PROTOTYPING FORM: 3D MODELING + PRINTING

CSE 599 Prototyping Interactive Systems | Lecture 7 | April 23

Jon Froehlich • Jasper Tran O'Leary (TA)

DESIGN USE BUILD

MAKEABILITY LAB

PAUL G. ALLEN SCHOOL OF COMPUTER SCIENCE & ENGINEERING

UNIVERSITY of WASHINGTON

LEARNING GOALS

PROTOTYPING WITH CAD MODELING + 3D PRINTING

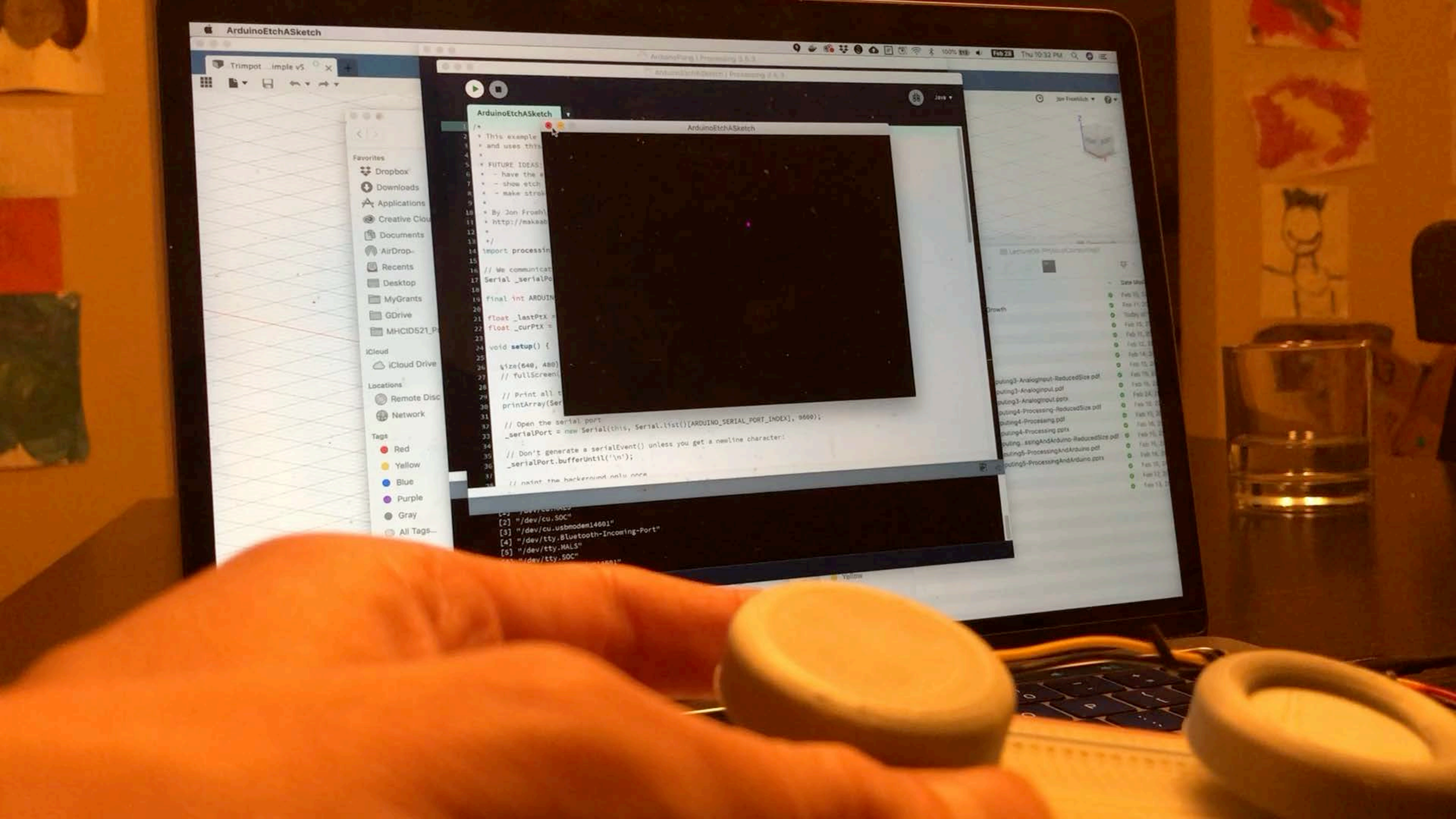
How **CAD tools** + **3D printing** can be used to **rapidly prototype form**

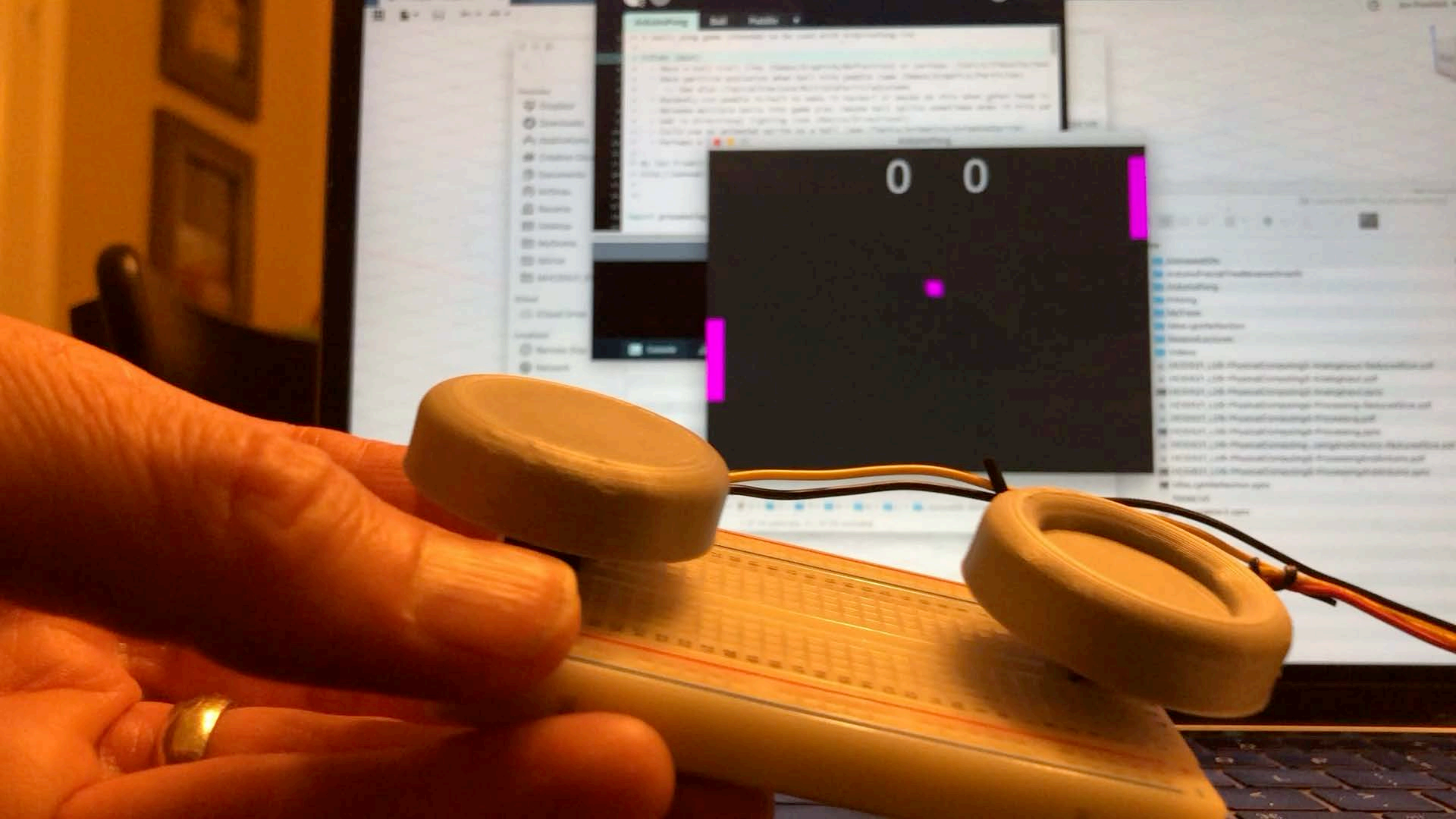
An introduction to two primary 3D printing methods: **SLA** and **FDM**

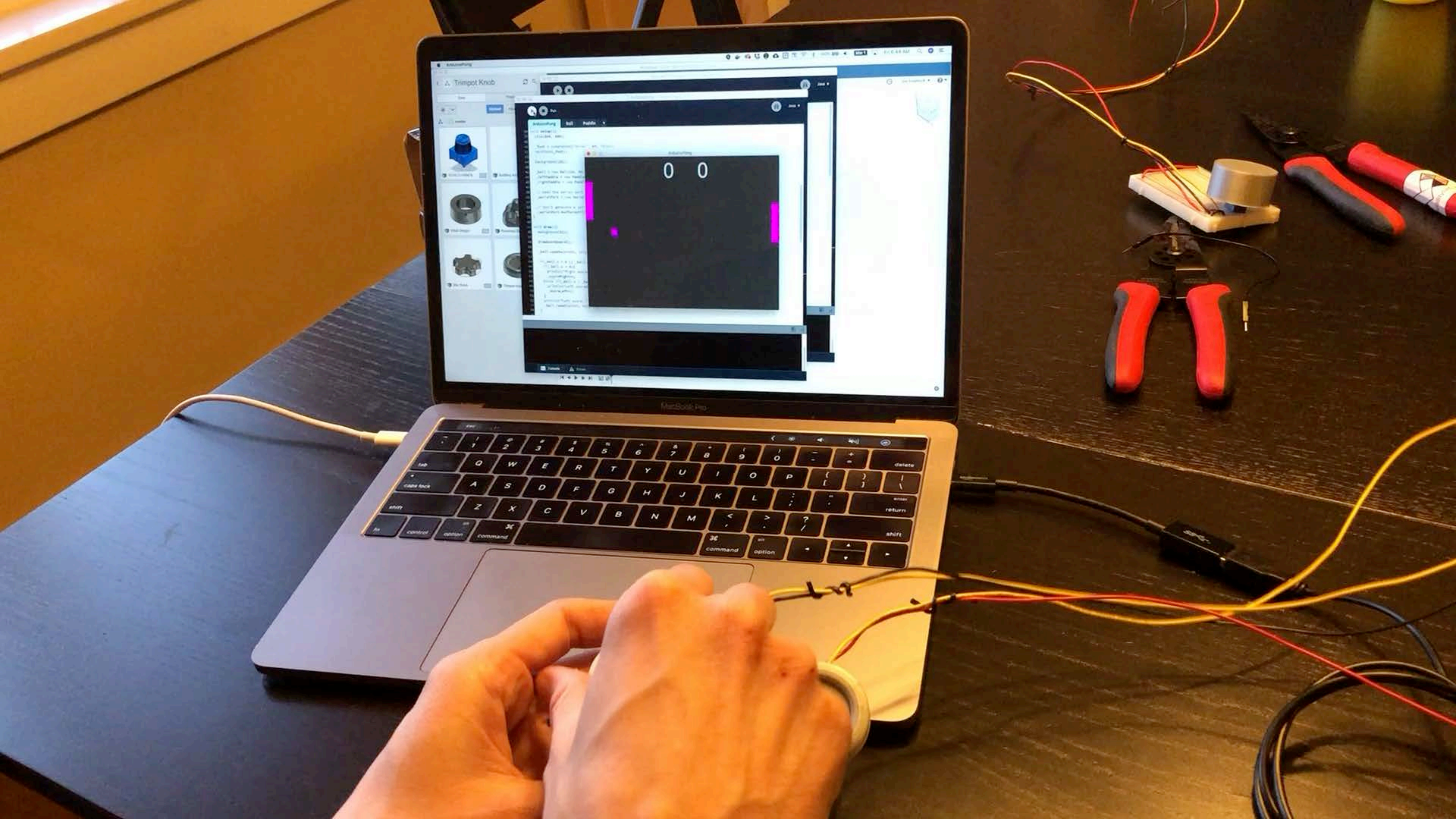
The **3D printing pipeline**

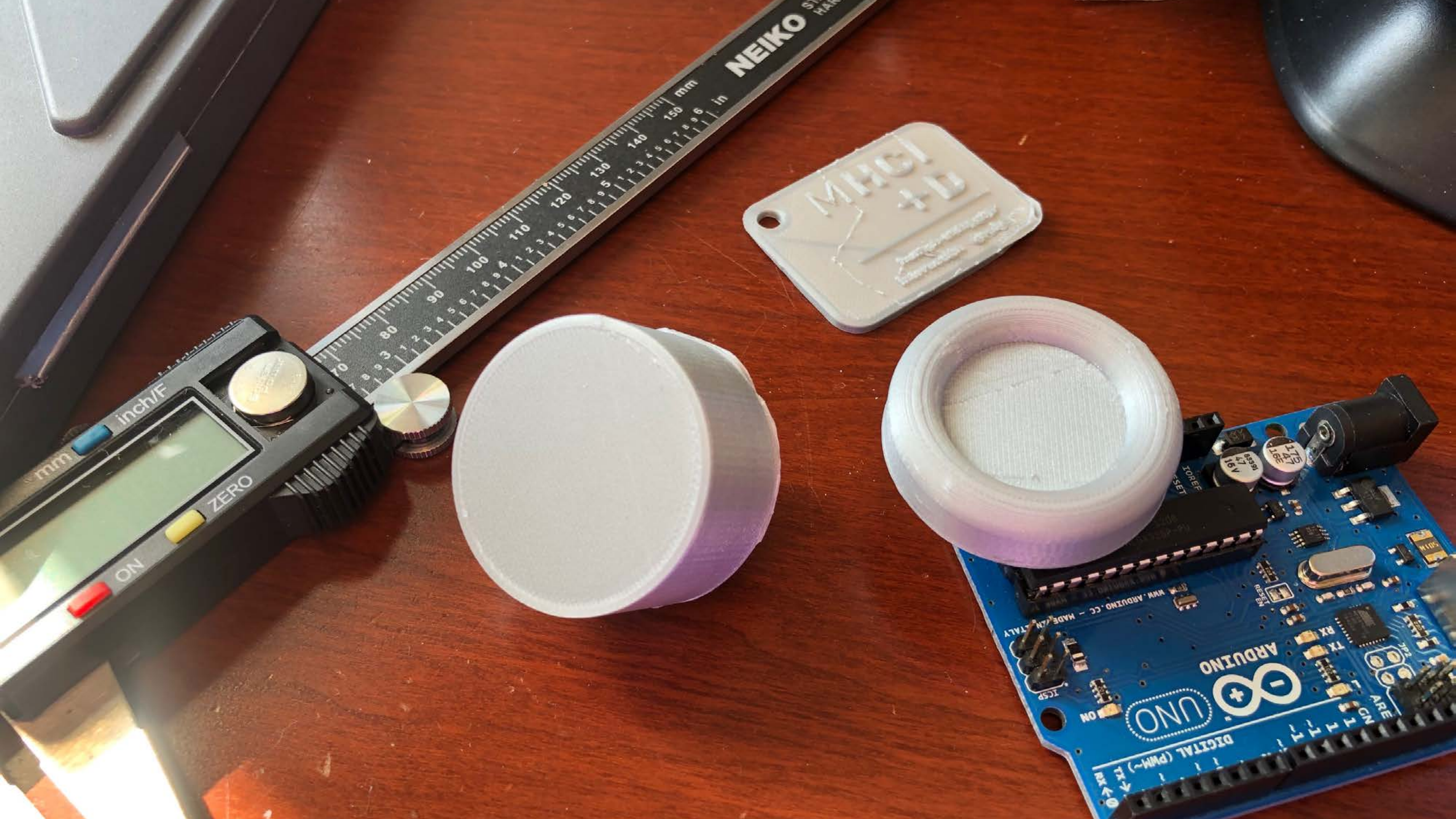
Modeling designs in **Fusion 360**

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


ArduinoEtchASketch
Trimpot ...imple v5
ArduinoEtchASketch
ArduinoEtchASketch
Favorites
Dropbox
Downloads
Applications
Documents
AirDrop
Recents
Desktop
MyGrants
GDrive
iCloud
iCloud Drive
Locations
Remote Disc
Network
Tags
Red
Yellow
Blue
Purple
Gray
All Tags...
// 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');
[2] "/dev/cu.SOC"
[3] "/dev/cu.usbmodem14601"
[4] "/dev/tty.Bluetooth-Incoming-Port"
[5] "/dev/tty.MALS"


0 0


Trimpot Knob
0 0

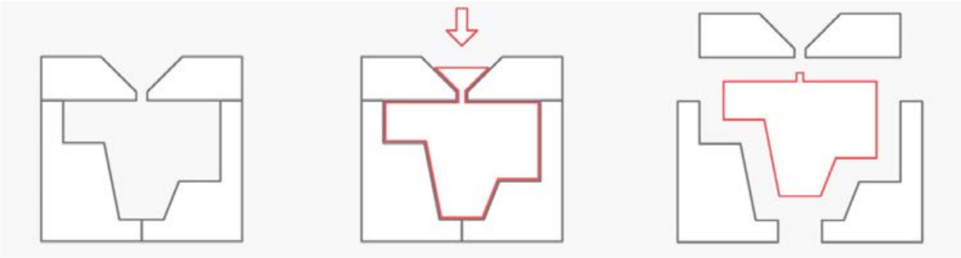

NEIKO
mm
in
inch/F
mm
ZERO
ON
MHCI
+D
ARDUINO
UNO
DIGITAL (PWM~)
WWW.ARDUINO.CC - MADE IN ITALY
RESET
ICSP
TX
RX
ON

3D PRINTING

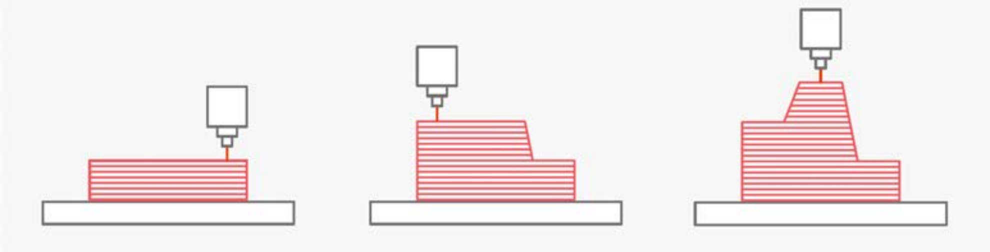
LIVE DEMO: CREATE TRIMPOT-BASED CONTROLLER

BACKGROUND

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.

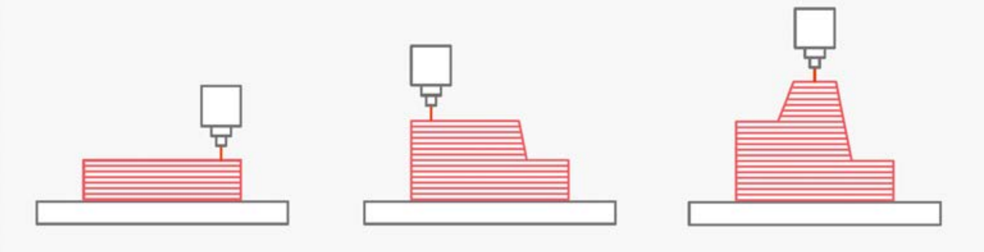
Subtractive manufacturing: lies in between formative and additive, being best suited for parts with relatively simple geometries, produced at low-to-mid volumes, and where materials like wood or metal are necessary

Source: Redwood *et al.,* The 3d Printing Handbook, 2017

BACKGROUND

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

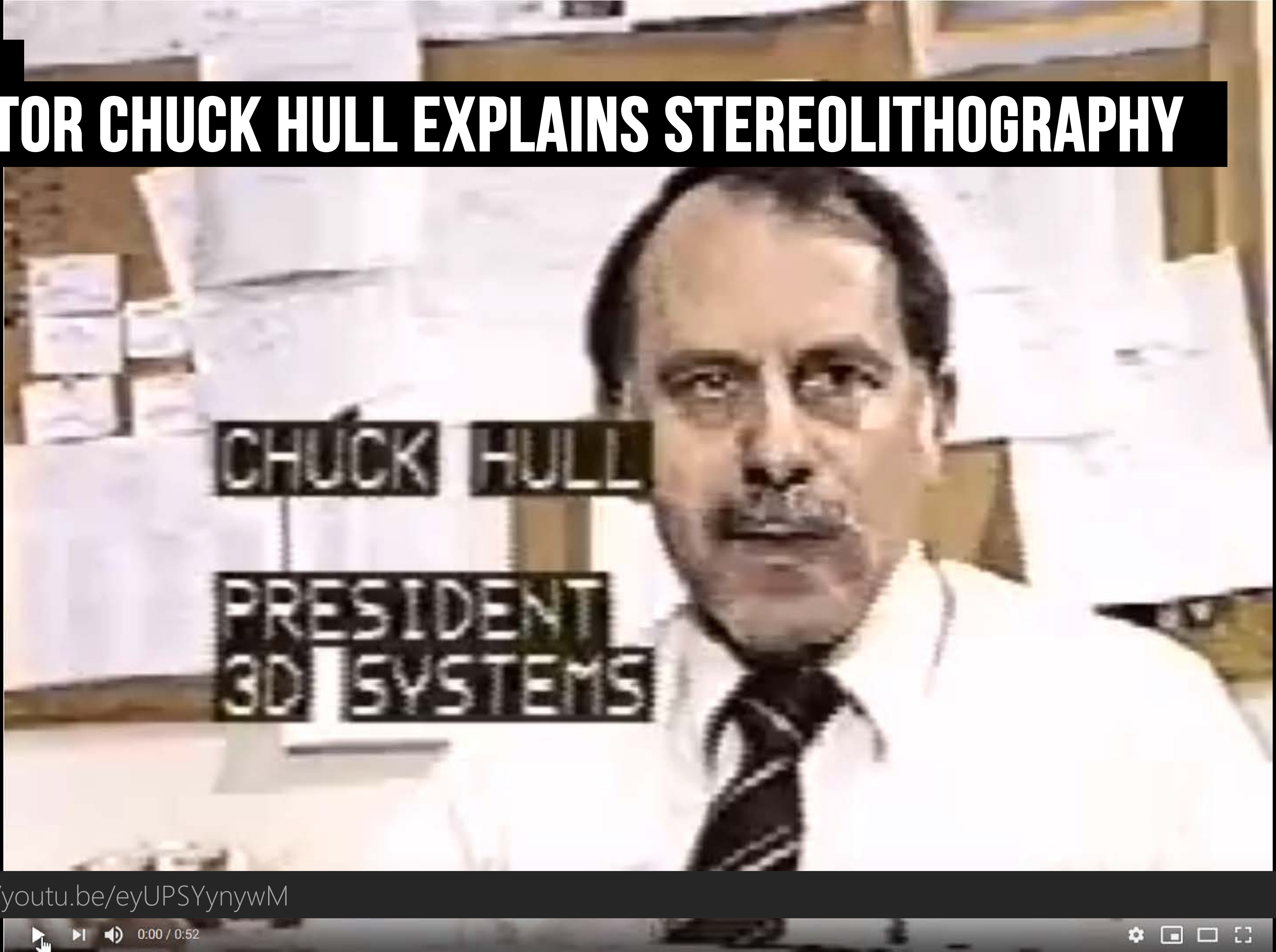
Source: Redwood *et al.,* The 3d Printing Handbook, 2017

1987

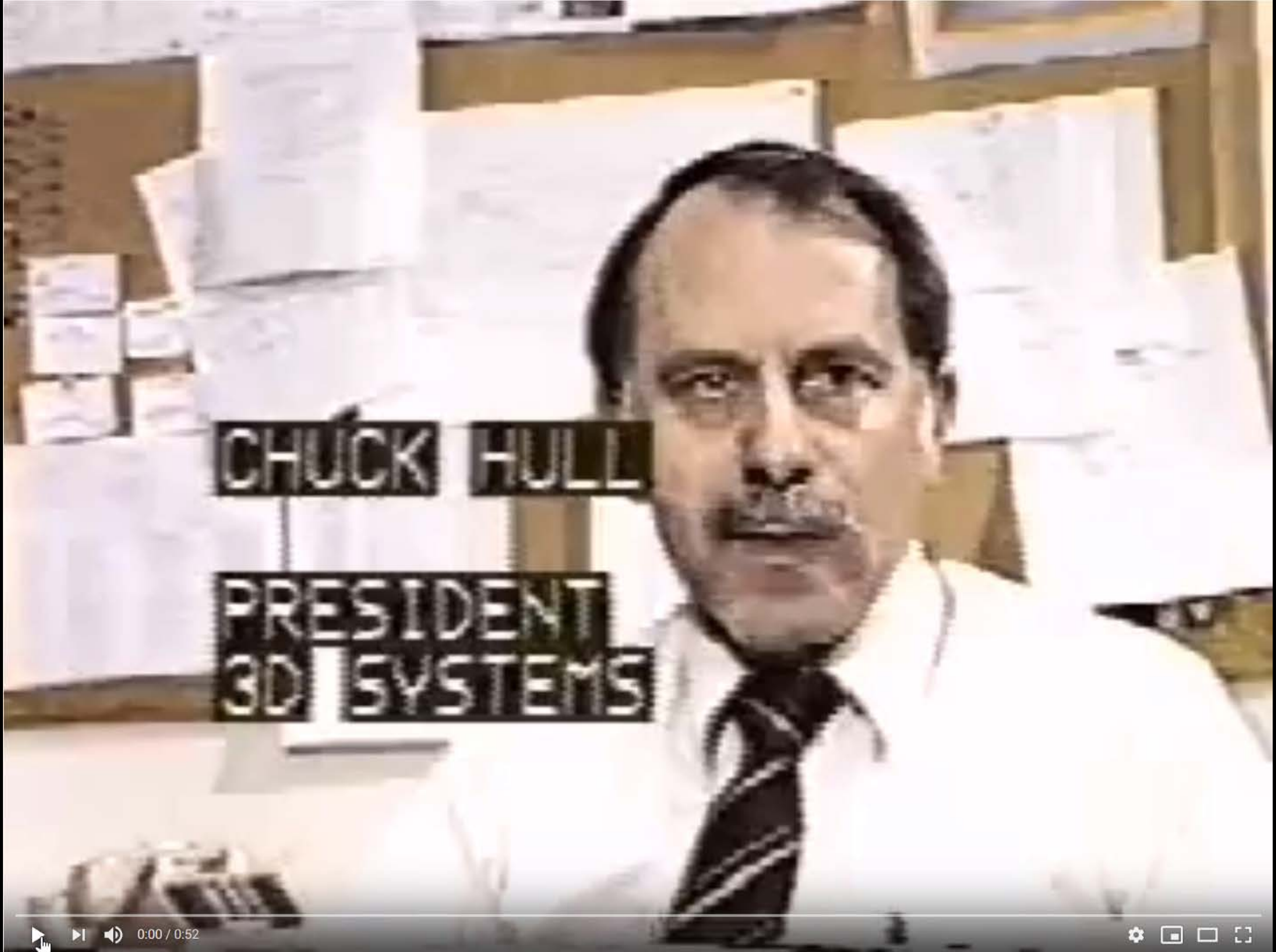
The first commercial 3D printer
SLA-1 printer by 3D Systems Inc.
Invented by Charles Hull

WHAT'S SLA?

INVENTOR CHUCK HULL EXPLAINS STEREOLITHOGRAPHY

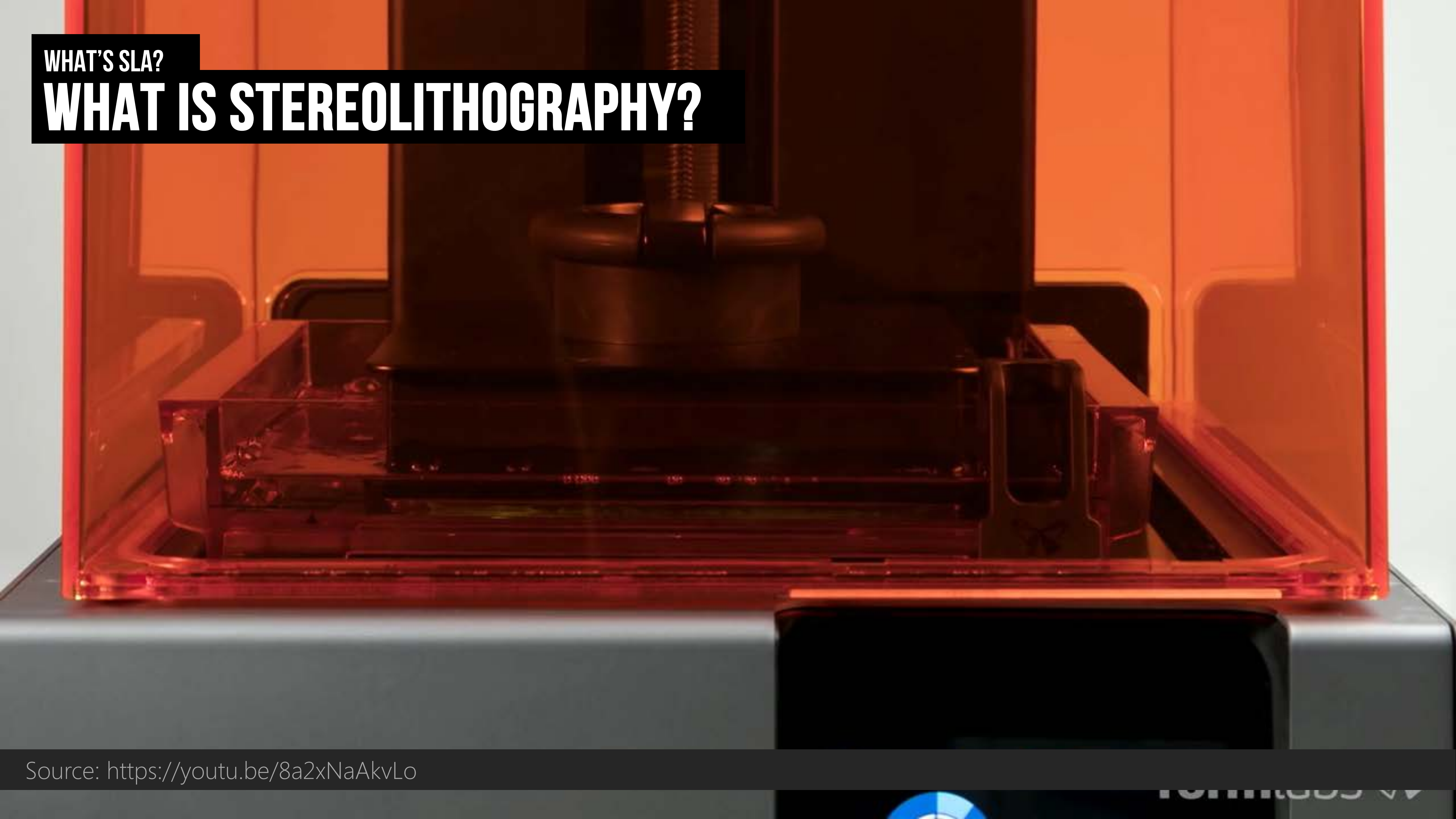


Source: https://youtu.be/eyUPSYynywM

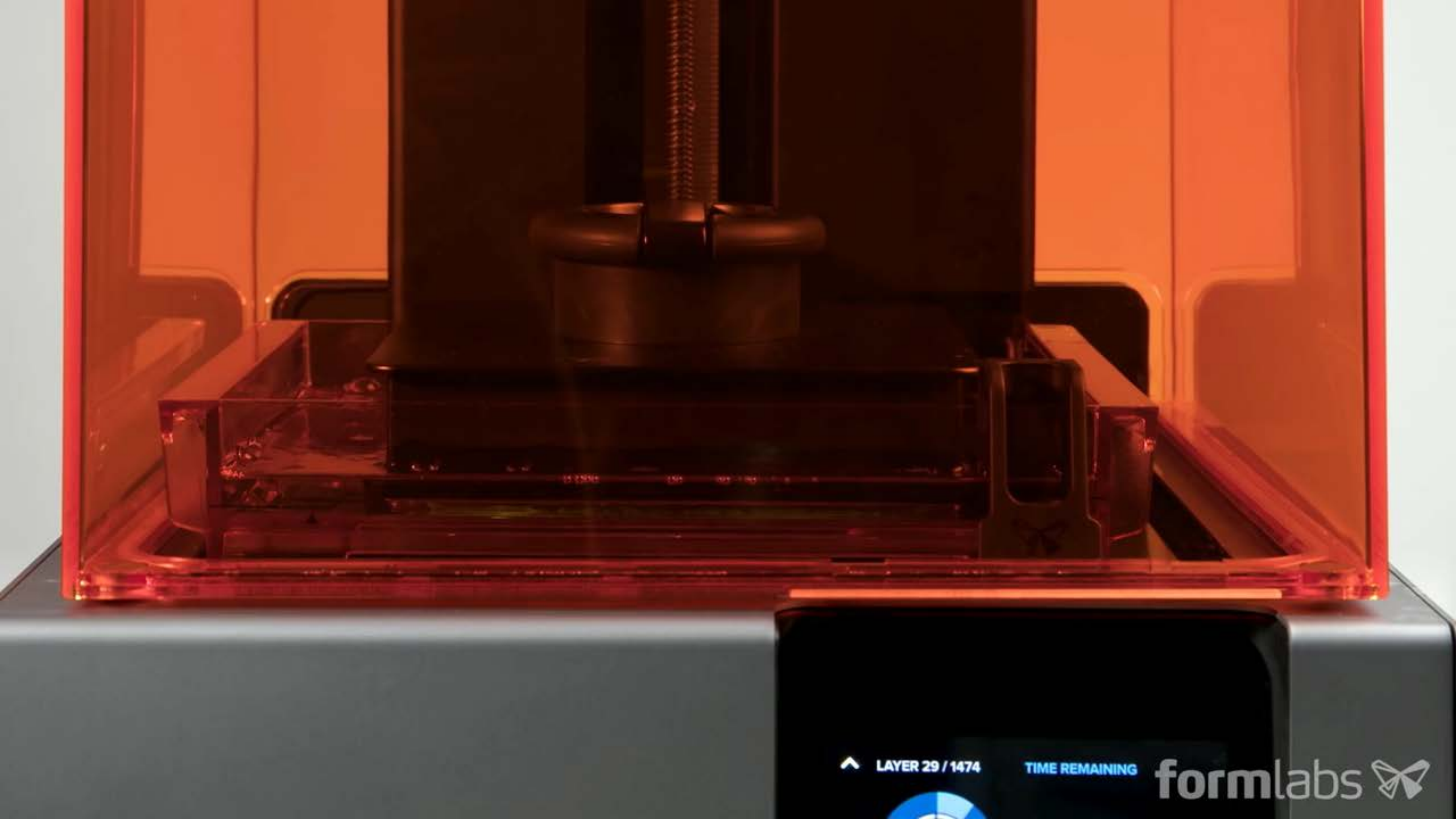

CHUCK HULL
PRESIDENT
3D SYSTEMS
0:00 / 0:52

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 dumping in isopropyl alchohol

1992

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

Source: https://en.wikipedia.org/wiki/Stratasys

1992

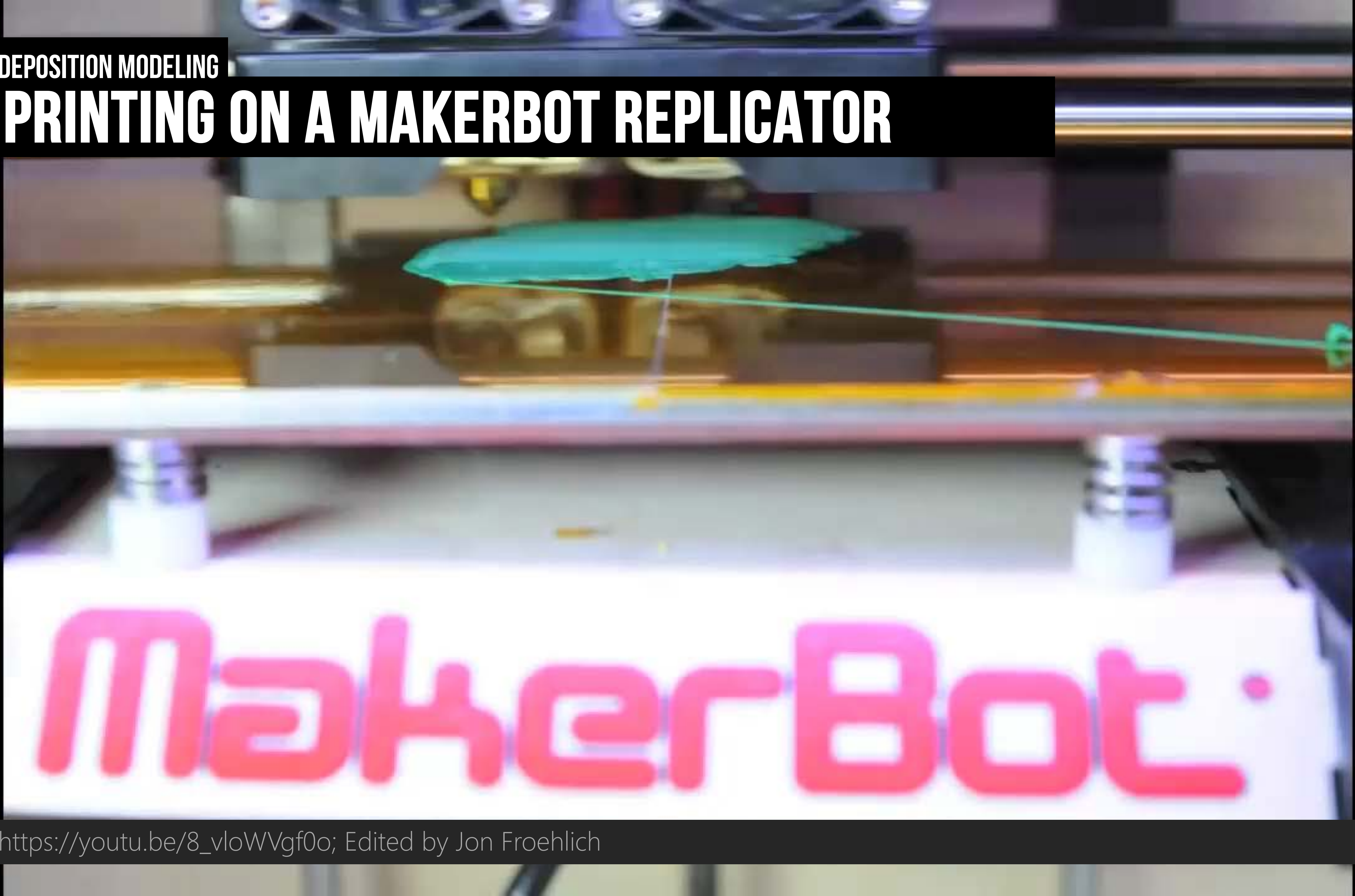
The first commercial FDM printer
3D Modeler by Stratasys, Inc.
Invented by Scott & Lisa Crump

"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."

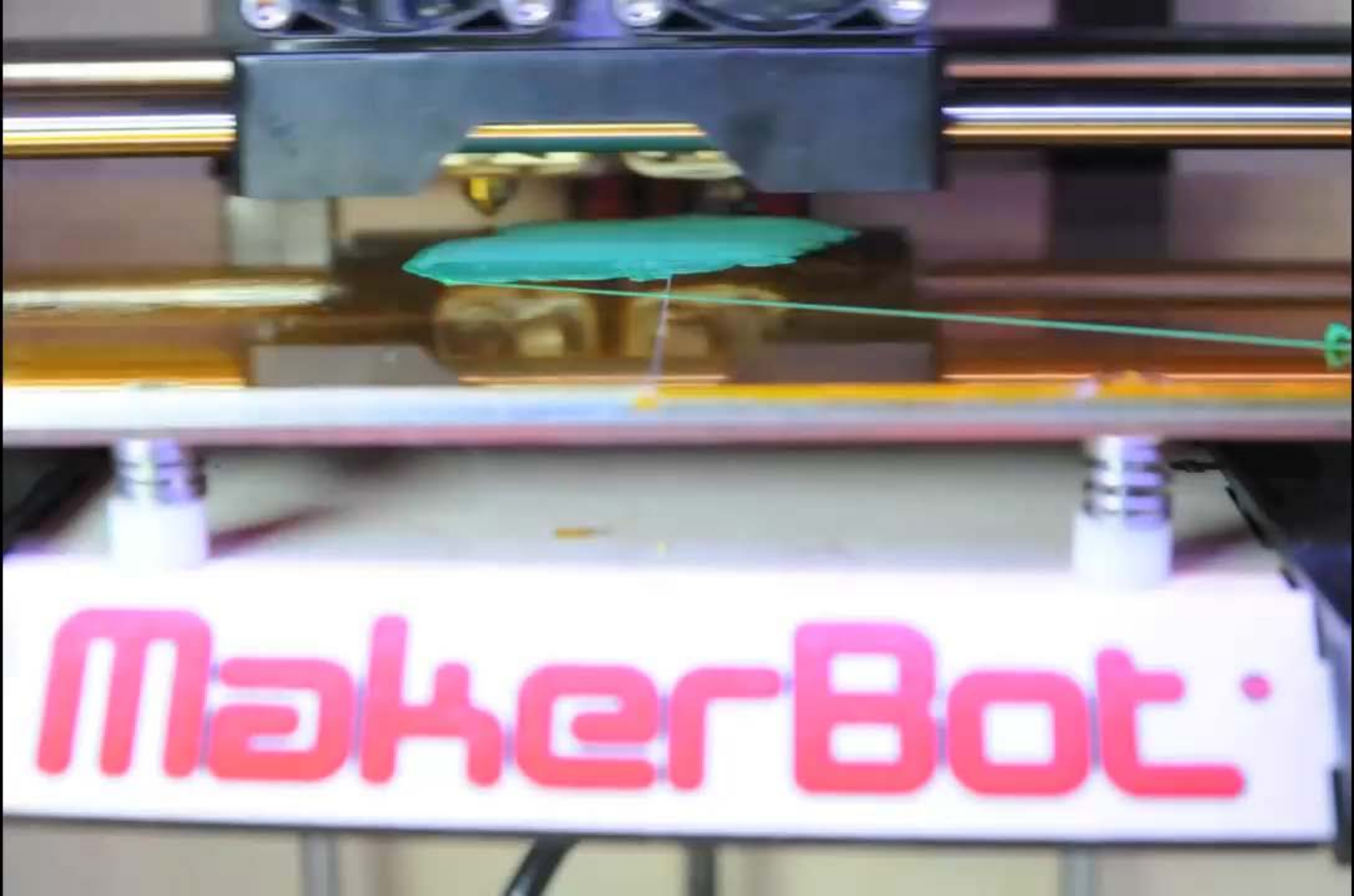
Source: https://en.wikipedia.org/wiki/Stratasys

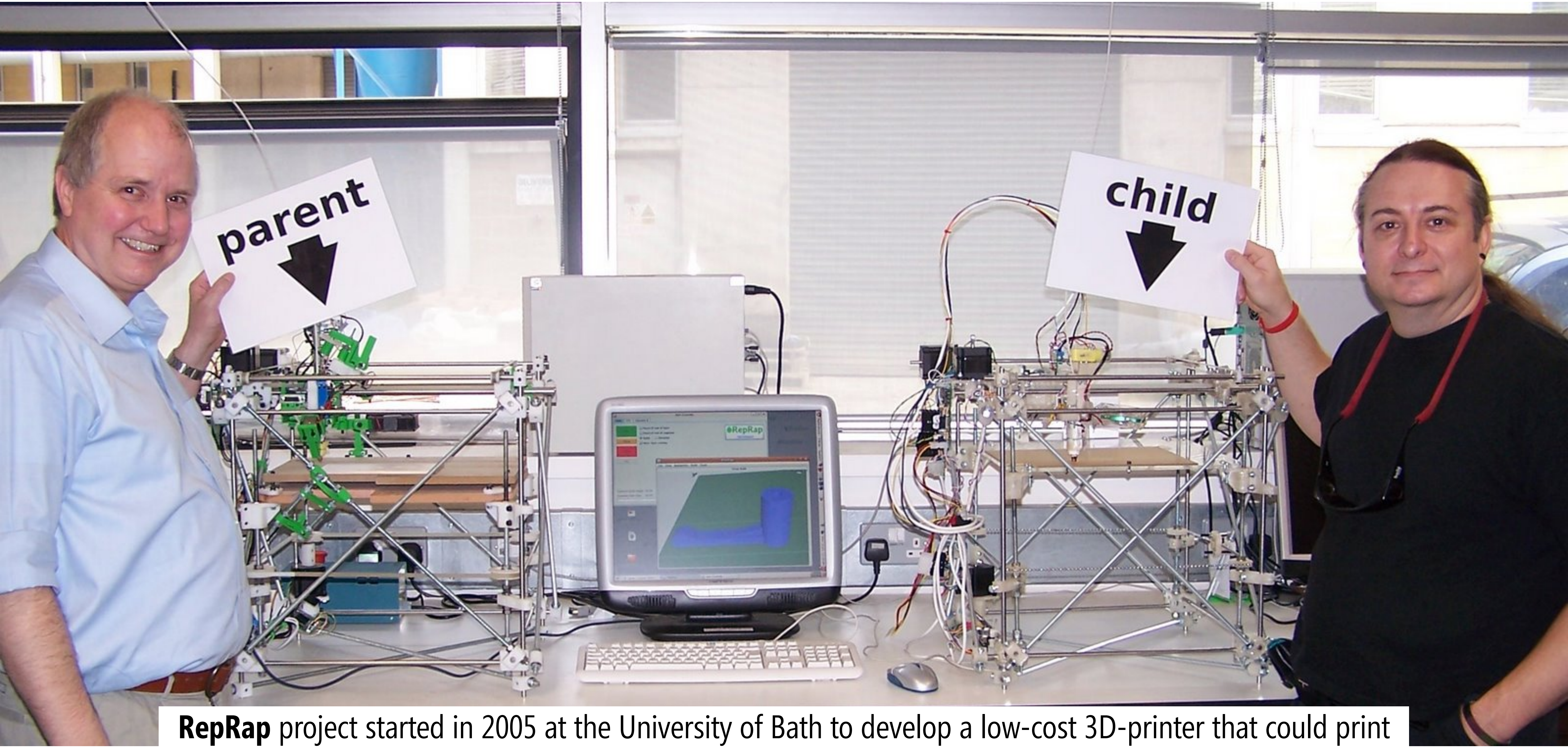
FUSED DEPOSITION MODELING

3D PRINTING ON A MAKERBOT REPLICATOR



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


MakerBot



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

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.

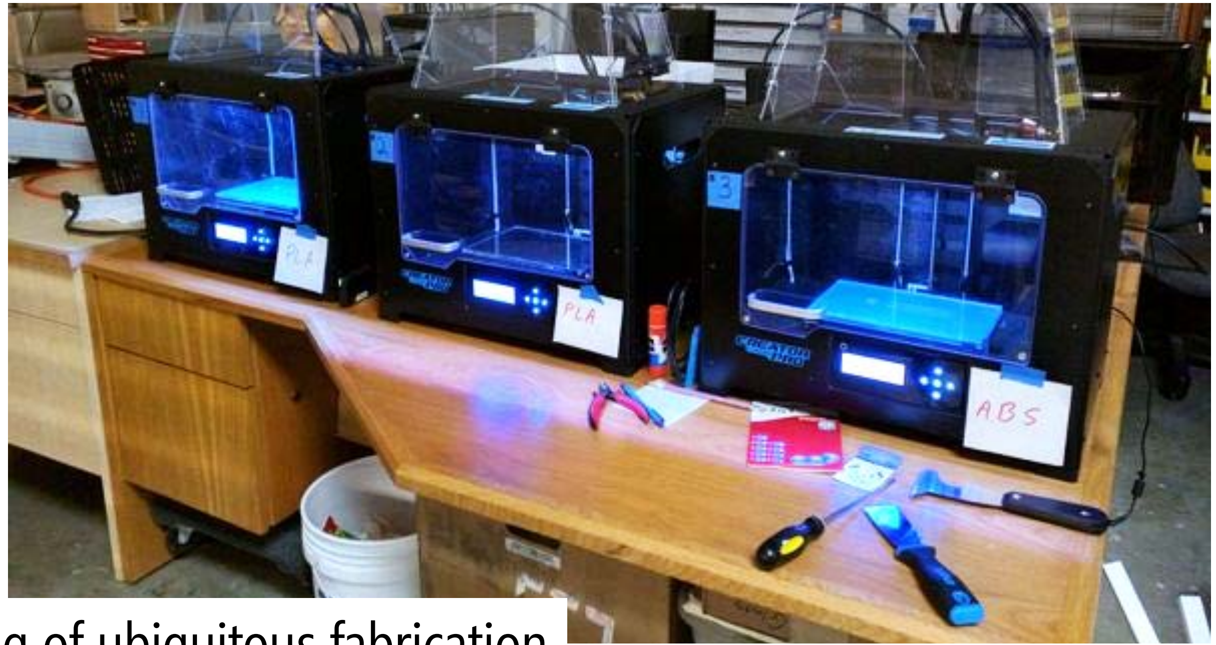
The next generation of additive manufacturing technologies are making their way down from the industrial market to desktops of consumers and retailers much like FDM did. Among these include patents for three specific 3D printing technologies: liquid-based, powder-based and metal-based printing processes.

More posts by this contributor

- 3D printing technologies explained
- Metal 3D printing takes flight

Liquid-Based Technology

2009 marked the beginning of ubiquitous fabrication



Slide based on Huaishu Peng's job talk;

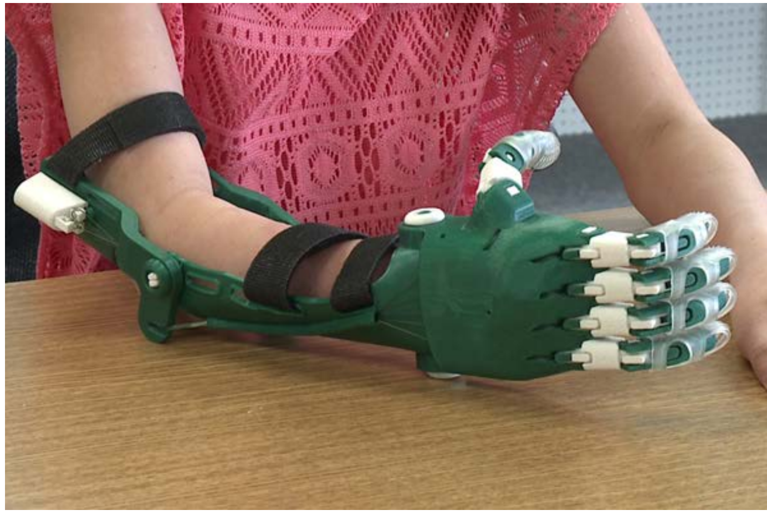
By **2012**
We reached the peak
of the "hype cycle"

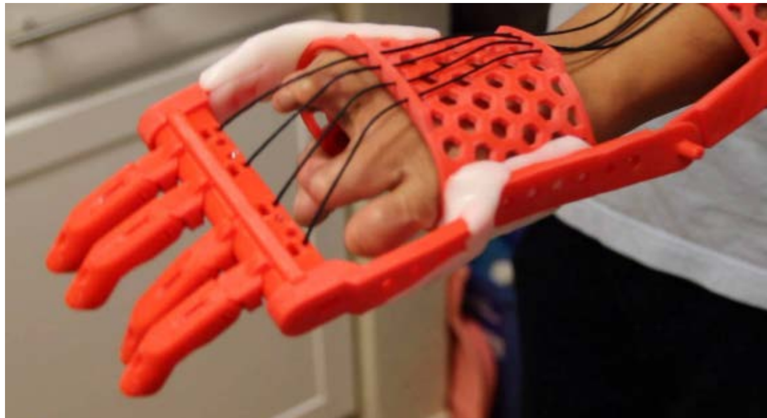
FDM 3D PRINTING

FASHION

FDM 3D PRINTING

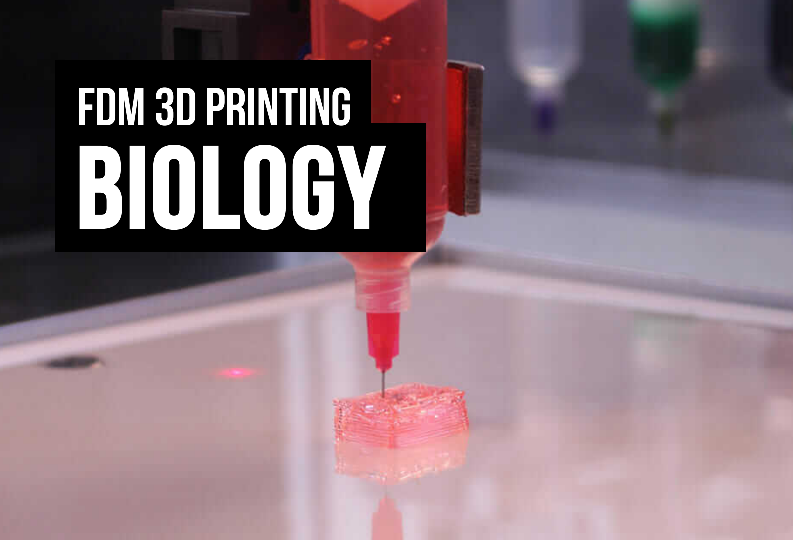
PROSTHETICS

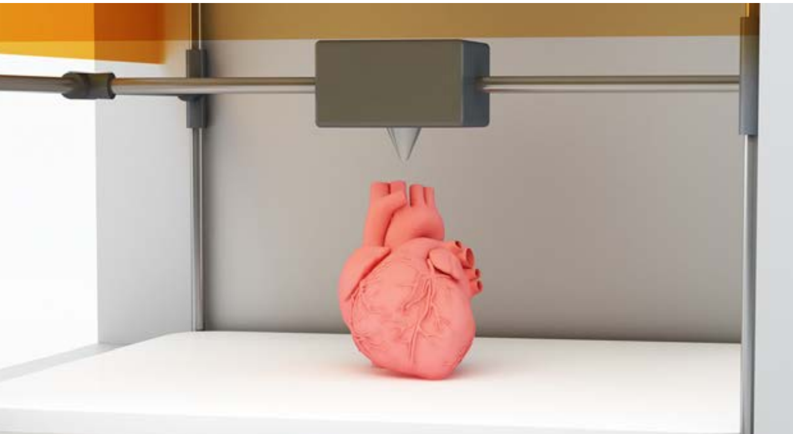


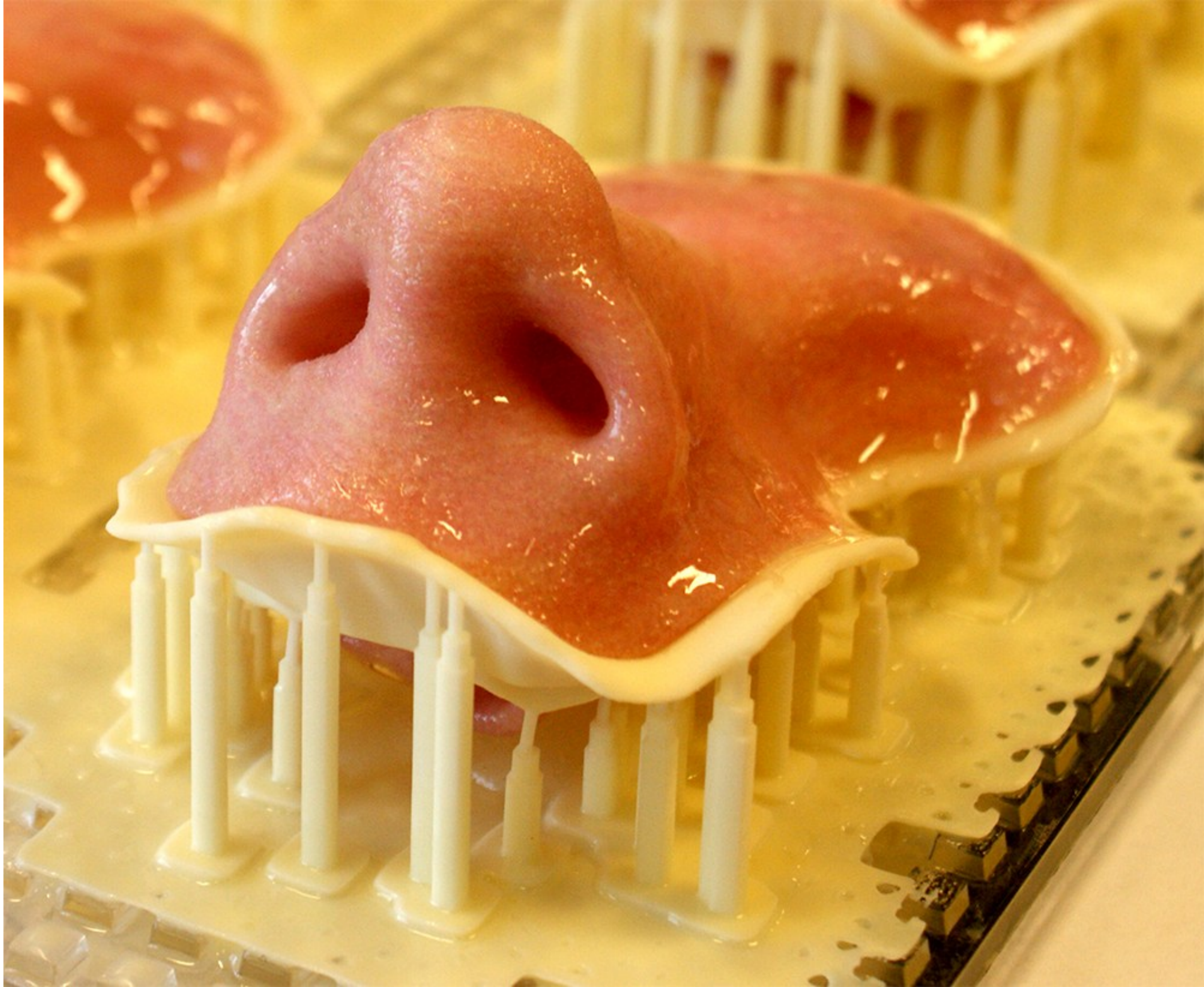


FDM 3D PRINTING

BIOLOGY







FDM 3D PRINTING
BUILDINGS

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

WIRED The 3D Printing Revolution That Wasn't SIGN IN | SUBSCRIBE

BUSINESS CULTURE GEAR IDEAS SCIENCE SECURITY TRANSPORTATION

THE RISE AND FALL OF THE EVERYMAN TYCOON

ANDREW ZALESKI BACKCHANNEL 12.01.16 12:00 AM

THE 3D PRINTING REVOLUTION THAT WASN'T

SHARE

13

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

WIRED

The 3D Printing Revolution That Wasn't

SHARE

13

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.

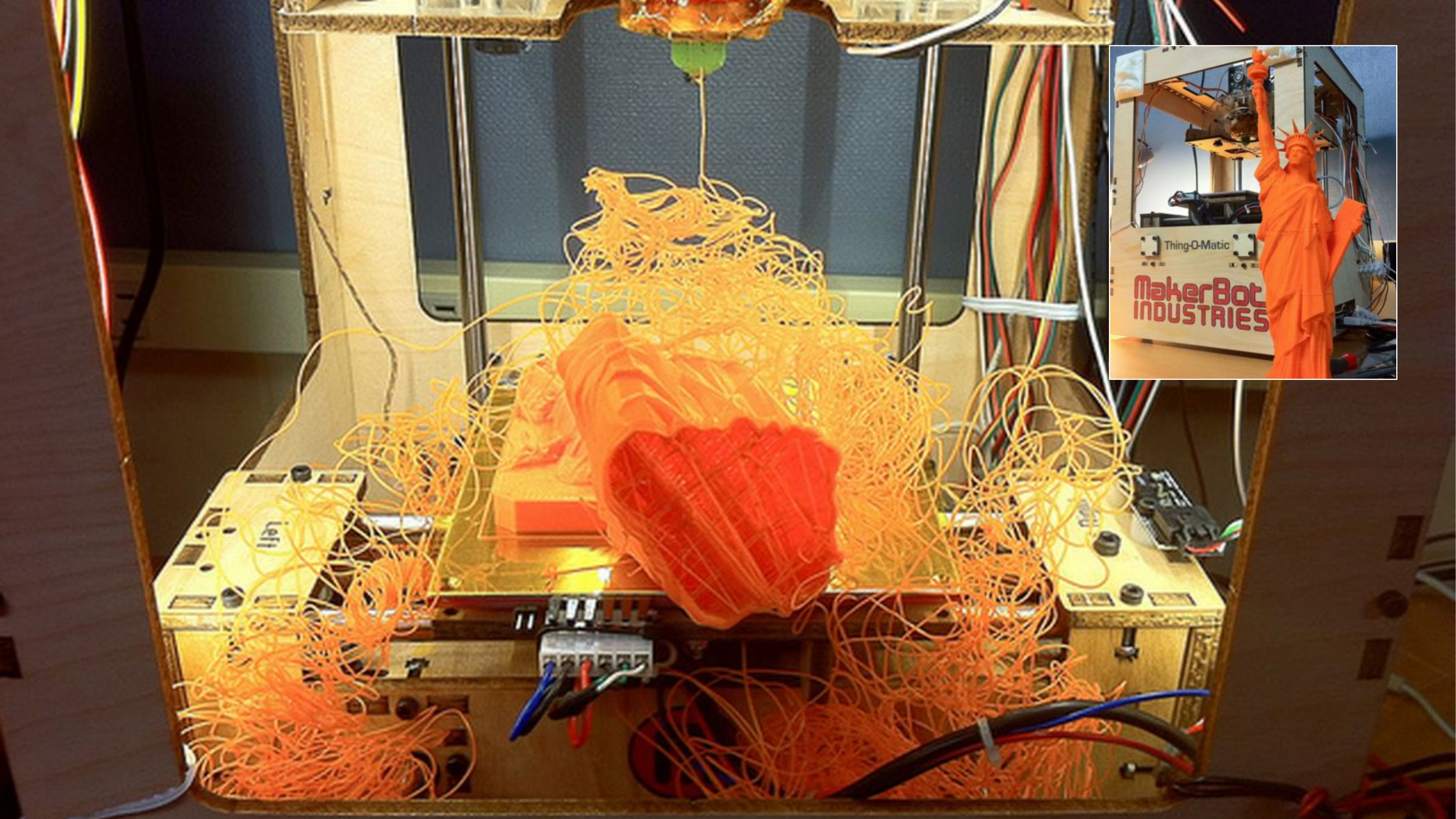
It's also not a simple process. If you want to print out original pieces, you need to know how to do 3D design, which admittedly has become much simpler thanks to online software like TinkerCAD. But an extruder head might become jammed during printing. The print bed might warp. The finished print might 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.

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.

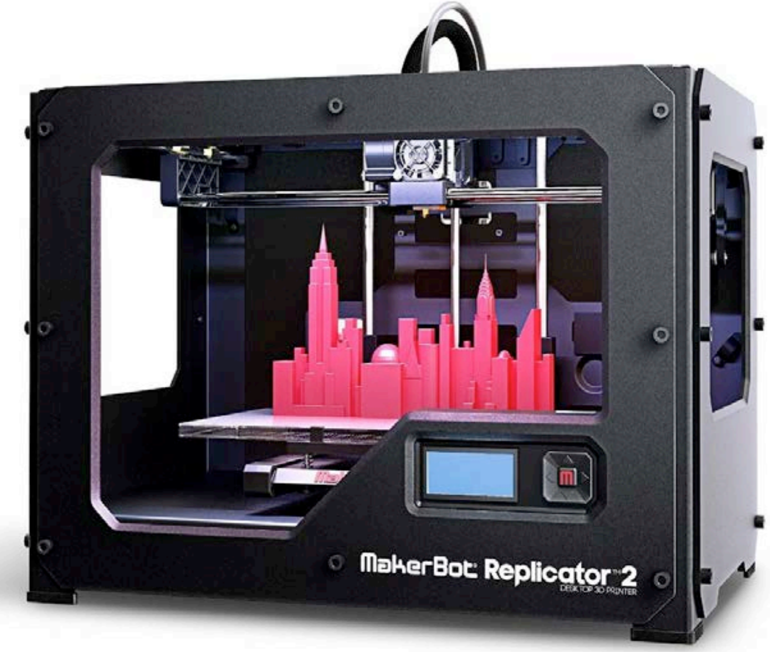
It's also not a simple process. If you want to print out original pieces, you need to know how to do 3D design, which admittedly has become much simpler thanks to online software like TinkerCAD. But an extruder head might become jammed during printing. The print bed might warp. The finished print might 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.

Source: https://www.wired.com/2016/12/the-3d-printing-revolution-that-wasnt/


Thing-O-Matic
MakerBot
INDUSTRIES


5-Year View

!=

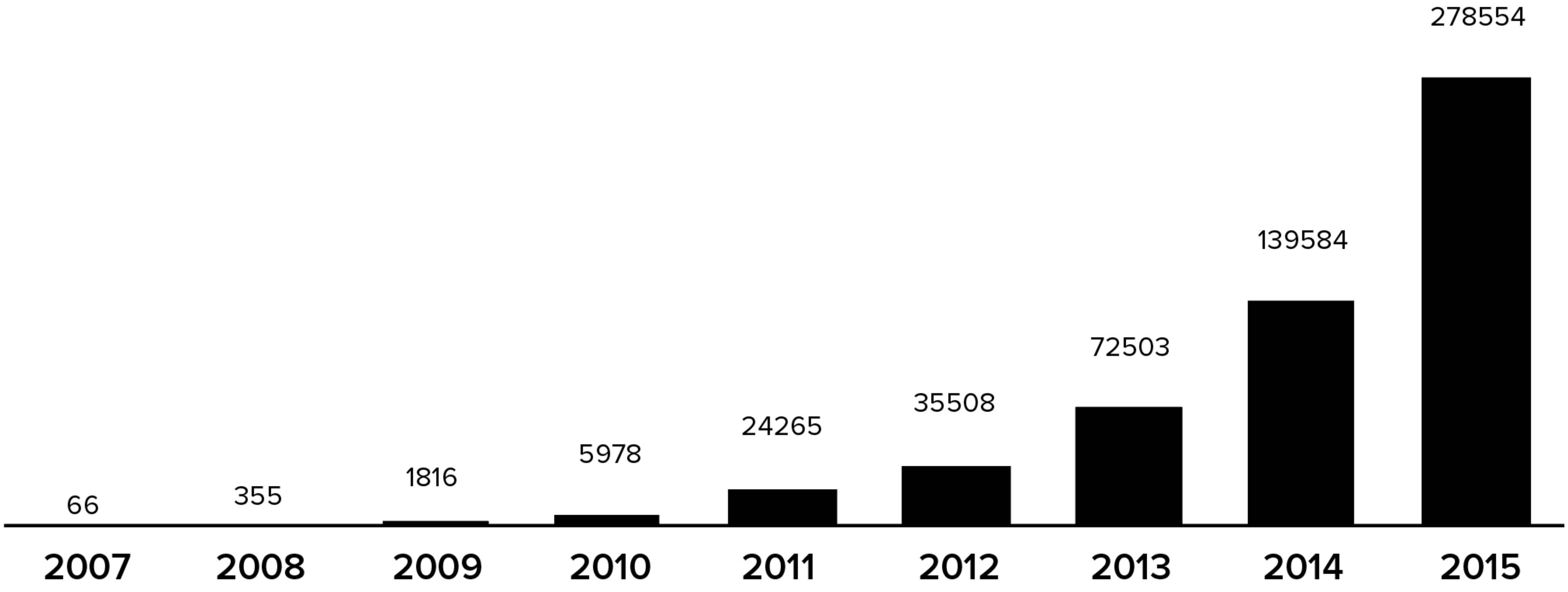

MakerBot Replicator 2

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



Source: https://www.3dhubs.com/knowledge-base/advantages-3d-printing; Original source: Wohlers Report, 2015

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.

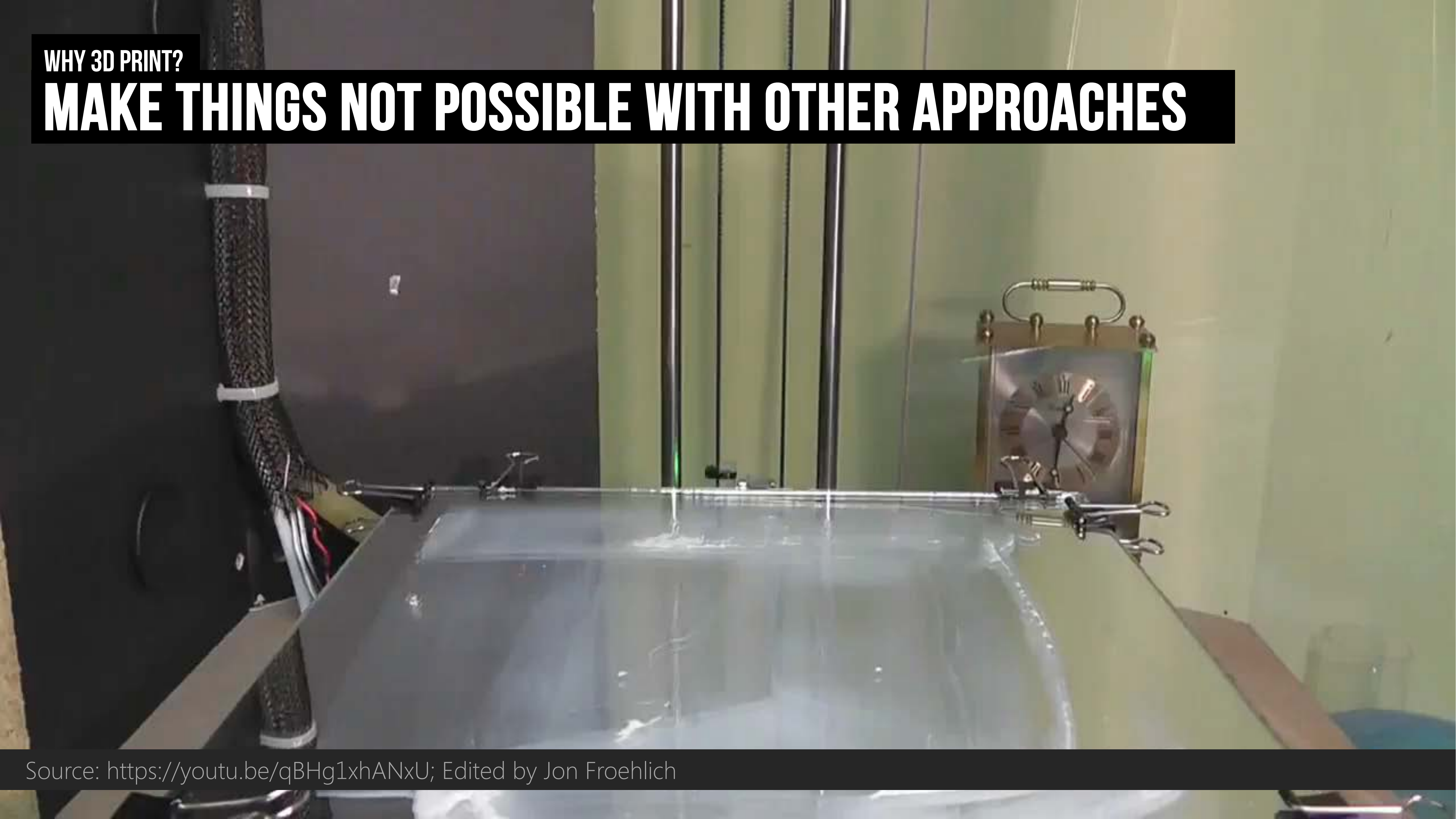
Iteration. Digital models can be easily tweaked & reprinted.

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.

Source: Redwood *et al.,* The 3d Printing Handbook, 2017; https://www.3dhubs.com/knowledge-base/advantages-3d-printing



WHY 3D PRINT?

MAKE THINGS NOT POSSIBLE WITH OTHER APPROACHES

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

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.

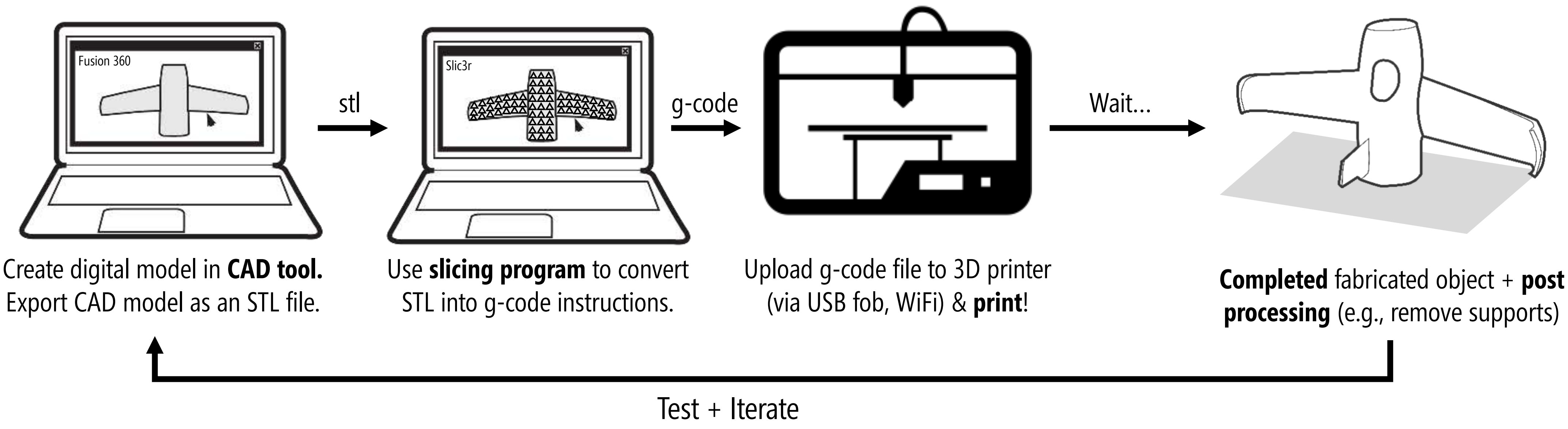
Ease of access. Unlike injection molding or even subtractive processes like CNC mills or laser cutters, 3D-printers are relatively cheap to buy and operate. Many public libraries and other community spaces provide access as well.

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.

Source: Redwood *et al.,* The 3d Printing Handbook, 2017; https://www.3dhubs.com/knowledge-base/advantages-3d-printing

3D-PRINTING PROCESS

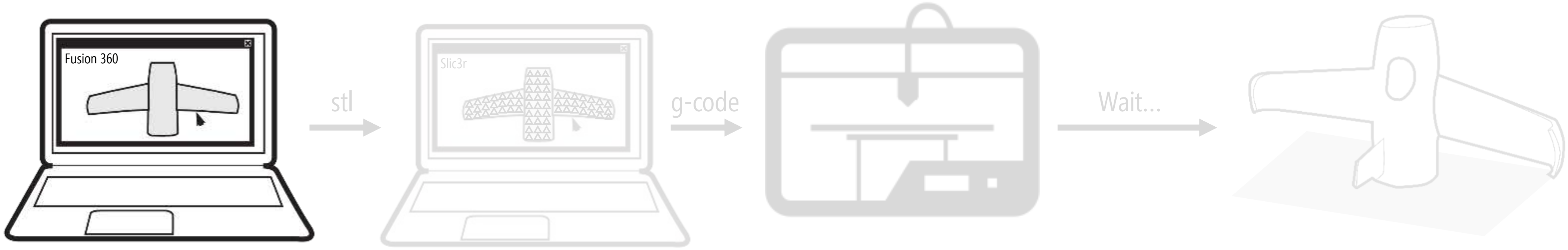
6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING



Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process

3D-PRINTING PROCESS

1. CREATE DIGITAL MODEL IN CAD TOOL



Create digital model in **CAD tool.** Export CAD model as an STL file.

Use **slicing program** to convert STL into g-code instructions.

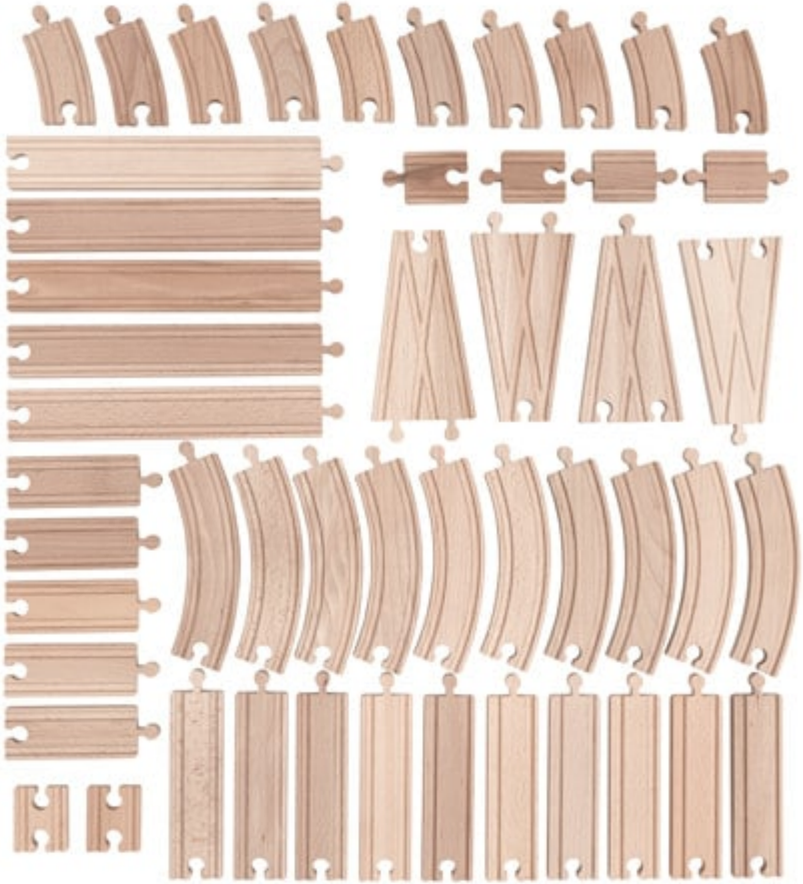
Upload g-code file to 3D printer (via USB fob, WiFi) & **print**!

Completed fabricated object + **post processing** (e.g., remove supports)

Iterate

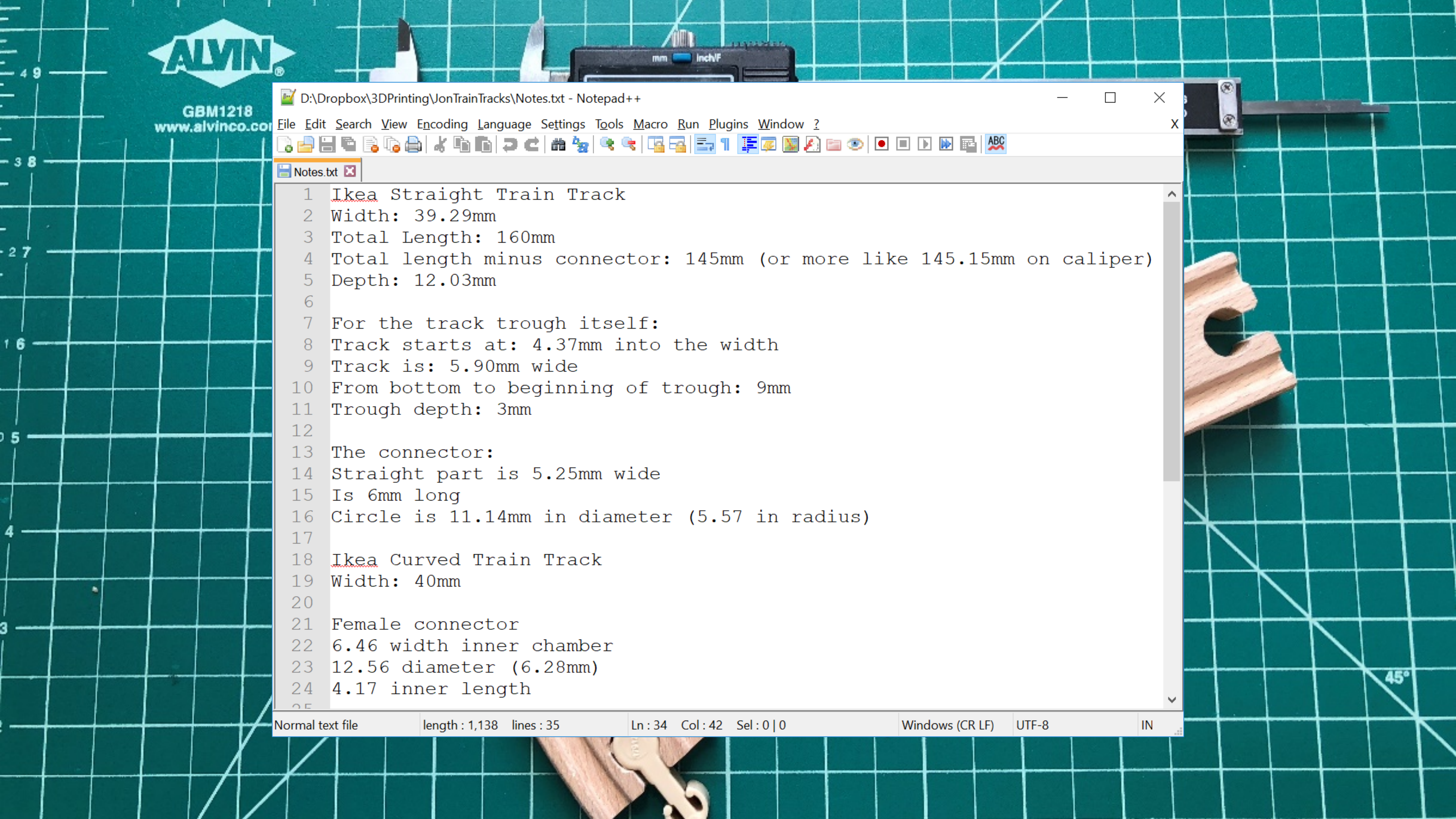
Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process

EXAMPLE: TRAIN TRACKS



STEP 0: MEASUREMENT

MEASURING!



Ikea Straight Train Track
Width: 39.29mm
Total Length: 160mm
Total length minus connector: 145mm (or more like 145.15mm on caliper)
Depth: 12.03mm

For the track trough itself:
Track starts at: 4.37mm into the width
Track is: 5.90mm wide
From bottom to beginning of trough: 9mm
Trough depth: 3mm

The connector:
Straight part is 5.25mm wide
Is 6mm long
Circle is 11.14mm in diameter (5.57 in radius)

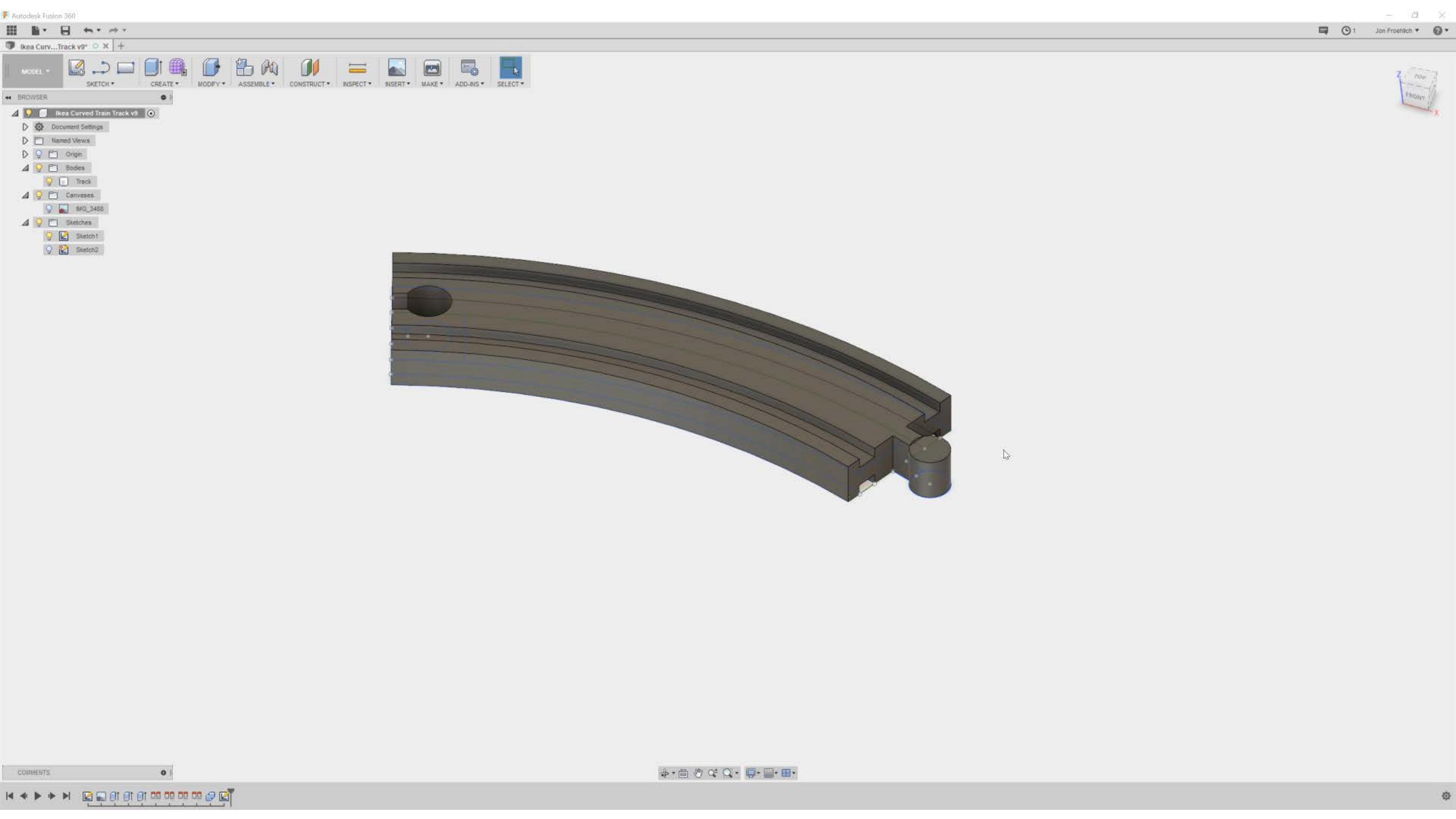
Ikea Curved Train Track
Width: 40mm

Female connector
6.46 width inner chamber
12.56 diameter (6.28mm)
4.17 inner length

STEP 1: CAD MODELING

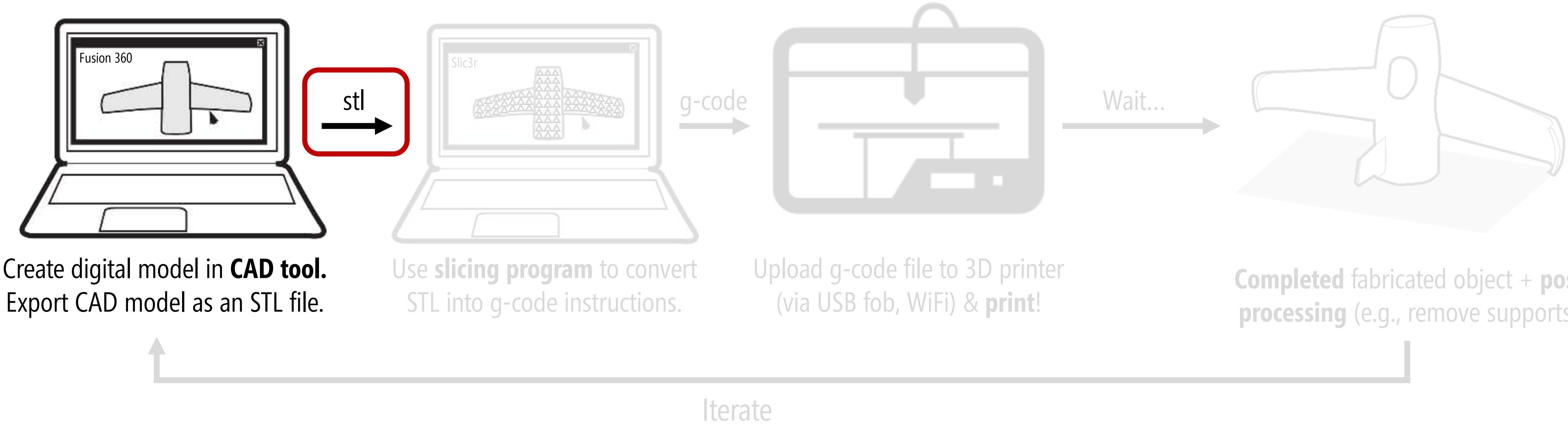
CREATING CUSTOM TRAIN TRACKS

Source: Jon Froehlich



Autodesk Fusion 360
Ikea Curv...Track v9*
Jon Froehlich
MODEL
SKETCH
CREATE
MODIFY
ASSEMBLE
CONSTRUCT
INSPECT
INSERT
MAKE
ADD-INS
SELECT
BROWSER
Ikea Curved Train Track v9
Document Settings
Named Views
Origin
Bodies
Track
Canvases
IMG_3488
Sketches
Sketch1
Sketch2
COMMENTS
TOP
FRONT

2. EXPORT CAD MODEL AS STL

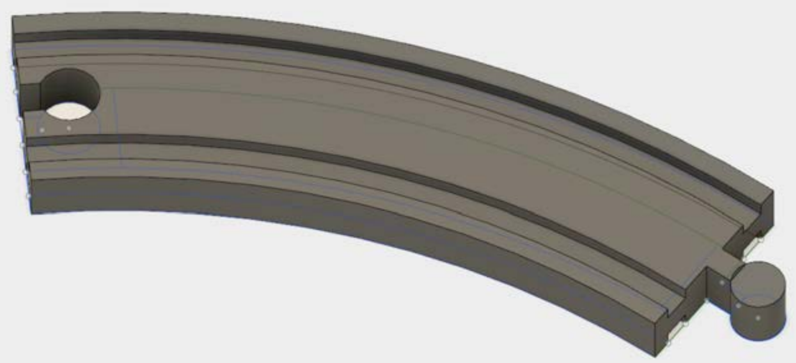


Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process

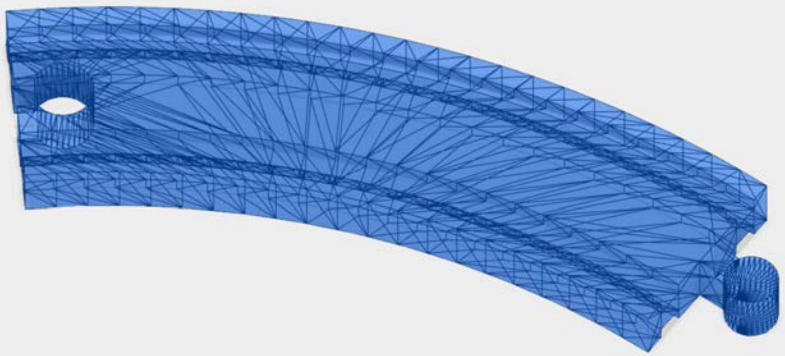
STEP 2: EXPORT TO STL FILE

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.



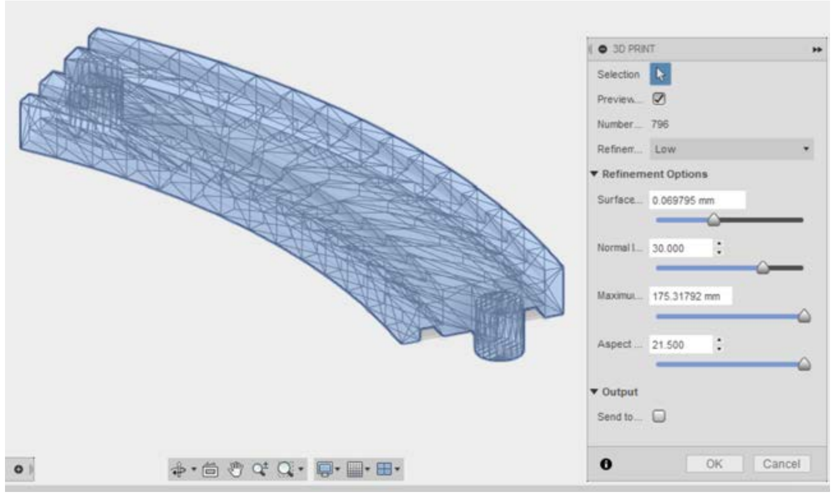
Raw CAD Model



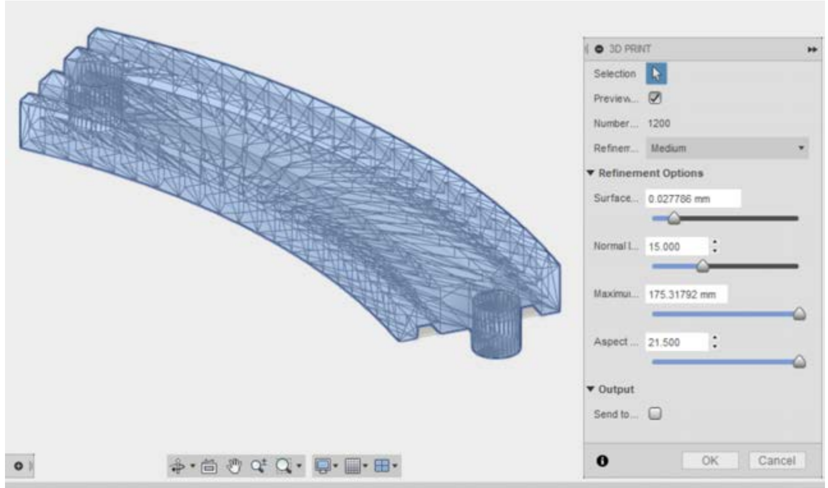
Converted to STL

See also: https://www.3dhubs.com/knowledge-base/3d-printing-stl-files-step-step-guide

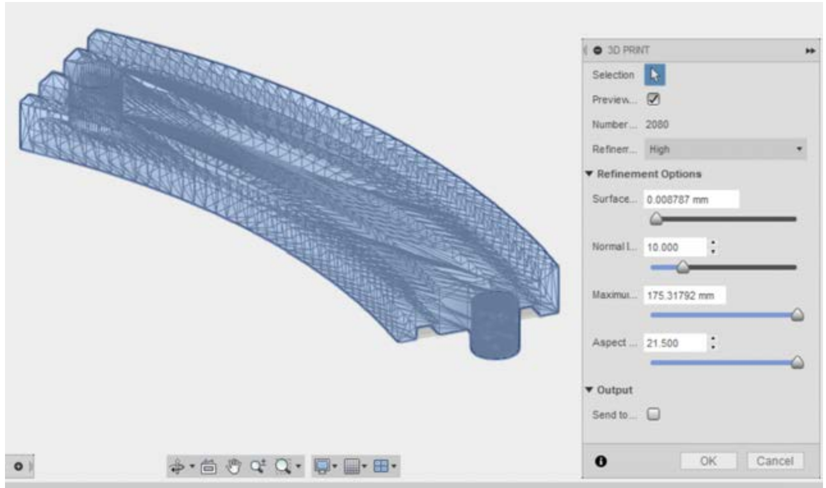
CONFIGURING EXPORT RESOLUTION (# OF TRIANGLES)



Export Quality: Low
Number of triangles: 796



Export Quality: Medium
Number of triangles: 1200



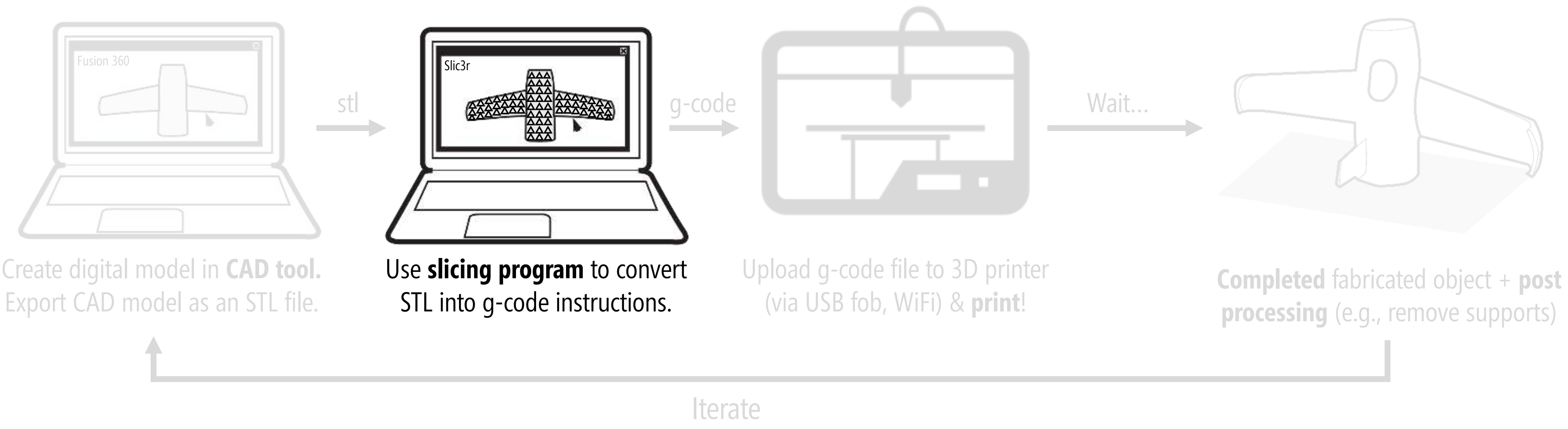
Export Quality: High
Number of triangles: 2080

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.

See also: https://www.3dhubs.com/knowledge-base/3d-printing-stl-files-step-step-guide

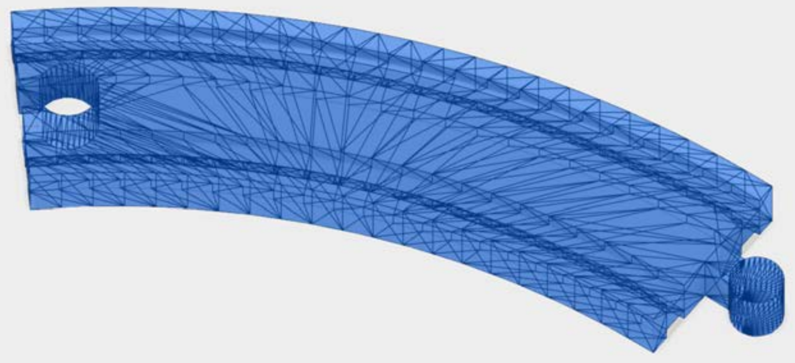
3. USE SLICING PROGRAM TO CONVERT STL TO G-CODE



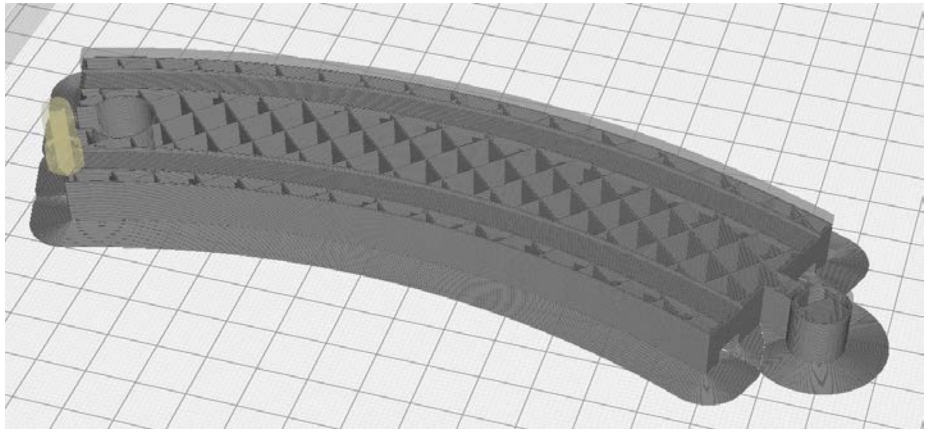
Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process

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.



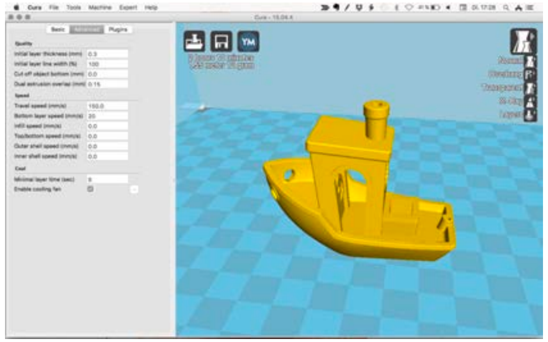
Load STL file into slicing program

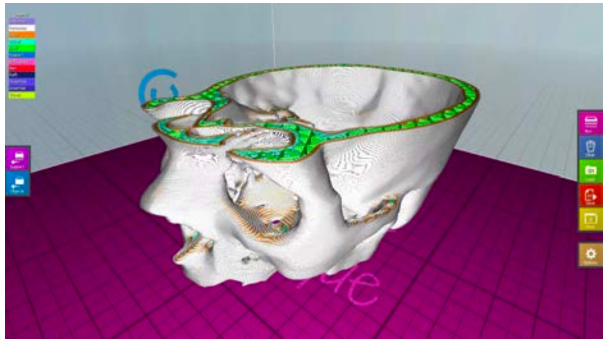


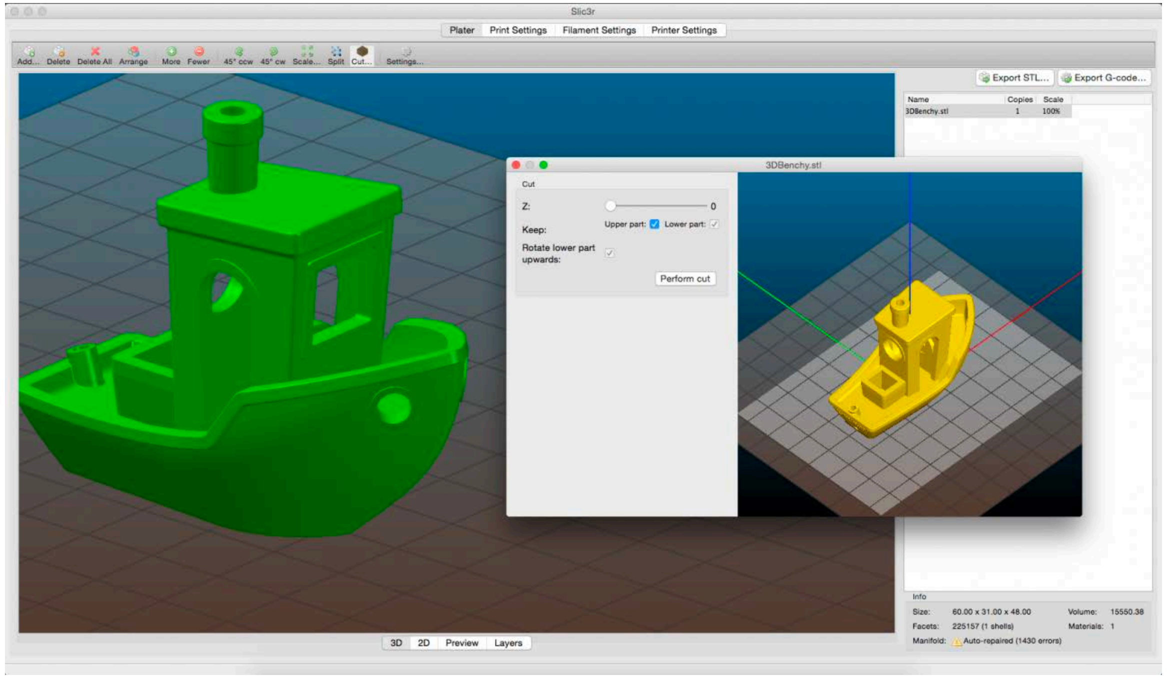
Slicer will create g-code (toolpath) instructions for printer

STEP 3: SLICING & GENERATING G-CODE

SLICER PROGRAMS





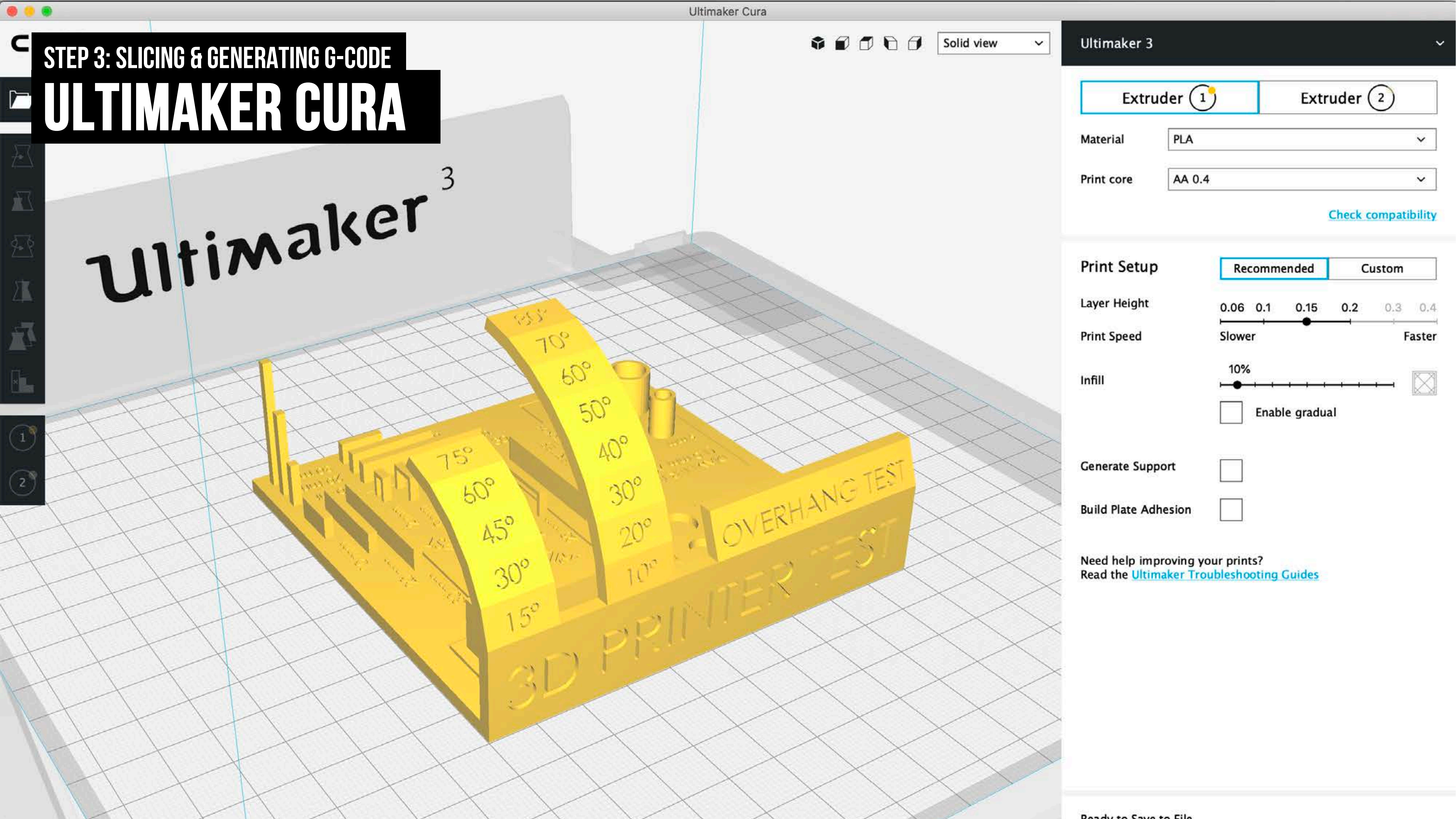


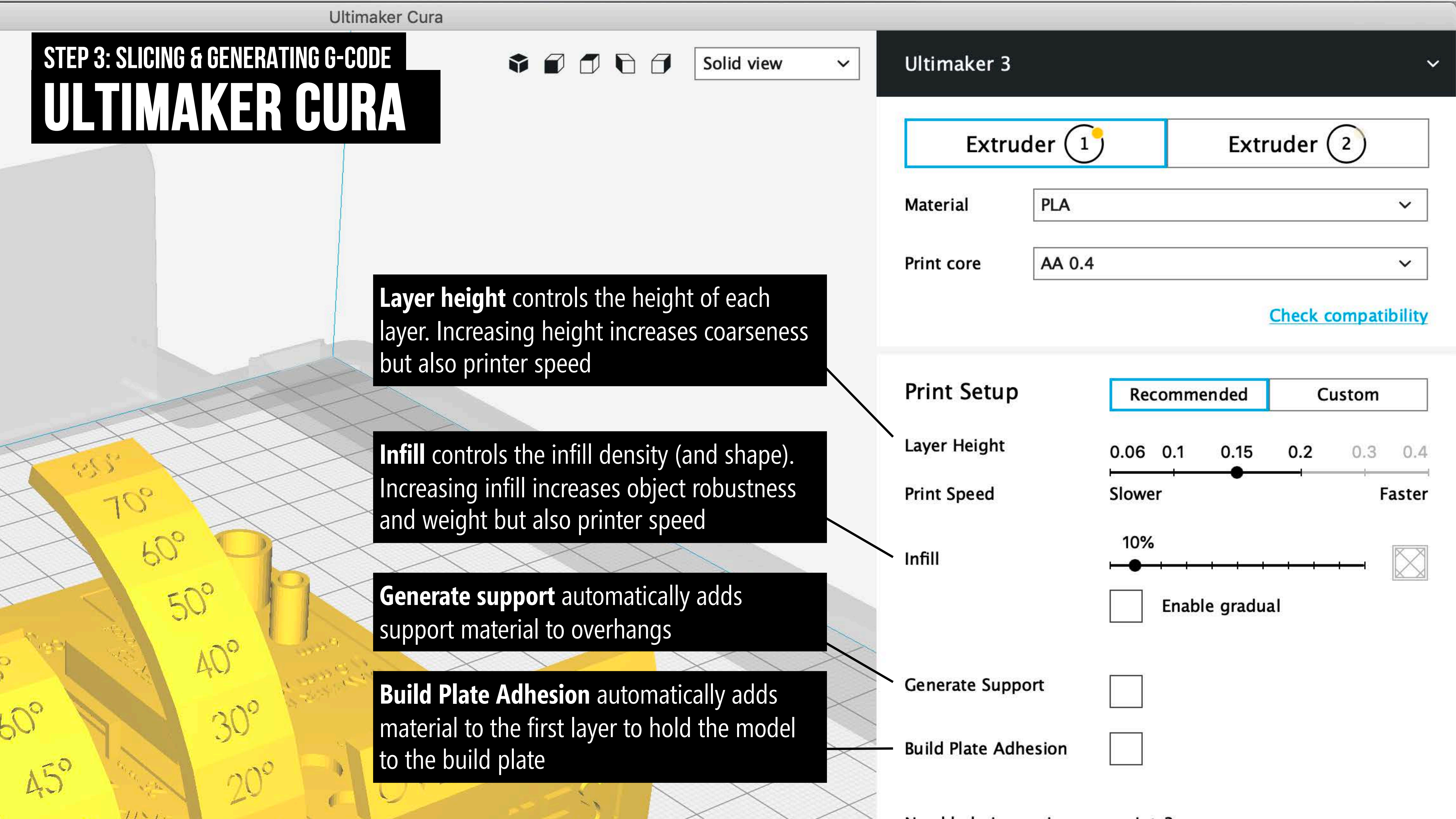
Software	User	Price	OS
3DPrinterOS	Beginners, Advanced Users	Freemium	Browser, Windows, Mac
Astroprint	Beginners, Advanced Users	Freemium	Browser, Raspberry Pi, pcDuino
CraftWare	Beginners, Advanced Users	Free	Windows, Mac, Linux
Cura	Beginners, Advanced Users	Free	Windows, Mac, Linux
IceSL	Advanced 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

https://all3dp.com/1/best-3d-slicer-software-3d-printer/

STEP 3: SLICING & GENERATING G-CODE

ULTIMAKER CURA



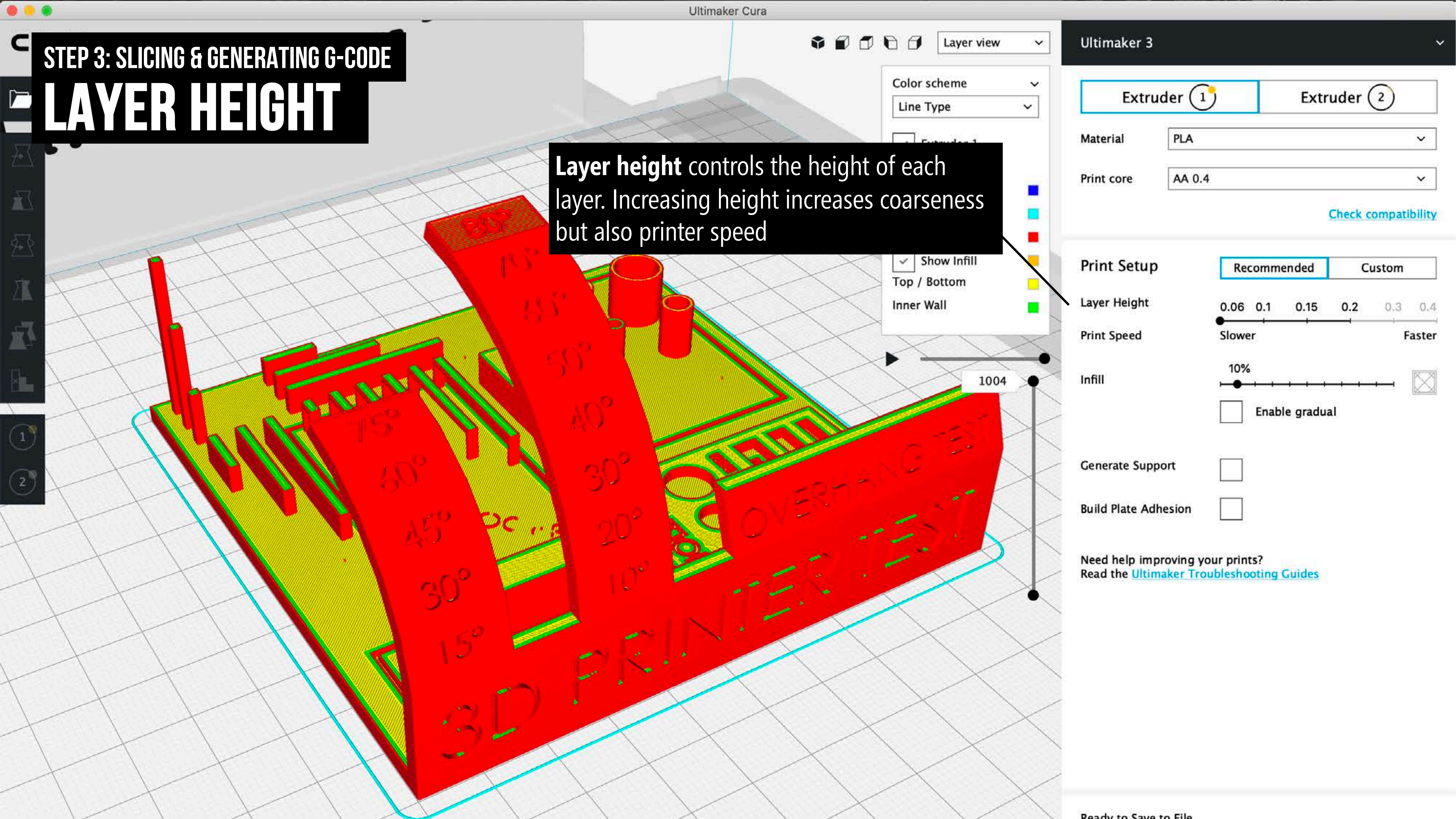


Ultimaker Cura
STEP 3: SLICING & GENERATING G-CODE
ULTIMAKER CURA
Solid view
Ultimaker 3
Extruder 1
Extruder 2
Material
PLA
Print core
AA 0.4
Check compatibility
Print Setup
Recommended
Custom
Layer Height
0.06 0.1 0.15 0.2 0.3 0.4
Print Speed
Slower
Faster
Infill
10%
Enable gradual
Generate Support
Build Plate Adhesion
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
80° 70° 60° 50° 40° 30° 20°
45°

STEP 3: SLICING & GENERATING G-CODE

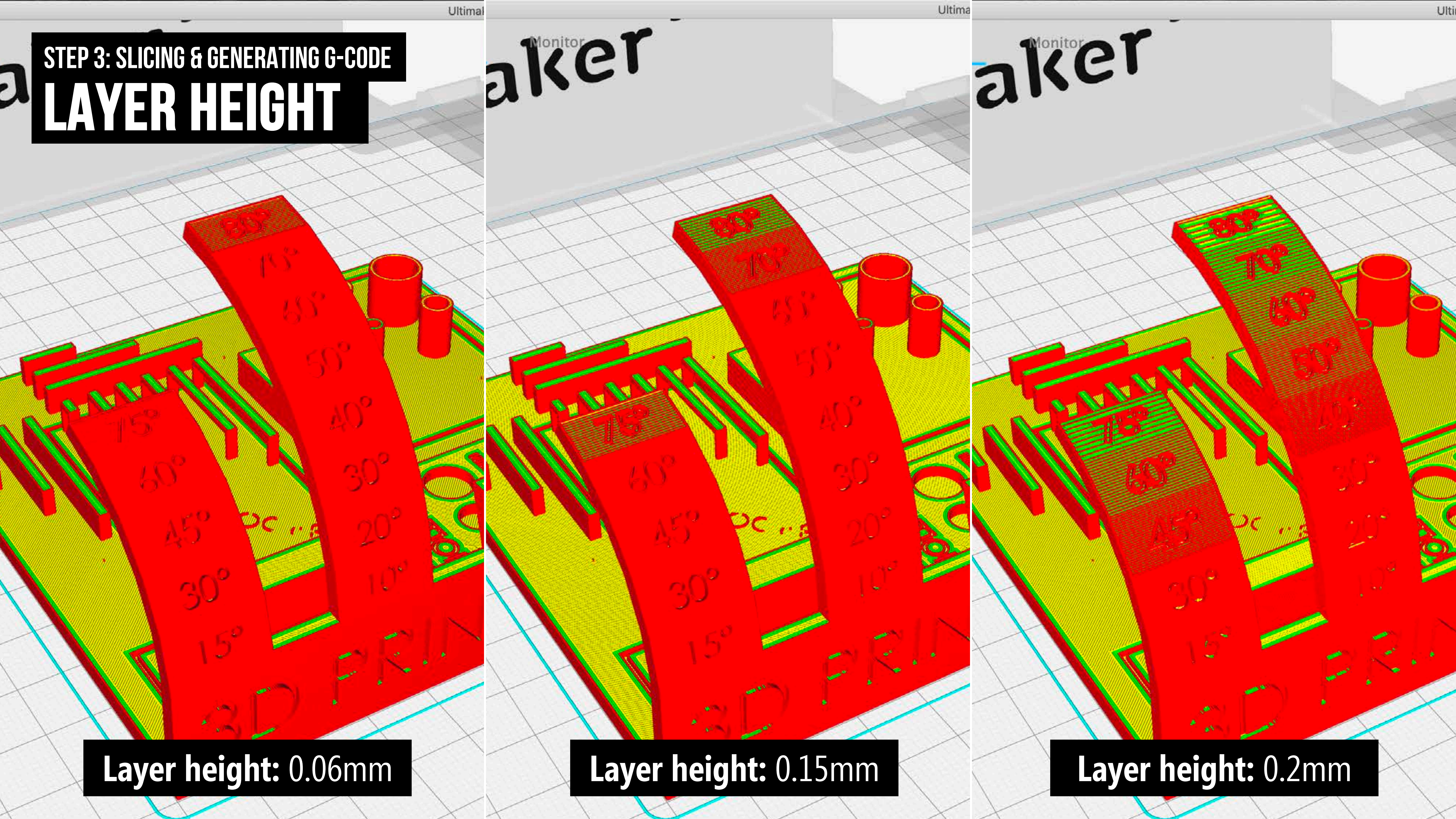
LAYER HEIGHT

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



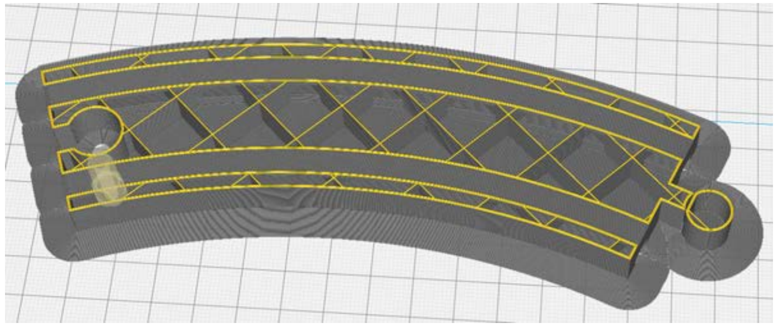
STEP 3: SLICING & GENERATING G-CODE

LAYER HEIGHT



STEP 3: SLICING & GENERATING G-CODE

SETTING INFILL

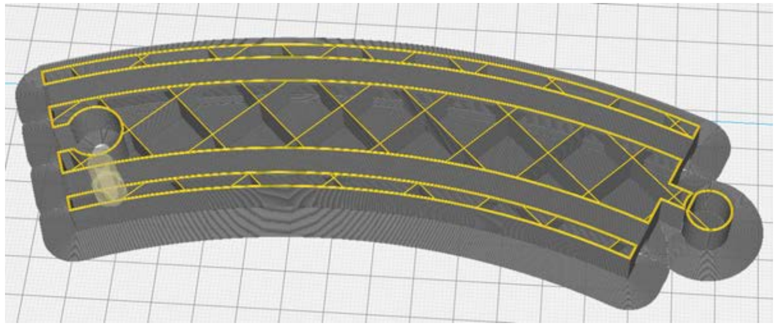


Infill Density: 5%

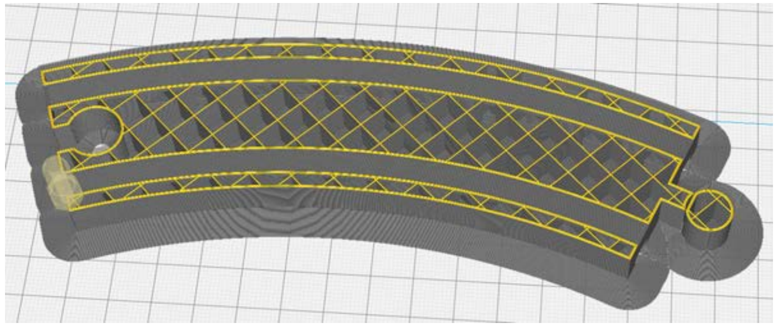
Estimated print time: 2h 53min

Estimated filament: 2.92 m / ~23g

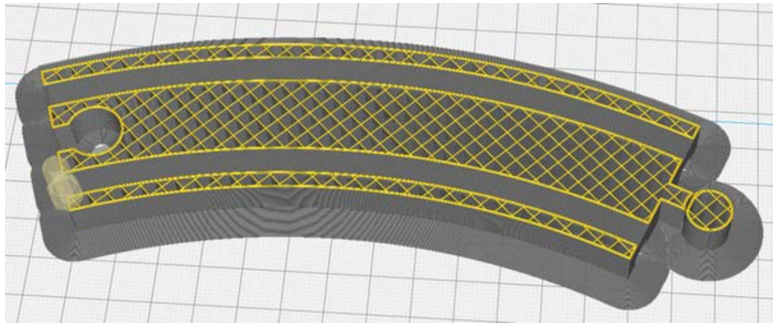
SETTING INFILL



Infill Density: 5%
Estimated print time: 2h 53min
Estimated filament: 2.92 m / ~23g



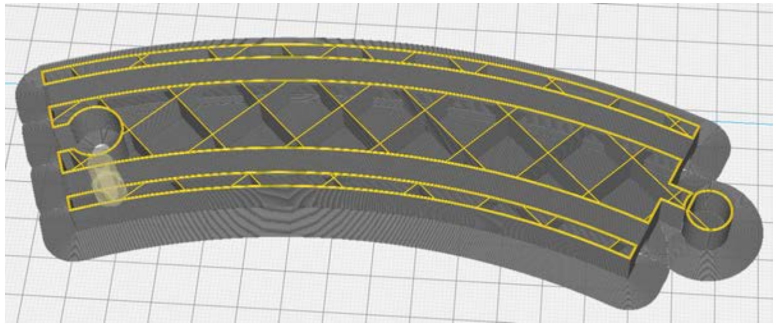
Infill Density: 10%
Estimated print time: 3h 06min
Estimated filament: 3.28 m / ~26g



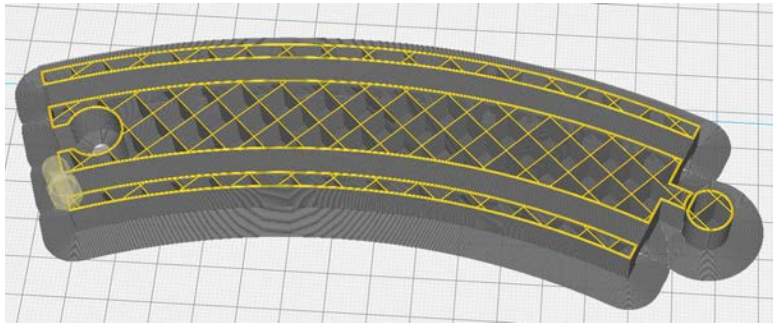
Infill Density: 25%
Estimated print time: 3h 35min
Estimated filament: 3.99 m / ~32g

STEP 3: SLICING & GENERATING G-CODE

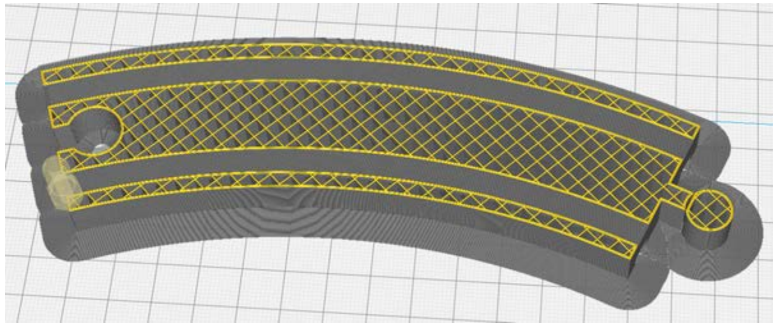
SETTING INFILL



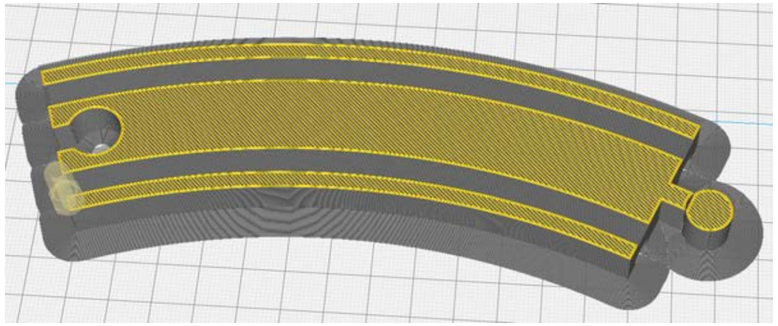
Infill Density: 5%
Estimated print time: 2h 53min
Estimated filament: 2.92 m / ~23g



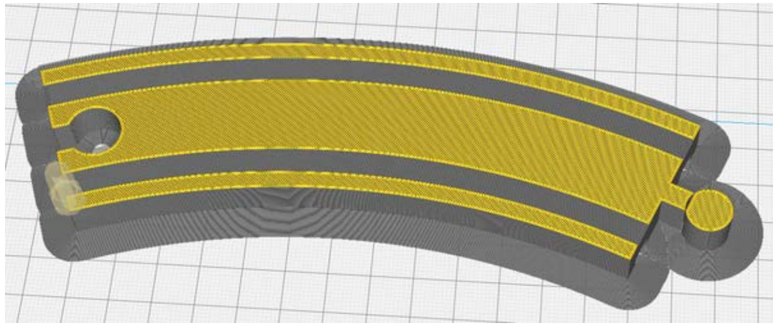
Infill Density: 10%
Estimated print time: 3h 06min
Estimated filament: 3.28 m / ~26g



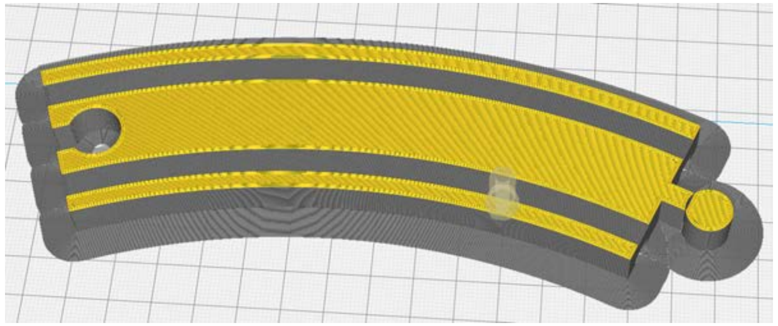
Infill Density: 25%
Estimated print time: 3h 35min
Estimated filament: 3.99 m / ~32g



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

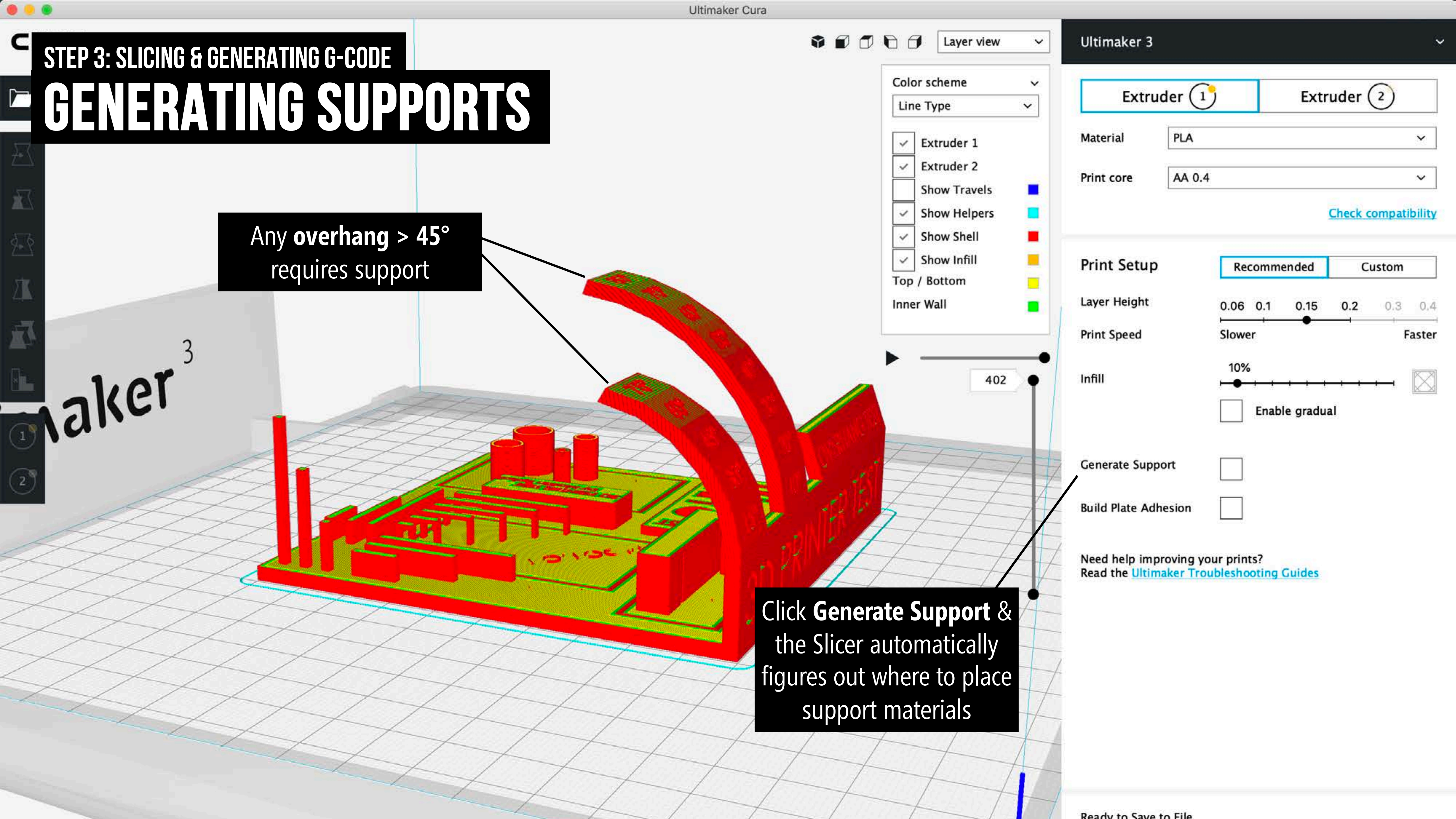


Infill Density: 100%
Estimated print time: 10h 53min
Estimated filament: 9.65 m / ~76g

STEP 3: SLICING & GENERATING G-CODE

GENERATING SUPPORTS

Any **overhang** > **45°** requires support

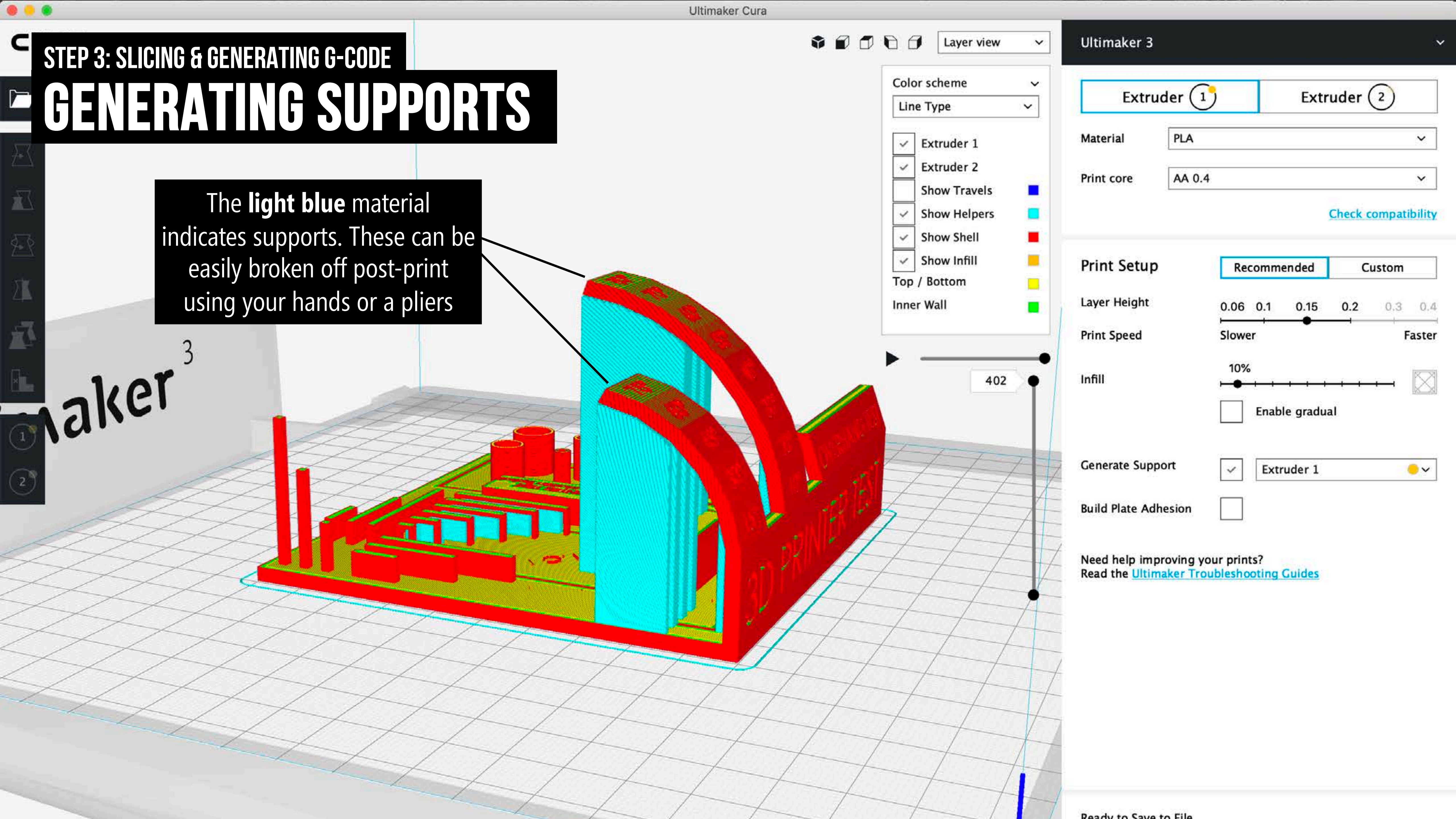


Click **Generate Support** & the Slicer automatically figures out where to place support materials

STEP 3: SLICING & GENERATING G-CODE

GENERATING SUPPORTS

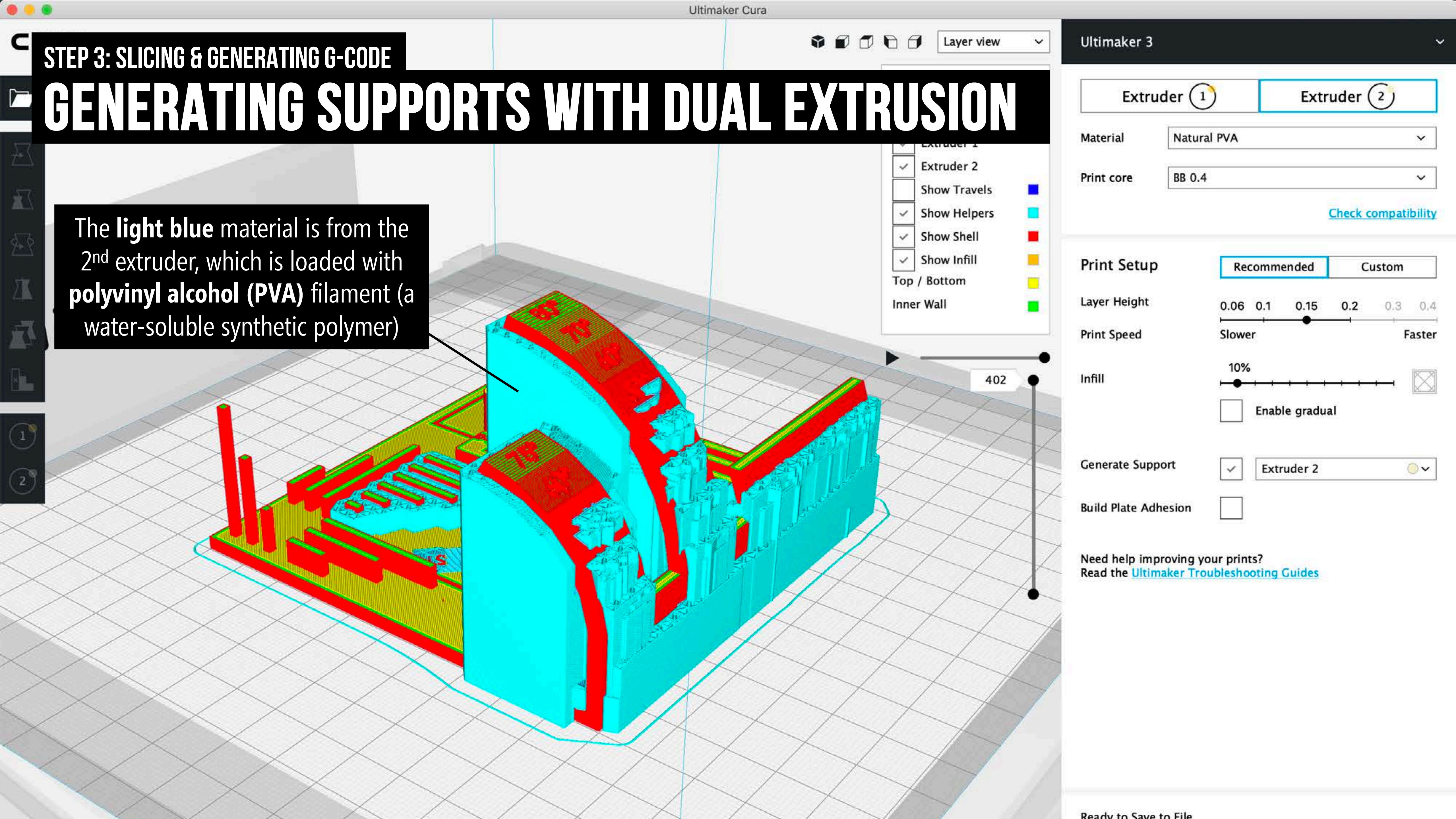
The **light blue** material indicates supports. These can be easily broken off post-print using your hands or a pliers



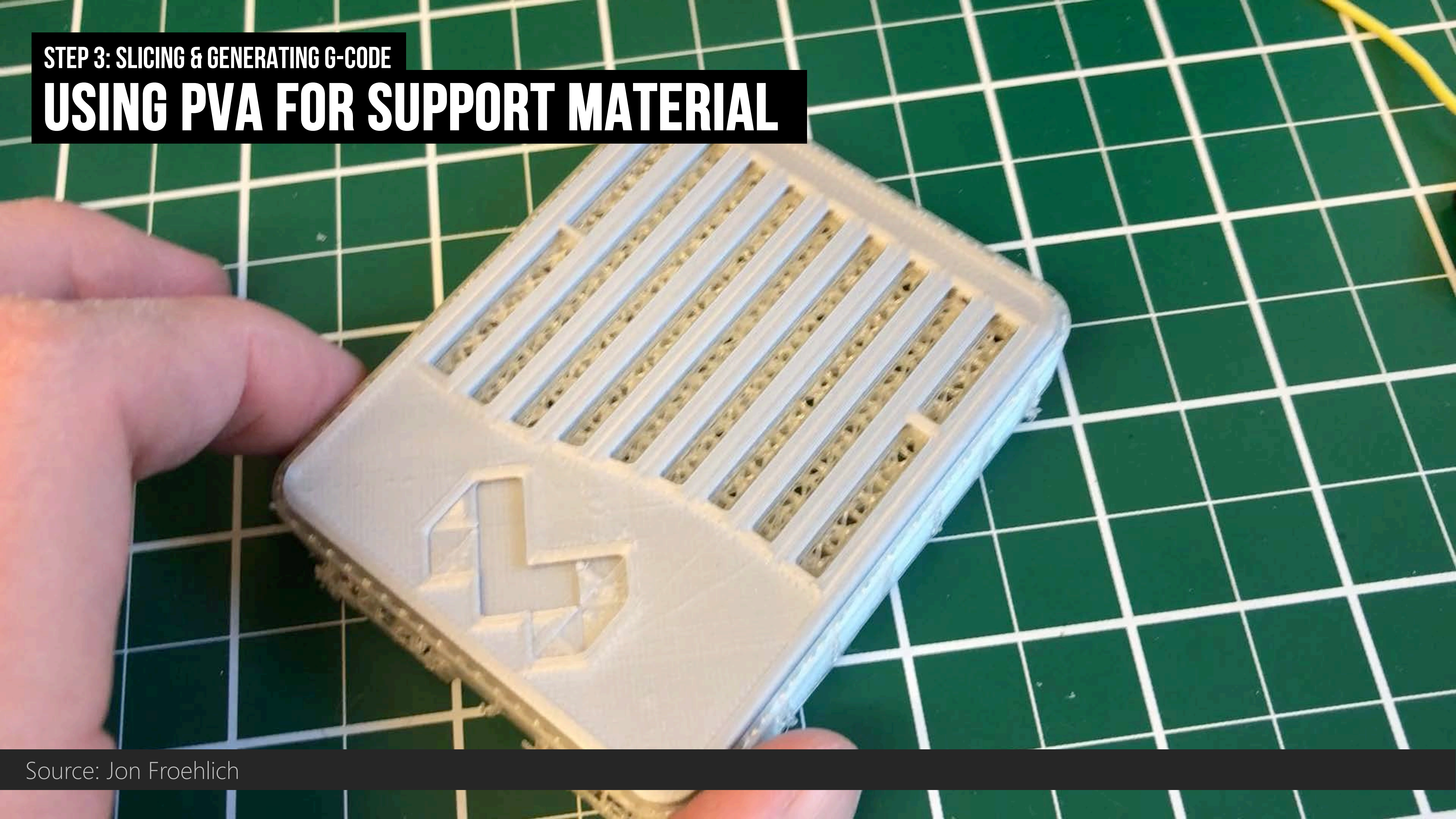
STEP 3: SLICING & GENERATING G-CODE

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)



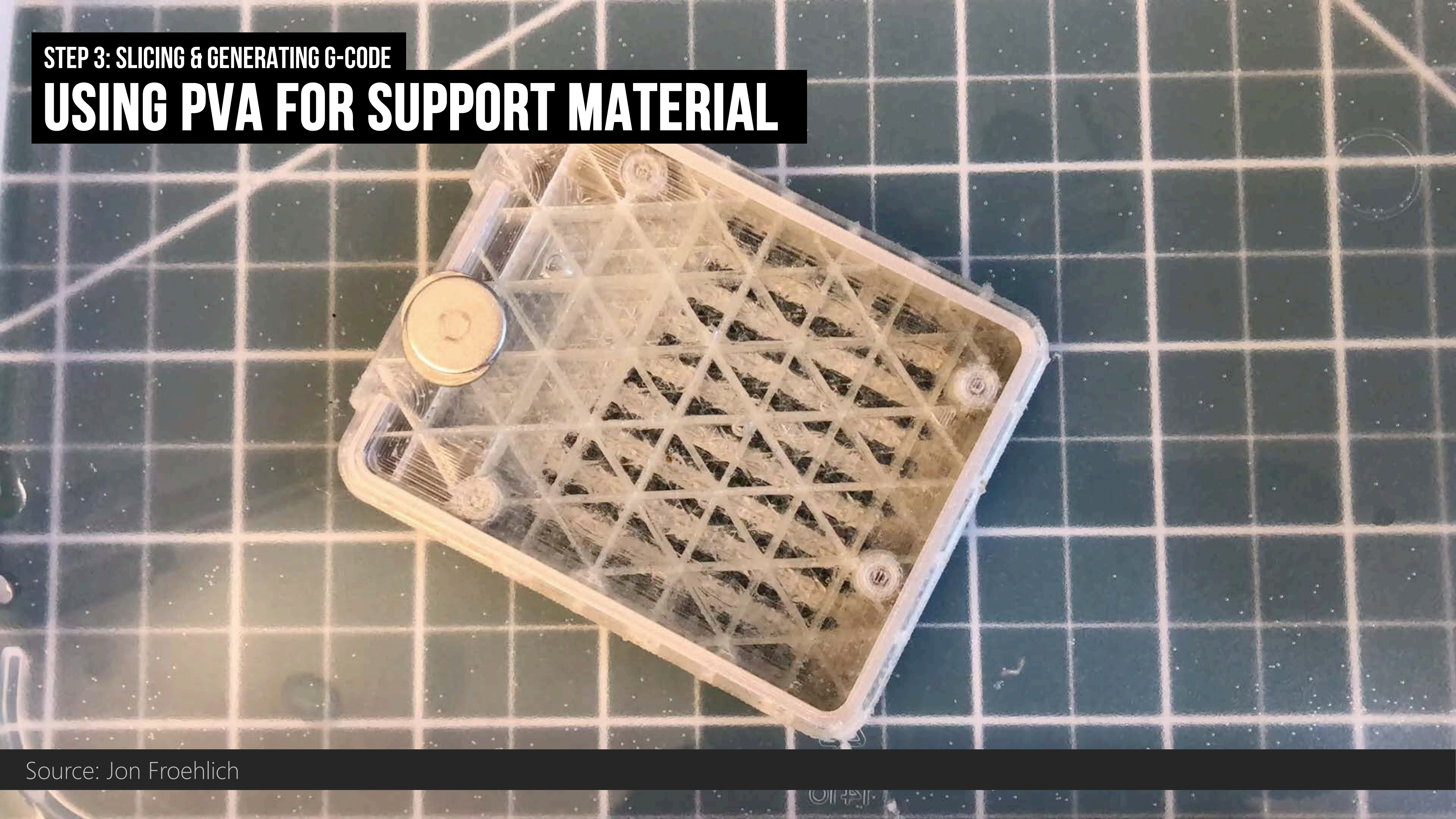
USING PVA FOR SUPPORT MATERIAL



Source: Jon Froehlich

STEP 3: SLICING & GENERATING G-CODE

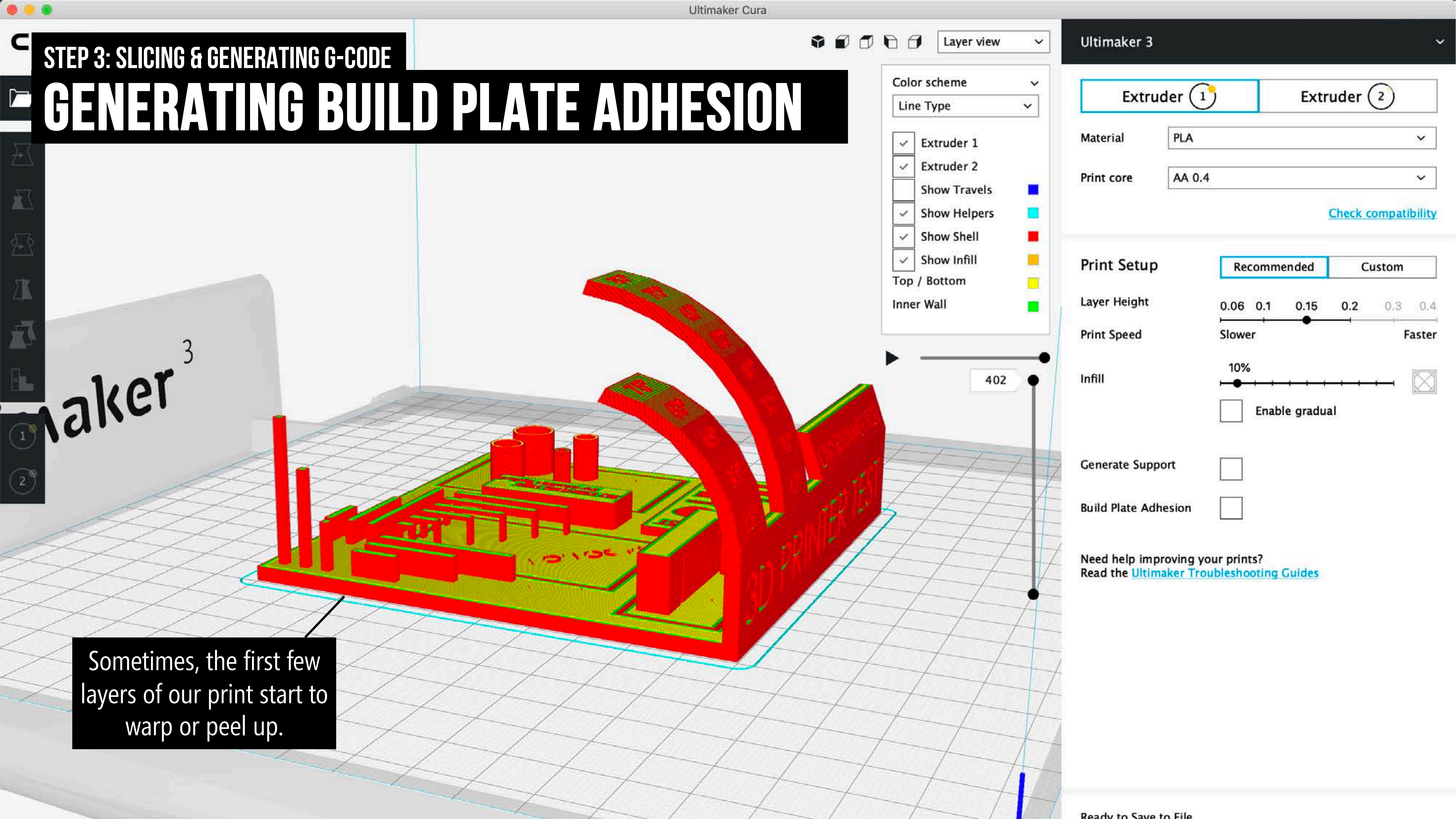
USING PVA FOR SUPPORT MATERIAL



Source: Jon Froehlich

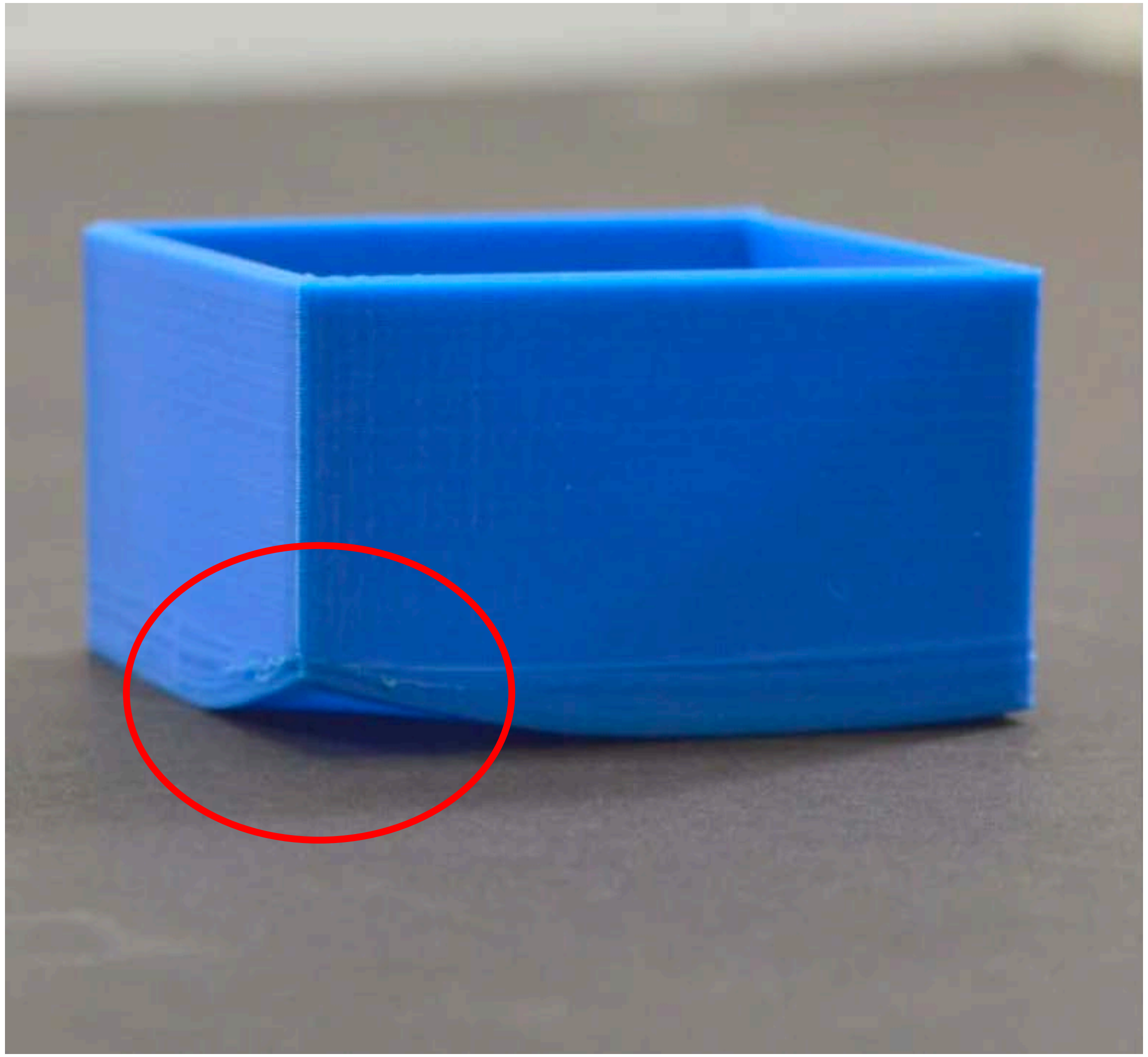
STEP 3: SLICING & GENERATING G-CODE

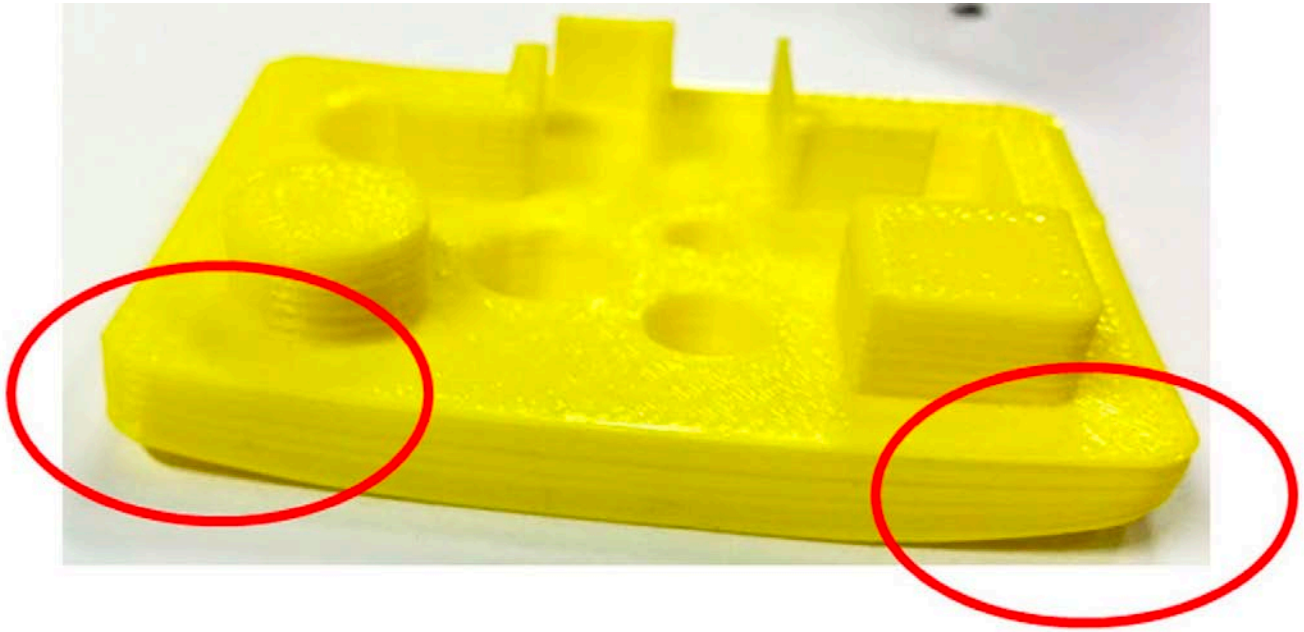
GENERATING BUILD PLATE ADHESION

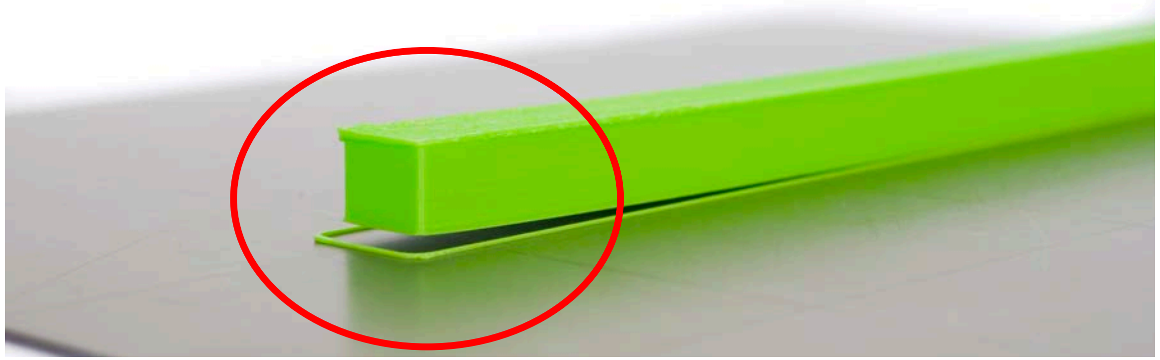


Sometimes, the first few layers of our print start to warp or peel up.

WARPING DUE TO POOR BUILD PLATE ADHESION

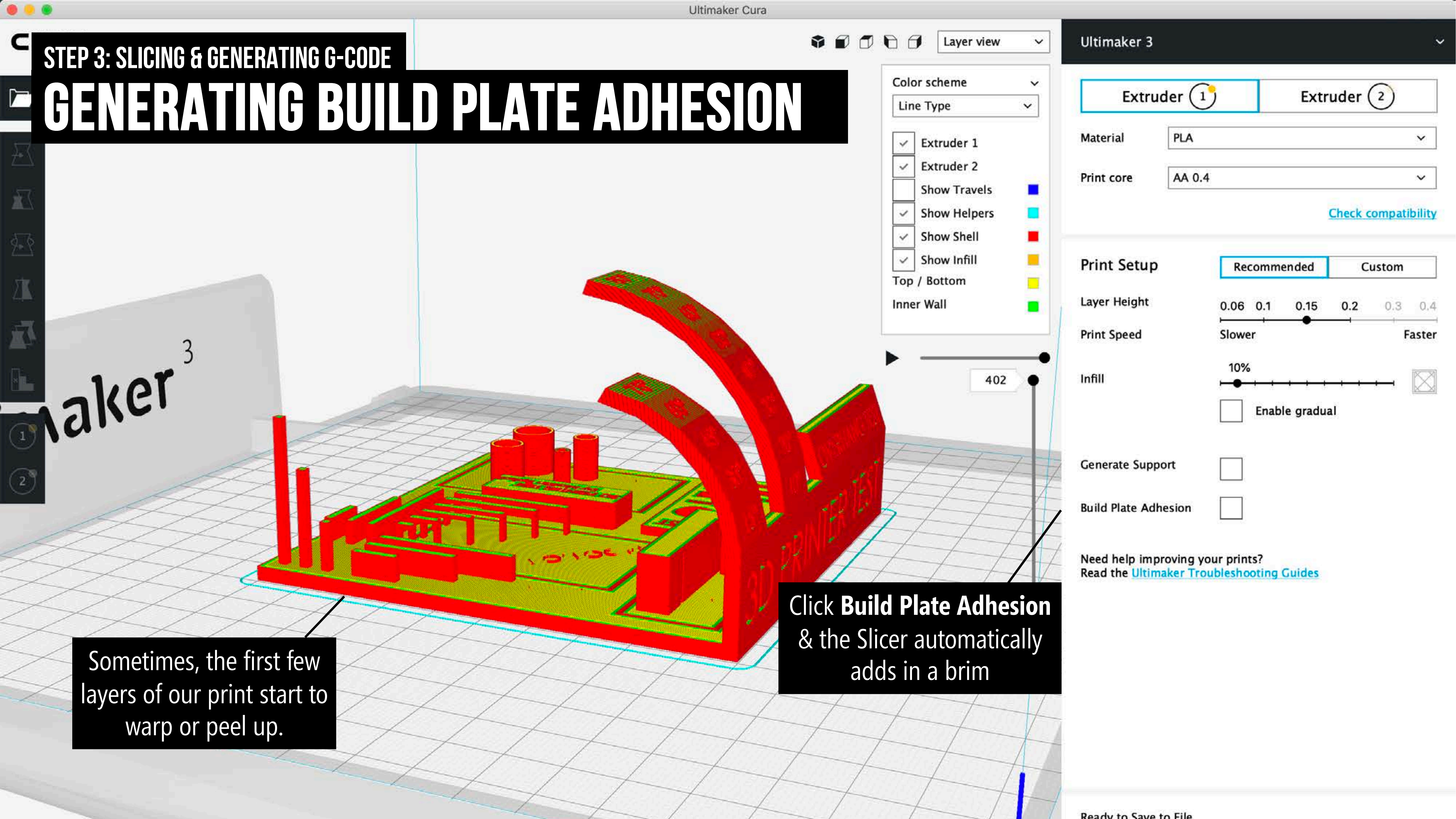






STEP 3: SLICING & GENERATING G-CODE

GENERATING BUILD PLATE ADHESION

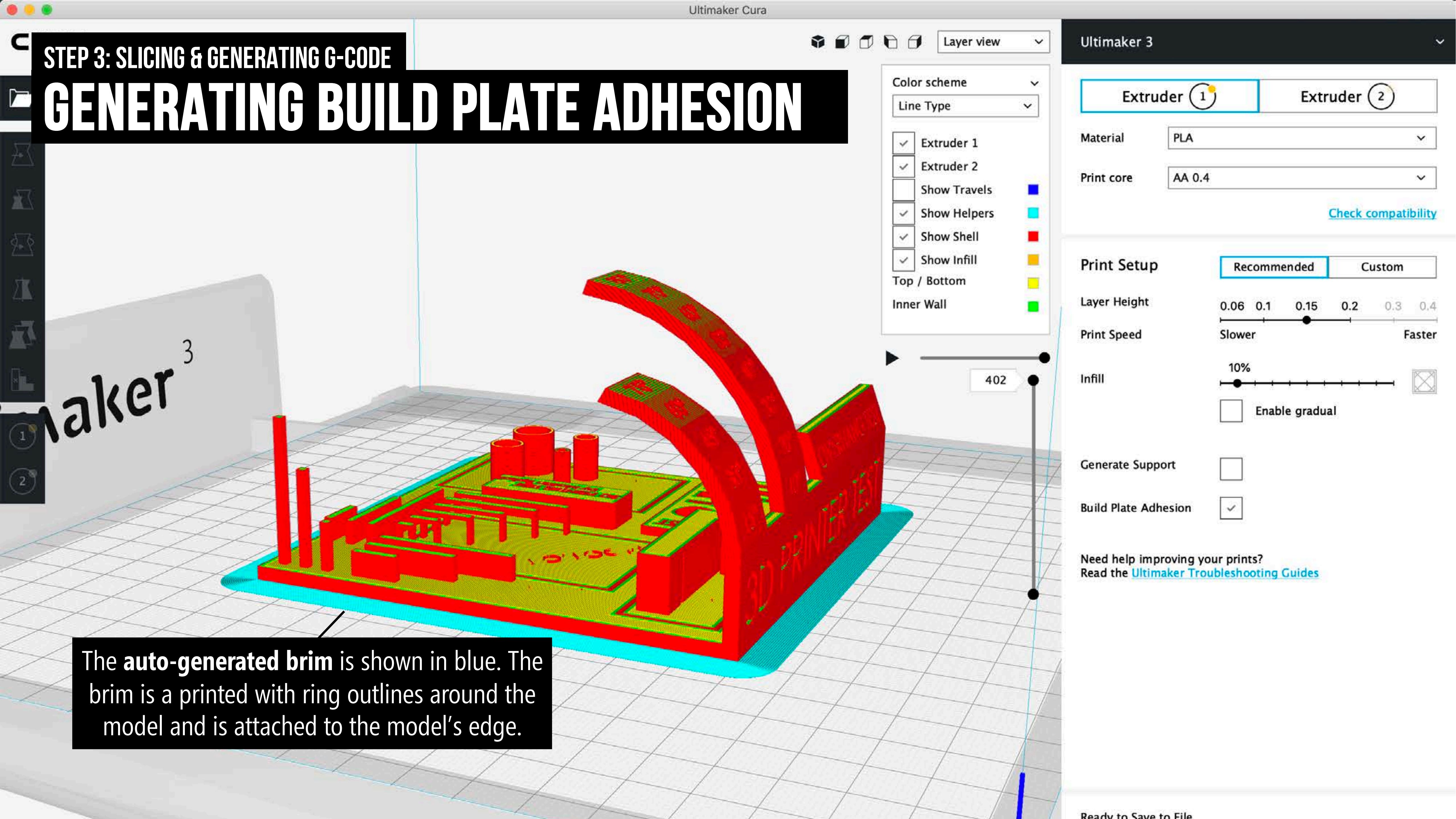


Sometimes, the first few layers of our print start to warp or peel up.

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

STEP 3: SLICING & GENERATING G-CODE

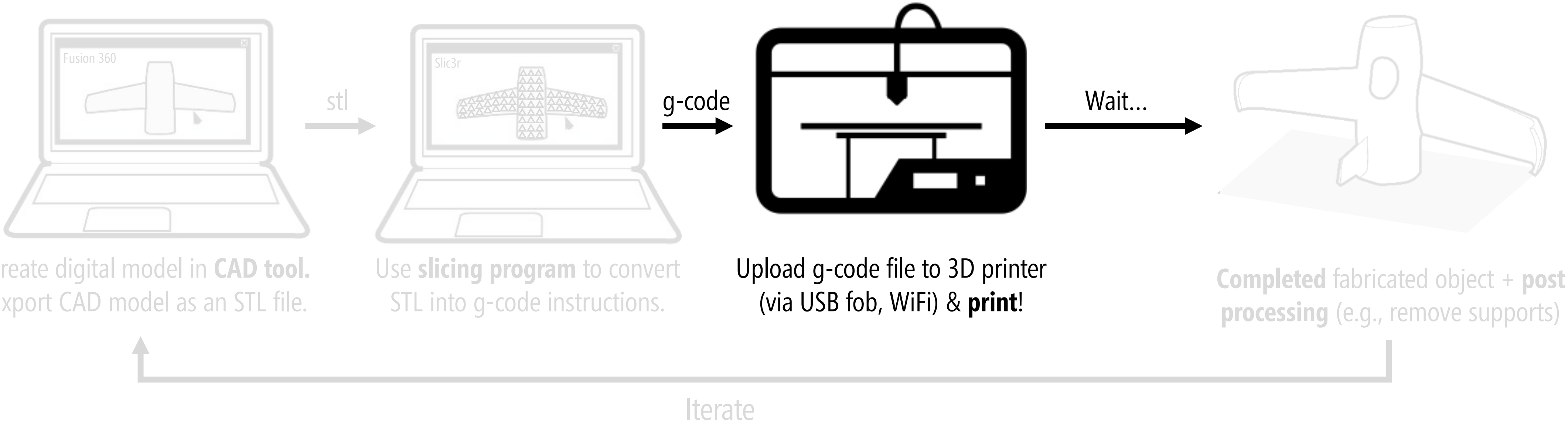
GENERATING BUILD PLATE ADHESION



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

3D-PRINTING PROCESS

4. LOAD G-CODE INTO PRINTER AND PRINT!

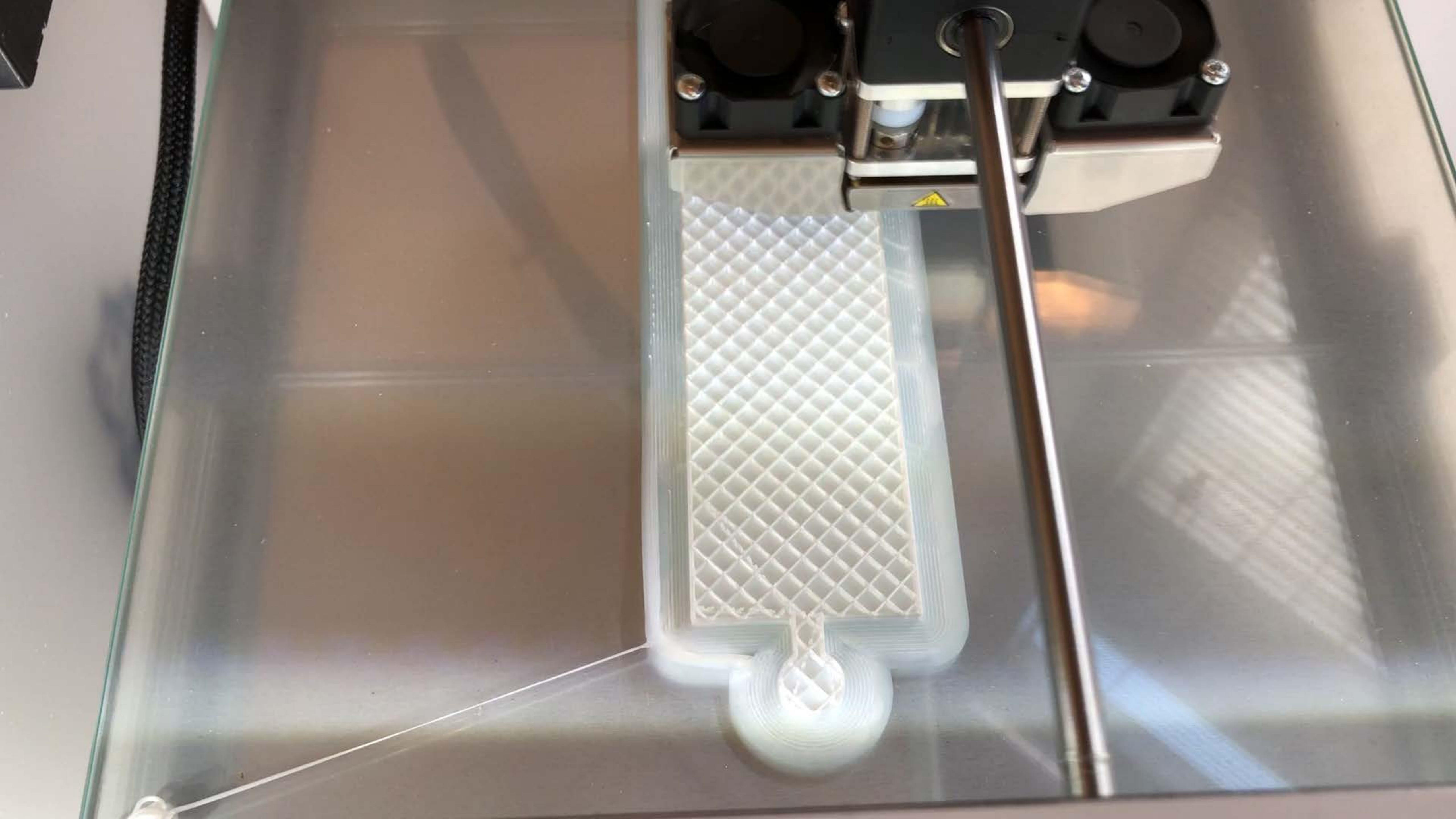


Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process

STEP 4: 3D PRINTING

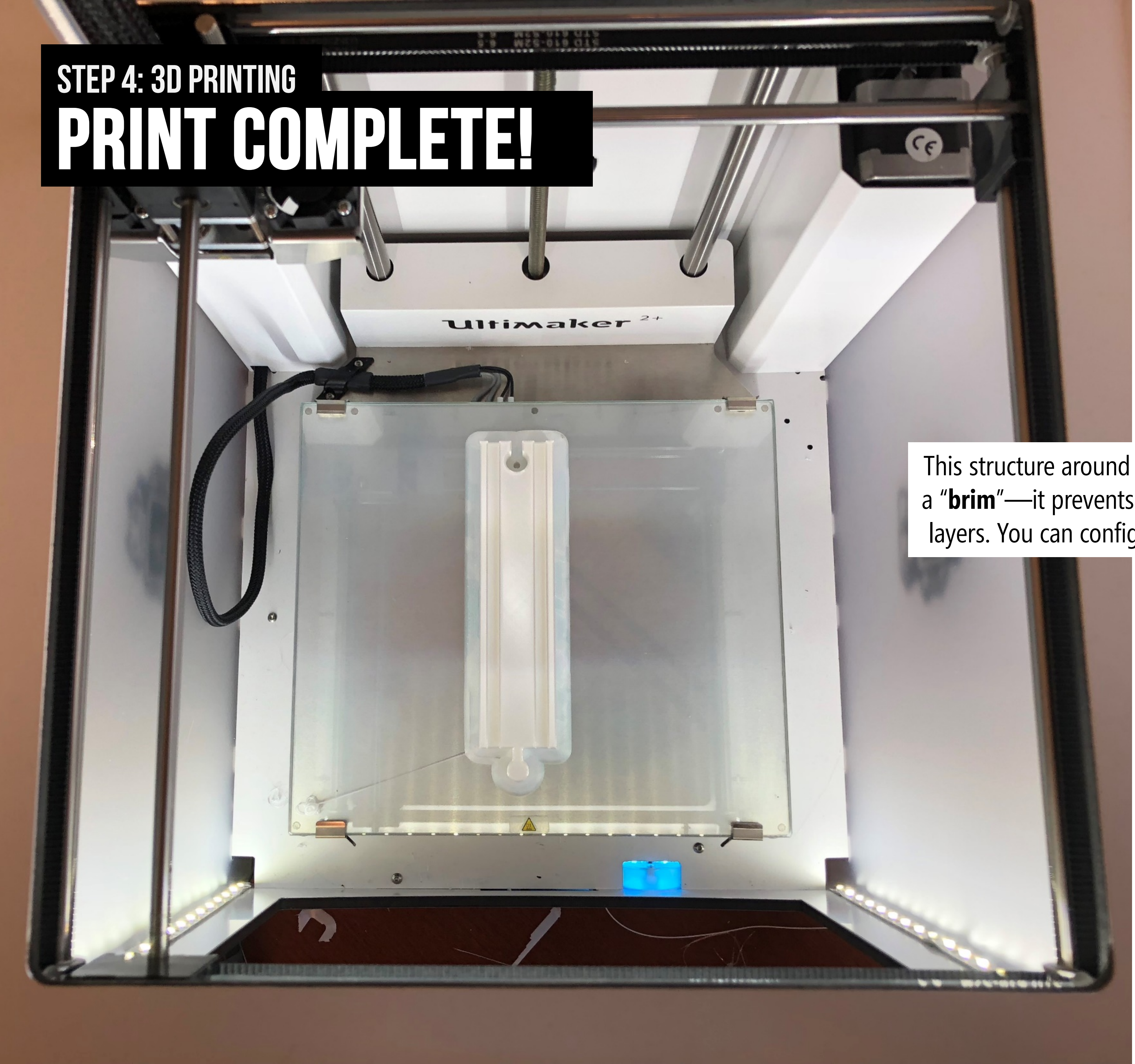
PRINTING ON AN ULTIMAKER 2+

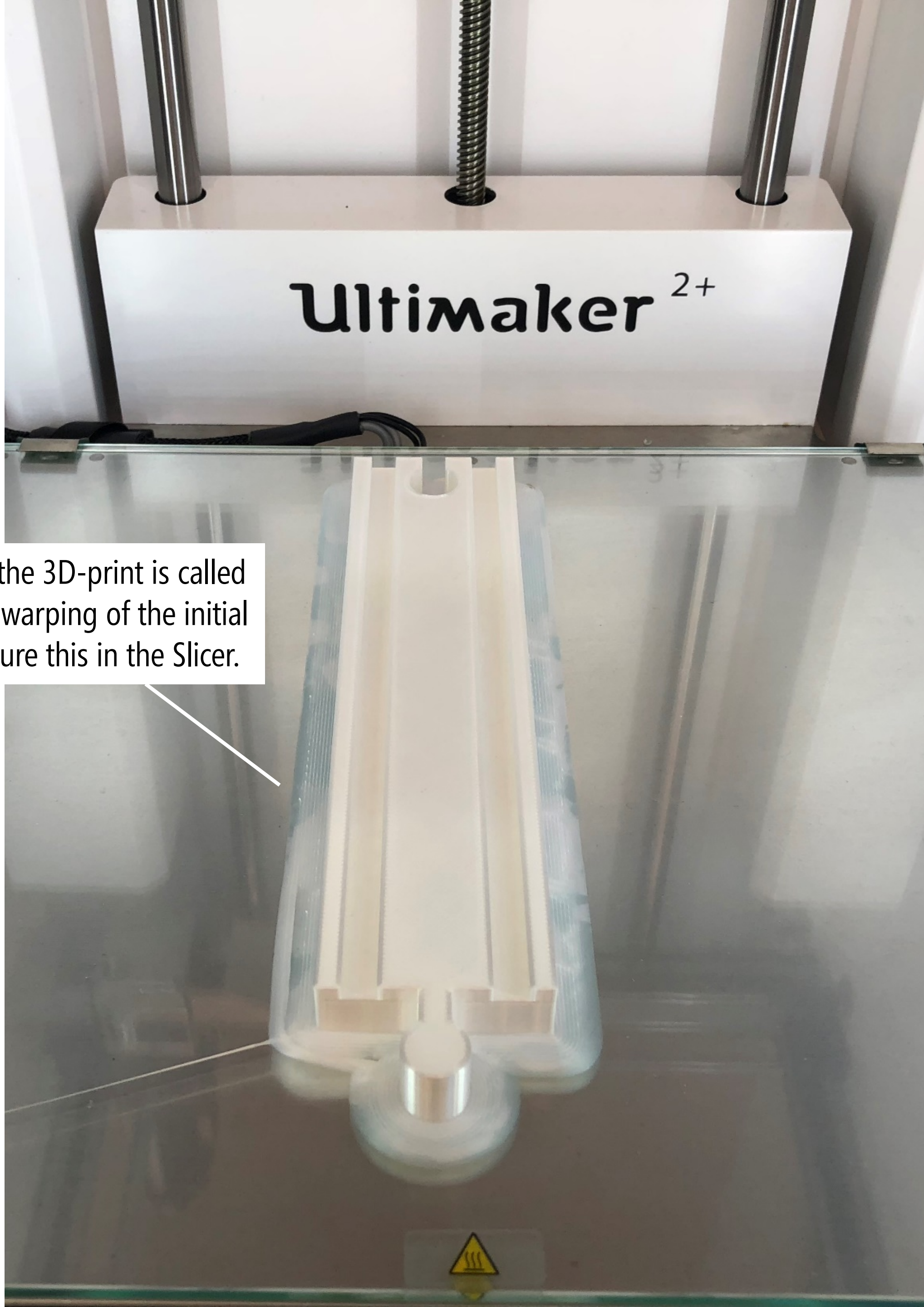
Source: Jon Froehlich



STEP 4: 3D PRINTING

PRINT COMPLETE!

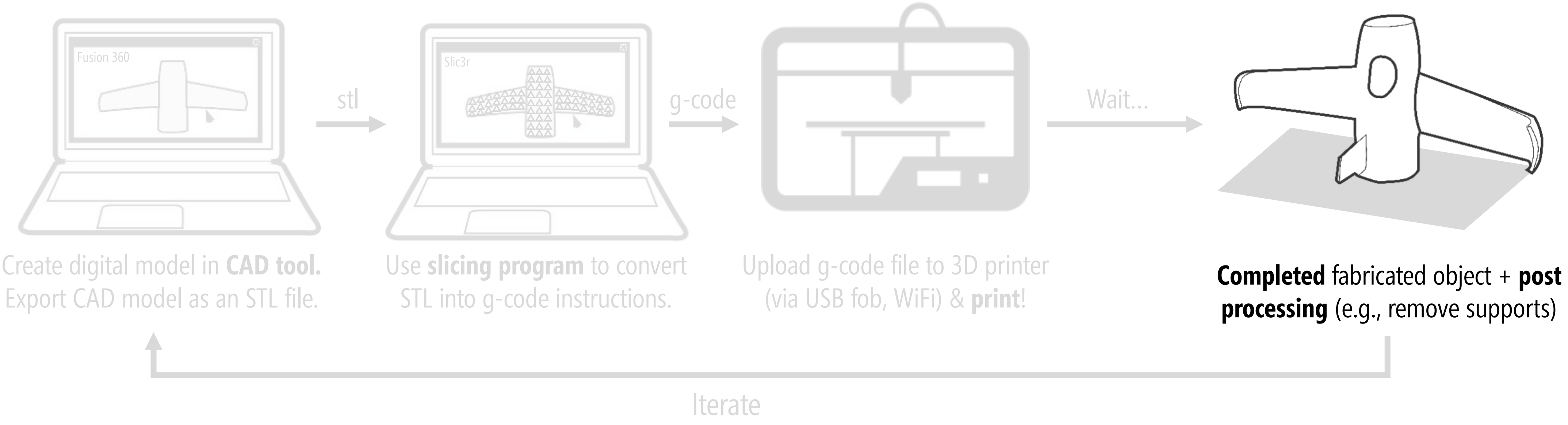




This structure around the 3D-print is called a “**brim**”—it prevents warping of the initial layers. You can configure this in the Slicer.

3D-PRINTING PROCESS

5. TAKE PRINTED OBJECT OFF PLATE + POST-PROCESSING



Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process

STEP 5: POST-PROCESSING

REMOVING PRINT FROM PRINT BED & POST-PROCESSING

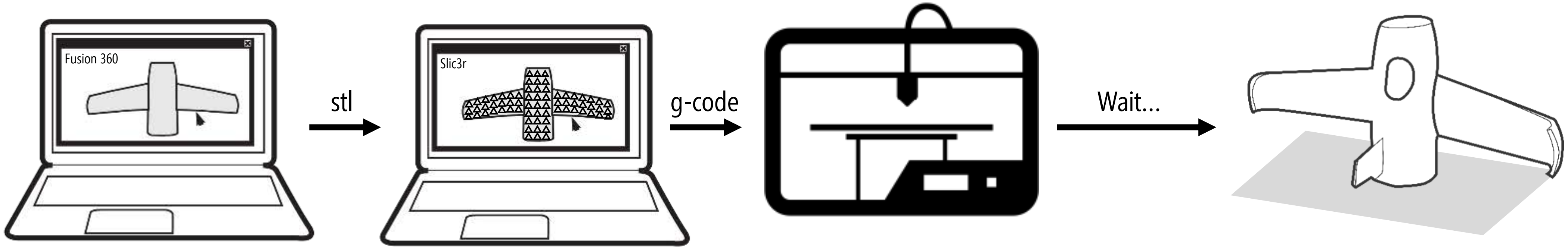
Source: Jon Froehlich


Ultimaker 2+
OVERHANG TEST
3D PRINTER TEST

STEP 6: TEST YOUR DESIGNS! ☺

TEST AND ITERATE ON YOUR DESIGNS

6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING



Create digital model in **CAD tool.** Export CAD model as an STL file.

Use **slicing program** to convert STL into g-code instructions.

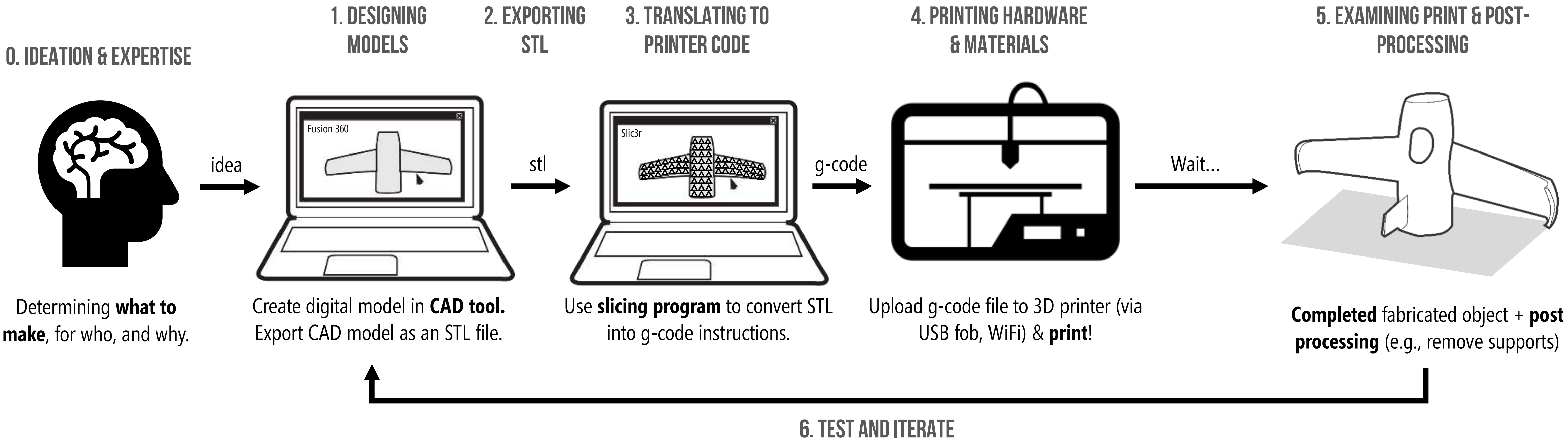
Upload g-code file to 3D printer (via USB fob, WiFi) & **print**!

Completed fabricated object + **post processing** (e.g., remove supports)

Test + Iterate

3D-PRINTING PROCESS

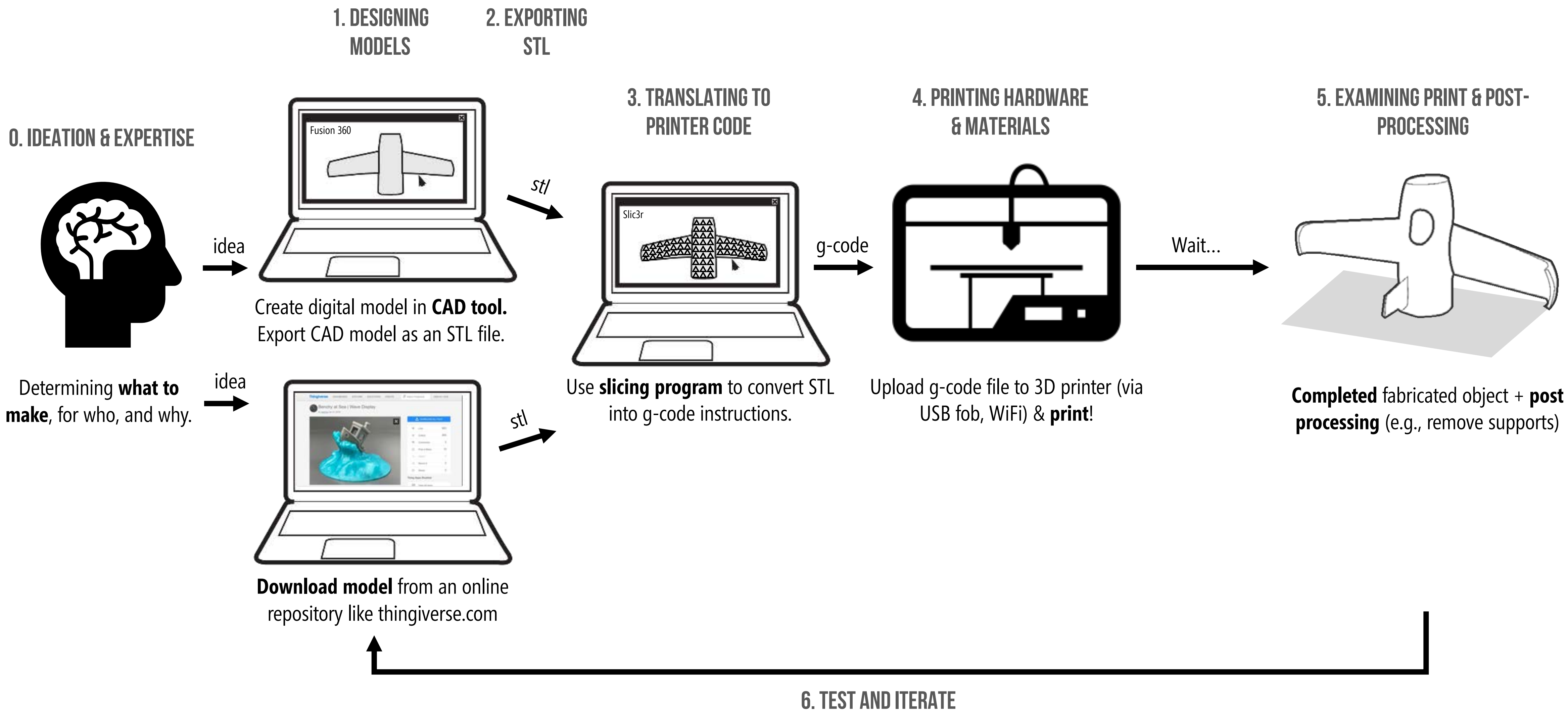
6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING



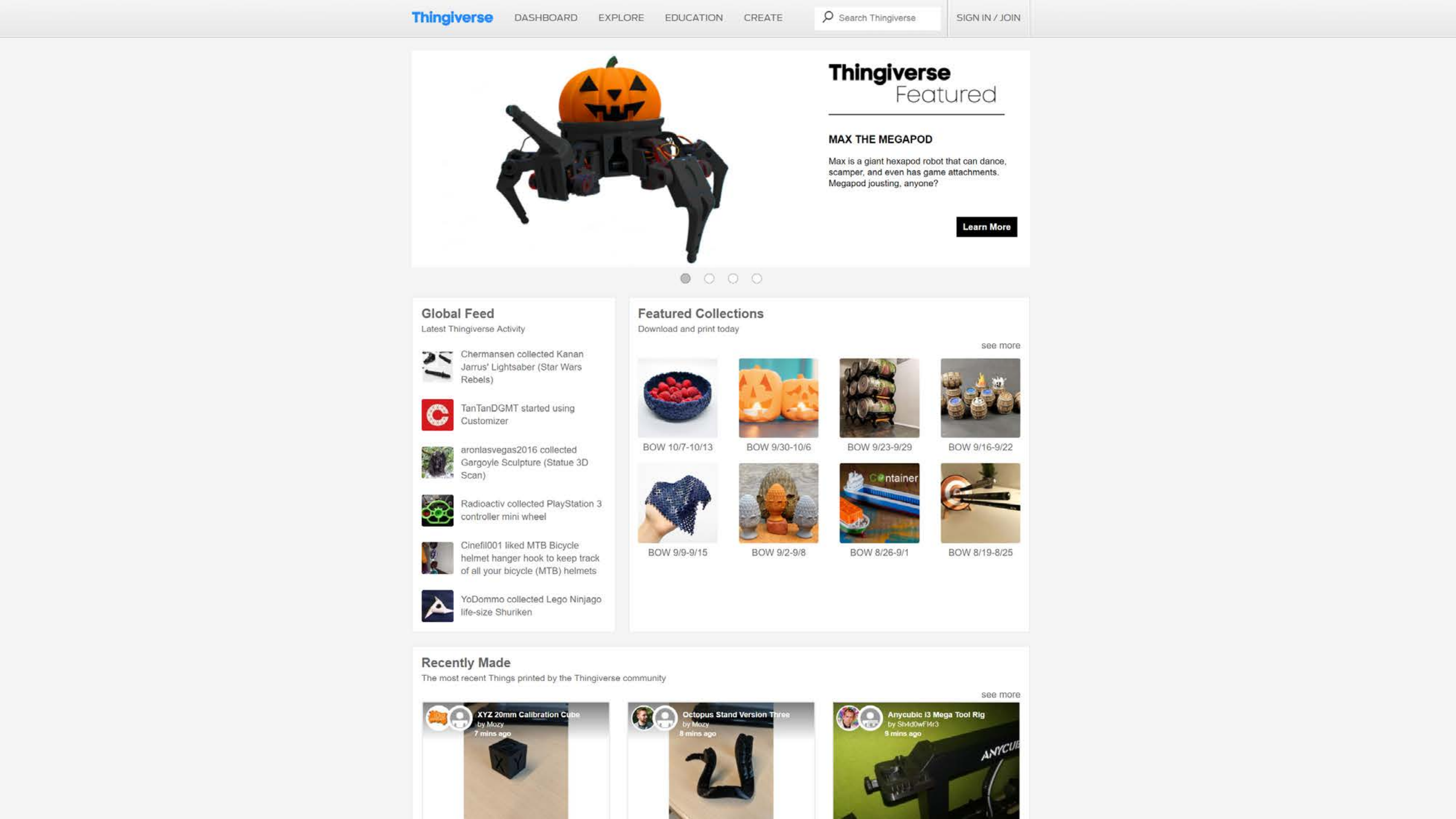
Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process

3D-PRINTING PROCESS

6-STEP ITERATIVE PROCESS FROM MODELING TO PRINTING



Slide based on Huaishu Peng's job talk; See also: https://www.3dhubs.com/knowledge-base/additive-manufacturing-process



Thingiverse DASHBOARD EXPLORE EDUCATION CREATE Search Thingiverse SIGN IN / JOIN

Thingiverse Featured

MAX THE MEGAPOD

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

Learn More

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

Featured Collections

Download and print today

see more

BOW 10/7-10/13

BOW 9/30-10/6

BOW 9/23-9/29

BOW 9/16-9/22

BOW 9/9-9/15

BOW 9/2-9/8

BOW 8/26-9/1

BOW 8/19-8/25

Recently Made

The most recent Things printed by the Thingiverse community

see more

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

SEARCH RESULTS

3,813 results matching star wars

# of Makes

star wars

SEARCH

FILTER BY

- Things
- Makes
- Users
- Collections
- Groups
- Apps

FOR EDUCATION

REFINE YOUR SEARCH

License Type

Any

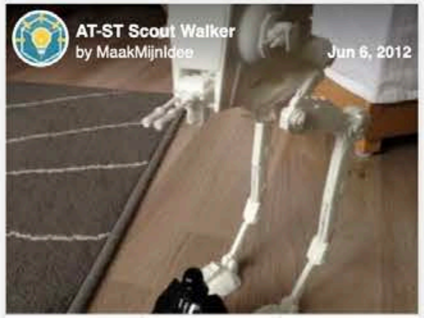
- Customizable
- Show Customized Creations
- Order A Print
- Has Makes
- Featured

19440 | 24292 | 200

6174 | 7567 | 176

5393 | 6220 | 53

2811 | 4176 | 41

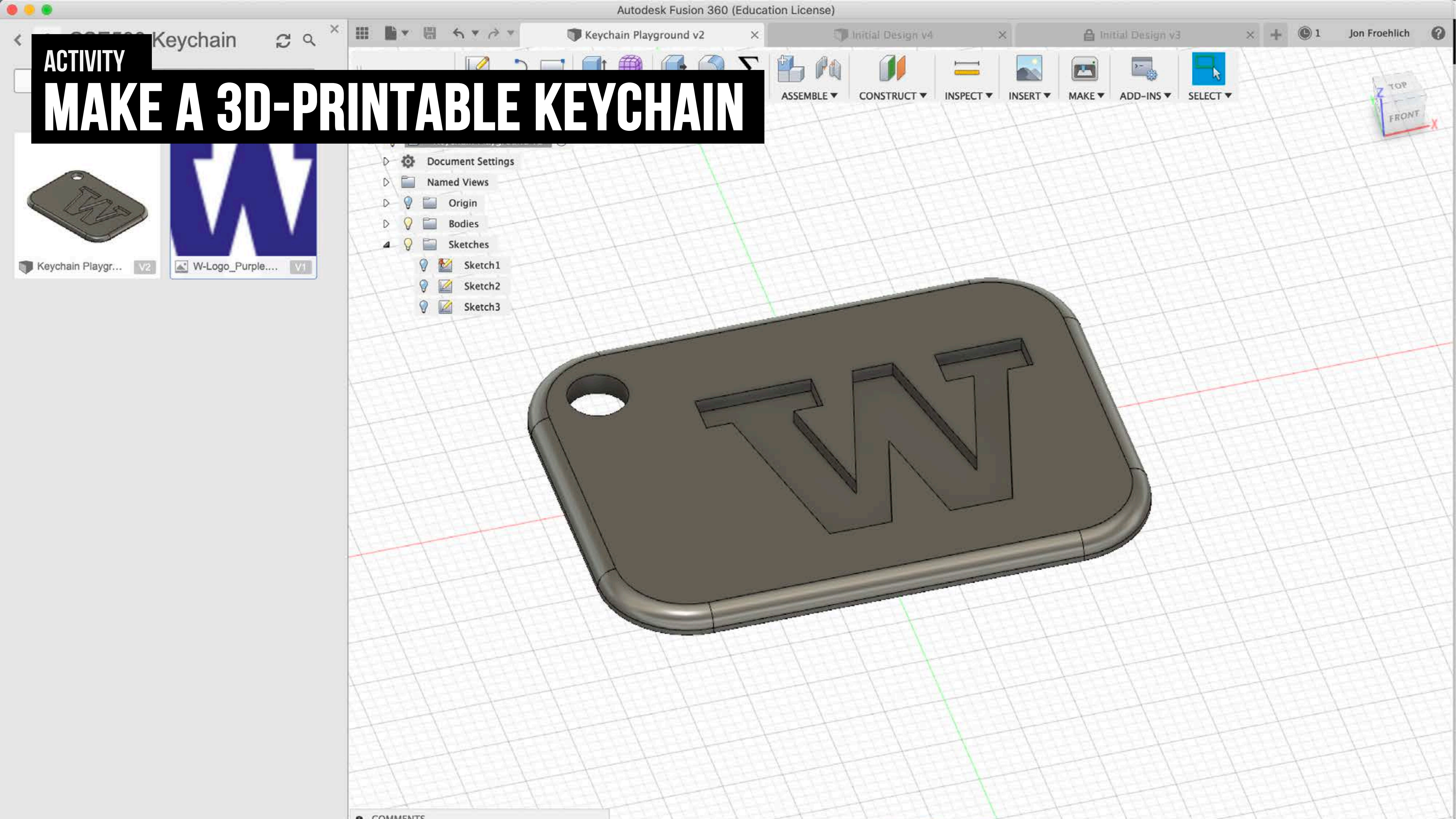


4136 | 5955 | 58

7697 | 9032 | 53

ACTIVITY

MAKE A 3D-PRINTABLE KEYCHAIN

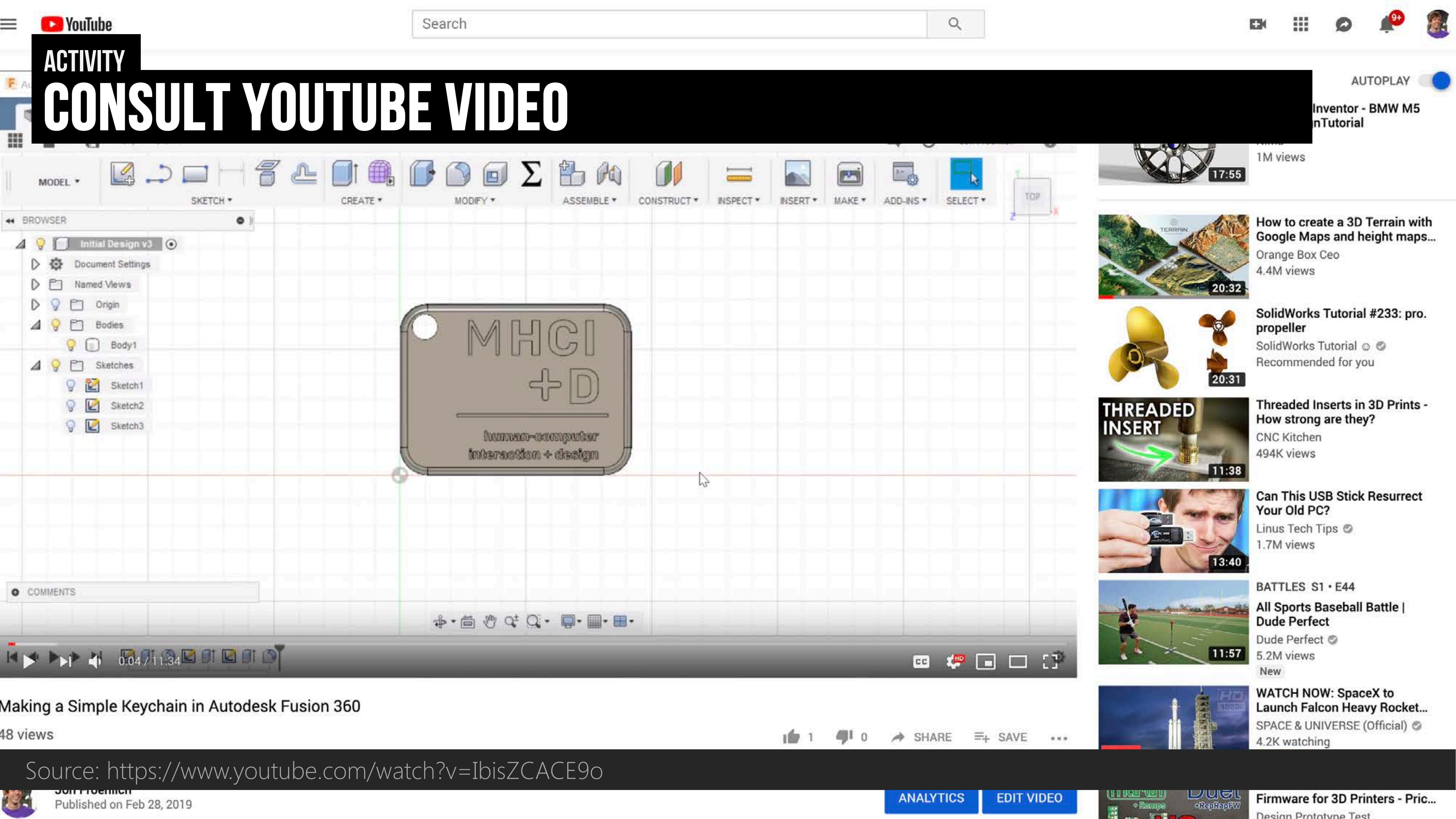


ACTIVITY

MAKE A 3D-PRINTABLE KEYCHAIN

ACTIVITY

CONSULT YOUTUBE VIDEO



Source: https://www.youtube.com/watch?v=IbisZCACE9o

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**

PROTOTYPING FORM: 3D MODELING + PRINTING

CSE 599 Prototyping Interactive Systems | Lecture 7 | April 23

Jon Froehlich • Jasper Tran O'Leary (TA)

DESIGN USE BUILD

MAKEABILITY LAB

PAUL G. ALLEN SCHOOL
OF COMPUTER SCIENCE & ENGINEERING

UNIVERSITY of
WASHINGTON