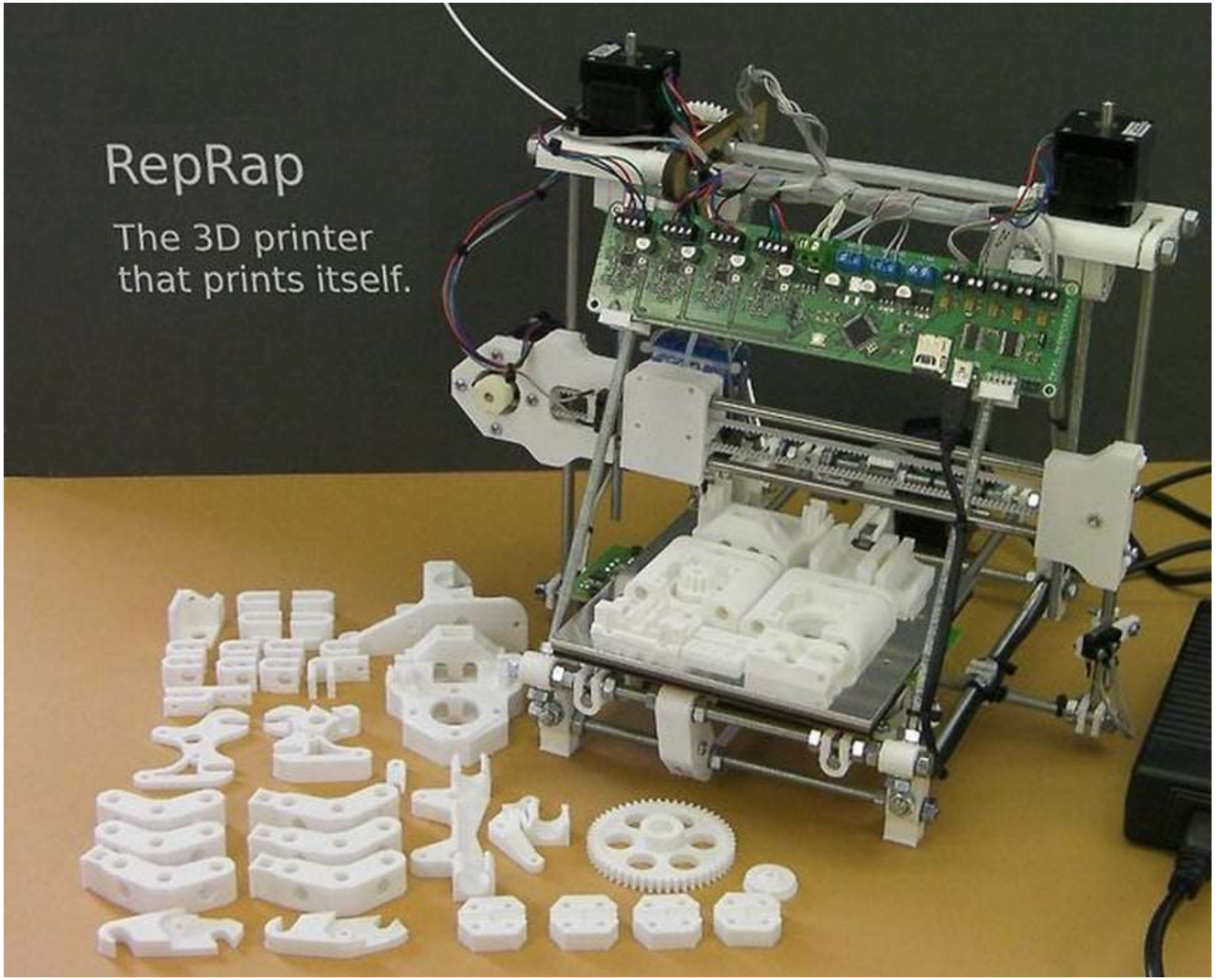
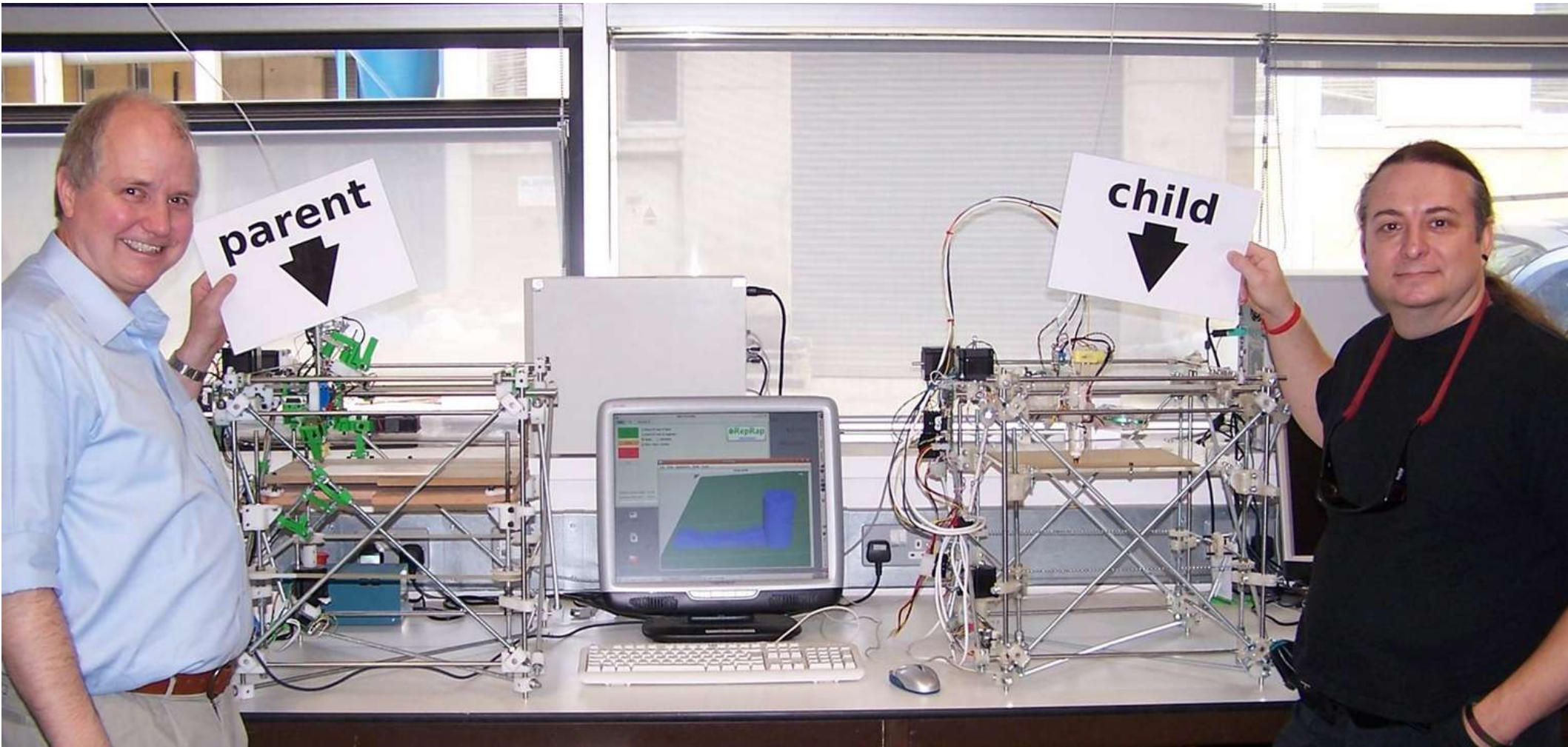
RepRap Background



Outline

- Background
- Design
- Use
- Troubleshoot

Self-replicating rapid prototyper...RepRap



Wealth without money
The background to the Bath Replicating Rapid Prototyper Project

AdrianBowyer - 2 Feb 2004

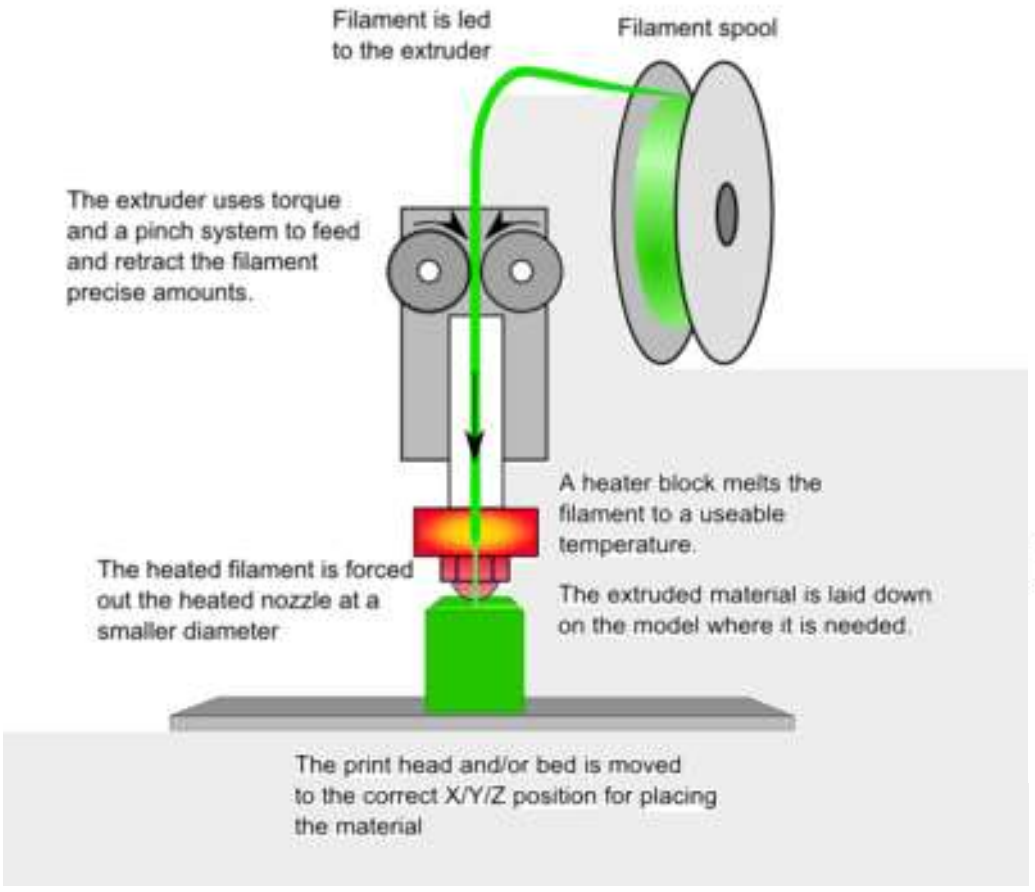
The three most important aspects of such a self-copying rapid-prototyping machine are that:

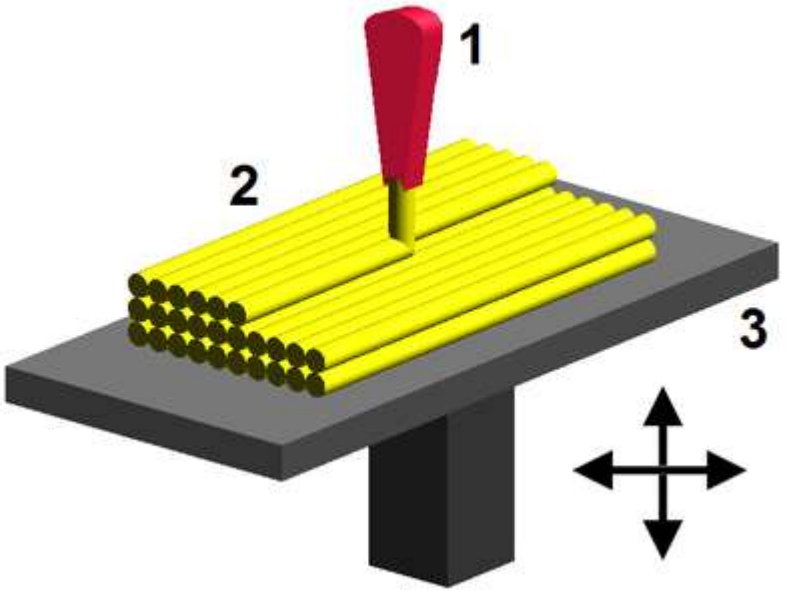
1. The number of them in existence and the wealth they produce can grow exponentially,

2. The machine becomes subject to evolution by artificial selection, and

3. The machine creates wealth with a minimal need for industrial manufacturing.

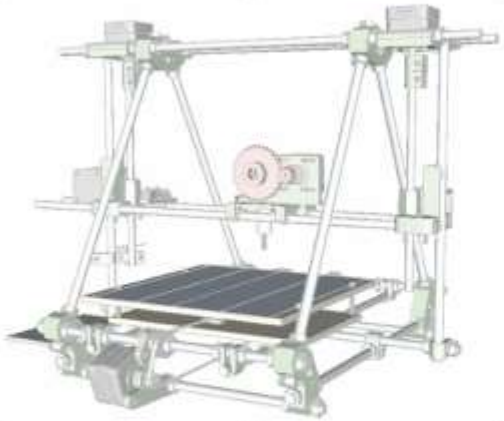
How do they work?





RepRap Family Tree

V2.9 (06-06-2011)



2006 2007 2008 2009 2010 2011

A.R.N.I.E
Tommelise
RepStrap
Zaphod

Darwin
lasercut /wooden Darwin
Ponoko lasercut Darwin
casted Darwin
Lego RepStrap

McWire
JunkStrap

Sells Mendel
Apollo
Megamendel
Catalyst
Foton
Eiffel
T-Rep
LeBigRep
Darwin Sampo
Mendel v2
MendeLego
Techzone Mondo
Orca
Techzone Mendel
Isaac Mendel
Wolfstrap
Mini-mendel
Huxley
Huxley Seedling
Rusty Huxley
eMaker Huxley
Techzone Huxley
Malthus
Mixtape mendel
Prusa Mendel
Robundel
Vinyl Tube mendel
RepRap 1x2
RepRap 1x2 Tallcat
RepRap 1x2 Shortcat
Clonedel
Makergear Prusa

Doboz
Kludgebot
Betzbot
Type A Printer MK1
DeltaBot
Helium Frog
FabPod
Bonsai RepStrap
Adderfab
RepOlaRap
A5 Powderbed printer
MetalicaRap

Ultimaker
Minimaker
Kinirap
Columbus
Shapercube 1.0
Shapercube 2.0
Upl 3d printer
Makergear Mosaic

Makerbot Cupcake
Makerbot Thing-o-matic
Cupcakestrap

Rapman Pro / Bfb 3000
Rapman

Fabaroni
Fab@home Model 1
Model 1.2
Model 2
Rap@Home

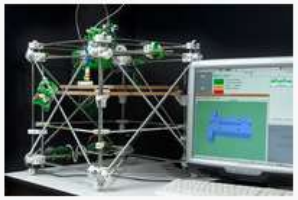
CandyFab 4000
CandyFab 5000
CandyFab 6000

- Working
- Experimental
- Concept
- Commercial
- Other oshw project
- Common
- Less common
- Work in progress

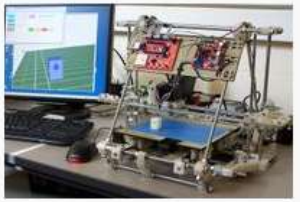
Emmanuel Gilloz

2006 2007 2008 2009 2010 2011

Mendel Rostock (*license: GPL*)



Darwin (*license: GPL*)



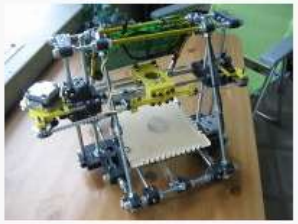
Mendel (*license: GPL*)

Prusa Mendel (*license: GPL*)

i3Berlin (*license: GPL*)

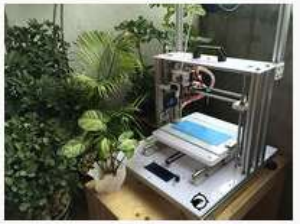
Prusa i3 (*license: GPL*)

K86 (*license: CC-BY-NC-SA*)

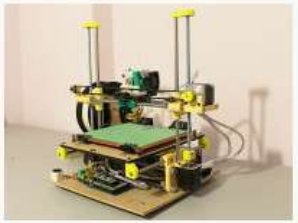


Huxley (*license: GPL*)

Holliger (*license: GPL*)



Wolfy1.1 (*license: GPL*)

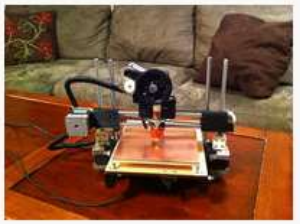


Mix G1 (*license: GPL*)

RepRap Morgan (*license: GPL*)

Simpson (*license: GPL*)

3DPrintMi (*license: GPL*)

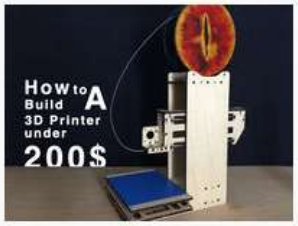


Printrbot (*license: CC-BY-SA*)

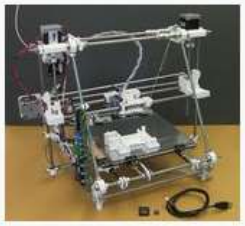
Wallace (*license: GPL*)

Tantillus (*license: GPL*)

Cartesio (*license: CC-BY-NC-SA*)



TowerSimpleXL (*license: GPL*)



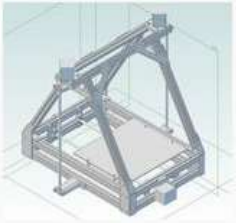
RepRapPro Mendel (*license: GPL*)

RepRapPro Huxley (*license: GPL*)

Eventorbot (*license: CC-BY-SA*)

Kossel(*license:GPL*)

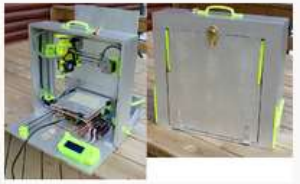
3drag (*license: CC-BY-SA*)



MendelMax (*license: GPL*)

MendelMax 2.0 (*license: GPL*)

Mendel90 (*license: GPL*)

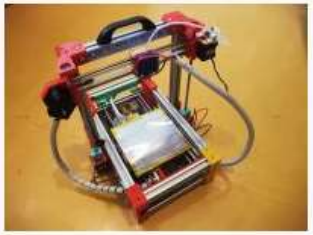


case-rap 2.0 (*license: GPL*)

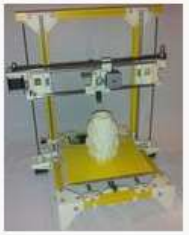
case-rap (*license: GPL*)

GolemD (*license: CC-BY-SA*)

(*license: CC-BY-NC-SA*)

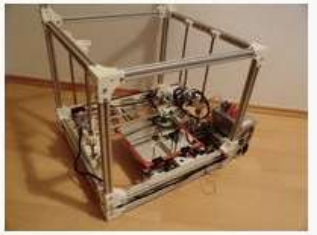


FoldaRap (*license: GPL*)



Adapto (*license: GPL*)

SibRap (*license: GPLv3*)

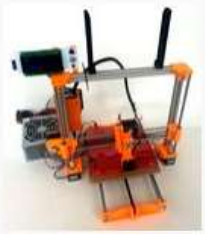


Haeckel (*license: GPL*)

Artifex (*license: CC-BY-SA*)

license: CC-BY-SA)

Smartrap mini (*license: GPL*)

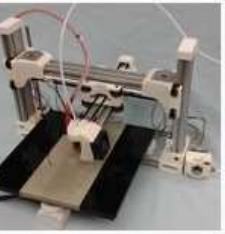


Wilson (*license: GPL*)

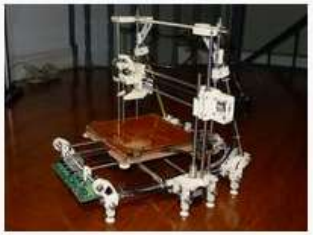
Kiwi remix (*license: GPL*)

Micro Delta (*license: CC-BY-NC-SA*)

Ormerod (*license: GPL*)

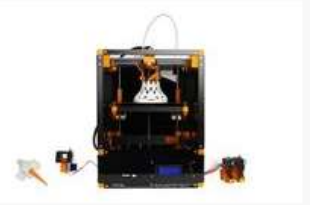


nse: CC-BY-SA)



Samuel (*license: GPL*)

Litone (*license: GPL*)



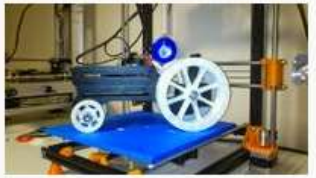
MM1 (*license: CC-BY-SA-NC*)

Ulticampy (*license: CC-BY-NC-SA*)

AtomX (*license: CC-BY-SA*)

i1 (*license: CC-BY-SA*)

Rostock Mini Pro (*license: GPL*)

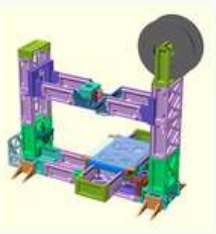


Abbas (*license: GPL*)

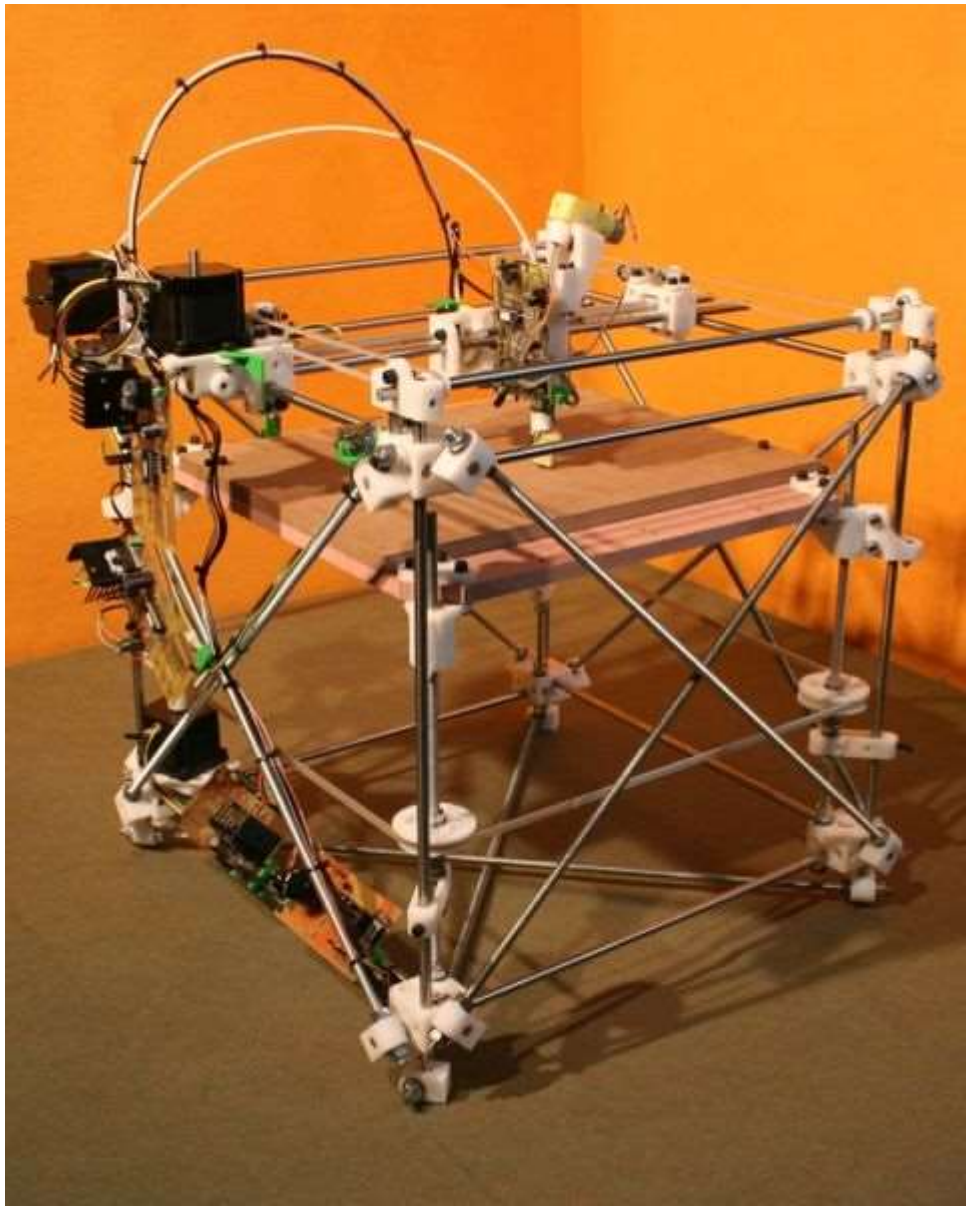
Adapto Flex (*license: GPL*)

E1x (*license: CC-BY-NC-SA*)

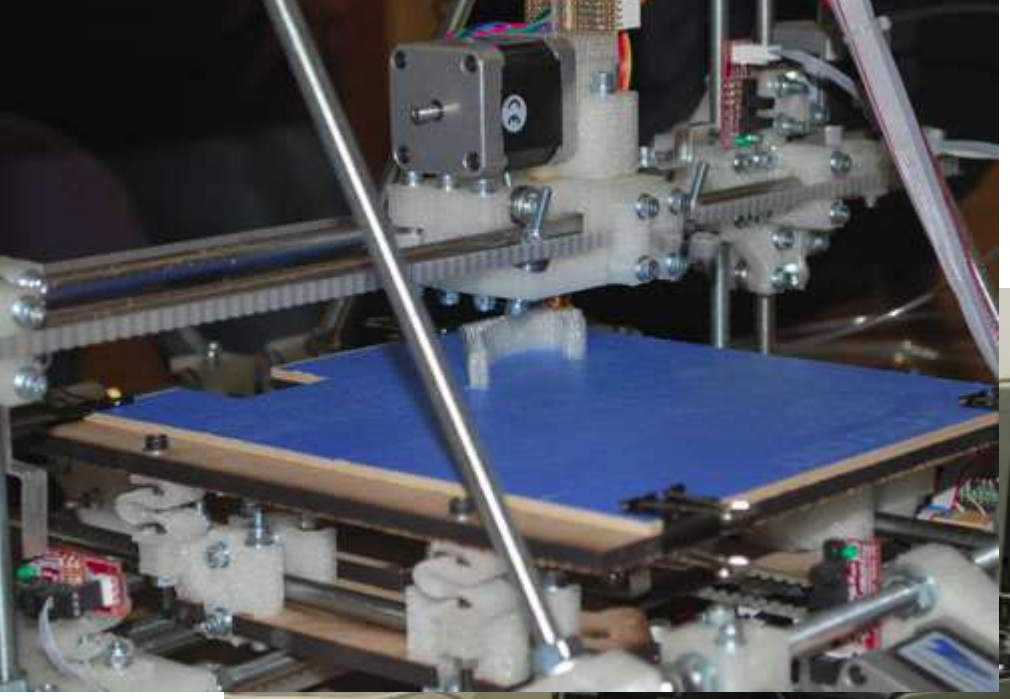
Nelu (*license: GPL*)

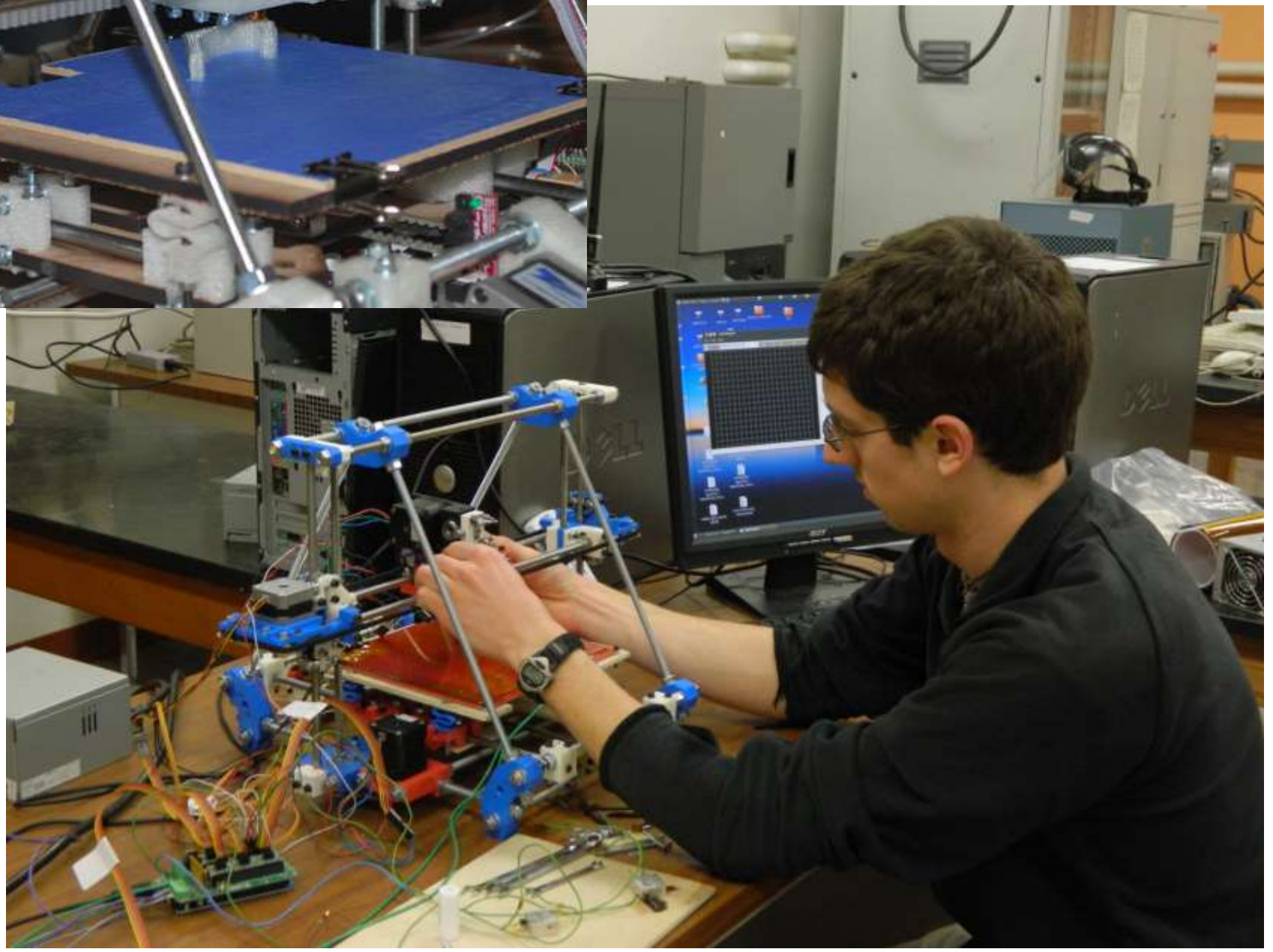


Open-Source 3-D Printing:RepRap v1

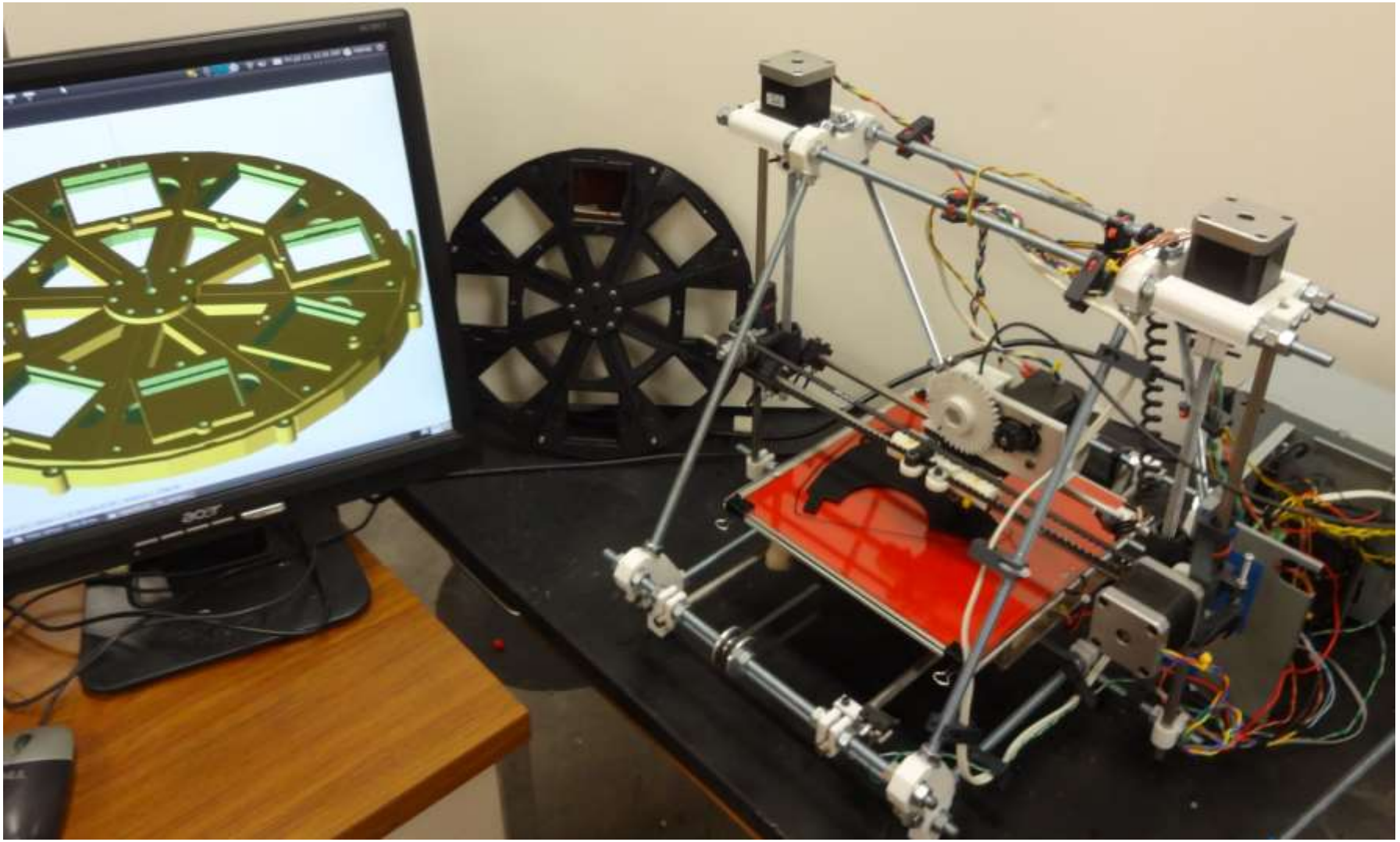


RepRap v2



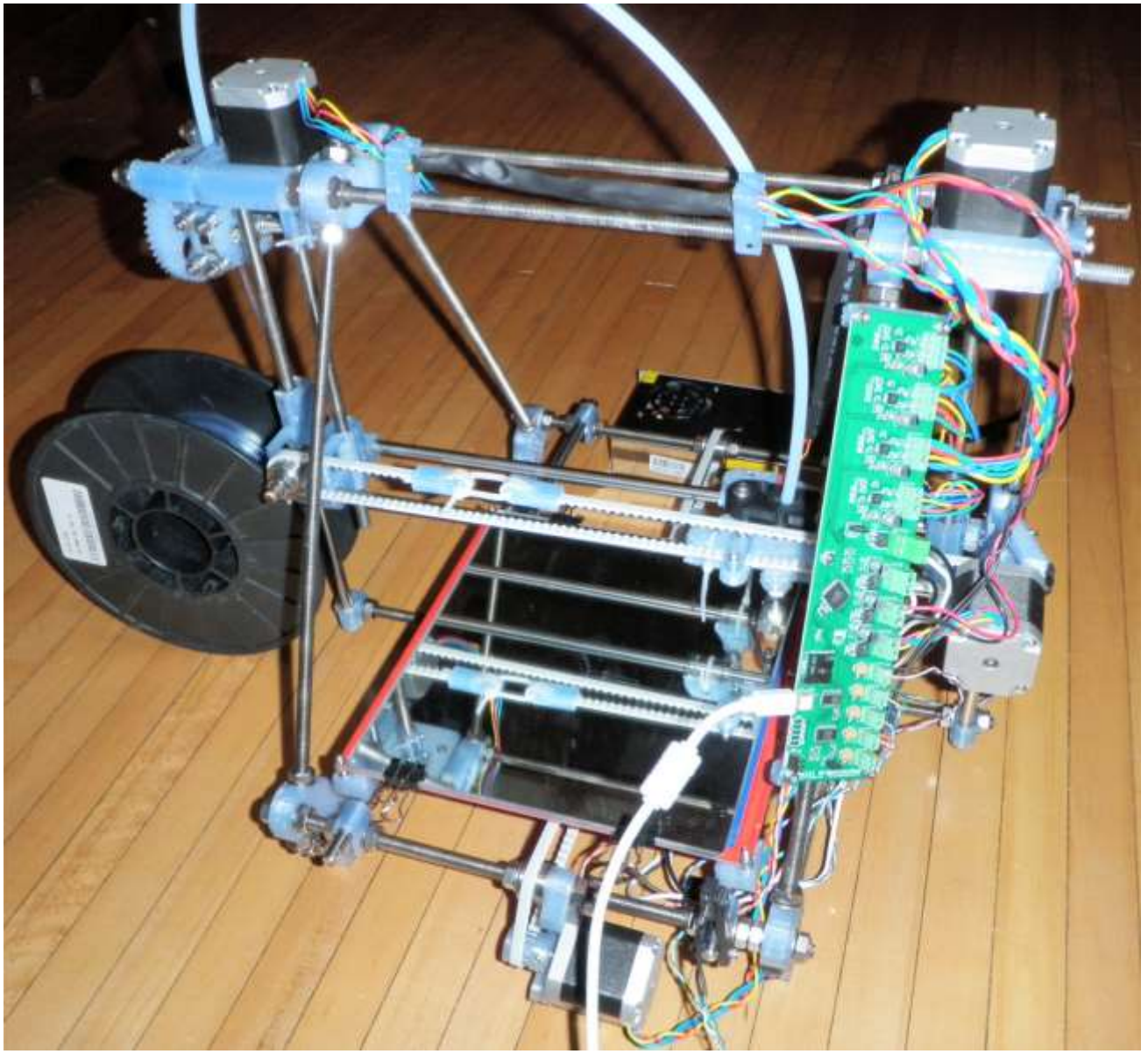


Linux, OpenSCAD, RepRapv3, OS automated filter wheel



Pearce, J. M. 2012. “Building Research Equipment with Free, Open-Source Hardware.” *Science* **337** (6100): 1303–1304.

V3.1 MTU HS RepRap



<$600

1 Newby build:

24 hours

Tandem build:

5 hours

Schelly, C., Anzalone, G., Wijnen, B., & Pearce, J. M. (2015). Open-source 3-D printing technologies for education: Bringing additive manufacturing to the classroom. *Journal of Visual Languages & Computing*, *28*, 226-237.

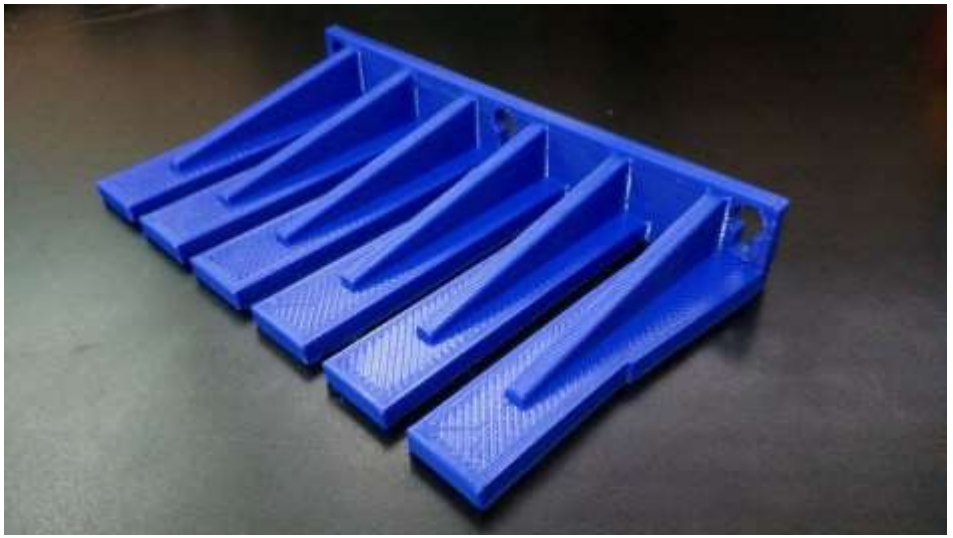
Michigan Tech

Michigan Technological University

Open Sustainability Technology Research Group

MOST DELTA

8hr build <$500



Open Source 3-D Printing Class

Entire class is open source:

http://www.appropedia.org/MY4777

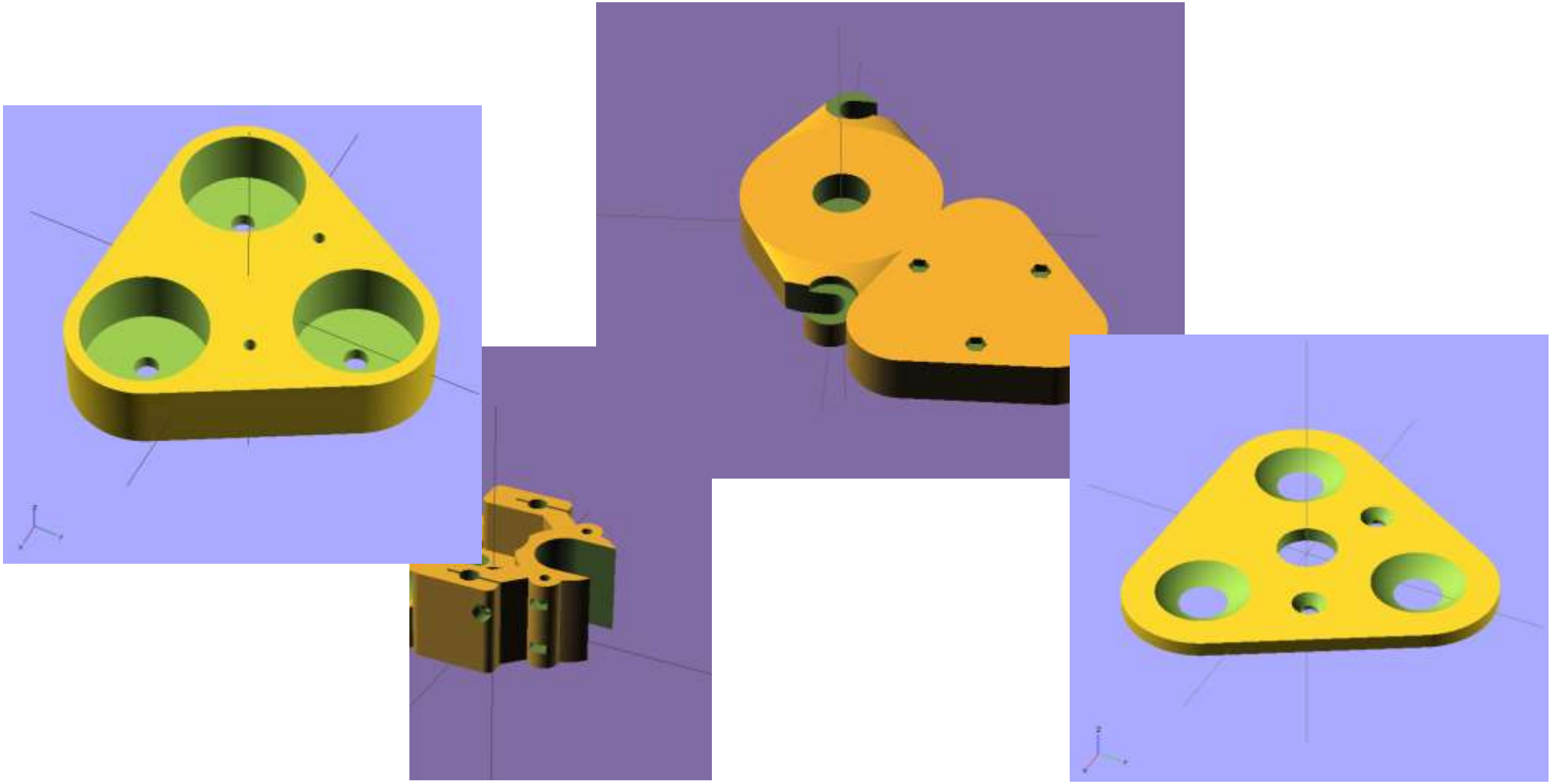
MOST Delta Mods

github.com/mtu-most

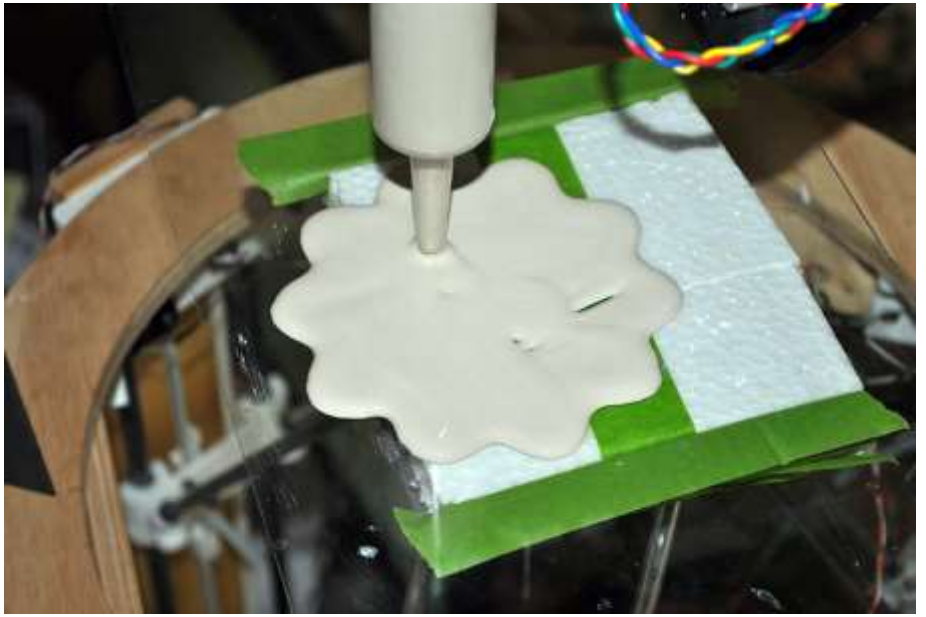
MOST Delta Convertible

Gerald Anzalone, Bas Wijnen, Joshua M. Pearce , (2015) "Multi-material additive and subtractive prosumer digital fabrication with a free and open-source convertible delta RepRap 3-D printer", *Rapid Prototyping Journal,* 21(5), pp.506 - 519.

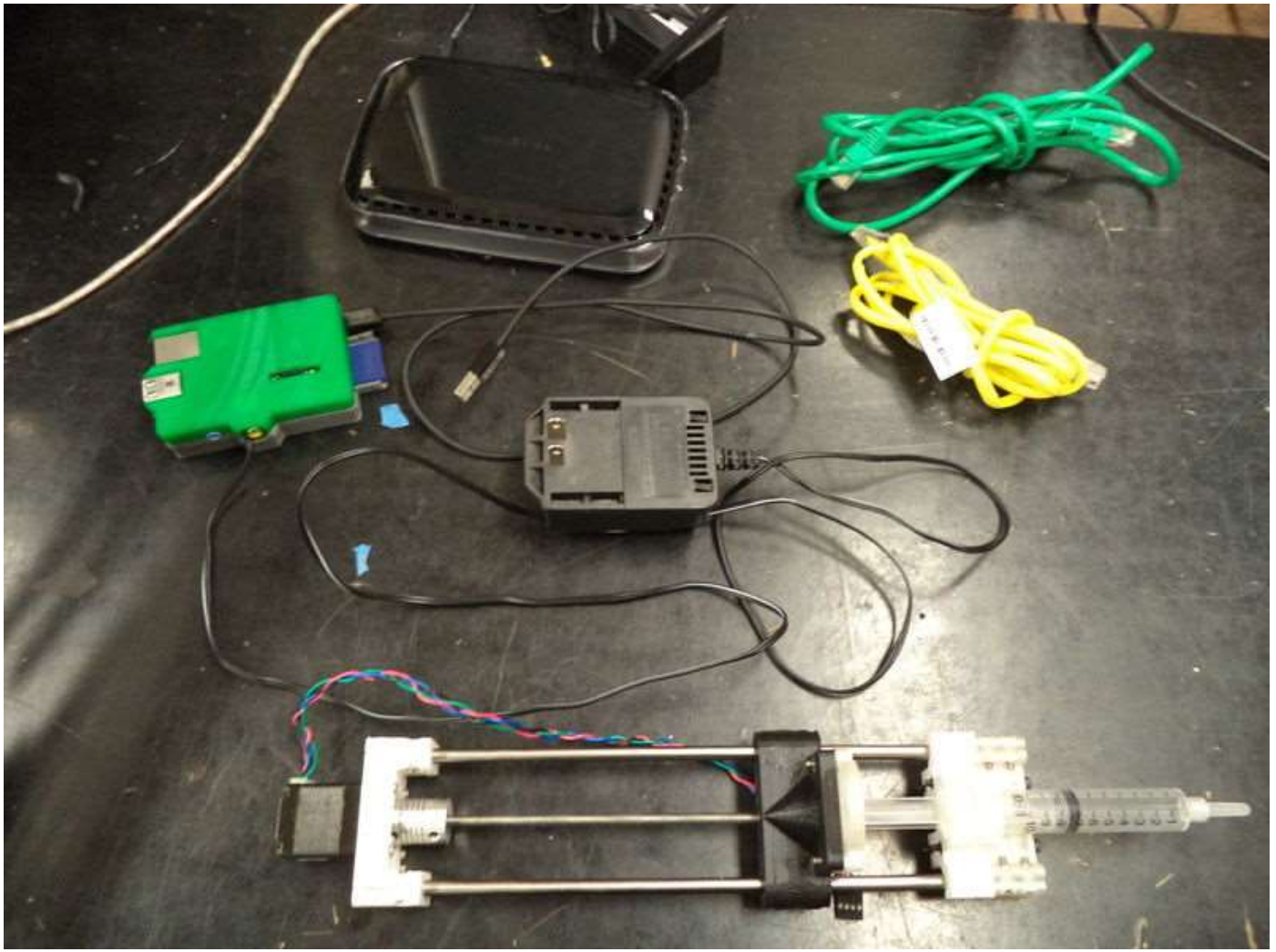
Magnetic Hot Swap



Syringe Pump Printing (linear actuator)

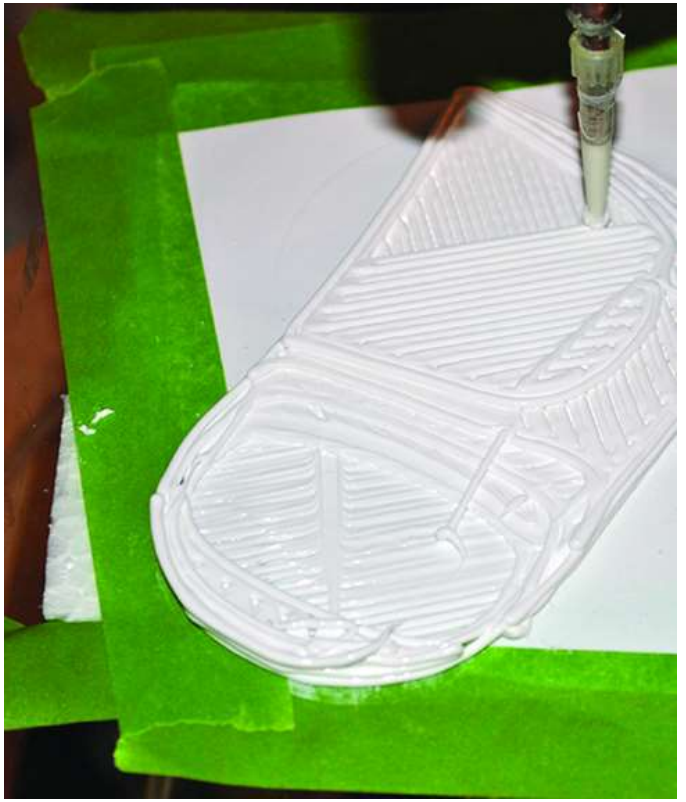


Syringe Pump Library

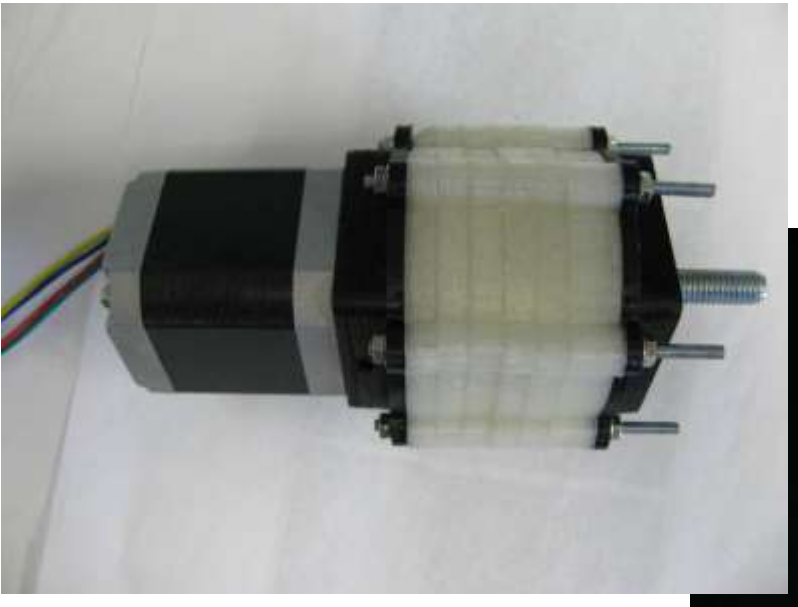


Bas Wijnen, Emily J. Hunt, Gerald C. Anzalone, Joshua M. Pearce, 2014. Open-source Syringe Pump Library, PLoS ONE 9(9): e107216

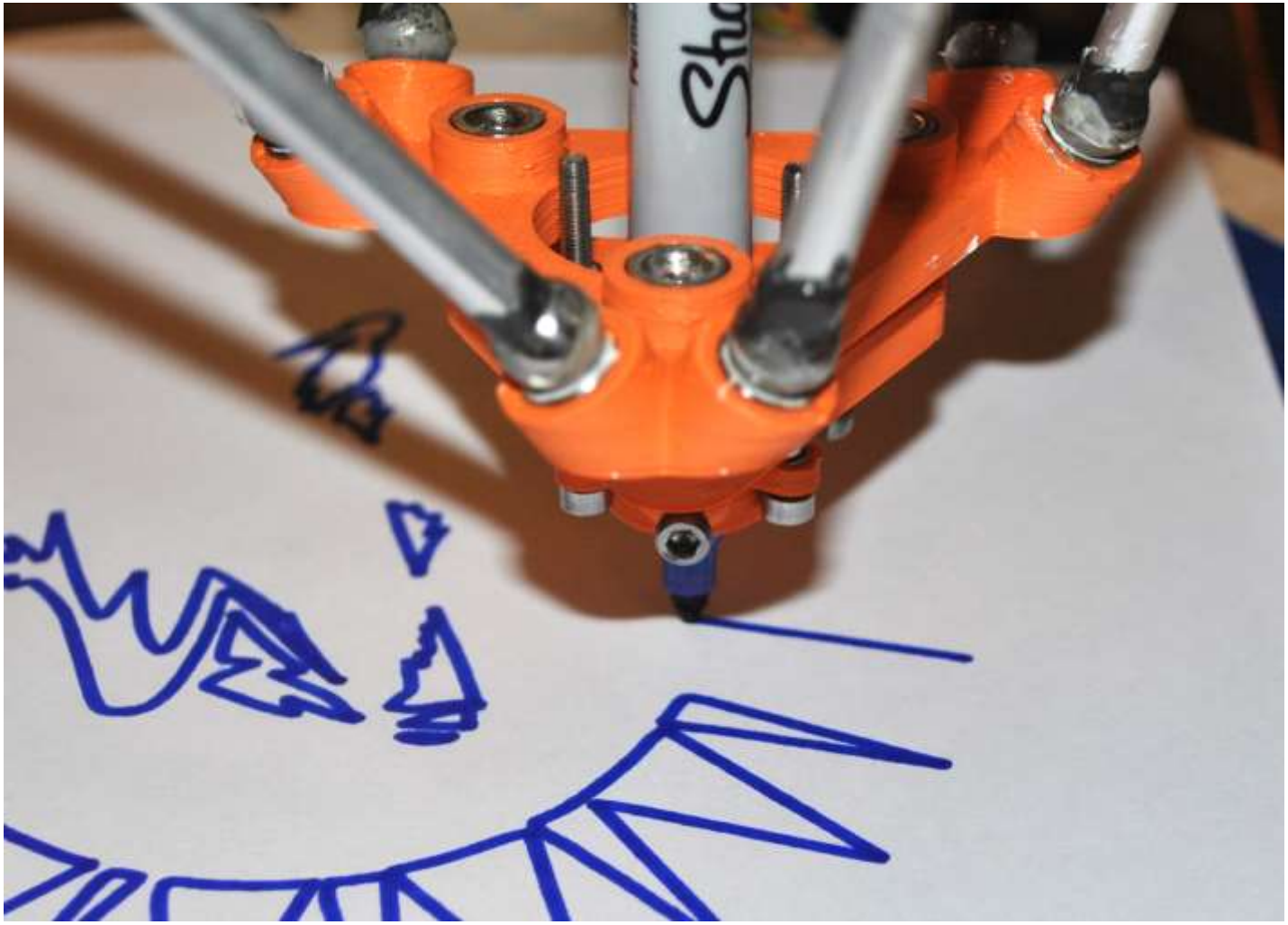
Caulkstruder Printing



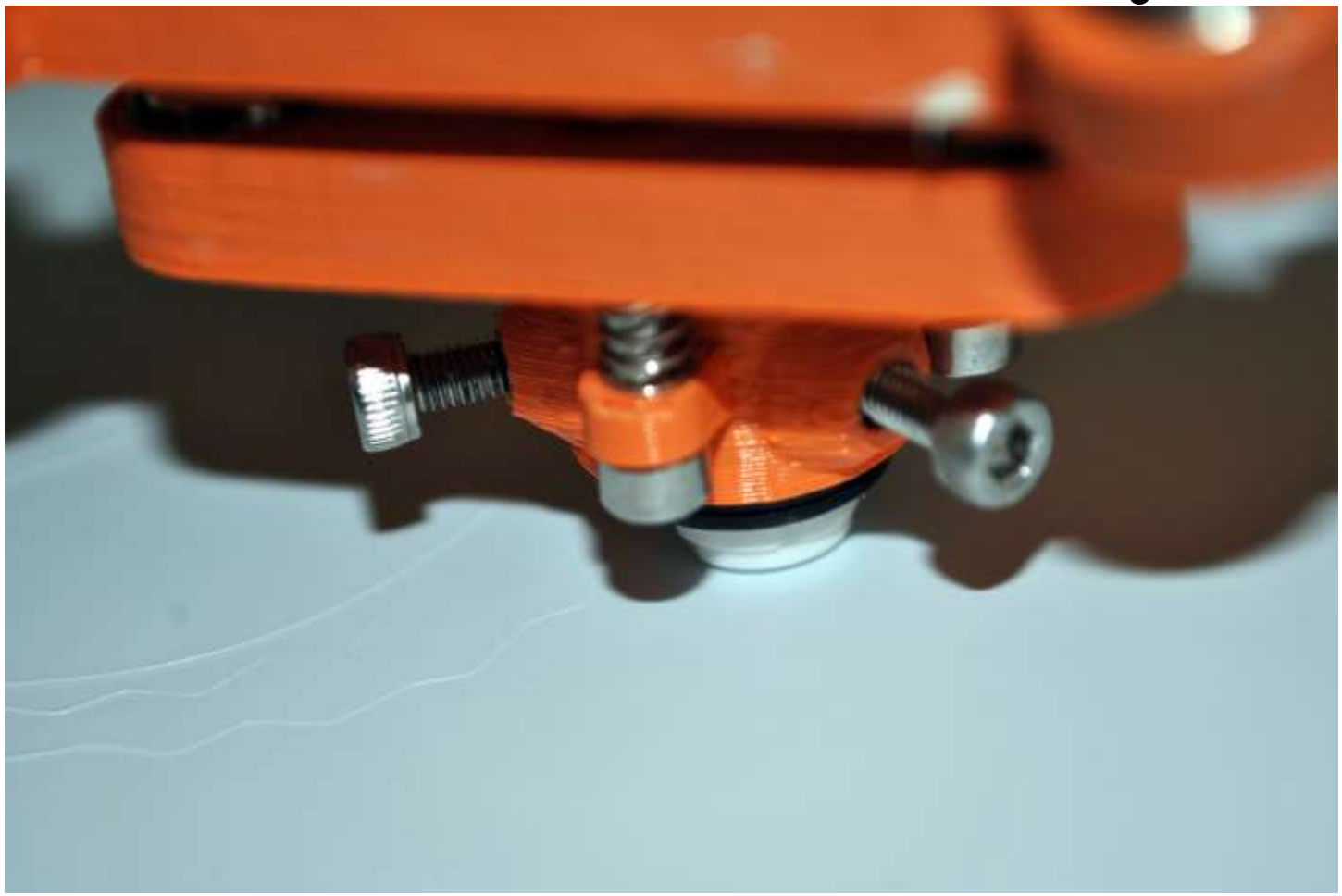
Caulkstruder uses Parametric Printable Planetary Gearbox

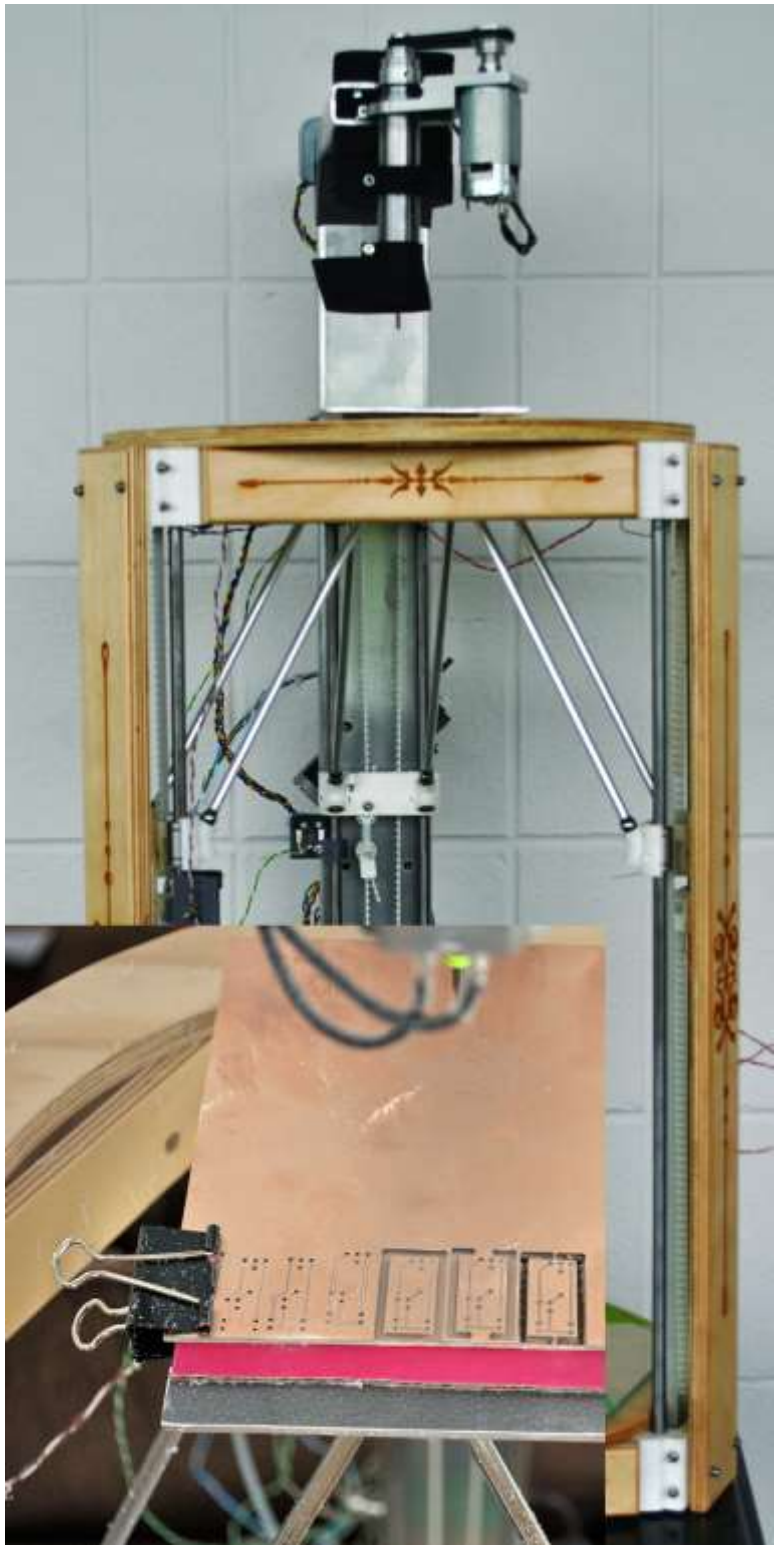


+ marker = Plotting



Cutting : tangent knife cutting a pattern in pressure sensitive adhesive-backed vinyl.





RepRap Milling

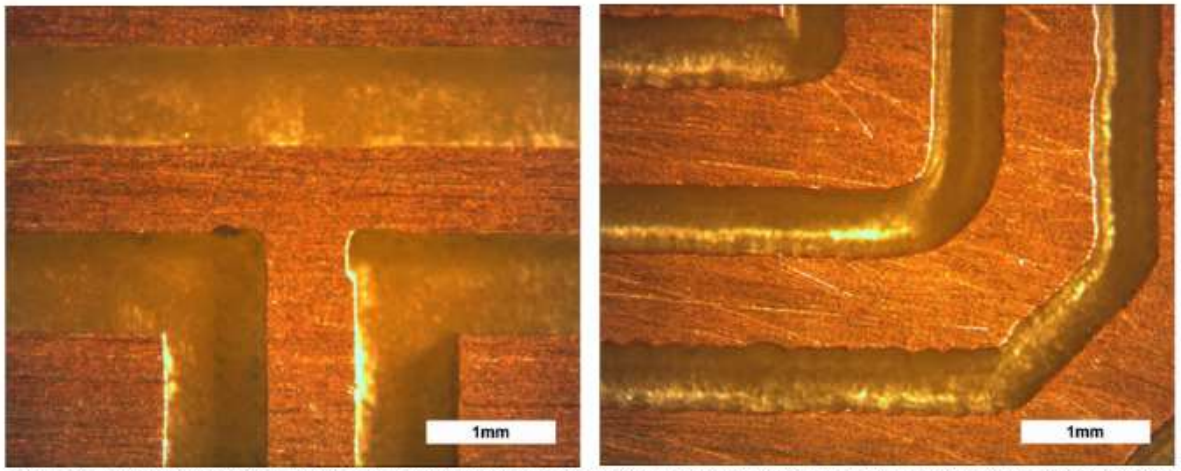
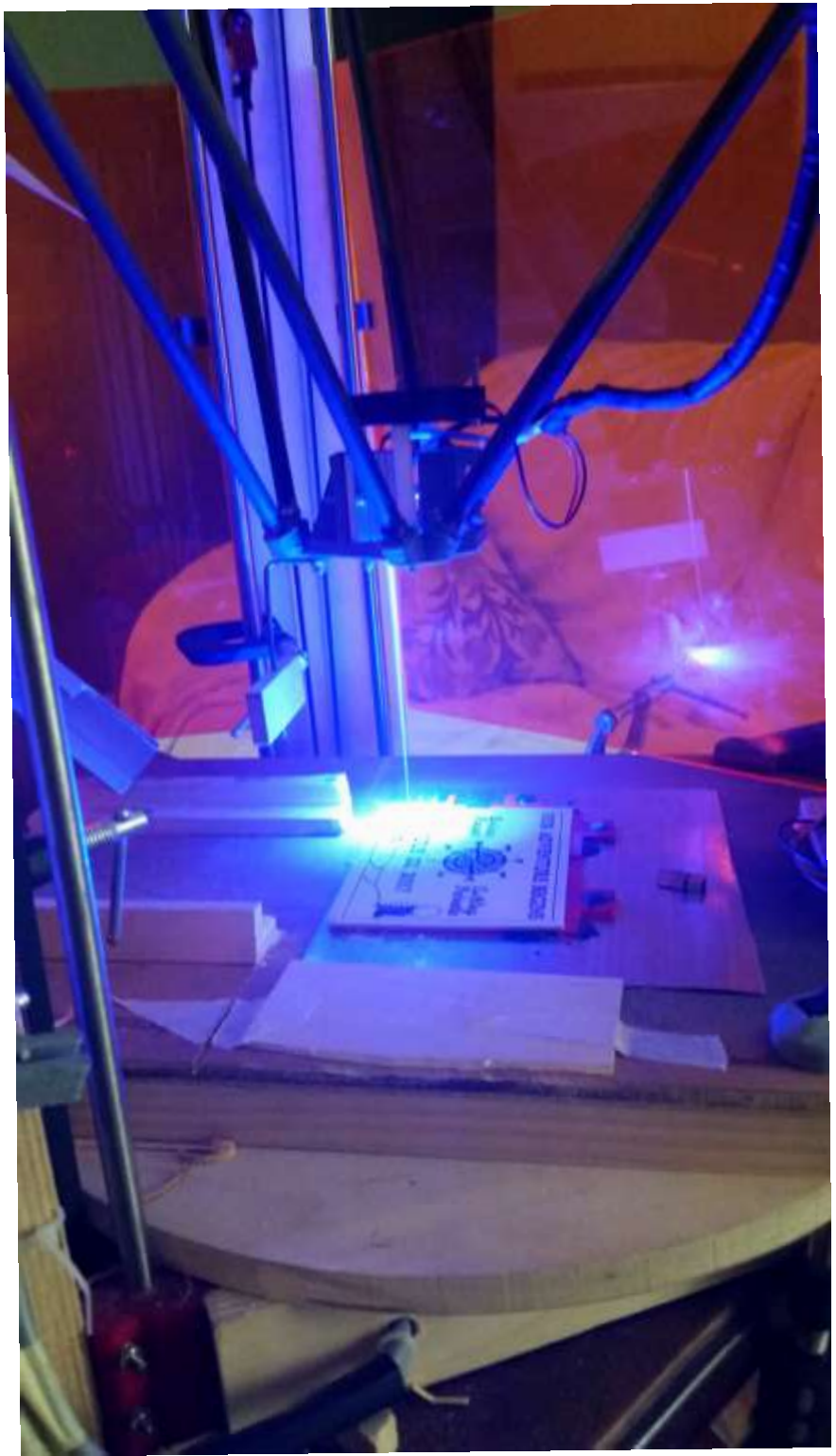


Figure 9. Digital micrographs of traces milled in printed circuit boards produced by a) a commercial PCB milling machine and b) the Convertible RepRap.

Old MOST Delta

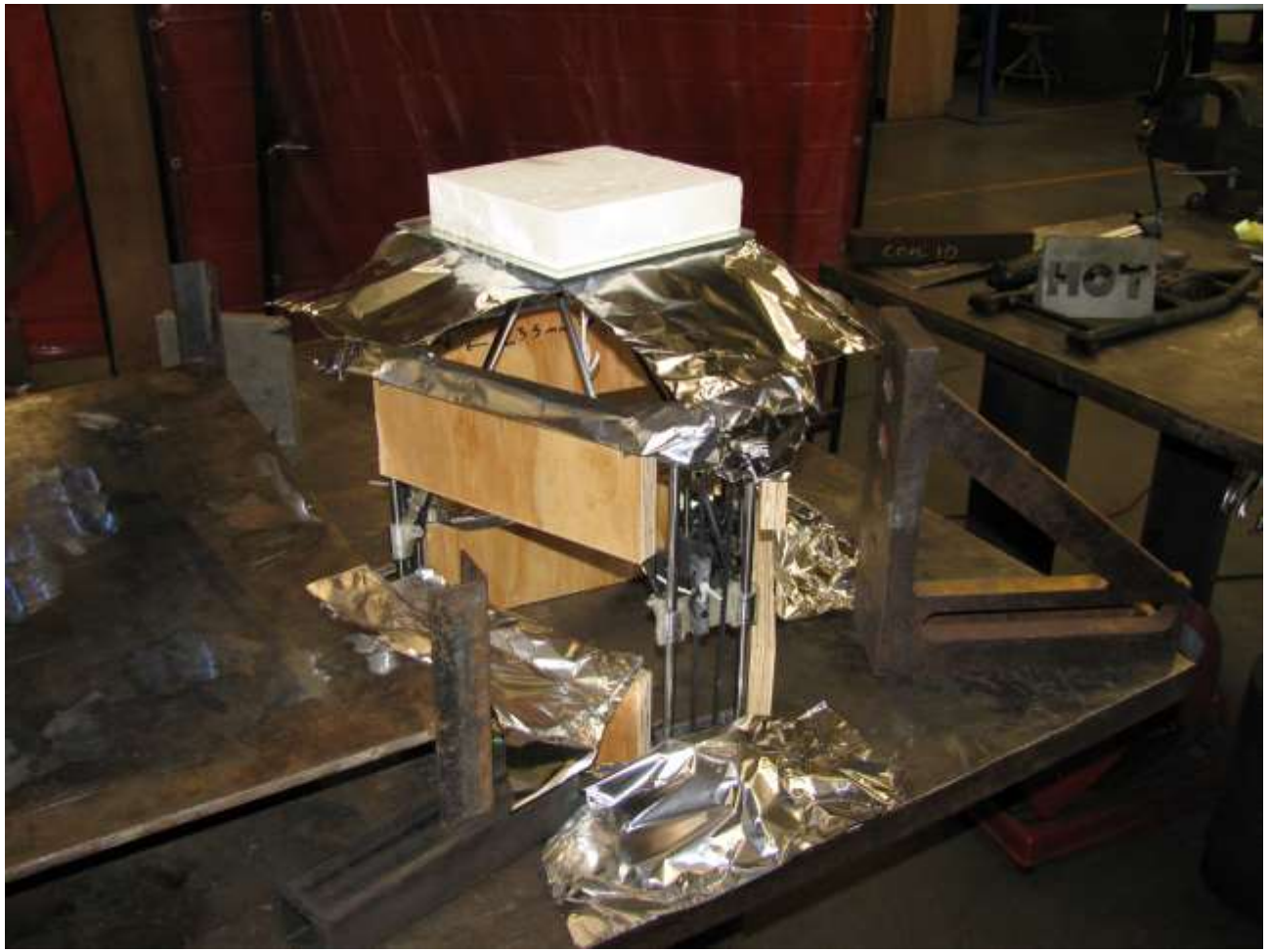
With Laser



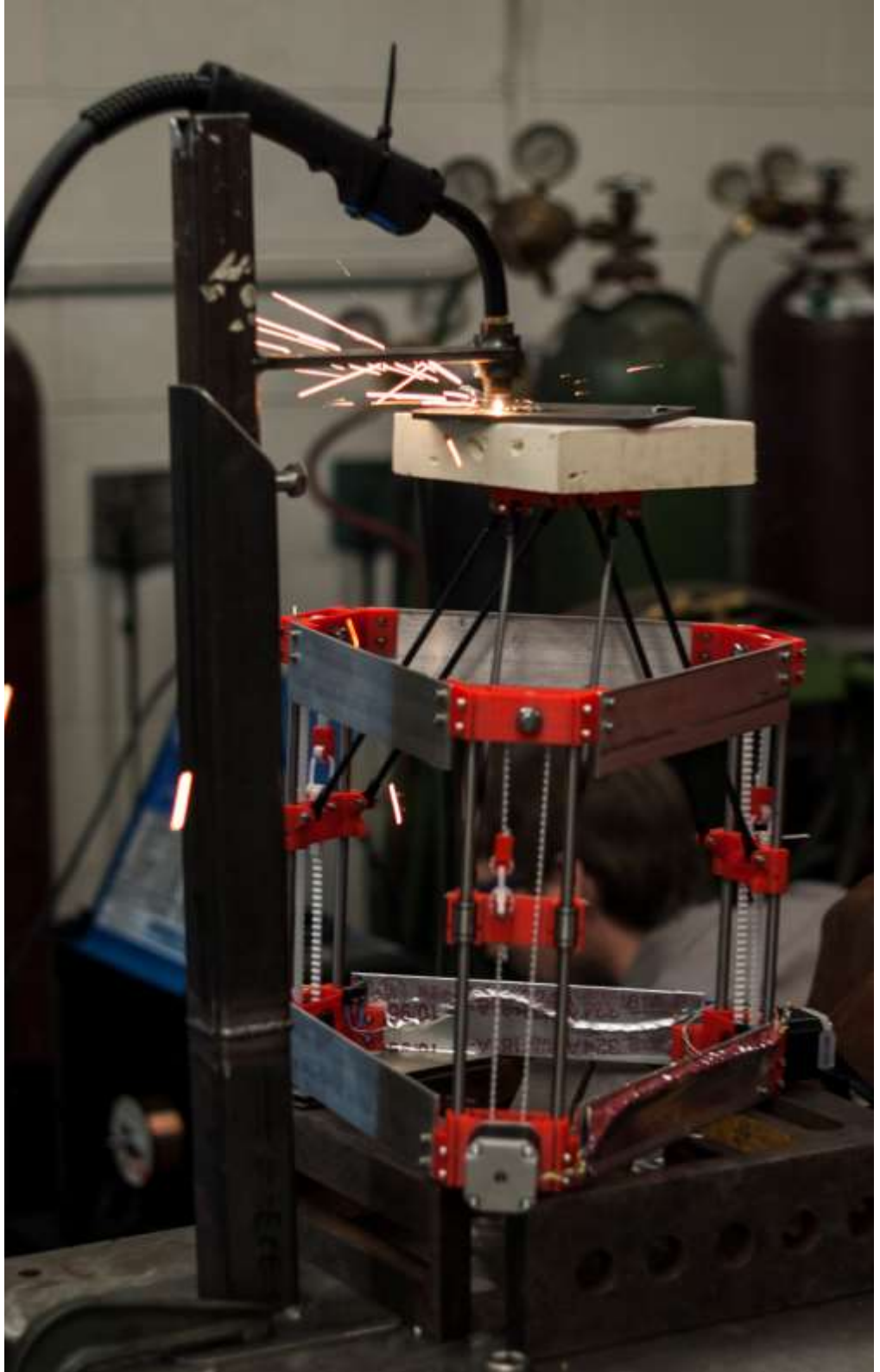
The World's First Metal Printing RepRap Made at MTU

Anzalone, et al. “Low-Cost Open-Source 3-D Metal Printing” *IEEE Access*, 1, pp.803-810, (2013).

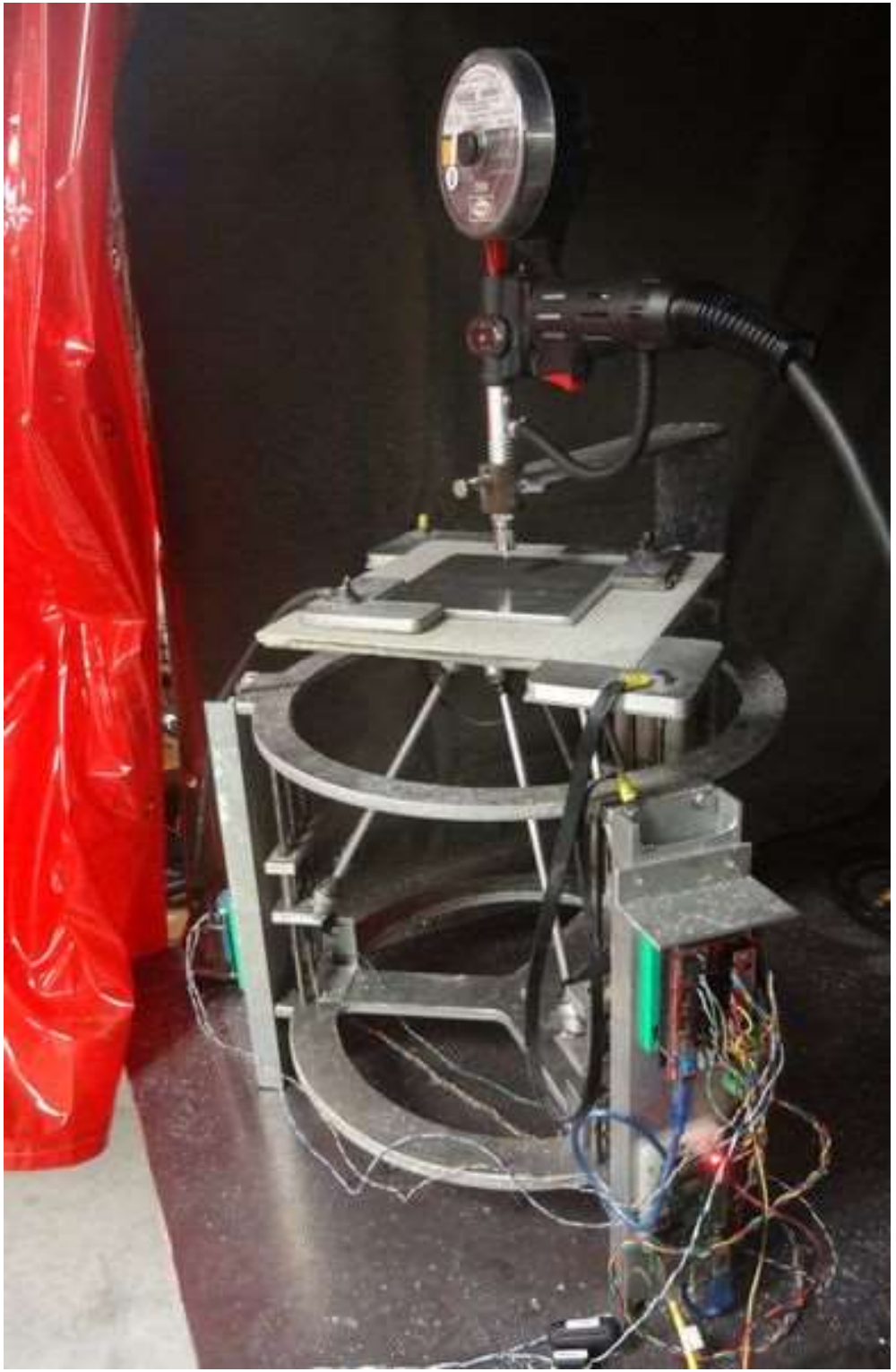
The actual first one...



The first holder...



Simpler than a FFF Delta



Where we are now


YOU REALLY
CAN DO
WHATEVER
YOU WANT

Open-Source Commercial + Distributed Manufacturing

OS Really is Better

Lulzbot TAZ

Mini Shoot Out Result

Use of TAZ and TAZ mini

- See TAZ manual
- Choose/make models with a solid surface on the print bed (e.g. don't print balls without support)
- Print with details up, 45 degree overhang or less unless bridged or supported
- 100 micron resolution, 0.5mm head
- Use TAZ profiles on https://www.lulzbot.com/taz-cura-profiles

Print Area: 280 mm x 280 mm x 250 mm (11.02 in x 11.02 in x 9.8 in)

Print Volume: 19,600 cm^3 (1,185 in^3) of usable space

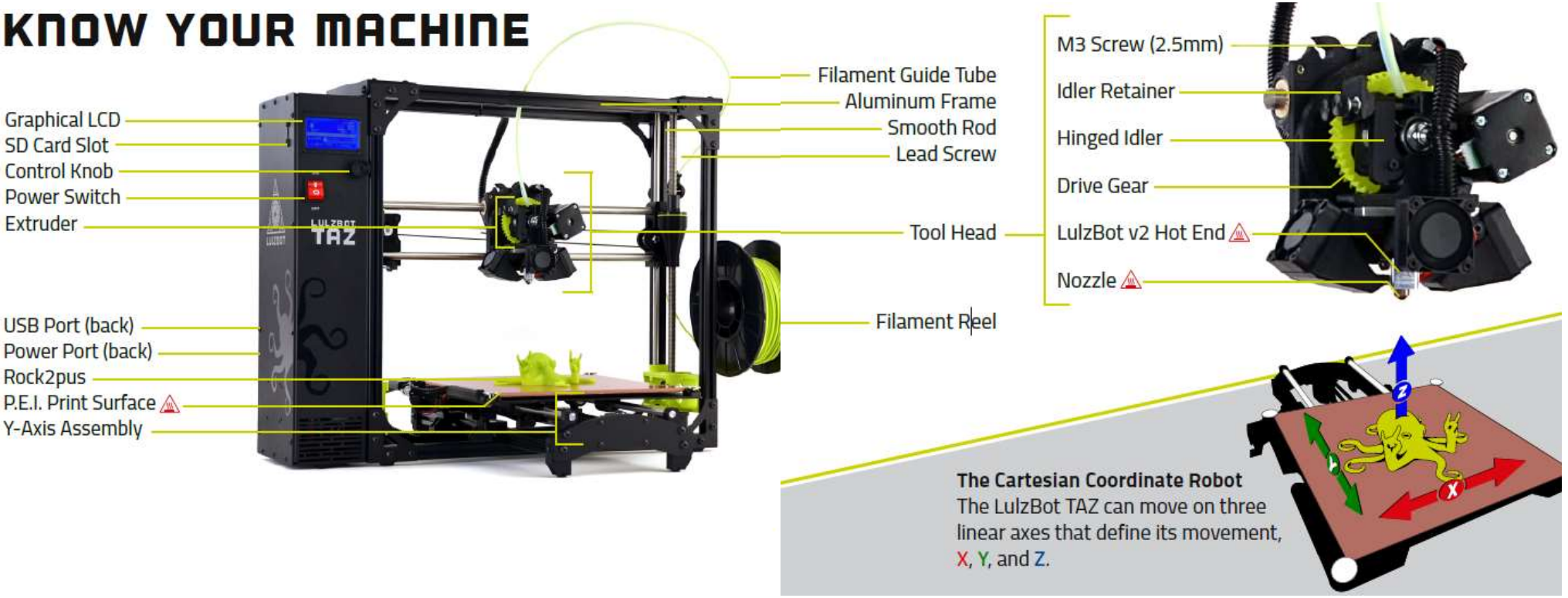
Top Print Speed: 200 mm/sec (7.9 in/sec)

Average Print Speed: 30 - 50 mm/sec (1.18 - 1.97in) Using default nGen profile

Layer Thickness with 0.5 mm nozzle: 0.050 mm to 0.5 mm (0.002 in - 0.02 in)

Capable Materials: ABS, PLA, HIPS, PVA, wood filled filaments, Polyester (Tritan), PETT, bronze, copper, stainless steel-filled filaments, Polycarbonate, Nylon, PETG, conductive PLA and ABS, UV luminescent filaments, PCTPE, PC-ABS, Alloy 910, and more every day.

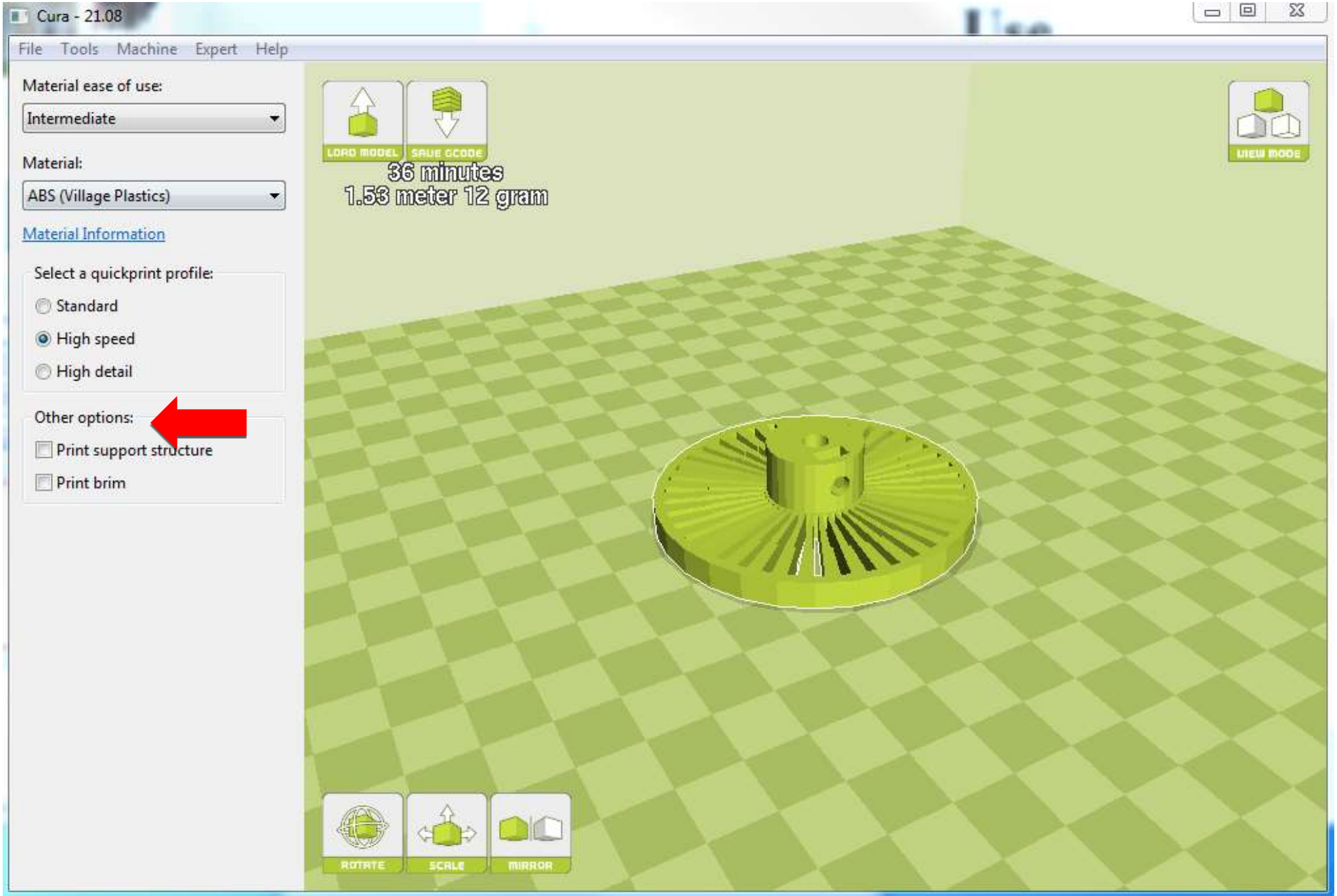
3-D Printer


KNOW YOUR MACHINE
Graphical LCD
SD Card Slot
Control Knob
Power Switch
Extruder
USB Port (back)
Power Port (back)
Rock2pus
P.E.I. Print Surface
Y-Axis Assembly
Filament Guide Tube
Aluminum Frame
Smooth Rod
Lead Screw
Tool Head
Filament Reel
M3 Screw (2.5mm)
Idler Retainer
Hinged Idler
Drive Gear
LulzBot v2 Hot End
Nozzle
The Cartesian Coordinate Robot
The LulzBot TAZ can move on three linear axes that define its movement, X, Y, and Z.

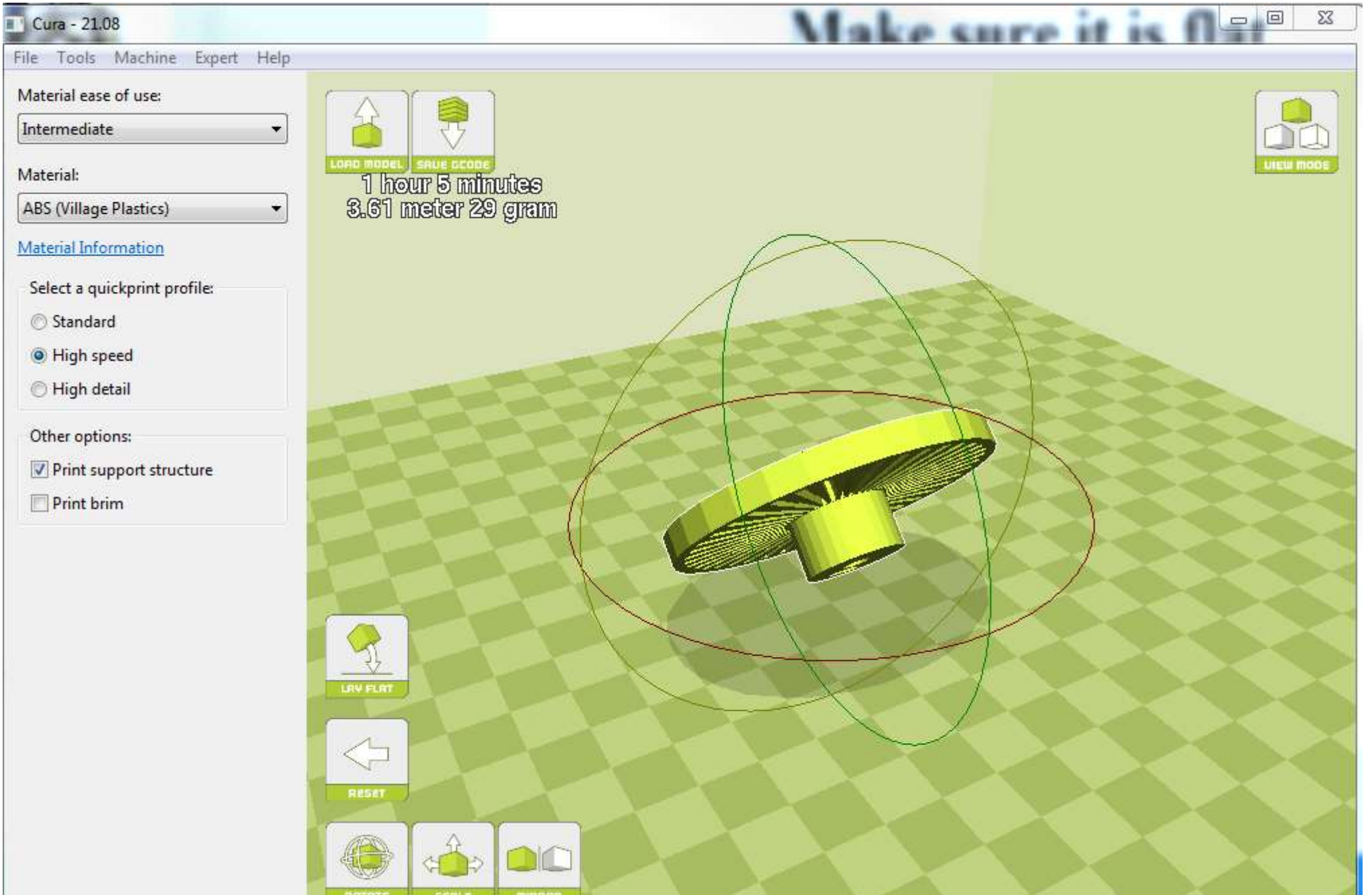
Software Tool Chain

- CAD (e.g. OpenSCAD) -- STL
- Slicer (e.g. Cura) -- Gcode
- Printer Controller (e.g. Printrun, Cura)
- Firmware (on printer)

Use


Cura - 21.08
File Tools Machine Expert Help
Material ease of use:
Intermediate
Material:
ABS (Village Plastics)
Material Information
Select a quickprint profile:
Standard
High speed
High detail
Other options:
Print support structure
Print brim
LOAD MODEL
SAVE GCODE
36 minutes
1.53 meter 12 gram
VIEW MODE
ROTATE
SCALE
MIRROR

Make sure it is flat



Scaling

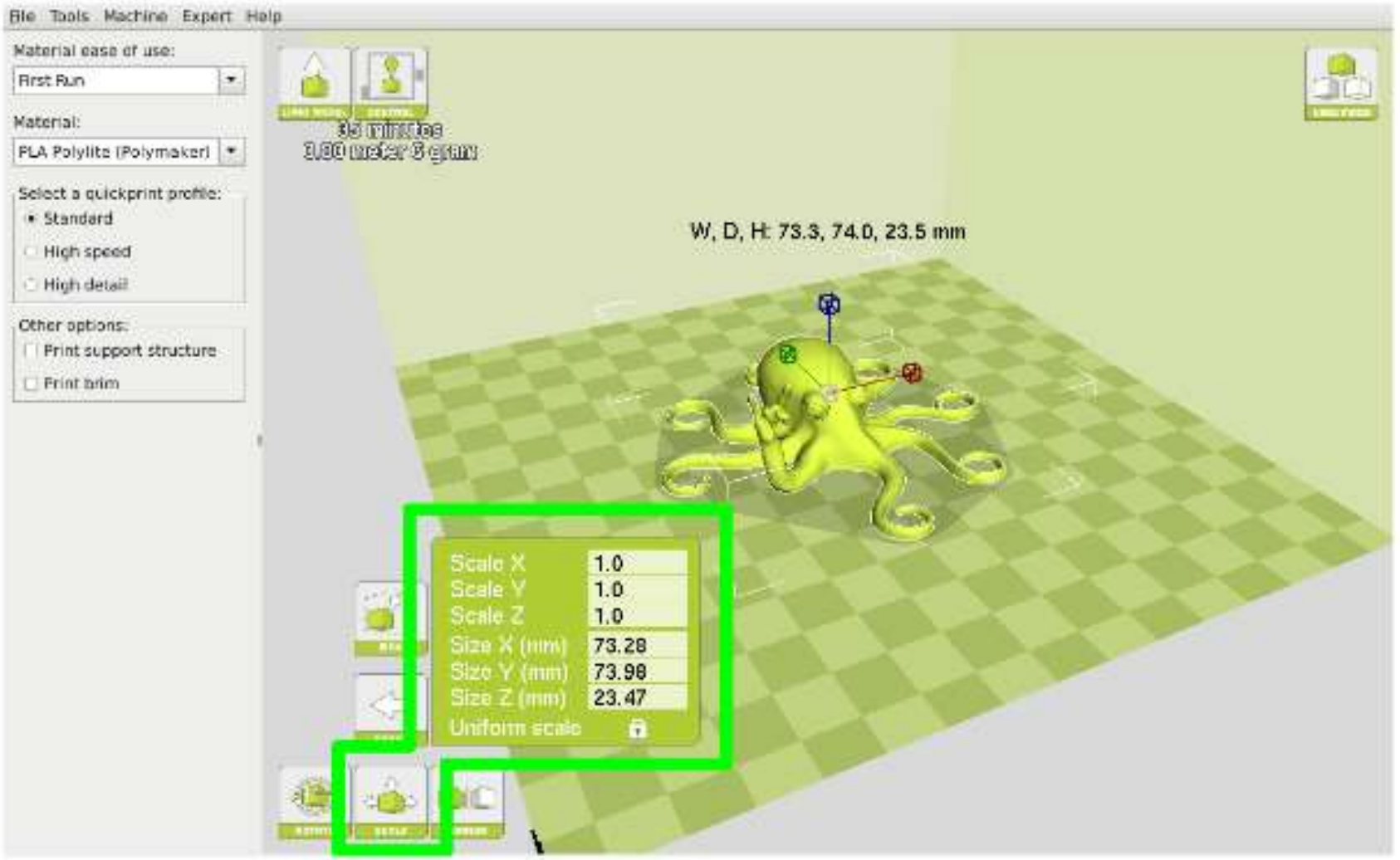


Figure 2.4: Scaling your Model

Viewing

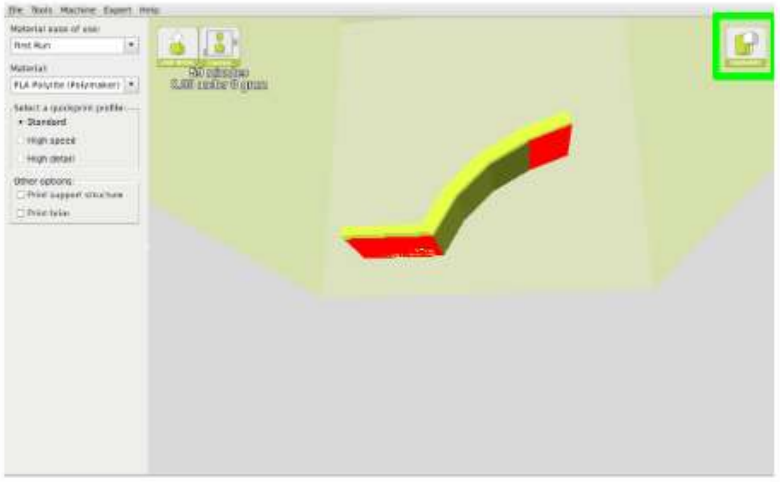


Figure 2.6: View in Overhang

Figure 2.7: View in Ghost

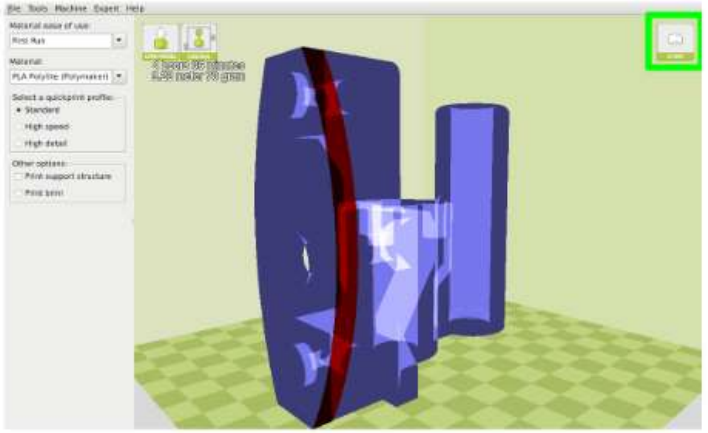
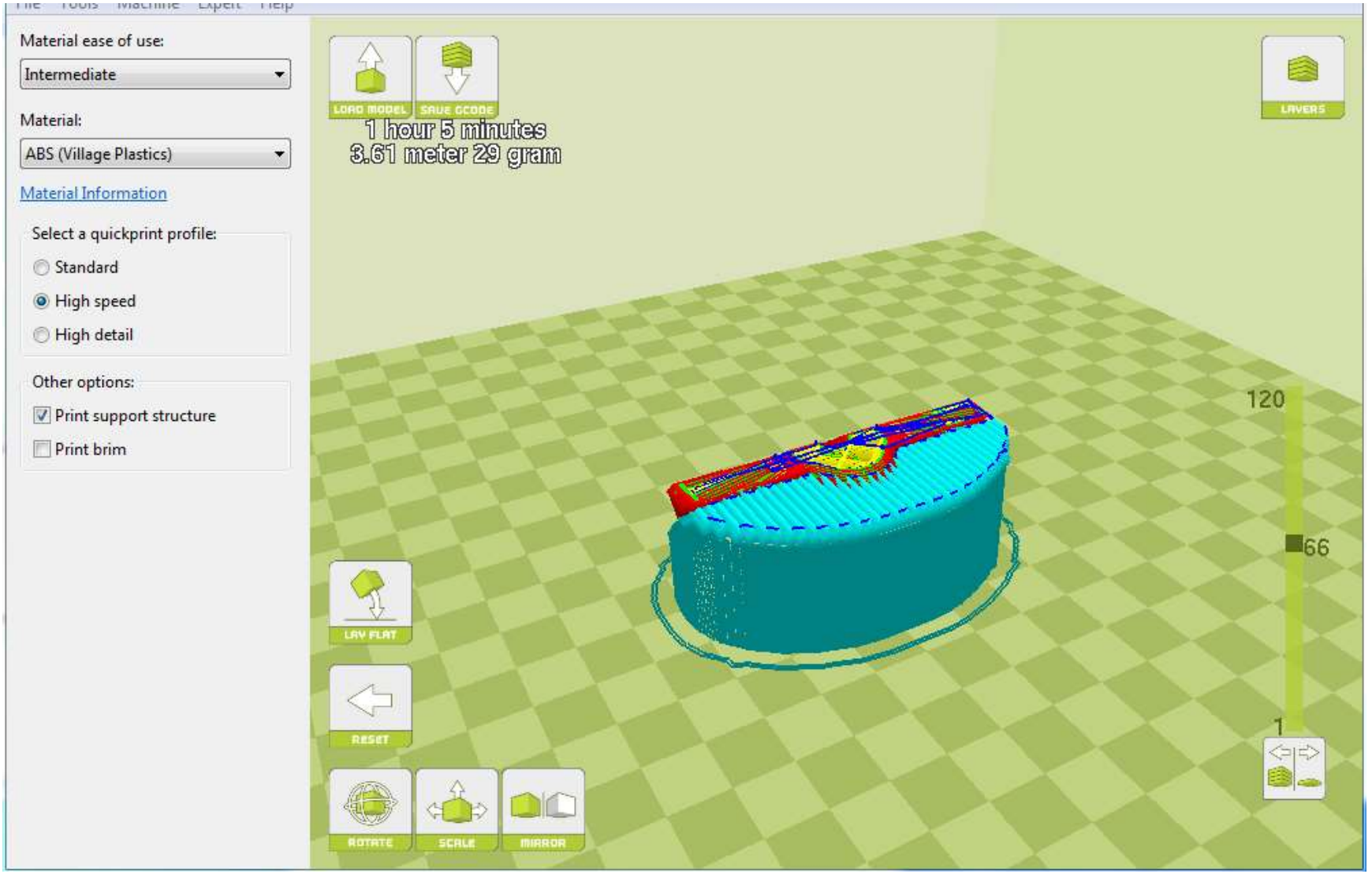


Figure 2.8: View in Xray

User Layer Tool



Basic- Full

Cura - 21.08

File Tools Machine Expert Help

Basic | Advanced | Plugins | Start/End-GCode

Quality

Layer height (mm) 0.38

Shell thickness (mm) 1.0

Enable retraction

Fill

Bottom/Top thickness (mm) .76

Fill Density (%) 20

Perimeters before Infill

Speed and Temperature

Print speed (mm/s) 50

Printing temperature (C) 240

Bed temperature (C) 110

Support

Support type None

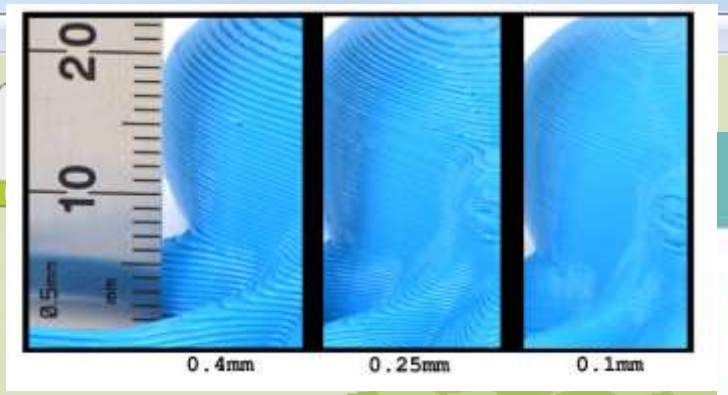
Platform adhesion type None

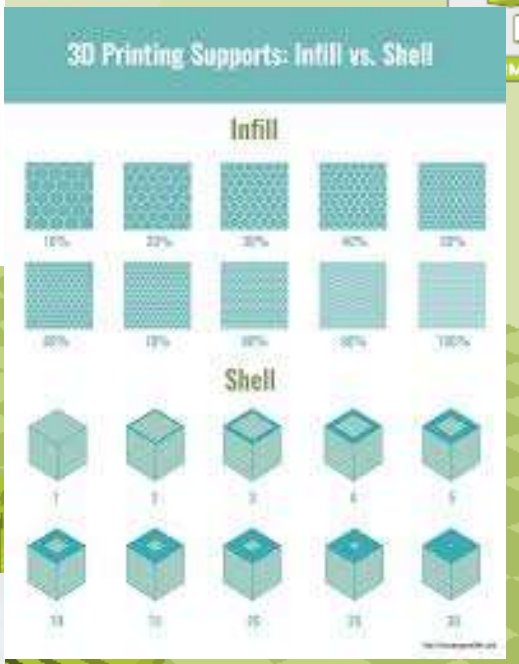
Brim or raft

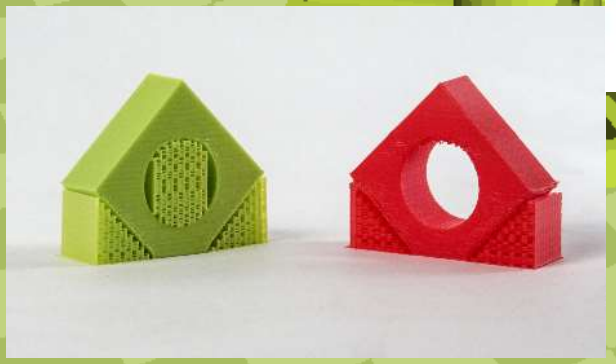
Filament

Diameter (mm) 2.85

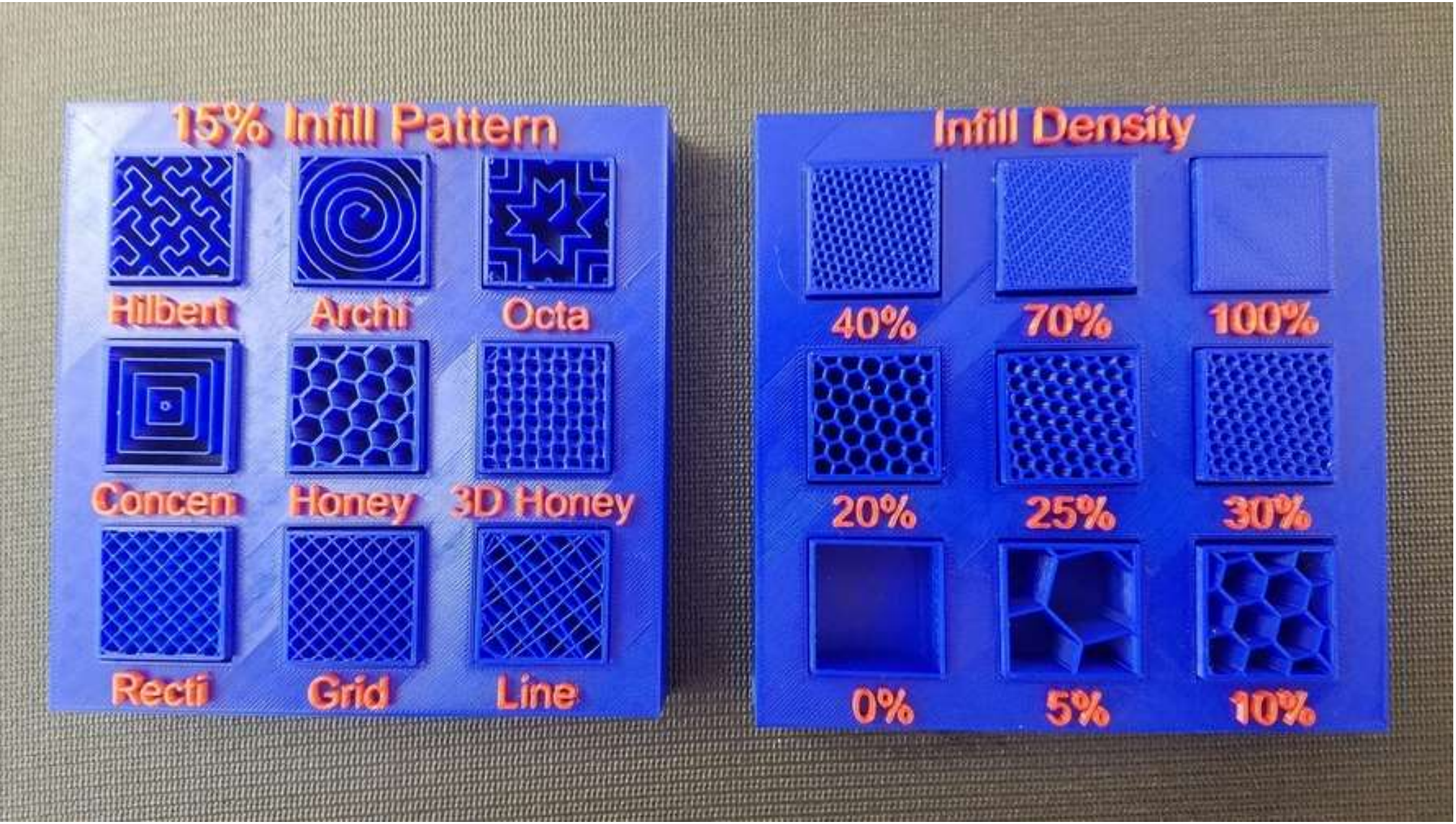
Flow (%) 100.0



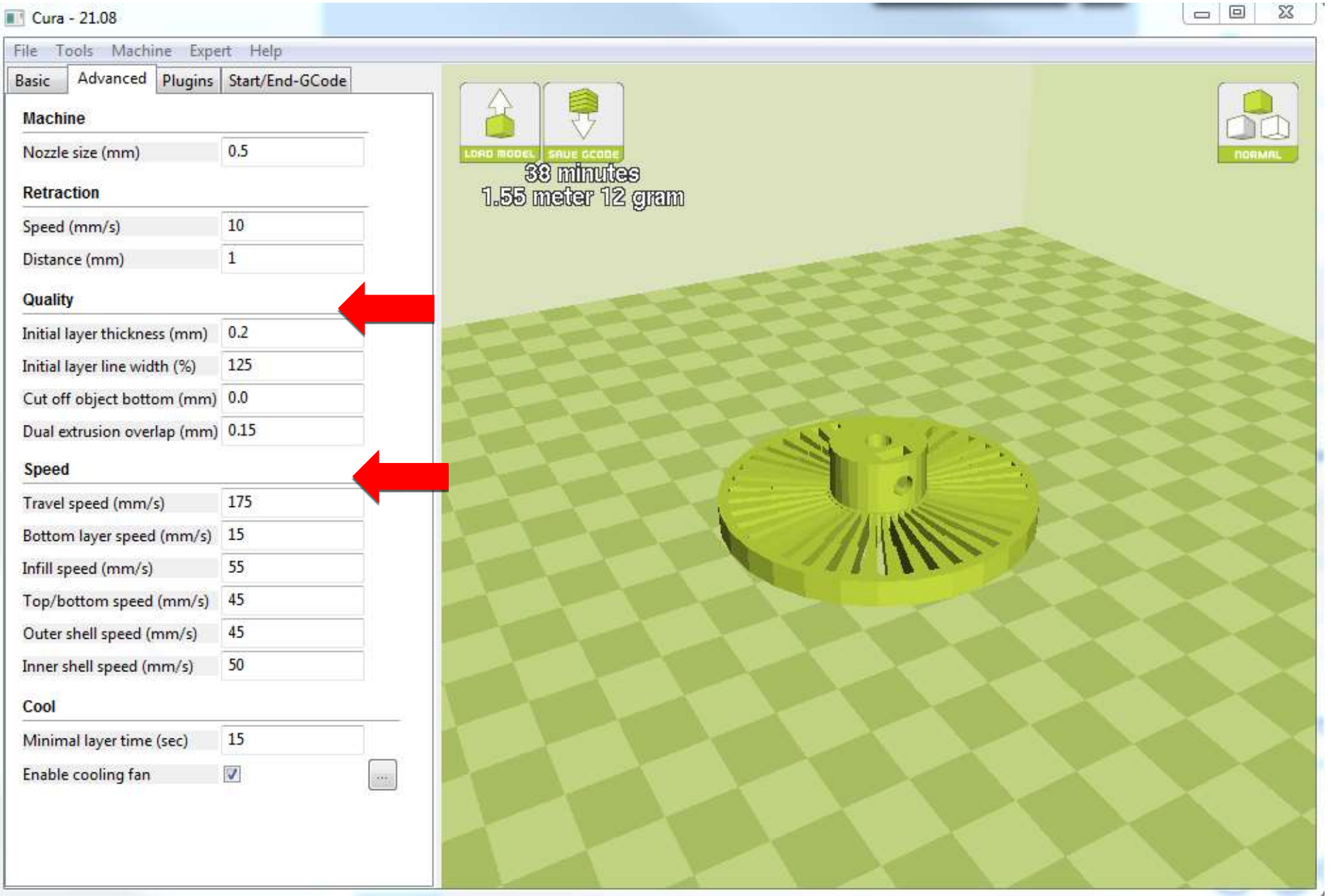




Infill


15% Infill Pattern
Hilbert
Archi
Octa
Concen
Honey
3D Honey
Recti
Grid
Line
Infill Density
40%
70%
100%
20%
25%
30%
0%
5%
10%

Advanced


Cura - 21.08
File Tools Machine Expert Help
Basic Advanced Plugins Start/End-GCode
Machine
Nozzle size (mm) 0.5
Retraction
Speed (mm/s) 10
Distance (mm) 1
Quality
Initial layer thickness (mm) 0.2
Initial layer line width (%) 125
Cut off object bottom (mm) 0.0
Dual extrusion overlap (mm) 0.15
Speed
Travel speed (mm/s) 175
Bottom layer speed (mm/s) 15
Infill speed (mm/s) 55
Top/bottom speed (mm/s) 45
Outer shell speed (mm/s) 45
Inner shell speed (mm/s) 50
Cool
Minimal layer time (sec) 15
Enable cooling fan
LOAD MODEL
SAVE GCODE
38 minutes
1.55 meter 12 gram
NORMAL

Printing


Operational, Temperature: 22 Bed: 22
Connect
Print
Motors off
UP
RETRACT
10
1
0.1
mm
10
10
DOWN
EXTRUDE
300
250
200
150
100
50
0
TEMPERATURE
0
°C
Set
BED TEMP
0
°C
Set

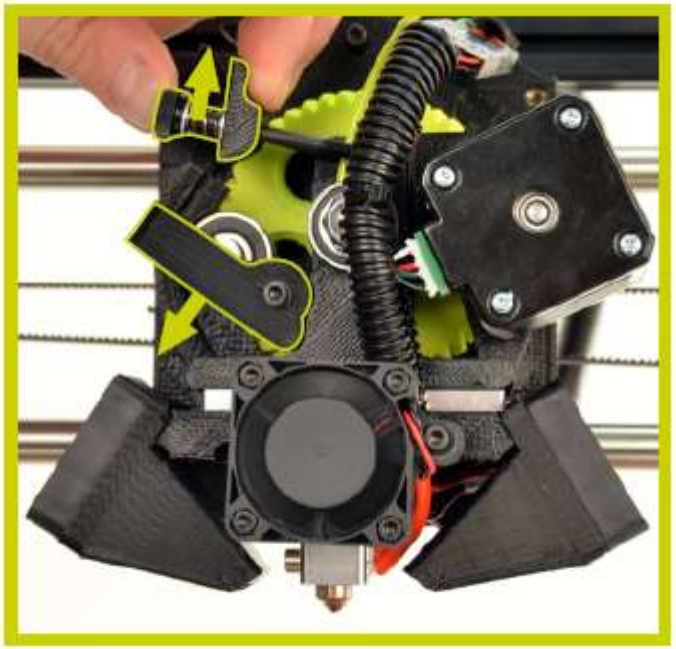
Materials

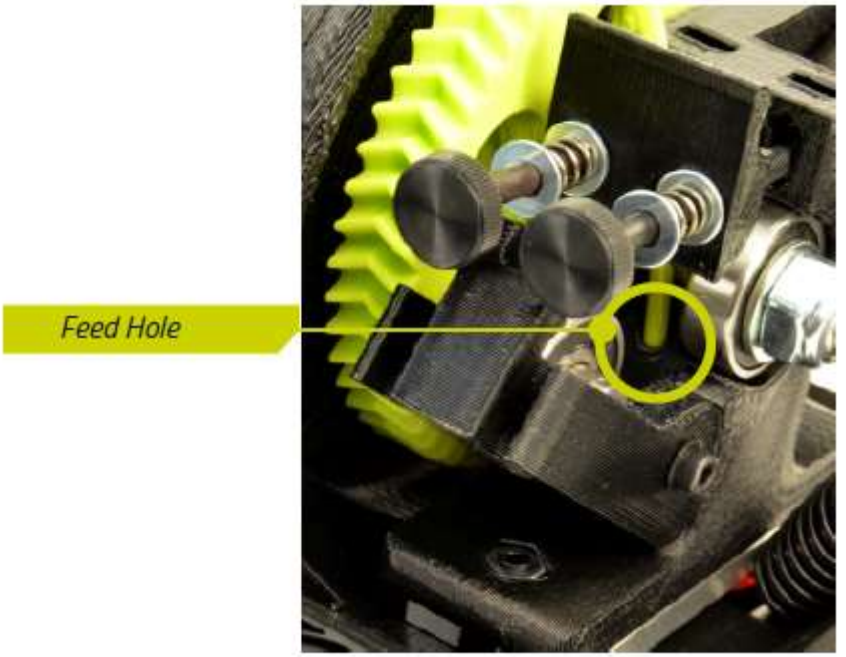
Purge on Change!

Filament	Purging Temperature (°C)	Safe Print Bed Temperature for Part Removal (°C)	Print Bed Preparation (See maintenance section for more information)
ABS, HIPS	240	50	Isopropyl alcohol wipe
PLA	205	45	Isopropyl alcohol wipe
Magnetic Iron, Stainless Steel PLA	230	50	Isopropyl alcohol wipe
nGen	230	50	PVA glue stick
n-vent, INOVA-1800, t-glase	240	50	PVA glue stick
Bridge, PCTPE, 910	240	60	PVA glue stick

Changing Filament

Get to Print Temp First!





Clear Clog

To clean your extruder follow these steps:

1. Slacken idler.
2. Push gently on filament while nozzle drops all the way down to room temperature.
3. Re-heat nozzle to Tg (60c for PLA, 105c for ABS)
4. When it overshoots, pull firmly but slowly.
5. If needed - Repeat going the opposite direction in T
6. Force filament through manually at extrusion T

Problems & Solutions 1/6

Pillowing

Top surfaces are not closed properly or come out bumpy.

Elephant's foot

The lowest layers of the print flare out.

Irregular circles

Circles come out misshapen and lines are not properly touching.

Pillowing: increase cooling, increase top layer thickness

Elephant foot: slice change, put a small chamfer on the bottom of your print, print on raft

Irregular circles: Tighten the belts of the printer

Problems & Solutions 2/6

Warping

Corners of the print lift and detach from the platform

Stringing

Unwanted strands of plastic span across the print

Ringing

Waves/shadows appear in the print

Warping: Level bed, increase bed temp, use glue stick, move to PLA, box printer, print with brim, change brim settings, cut cooling

Stringing: Use retraction, increase travel speed, lower print temp

Ringing: reduce acceleration, print infill after perimeter, reduce T, rotate print 45 degrees

Problems & Solutions 3/6

Ugly overhangs

The lower surface of overhangs come out ugly

Gaps in bottom surface

Lines are overly visible or spaced apart on the first layer

Shifted layers

Parts of the print suddenly shift along the X or Y axis.

Ugly overhangs: thicker layer heights, cooling 100%, add more fans, slow down print, reduce T, orient object to minimize overhangs

Gaps at bottom: buid level, move head closer to surface, ensure no clogged nozel

Shifted: check belts and tighten, rod alignment, check bed, hardware issue

Problems & Solutions 4/6

Prints are leaning

Prints gradually lean over or become skewed

Under extrusion

The printer is not extruding enough plastic leaving gaps in the print

Walls not touching

Parts of, or entire walls of the print are not fused and touching

Leaning: friction on belts, check hardware

Under Extrusion: clogged nozzle, check T, bad filament, check tightness of thumb screws, move nozzle away from bed, caught filament, ground filament

Walls not touching: reduce print speed, slicer settings

Problems & Solutions 5/6

Lower parts of the print cave in

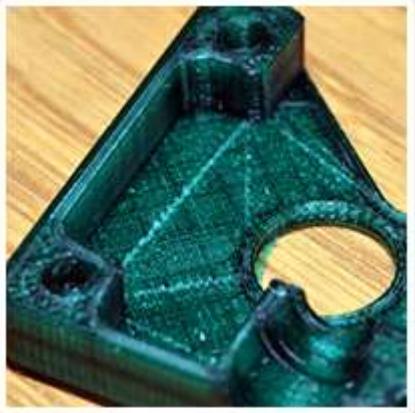
The lowest parts of the print appear to shrink before reaching the proper dimensions

Filament grinding

The feeder screw has ground a groove into the filament

Random fill layers / Voids being closed up

An opening or a void in a model has "random" fill layers. Expected voids are completely filled in.



Scratched top surface

The nozzle moves across the top surface and causes what looks like scratches.

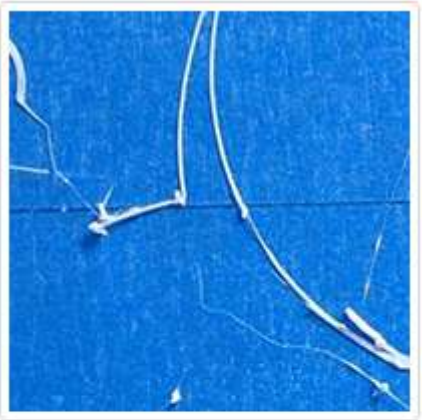
Cave in: Lower bed temp, turn on fans, add fans

Filament grinding: tangled filament, clog nozzle

Random: bad design, fix your model, fix horrible

Scratch: enable z hop in expert, reduce T

Problems & Solutions 6/6



First layer not sticking / Parts coming loose

The first layer of your print doesn't seem to want to stick or your parts come unstuck partway through the print.

"Hairy" prints

Very thin strands of plastic appear on the surface of the print.

Skipped layer/Bed drop

You find that a layer or more is missing in the middle of a print or you hear/see that the bed suddenly drops down too far.

No stick:bed level, bed temp, move closer to bed

Hairy:clean nozzle, change filament

Skipped: under extrusion, overheating, mech issue of feeding