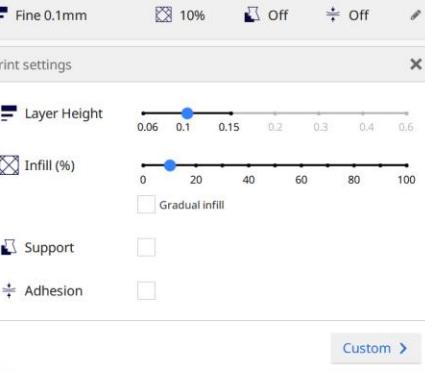
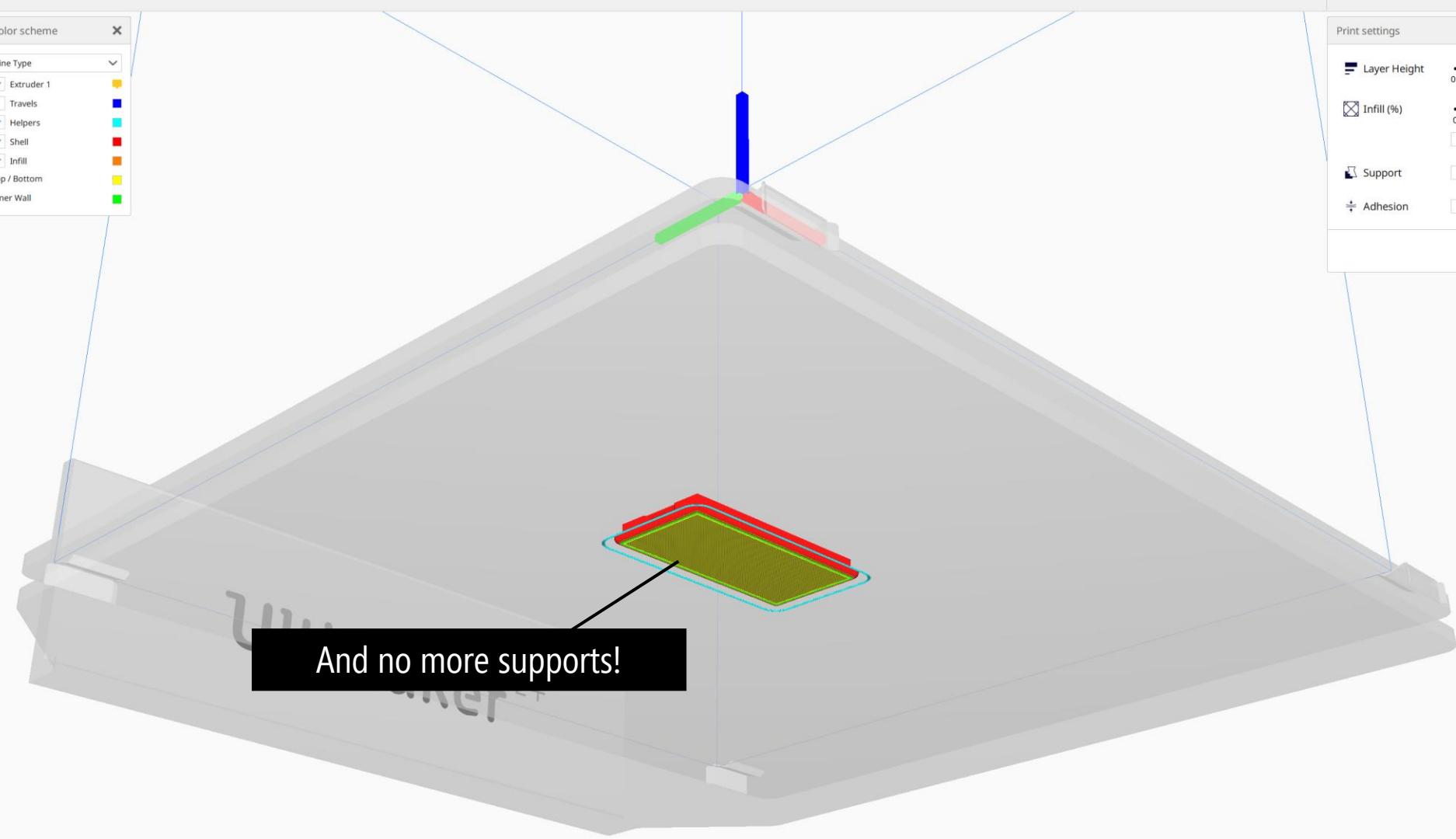
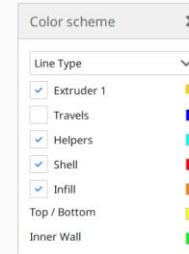
1 hour 2 minutes

4g · 0.50m

Save to Removable Drive

View type Layer view

Color scheme Line Type



Object list

UM2_d9b8389e-175d-4d78-aa5c-4119eaeb4cc8

55.8 x 27.9 x 5.0 mm



1 hour 2 minutes

4g · 0.50m

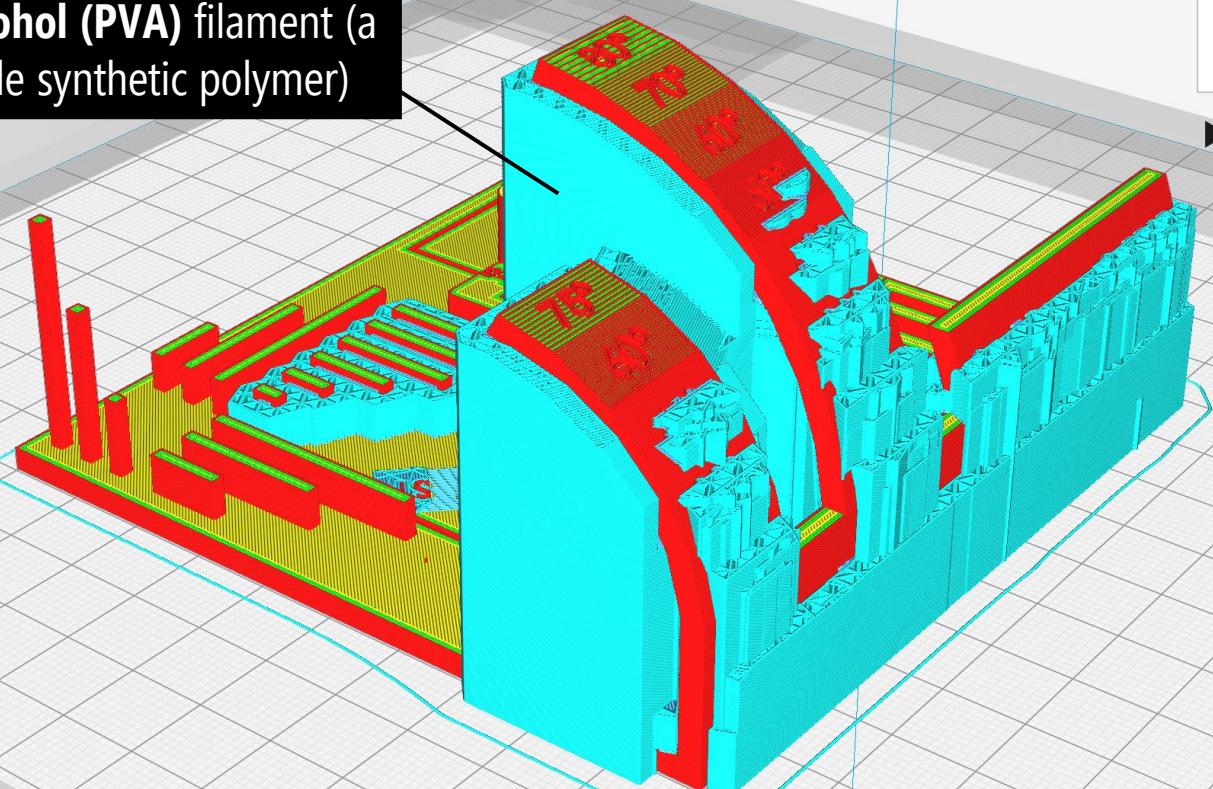
Save to Removable Drive



STEP 3: SLICING & GENERATING G-CODE

GENERATING SUPPORTS WITH DUAL EXTRUSION

The **light blue** material is from the 2nd extruder, which is loaded with **polyvinyl alcohol (PVA)** filament (a water-soluble synthetic polymer)



Layer view

Ultimaker 3

- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill
- Top / Bottom
- Inner Wall

Extruder 1

Extruder 2

Material

Natural PVA

Print core

BB 0.4

[Check compatibility](#)

Print Setup

Recommended

Custom

Layer Height

0.06 0.1 0.15 0.2 0.3 0.4

Print Speed

Slower Faster

Infill

10%

 Enable gradual

Generate Support

 Extruder 2

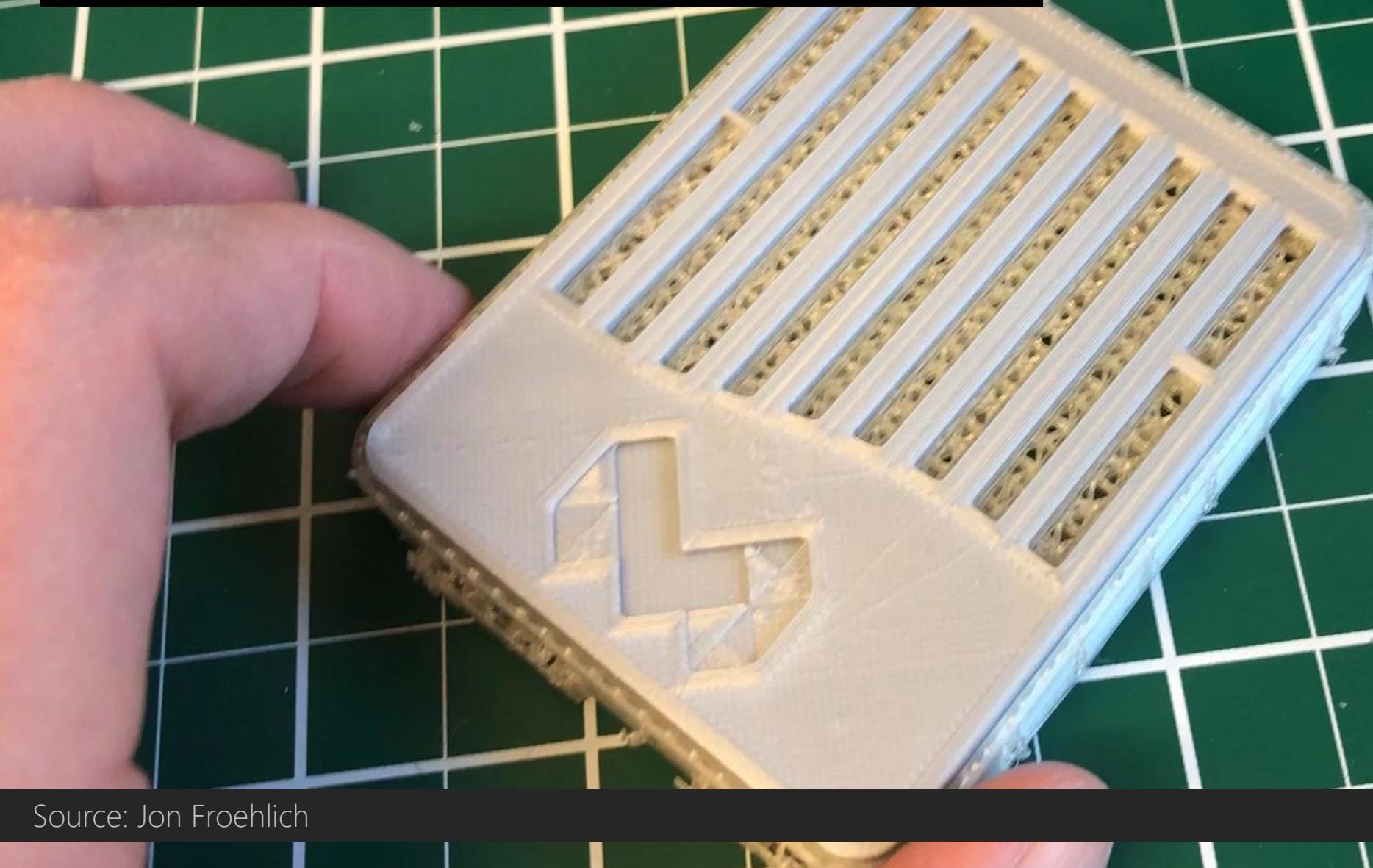
Build Plate Adhesion

Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

STEP 3: SLICING & GENERATING G-CODE

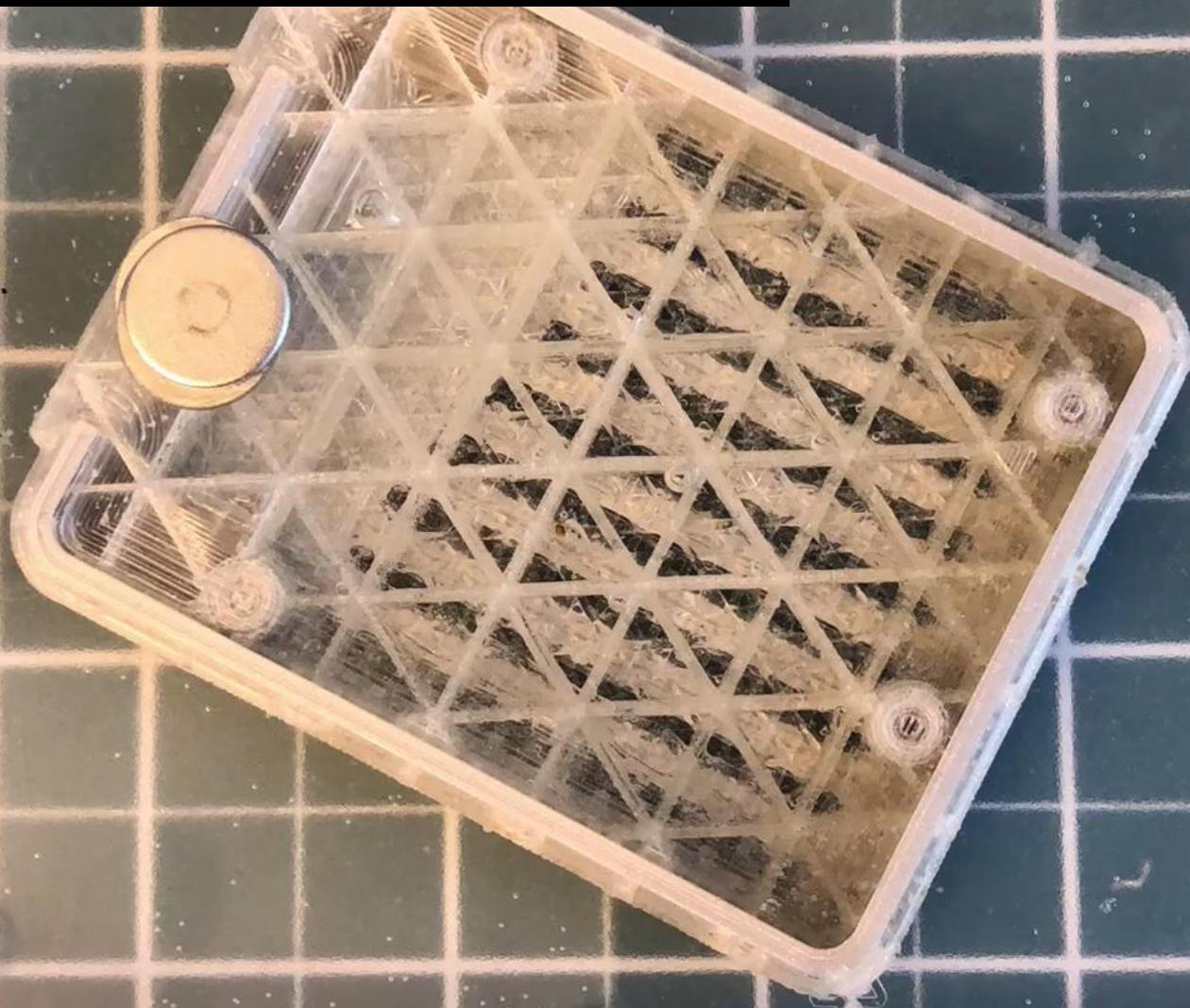
USING PVA FOR SUPPORT MATERIAL



Source: Jon Froehlich

STEP 3: SLICING & GENERATING G-CODE

USING PVA FOR SUPPORT MATERIAL



Source: Jon Froehlich

STEP 3: SLICING & GENERATING G-CODE

GENERATING BUILD PLATE ADHESION

Sometimes, the first few layers of our print start to warp or peel up.

Ultimaker Cura

Layer view

Color scheme

Line Type

Extruder 1

Extruder 2

Show Travels

Show Helpers

Show Shell

Show Infill

Top / Bottom

Inner Wall

Extruder 1

Extruder 2

Material PLA

Print core AA 0.4

Check compatibility

Print Setup Recommended

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 10% Enable gradual

Generate Support

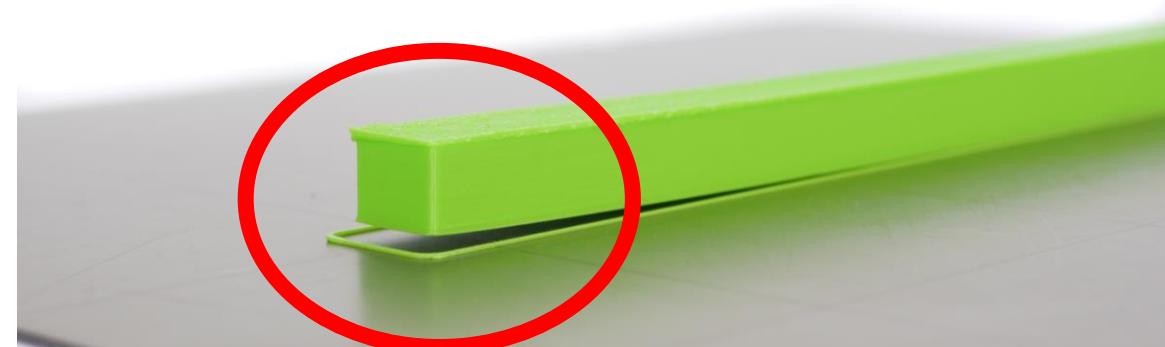
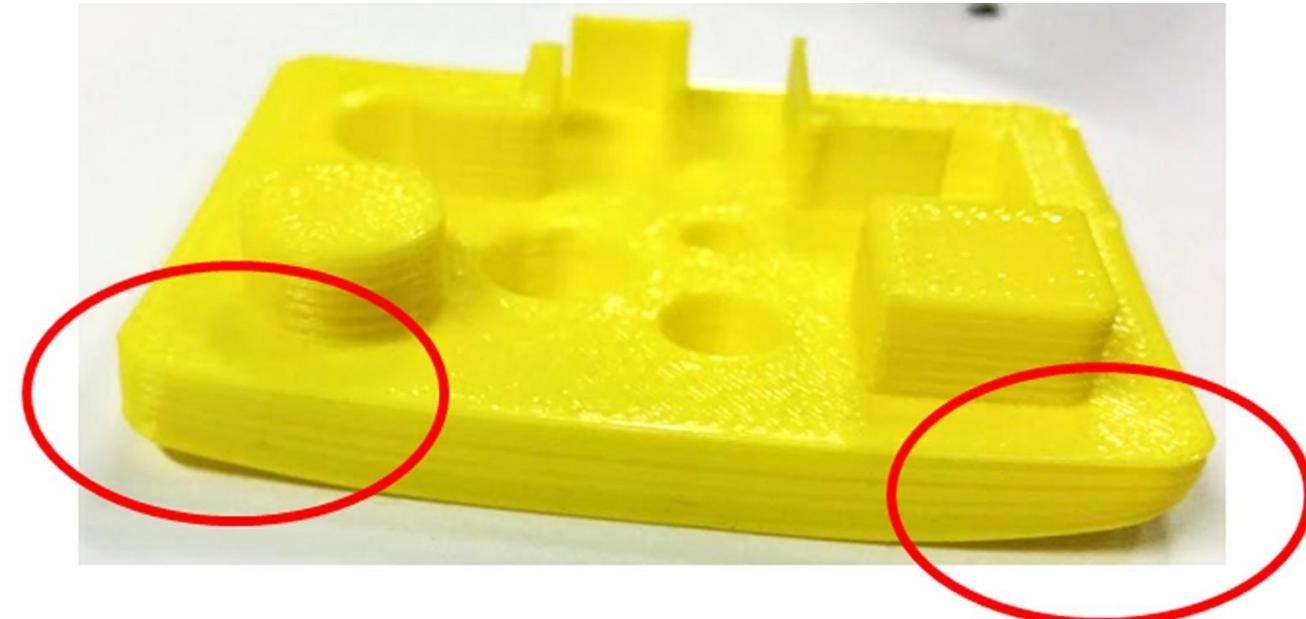
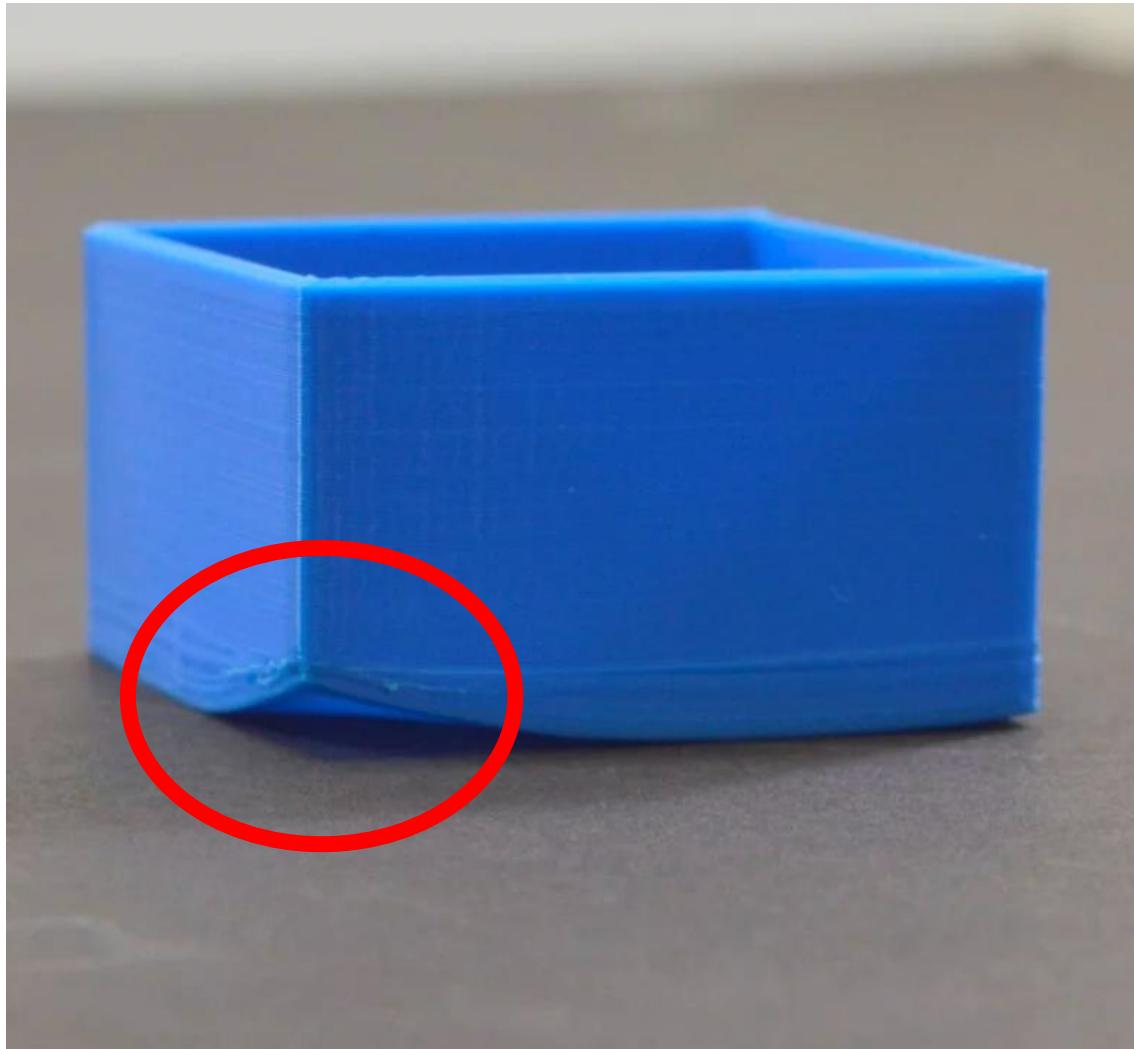
Build Plate Adhesion

Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

STEP 3: SLICING AND GENERATING G-CODE

WARPING DUE TO POOR BUILD PLATE ADHESION



STEP 3: SLICING & GENERATING G-CODE

GENERATING BUILD PLATE ADHESION

Sometimes, the first few layers of our print start to warp or peel up.

Click **Build Plate Adhesion** & the Slicer automatically adds in a brim

Ultimaker Cura

Layer view

Color scheme

Line Type

Extruder 1

Extruder 2

Show Travels

Show Helpers

Show Shell

Show Infill

Top / Bottom

Inner Wall

Extruder 1

Extruder 2

Material PLA

Print core AA 0.4

Check compatibility

Print Setup Recommended Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4 Slower Faster

Print Speed

Infill 10% Enable gradual

Generate Support

Build Plate Adhesion

Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

STEP 3: SLICING & GENERATING G-CODE

GENERATING BUILD PLATE ADHESION

The **auto-generated brim** is shown in blue. The brim is a printed ring outline around the model and is attached to the model's edge.

Color scheme

- Line Type
- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill
- Top / Bottom
- Inner Wall

Extruder 1

Extruder 2

Material PLA

Print core AA 0.4

Check compatibility

Print Setup

- Recommended
- Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 10% Enable gradual

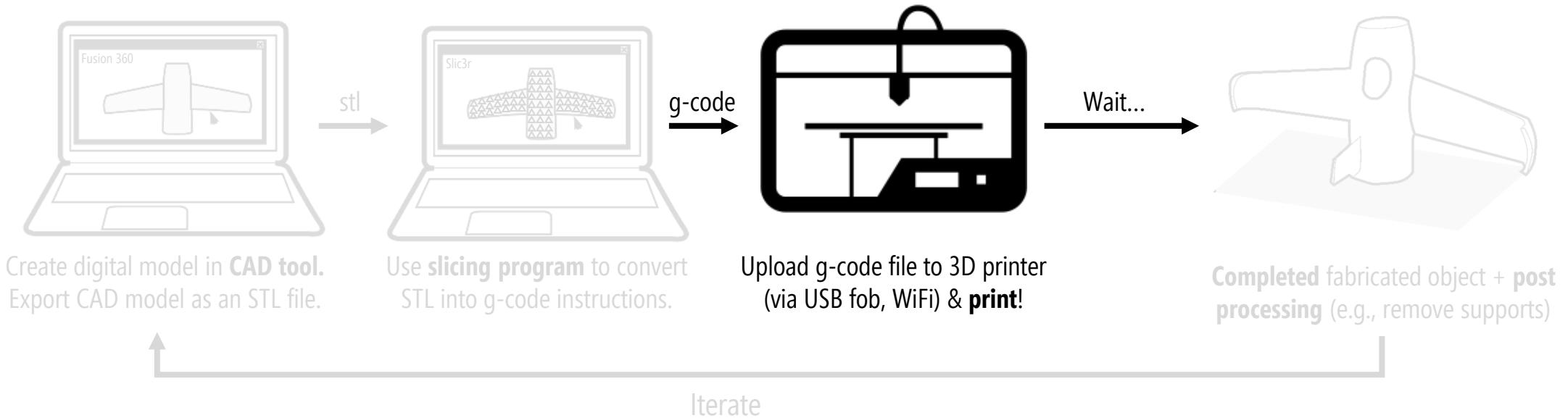
Generate Support

Build Plate Adhesion

Need help improving your prints?
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

4. LOAD G-CODE INTO PRINTER AND PRINT!

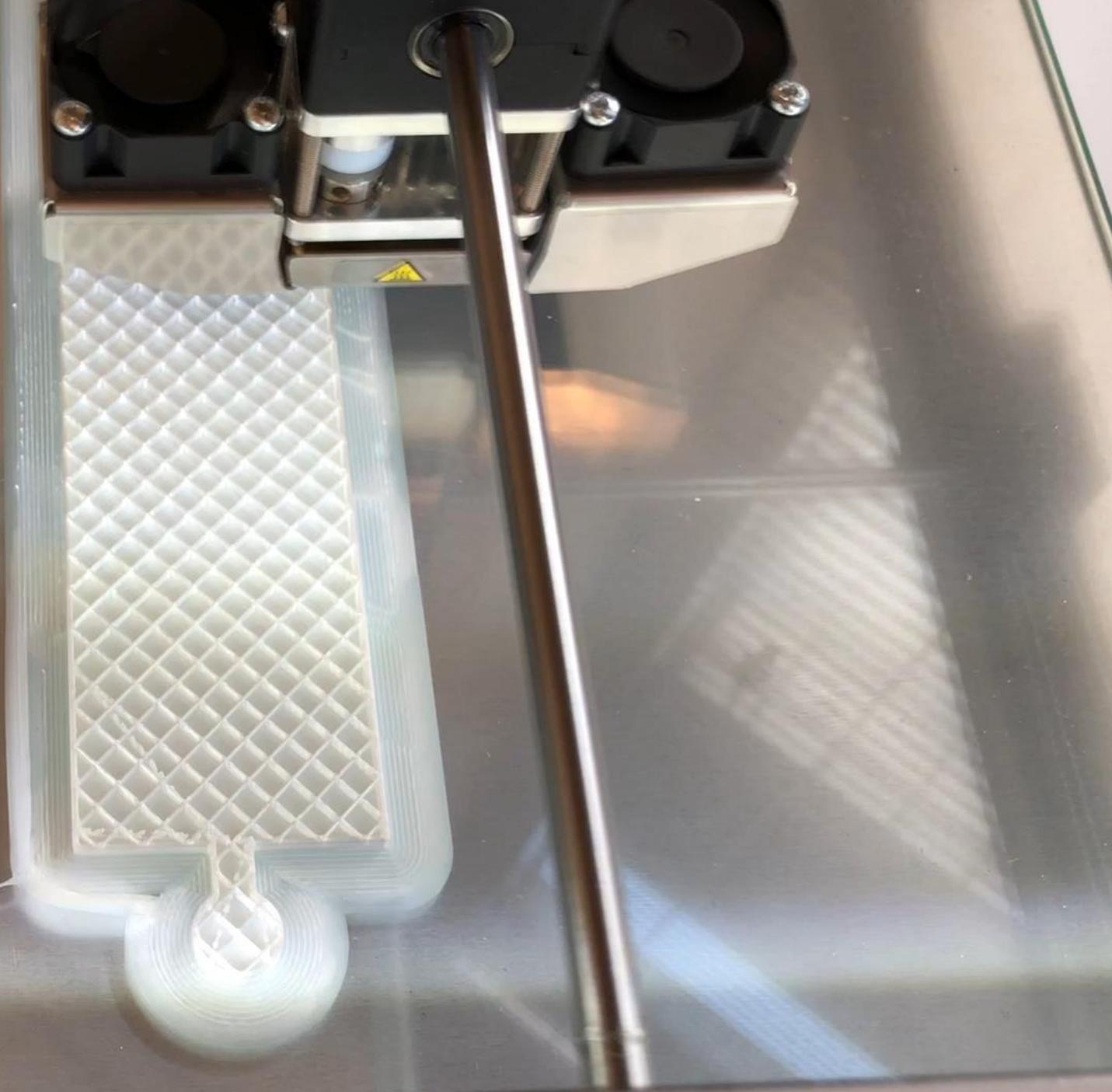


STEP 4: 3D PRINTING

PRINTING ON AN ULTIMAKER 2+

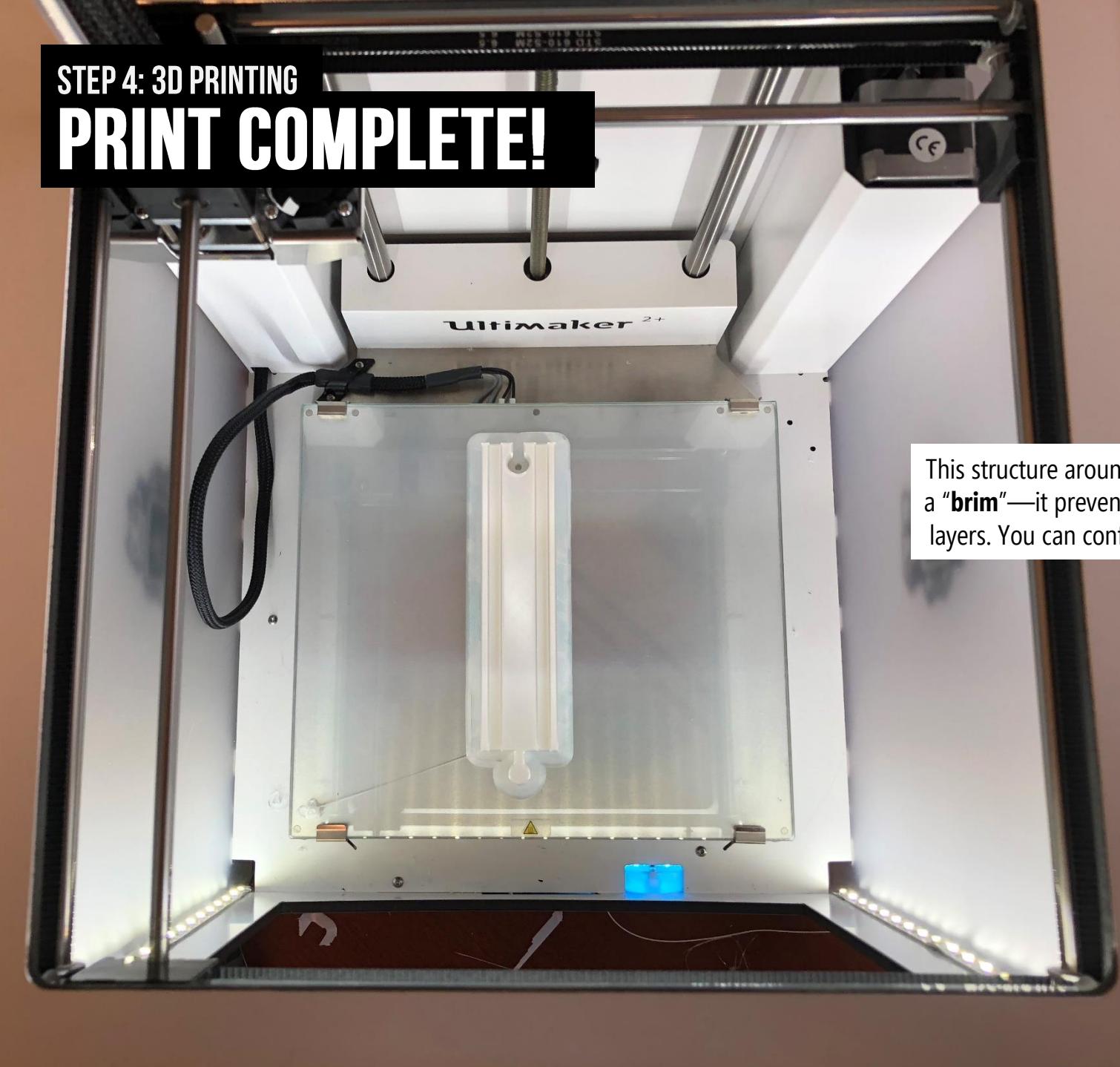


Source: Jon Froehlich



STEP 4: 3D PRINTING

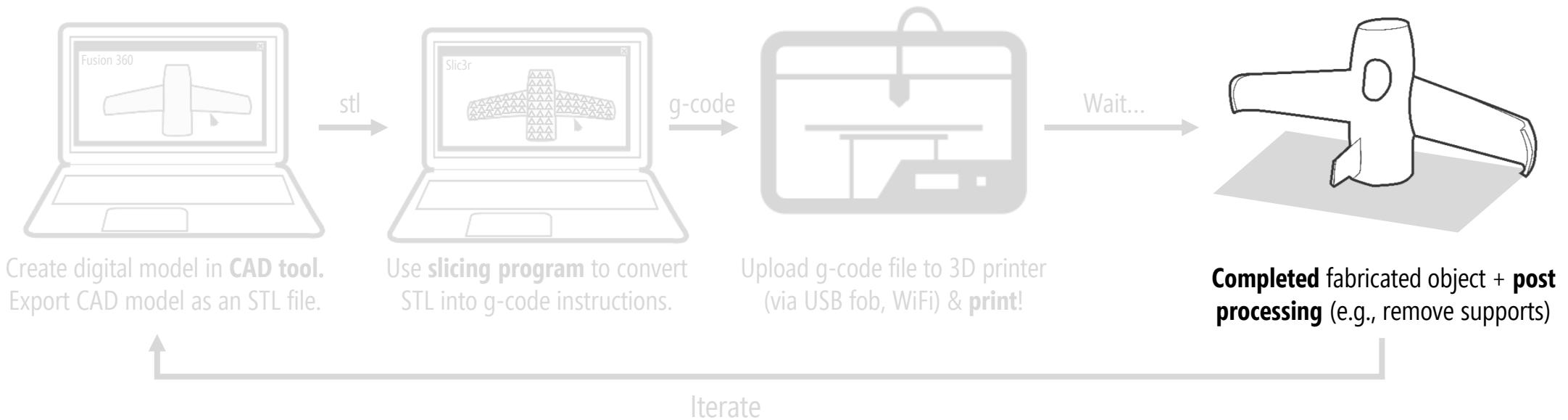
PRINT COMPLETE!



This structure around the 3D-print is called a “**brim**

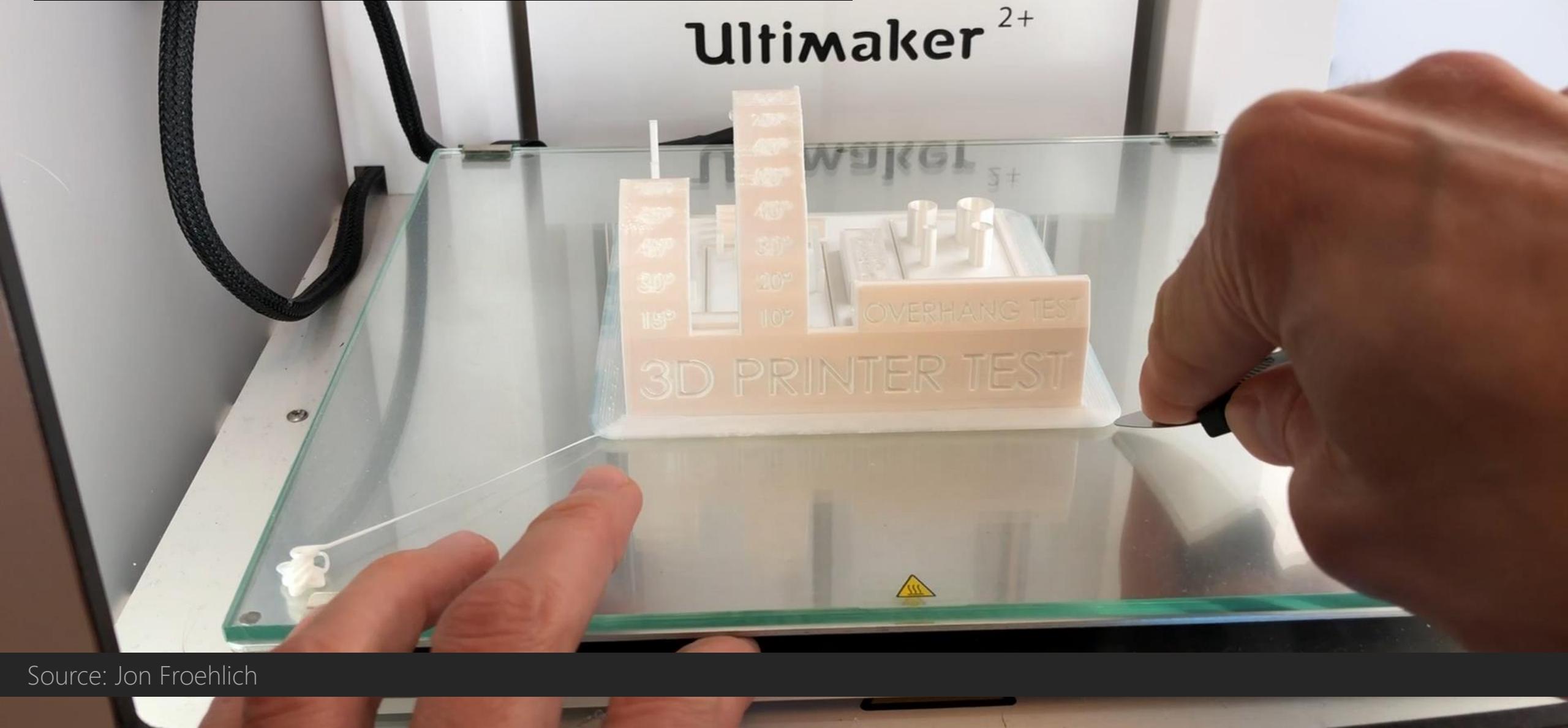


5. TAKE PRINTED OBJECT OFF PLATE + POST-PROCESSING



STEP 5: POST-PROCESSING

REMOVING PRINT FROM PRINT BED



Source: Jon Froehlich

ultimaker²⁺



STEP 7: POST-PROCESSING

POST-PROCESSING TECHNIQUES



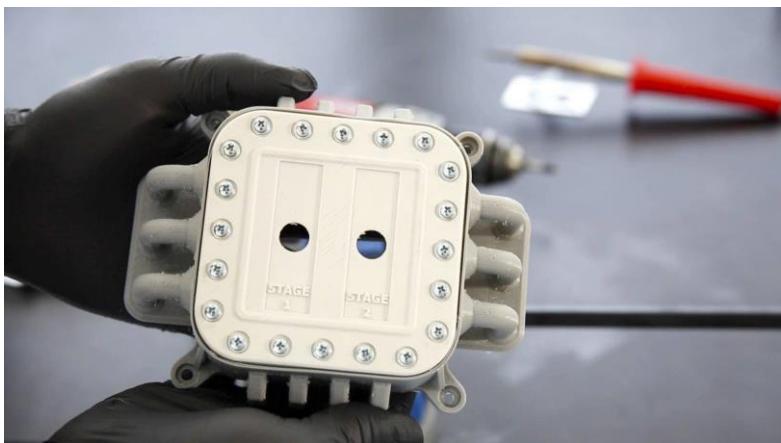
Sanding



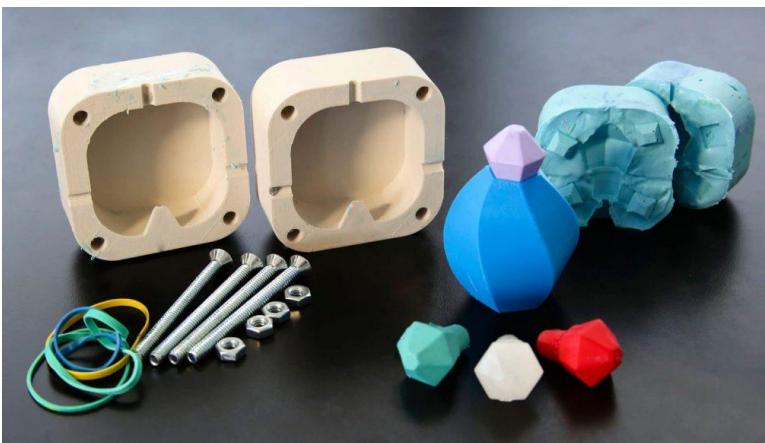
Gluing



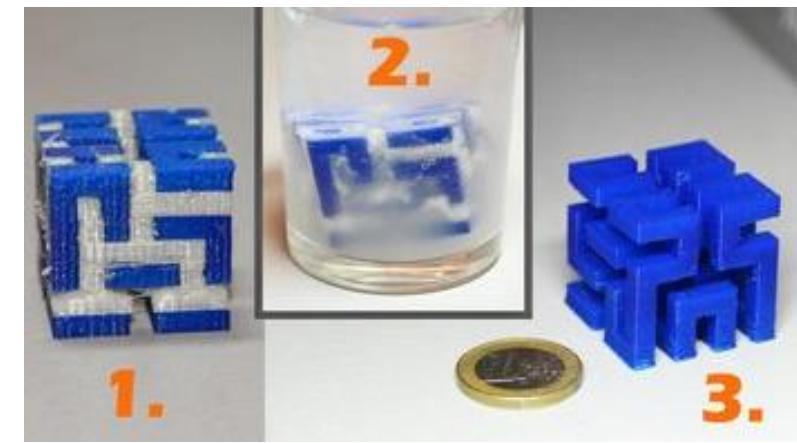
Painting



Inserts



Silicone Molding



Support Removal

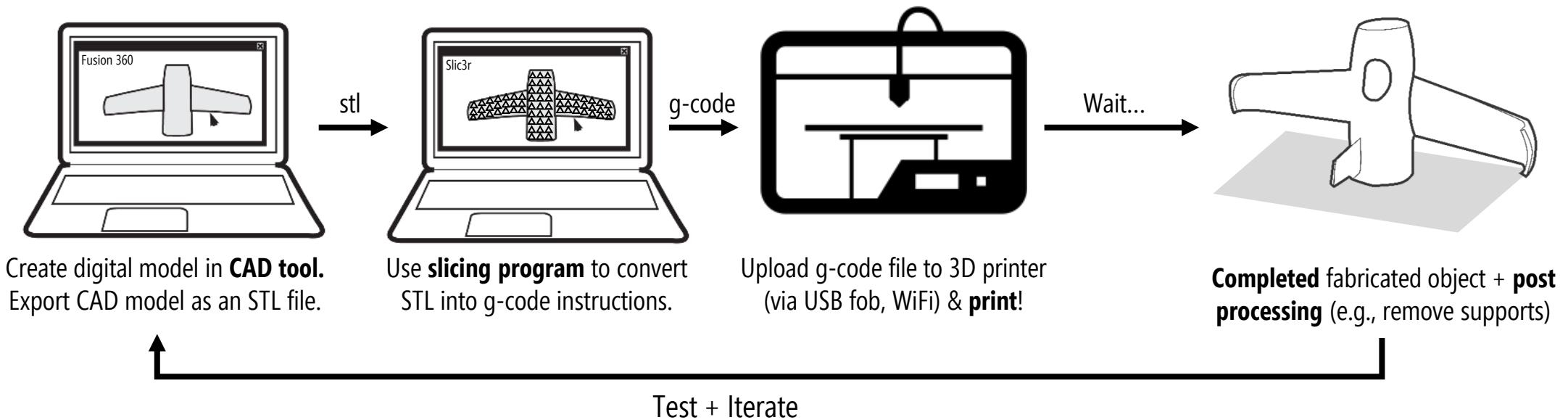
STEP 6: TEST YOUR DESIGNS! 😊

TEST AND ITERATE ON YOUR DESIGNS



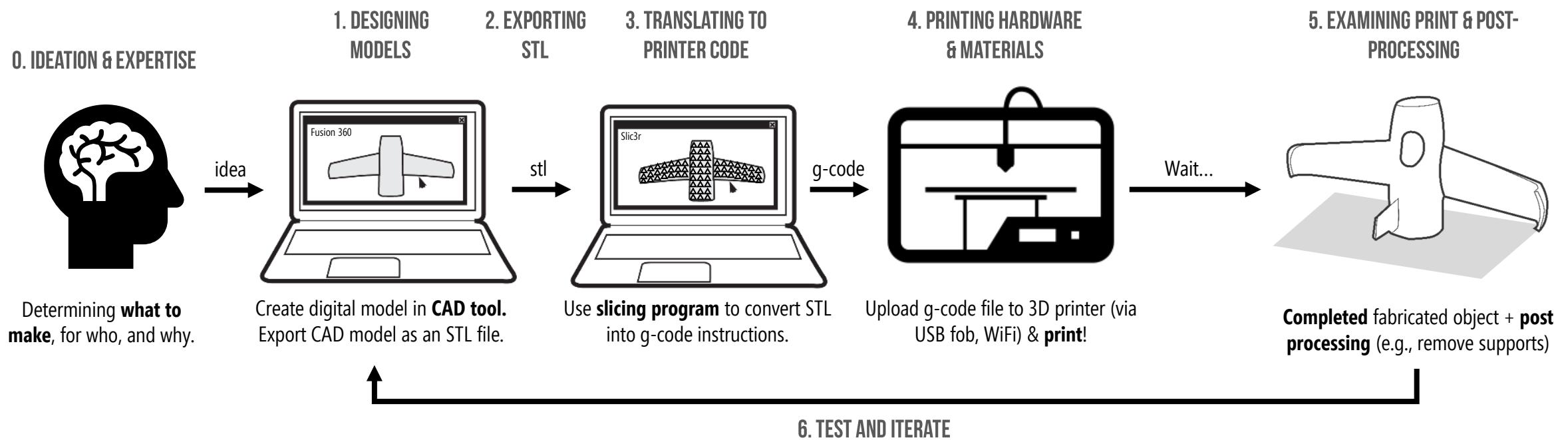


6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING



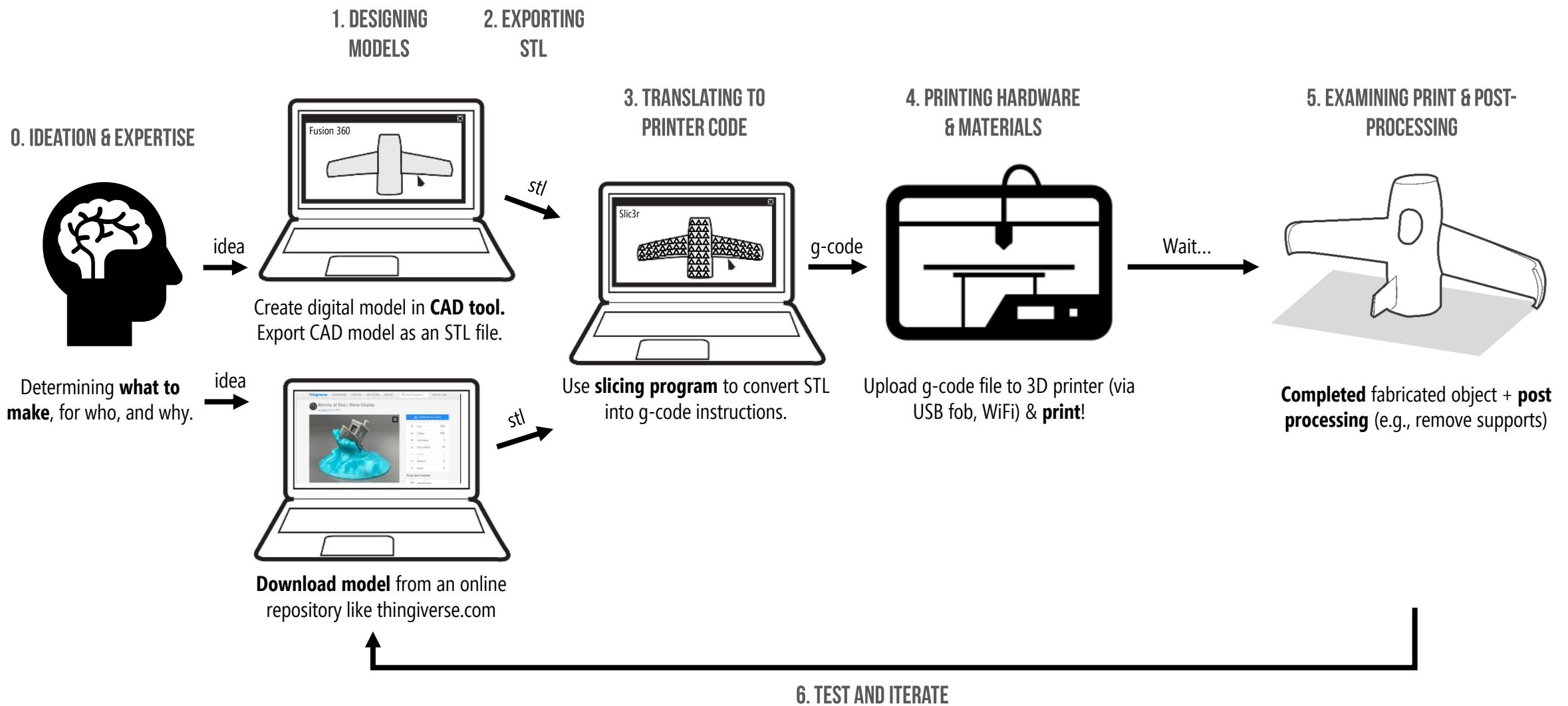
3D-PRINTING PROCESS

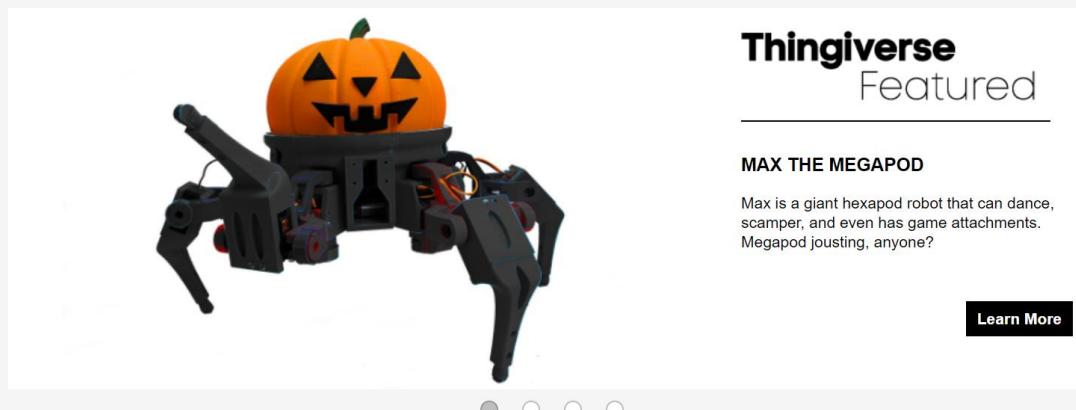
6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING



3D-PRINTING PROCESS

6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING





Thingiverse Featured

MAX THE MEGAPOD

Max is a giant hexapod robot that can dance, scamper, and even has game attachments. Megapod jousting, anyone?

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Global Feed

Latest Thingiverse Activity



Chermansen collected Kanan Jarrus' Lightsaber (Star Wars Rebels)



TanTanDGMT started using Customizer



aronlasvegas2016 collected Gargoyle Sculpture (Statue 3D Scan)



Radioactiv collected PlayStation 3 controller mini wheel



Cinefil001 liked MTB Bicycle helmet hanger hook to keep track of all your bicycle (MTB) helmets



YoDommo collected Lego Ninjago life-size Shuriken

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BOW 9/30-10/6



BOW 9/23-9/29



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BOW 9/2-9/8



BOW 8/26-9/1



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The most recent Things printed by the Thingiverse community



XYZ 20mm Calibration Cube
by Mozy
7 mins ago



Octopus Stand Version Three
by Mozy
8 mins ago



Anycubic i3 Mega Tool Rig
by Sh4d0wF14r3
9 mins ago

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of Makes

star wars

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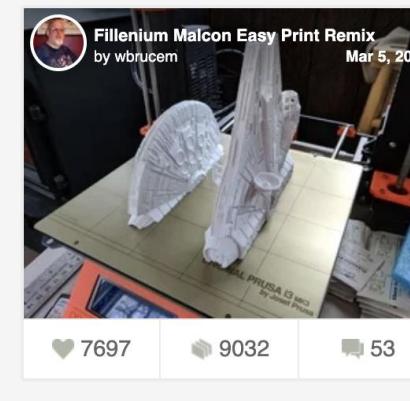
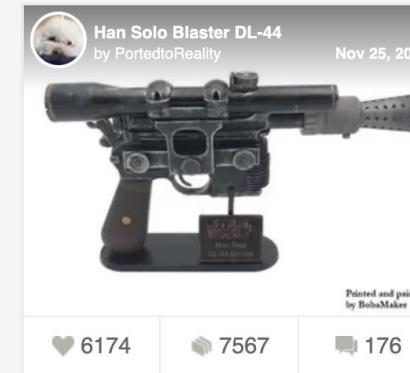
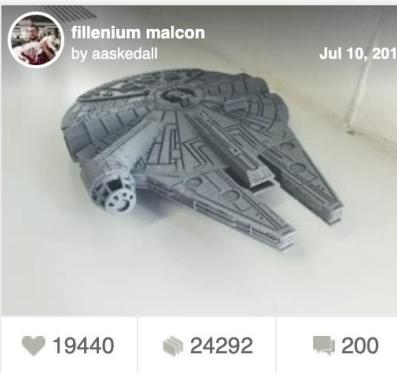
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FOR EDUCATION

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TROUBLESHOOTING

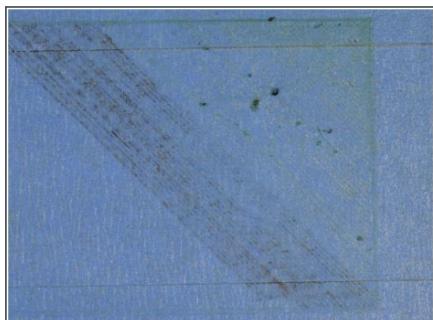


Print Quality Troubleshooting Guide

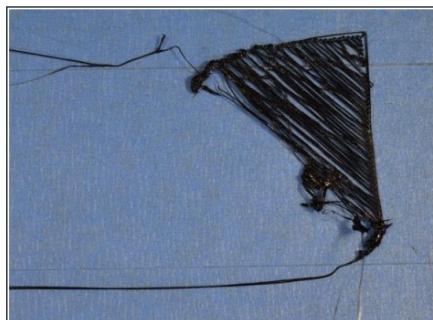
This guide is a great place to start if you are trying to improve the quality of your 3D printed parts. We have compiled an extensive list of the most common 3D printing issues along with the software settings that you can use to solve them. Best of all, the guide uses a large collection of real-world images to make each issue easy to identify when examining your own 3D printed parts. So let's get started!

Thumbnail Overview

Use the thumbnails below to identify the picture that most closely represents the quality issue that you are seeing in your own 3D printed parts. You can click on the thumbnail to jump to that portion of the guide for immediate recommendations on how to resolve the issue. If you are not able to locate your issues from the thumbnails, feel free to scroll down and read through each section of the guide in more detail. There are plenty of useful tips to learn that can help improve your 3D printed results!

**Not Extruding At Start**

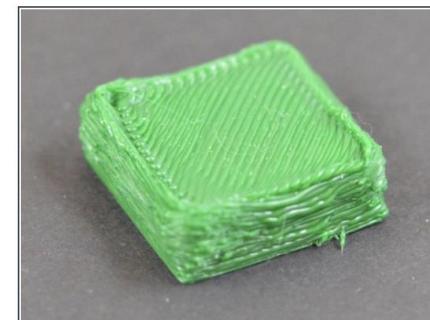
Printer does not extrude plastic at the beginning of the print

**Not Sticking To Bed**

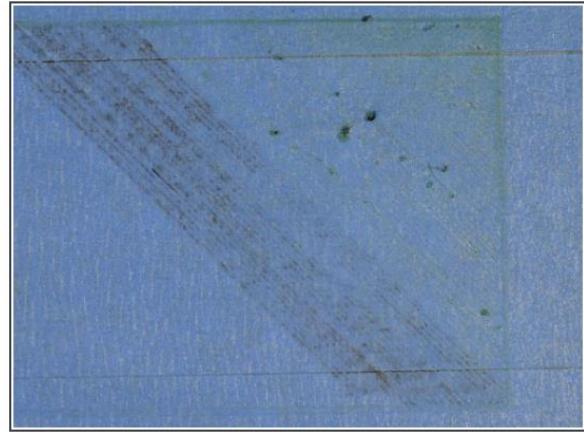
The first layer does not stick to the bed and the print quickly fails

**Under-Extrusion**

Printer does not extrude enough plastic, gaps between perimeters and infill

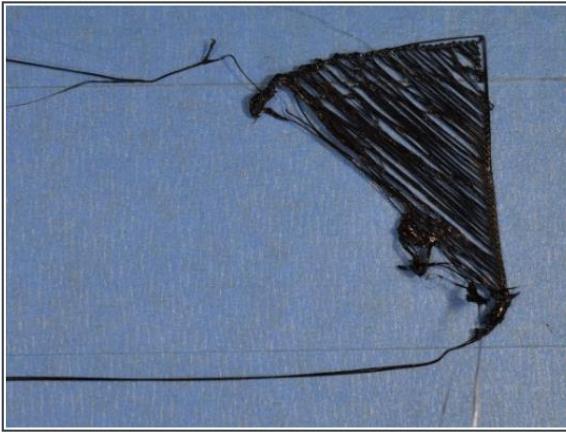
**Over-Extrusion**

Printer extrudes too much plastic, prints looks very messy



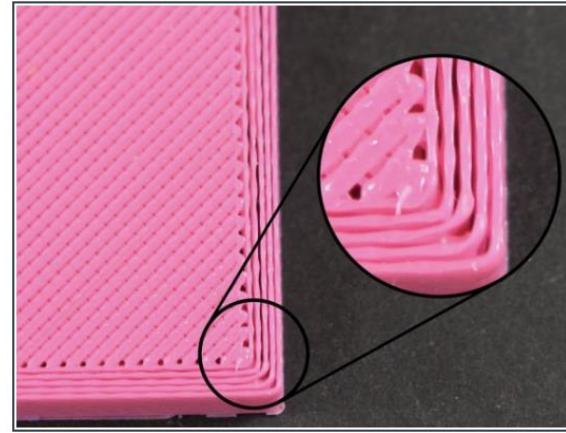
Not Extruding At Start

Printer does not extrude plastic at the beginning of the print



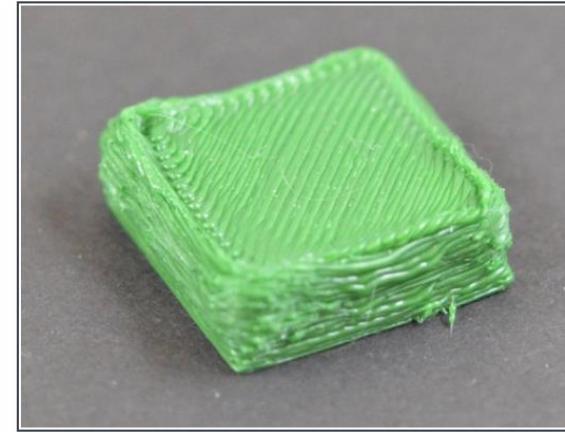
Not Sticking To Bed

The first layer does not stick to the bed and the print quickly fails



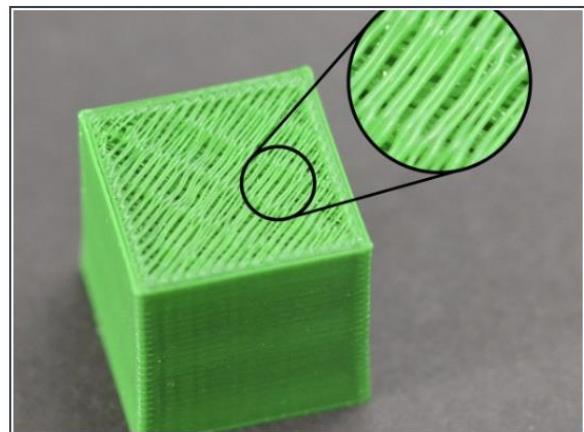
Under-Extrusion

Printer does not extrude enough plastic, gaps between perimeters and infill



Over-Extrusion

Printer extrudes too much plastic, prints looks very messy



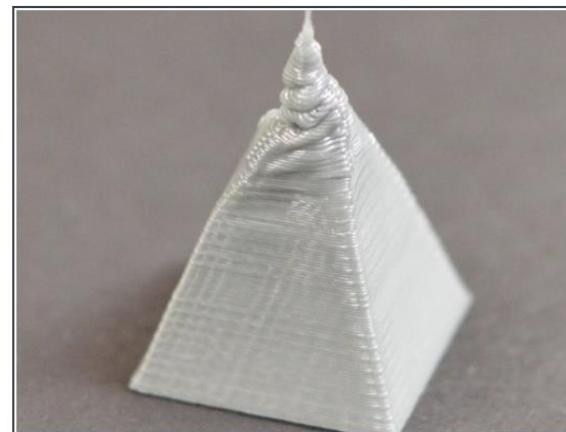
Gaps in Top Layers

Holes or gaps in the top layers of the print



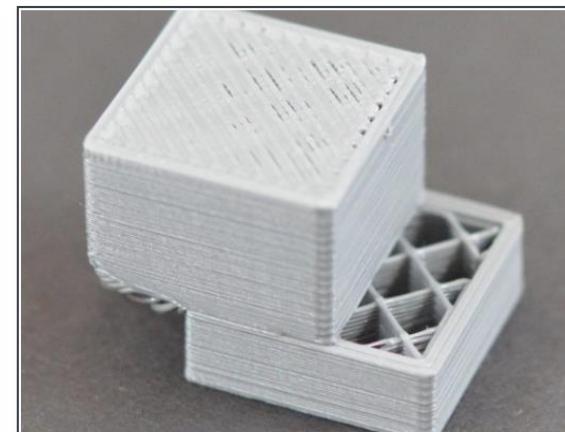
Stringing or Oozing

Lots of strings and hairs left behind when moving between different sections of the print



Overheating

Small features become overheated and deformed



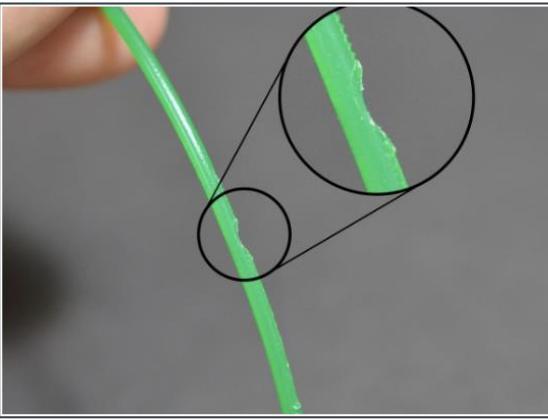
Layer Shifting

Layers are misaligned and shift relative to one another



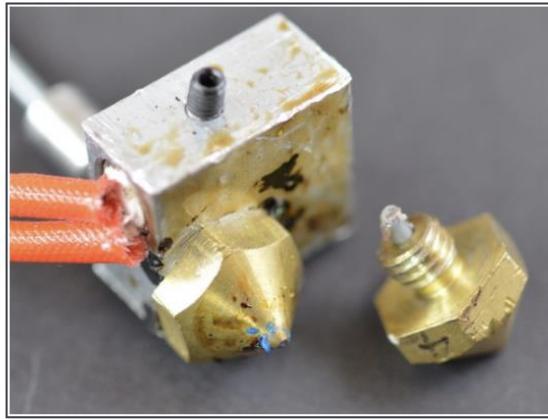
Layer Separation and Splitting

Layers are separating and splitting apart while printing



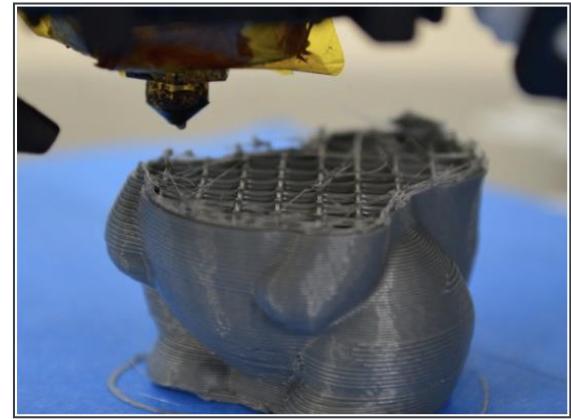
Grinding Filament

Plastic is being ground away until the filament no longer moves, otherwise known as "stripped" filament



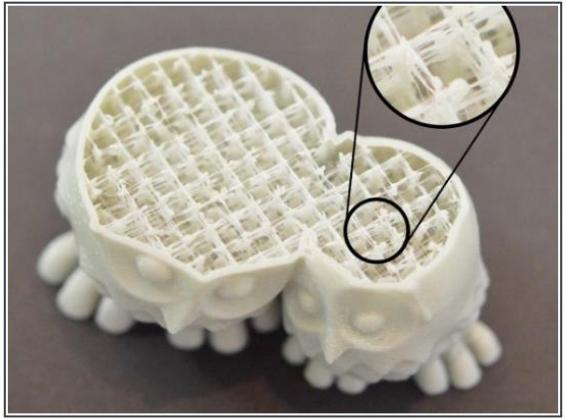
Clogged Extruder

Extruder is clogged or jammed and will no longer extrude plastic from the nozzle tip



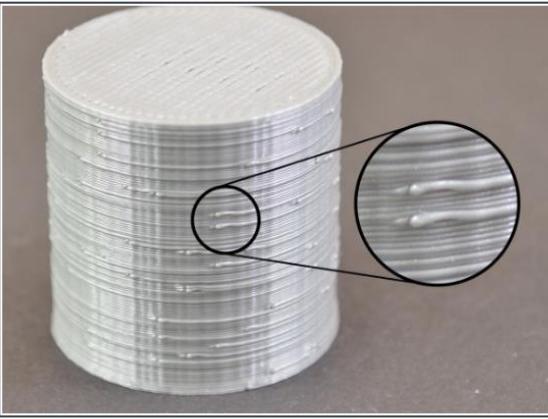
Stops Extruding Mid Print

Printer stops extruding plastic randomly in the middle of a print



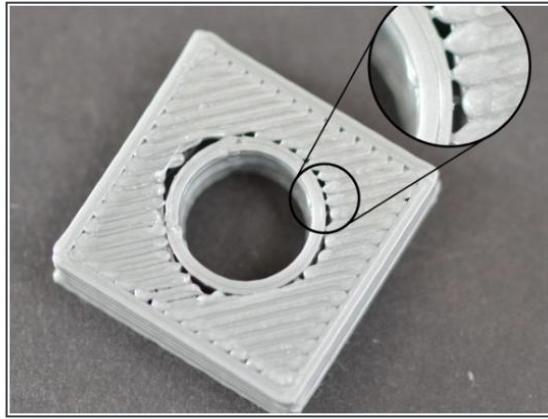
Weak Infill

Very thin, stringy infill that creates a weak interior and does not bond together well



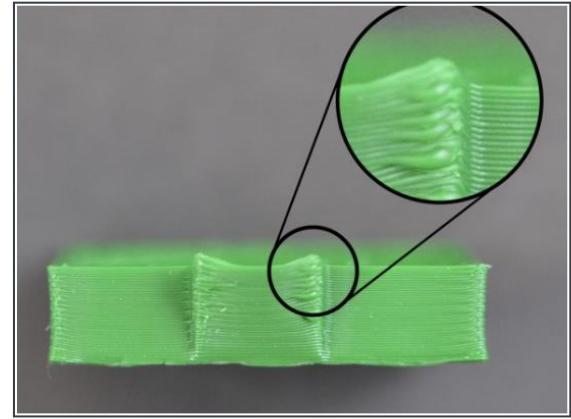
Blobs and Zits

Small blobs on the surface of print, otherwise known as zits



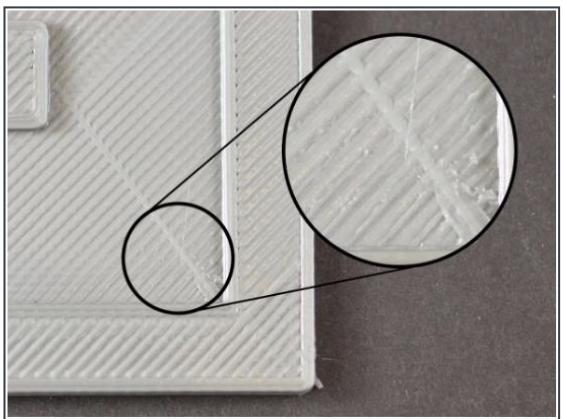
Gaps Between Infill and Outline

Gaps between the outline of the part and the outer solid infill layers



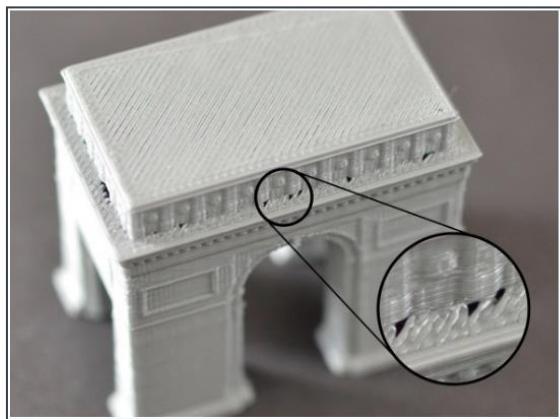
Curling or Rough Corners

Corners of the print tend to curl and deform after they are printed



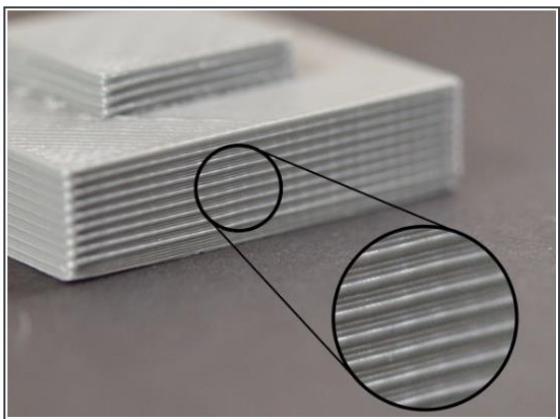
Scars on Top Surface

The nozzle drags across the top of the print and creates a scar on the surface



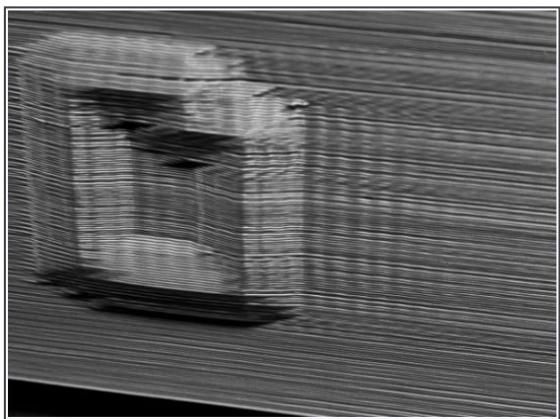
Gaps in Floor Corners

Gaps in the corners of the print, where the top layer does not join to the outline of the next layer



Lines on the Side of Print

Side walls are not smooth, lines are visible on the side of the print



Vibrations and Ringing

Vibrations that cause oscillations on the surface of the print, otherwise known as "ringing"



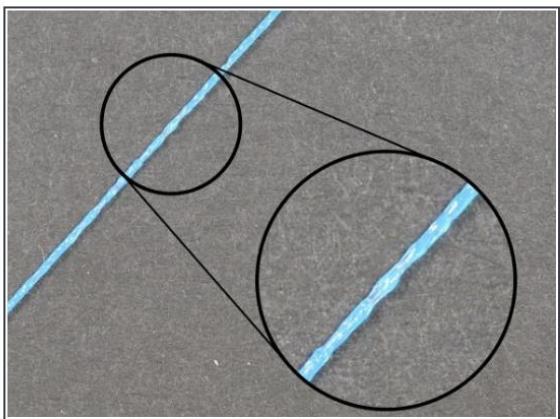
Gaps in Thin Walls

Gaps between thin walls of the print where the perimeters do not touch



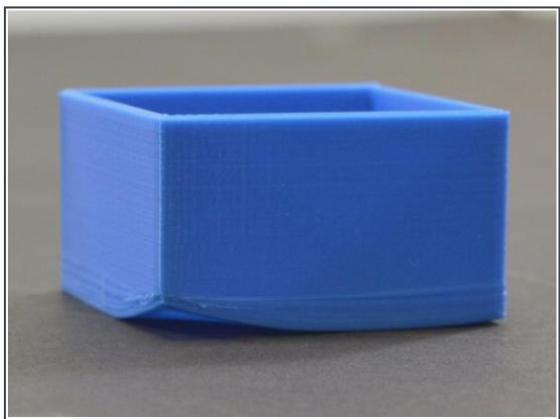
Small Features Not Printed

Very small features are not printed or are missing from the software preview



Inconsistent Extrusion

Extrusion amount tends to vary and is not consistent enough to produce an accurate shape

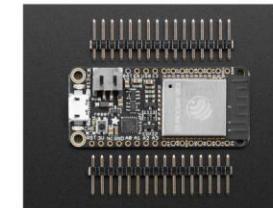


Warping

Warping of large parts, particularly with high temperature materials such as ABS



Explore & Learn



Adafruit HUZZAH32 - ESP32 Feather

WiFi, Bluetooth, peripherals
galore!

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INTERNET OF THINGS - IOT / BLUEFRUIT / BLE



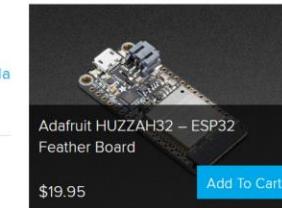
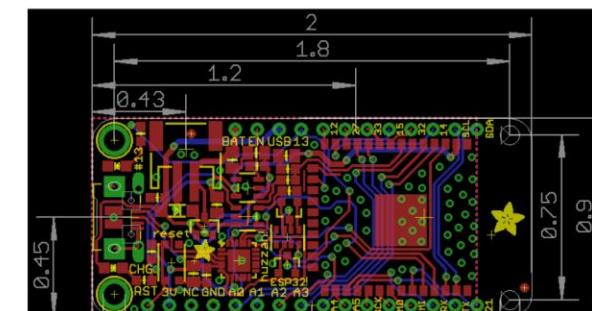
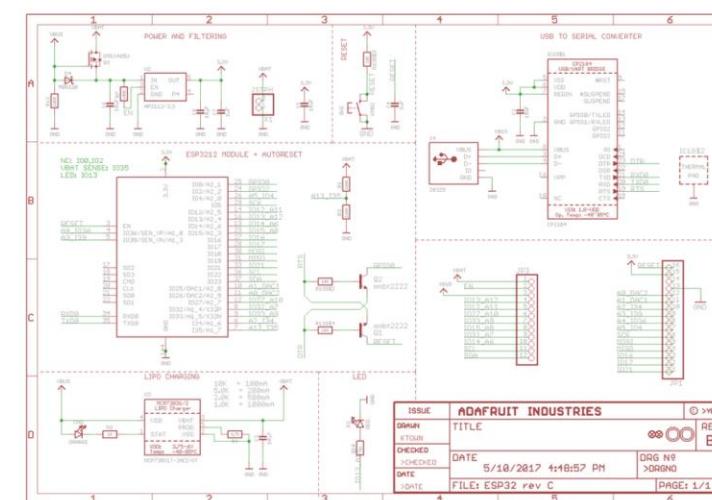
Downloads

by lady ada

Files

- [ESP32 WROOM32 Datasheet](#)
- [ESP32 Technical Manual](#)
- [Don't forget to visit esp32.com for the latest and greatest in ESP32 news, software and gossip!](#)
- [EagleCAD PCB files on github](#)
- [Fritzing object in the Adafruit Fritzing library](#)

Schematic and Fabrication print



Adafruit HUZZAH32 – ESP32
Feather Board

\$19.95

Add To Cart



Lithium Ion Polymer Battery - 3.7v
500mAh

Out Of Stock



Lithium Ion Polymer Battery - 3.7v
1200mAh

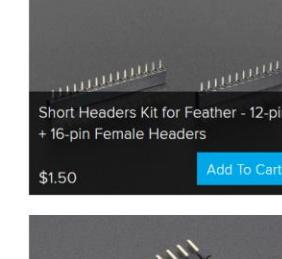
Out Of Stock



Stacking Headers for Feather - 12-pin
and 16-pin female headers

\$1.25

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Short Headers Kit for Feather - 12-pin
+ 16-pin Female Headers

\$1.50

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adafruit/Adafruit-HUZZAH32-ESP32-Feather-PCB

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Code Issues 0 Pull requests 0 Actions Projects 0 Security Insights

PCB files for the Adafruit HUZZAH32 ESP32 Feather

4 commits 1 branch 0 releases 2 contributors View license

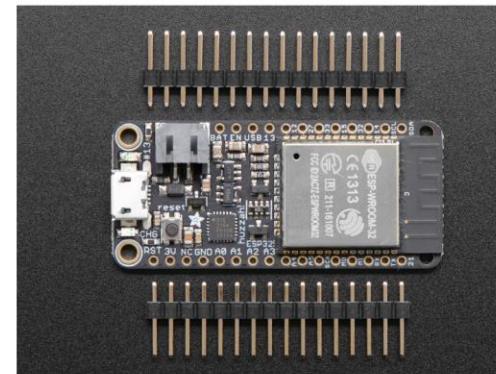
Branch: master New pull request Create new file Upload files Find file Clone or download

TheKitty Update README.md Latest commit 4d9d4c7 on Jun 28

	Add files via upload	4 months ago
assets	w00t	3 years ago
Adafruit HUZZAH32 ESP32 Feather.brd	w00t	3 years ago
Adafruit HUZZAH32 ESP32 Feather.sch		
README.md	Update README.md	4 months ago
license.txt	Add files via upload	4 months ago

README.md

Adafruit HUZZAH32 ESP32 Feather



Click here to purchase one from the Adafruit shop

PCB files for the Adafruit Feather ESP32 HUZZAH32. Format is EagleCAD schematic and board layout

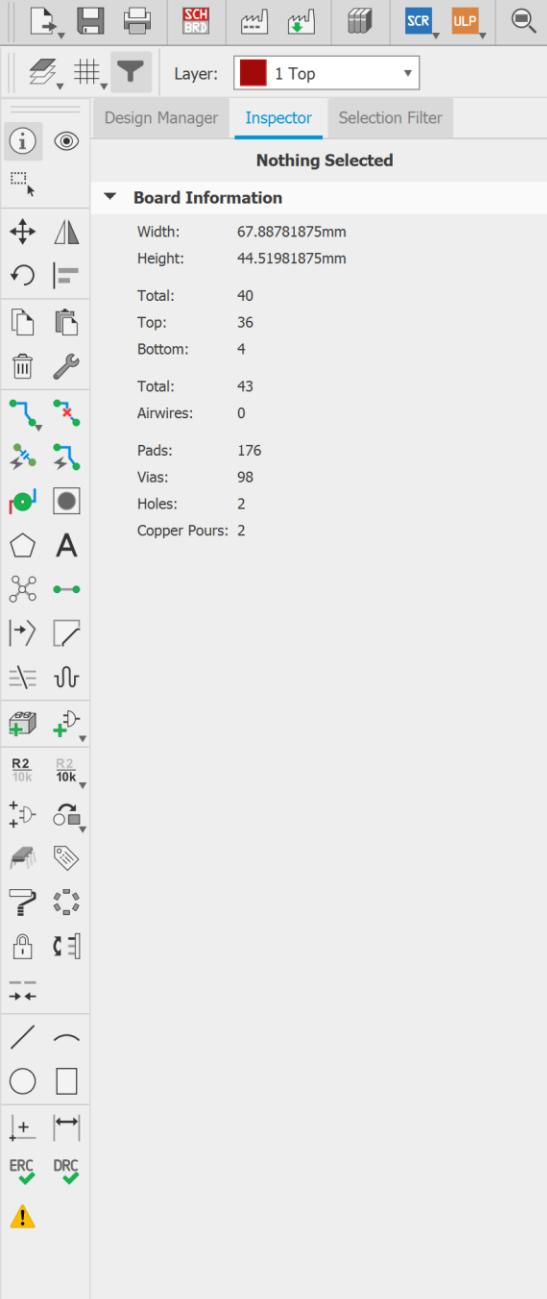
For more details, check out the product page at

- <https://www.adafruit.com/product/3405>

Description

Aww yeah, it's the Feather you have been waiting for! The HUZZAH32 is our ESP32-based Feather, made with the official WROOM32 module. We packed everything you love about Feathers: built in USB-to-Serial converter, automatic bootloader, reset, Lithium Ion/Polymer charger, and just about all of the GPIOs brought out so you can use it with any of our Feather

File Edit Draw View Tools Library Options Window Help



0.0025 inch (-0.4700 1.3700)

50.80

45.72

30.48

10.80

11.43

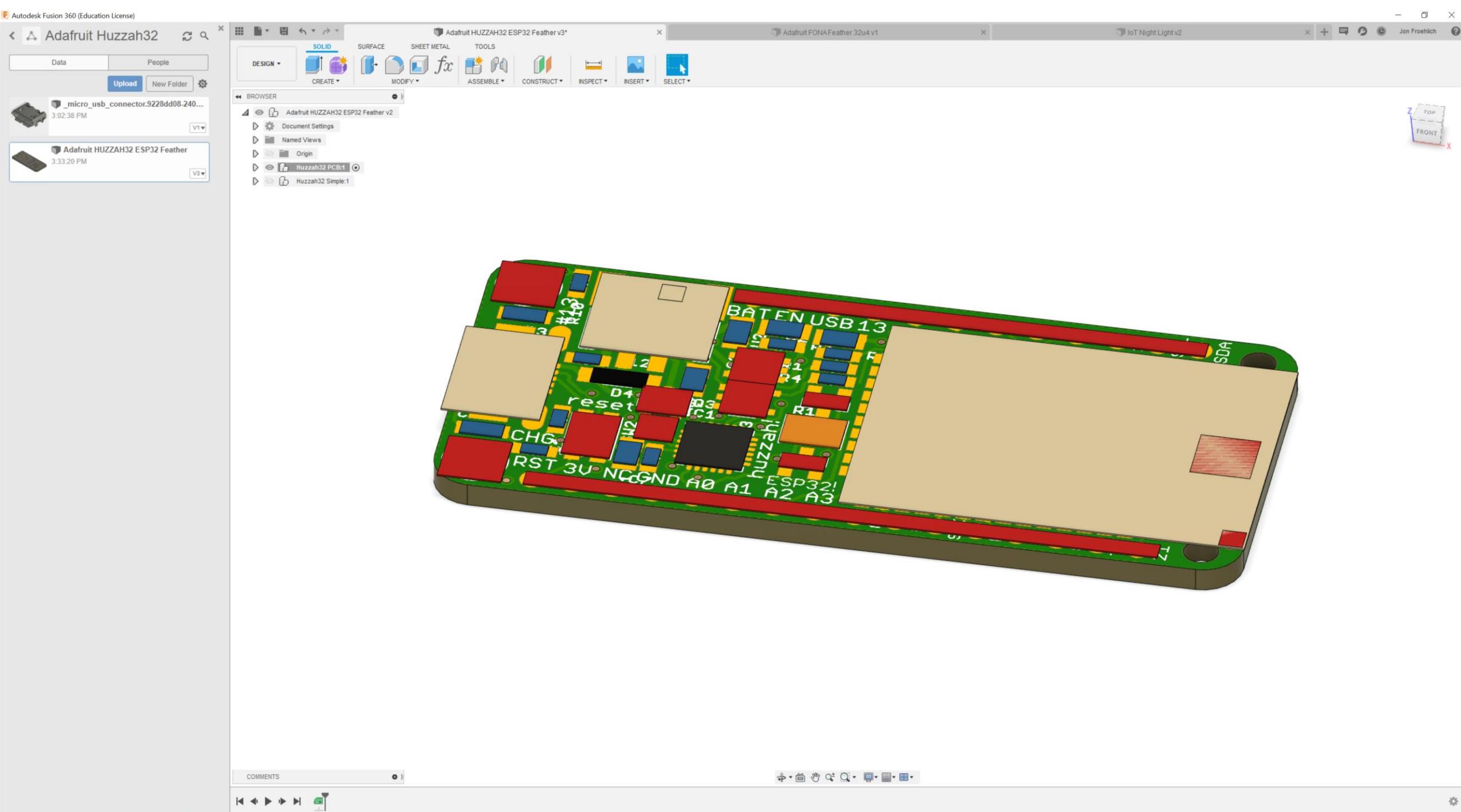
19.05

22.86

2.54

25.40

2.29



Autodesk Fusion 360 (Education License)

IoT Night Light

DATA PEOPLE

Upload New Folder

Huzzah32 Simple 3:42:08 PM V1

Huzzah32 Simple 2 5:24:57 PM V1

IoT Night Light 5:24:30 PM V4

SOLID SURFACE SHEET METAL TOOLS

CREATE MODIFY fx ASSEMBLE CONSTRUCT INSPECT INSERT SELECT POSITION

BROWSER

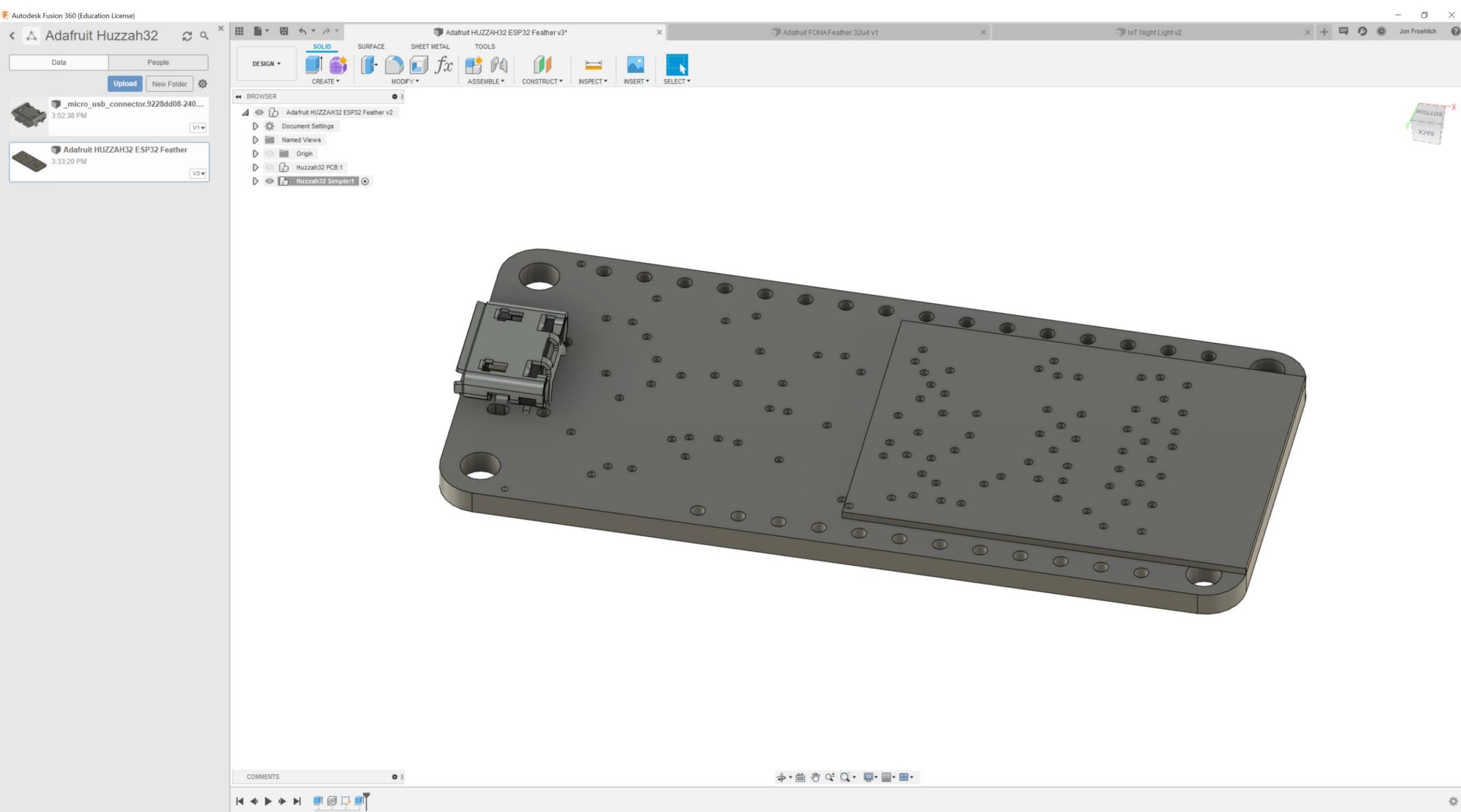
- Adafruit HUZZAH32 ESP32 Feather v5*
- Document Settings
- Named Views
- Origin
- Huzzah32 PCB-1
- Huzzah32 Simple:1
 - Origin
 - Bodies
 - Board
 - ESP32
 - Sketches
 - Sketch1
 - _micro_usb_connector.92...

TOP FRONT X

The image shows a 3D rendering of the Adafruit HUZZAH32 ESP32 Feather v5* IoT Night Light. The PCB is green with various components and labels. It features a USB Type-C port on the left, labeled 'reset' and 'CHG'. On the right, there's a large area with many circular mounting holes. The board is shown from a top-down perspective, slightly angled.

COMMENTS

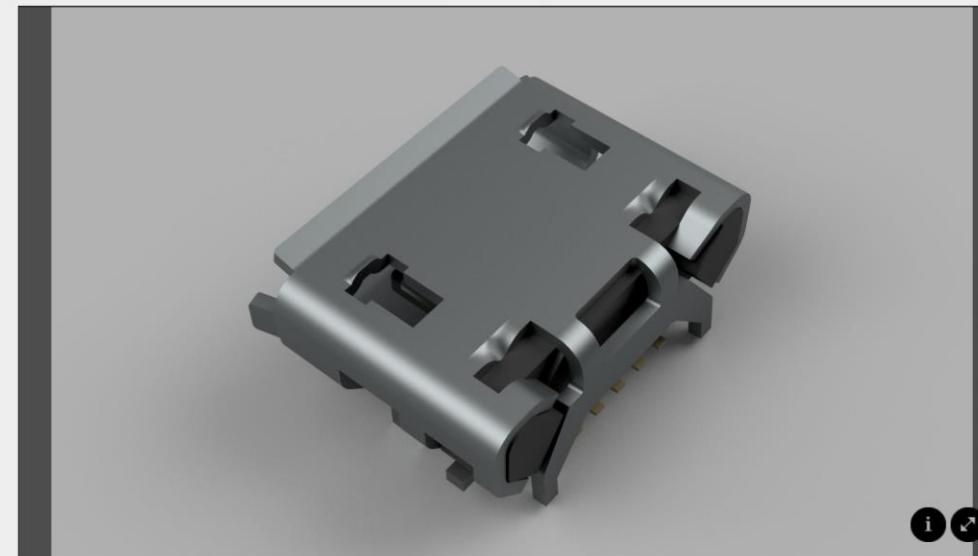
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FEATURED

USB Micro Socket F360 Sheet Metal

9/3/2017



Description

Molex 1013594 USB Micro-B Socket modeled mostly using Fusion 360's sheet metal environment

Comments

Please add your comment...

Add Comment



Great model, thank you.

10 months ago

More from the publisher



Aron Rubin

NJ, UNITED STATES OF AMERICA



OPEN/DOWNLOAD THE MODEL

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_micro_usb_con...f3d 3.55 MB

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Keychain



ACTIVITY

MAKE A 3D-PRINTABLE KEYCHAIN

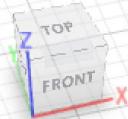
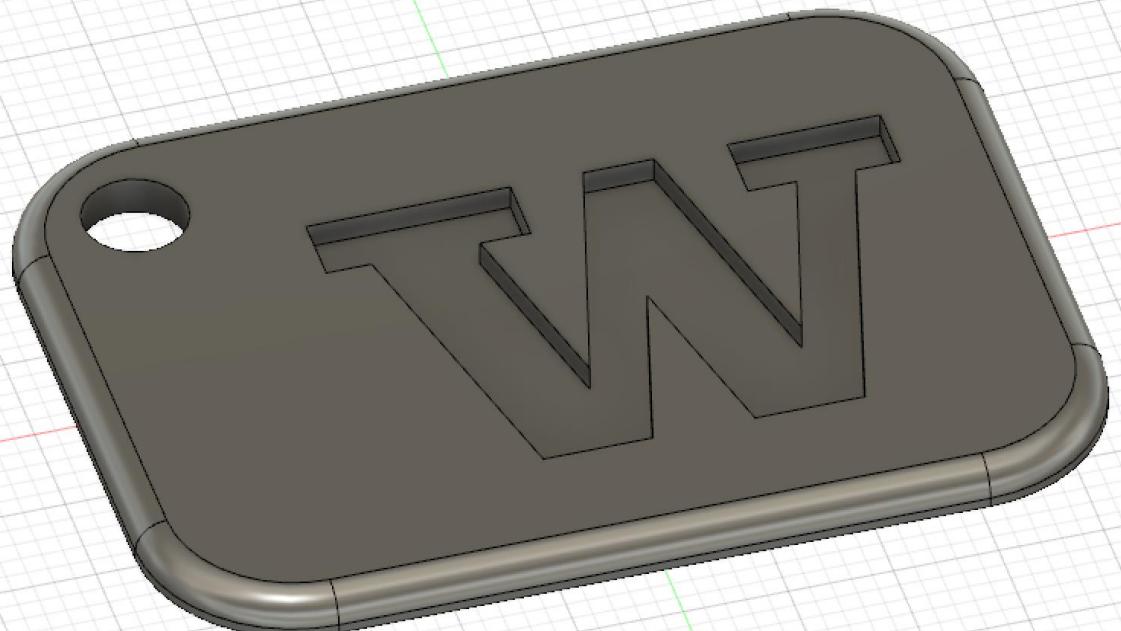


Keychain Playgr... V2



W-Logo_Purple.... V1

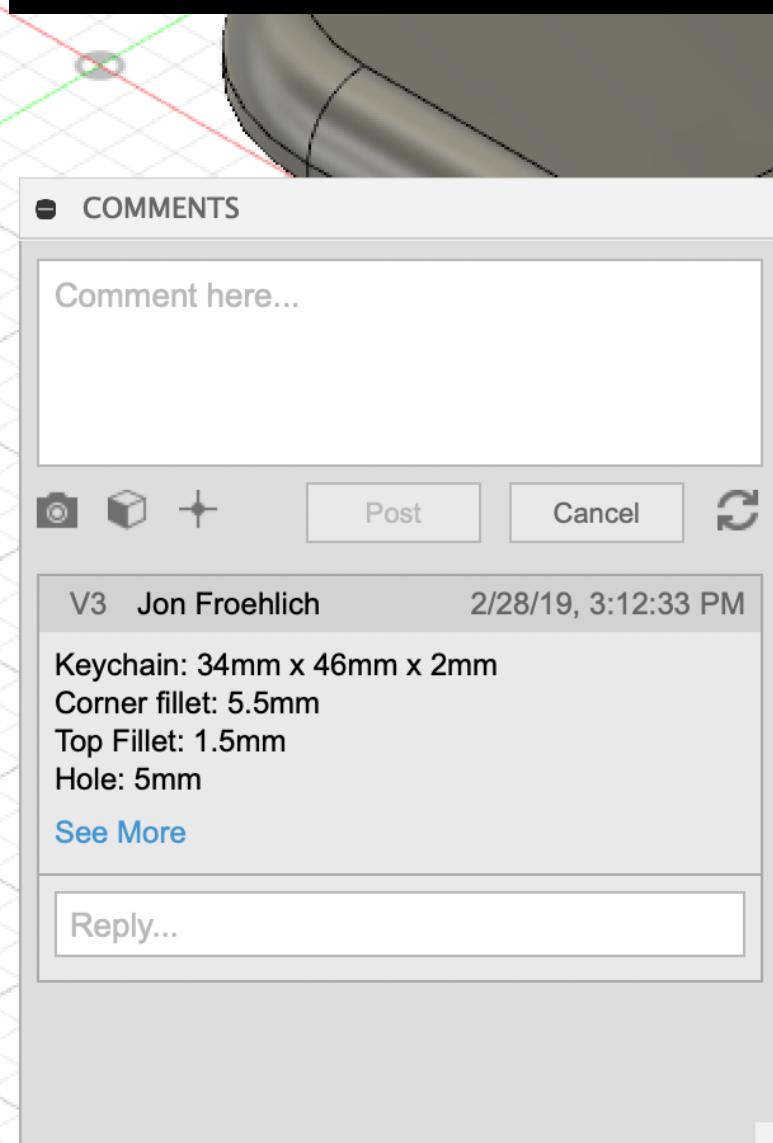
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1 Jon Froehlich

ACTIVITY

MAKE A 3D-PRINTABLE KEYCHAIN



V3 Jon Froehlich

2/28/19, 3:12:33 PM

Keychain: 34mm x 46mm x 2mm

Corner fillet: 5.5mm

Top Fillet: 1.5mm

Hole: 5mm

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ACTIVITY

CONSULT YOUTUBE VIDEO

Making a Simple Keychain in Autodesk Fusion 360

48 views

0:04 / 11:34

04:11:34

CC HD

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Jon Froehlich

Published on Feb 28, 2019

Source: <https://www.youtube.com/watch?v=lbisZCACE9o>

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How **CAD tools + 3D printing** can be used to **rapidly prototype form**

An introduction to two primary 3D printing methods: **SLA** and **FDM**

The **3D printing pipeline**

Modeling designs in **Fusion 360**

What is **slicing** and **what do we use it for**

PROTOTYPING FORM 1: 3D MODELING + PRINTING

CSE 599 Prototyping Interactive Systems | Lecture 7 | Oct 17

Jon Froehlich • Liang He (TA)

