3D Printing

A Revolution??
or a Ruckus over Nothing??

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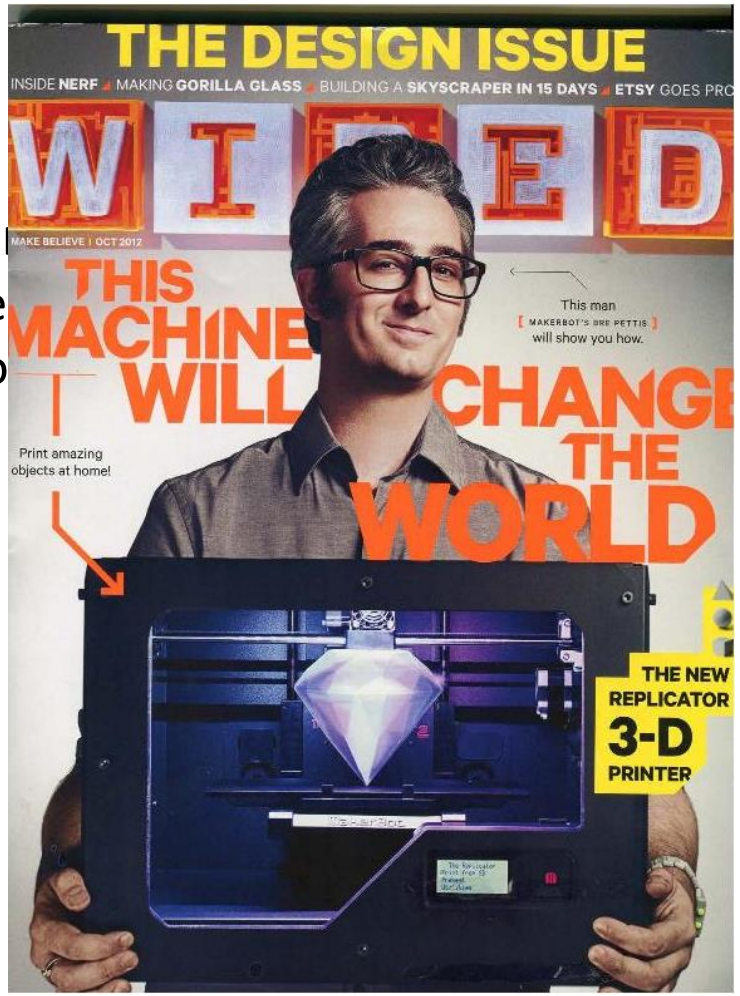
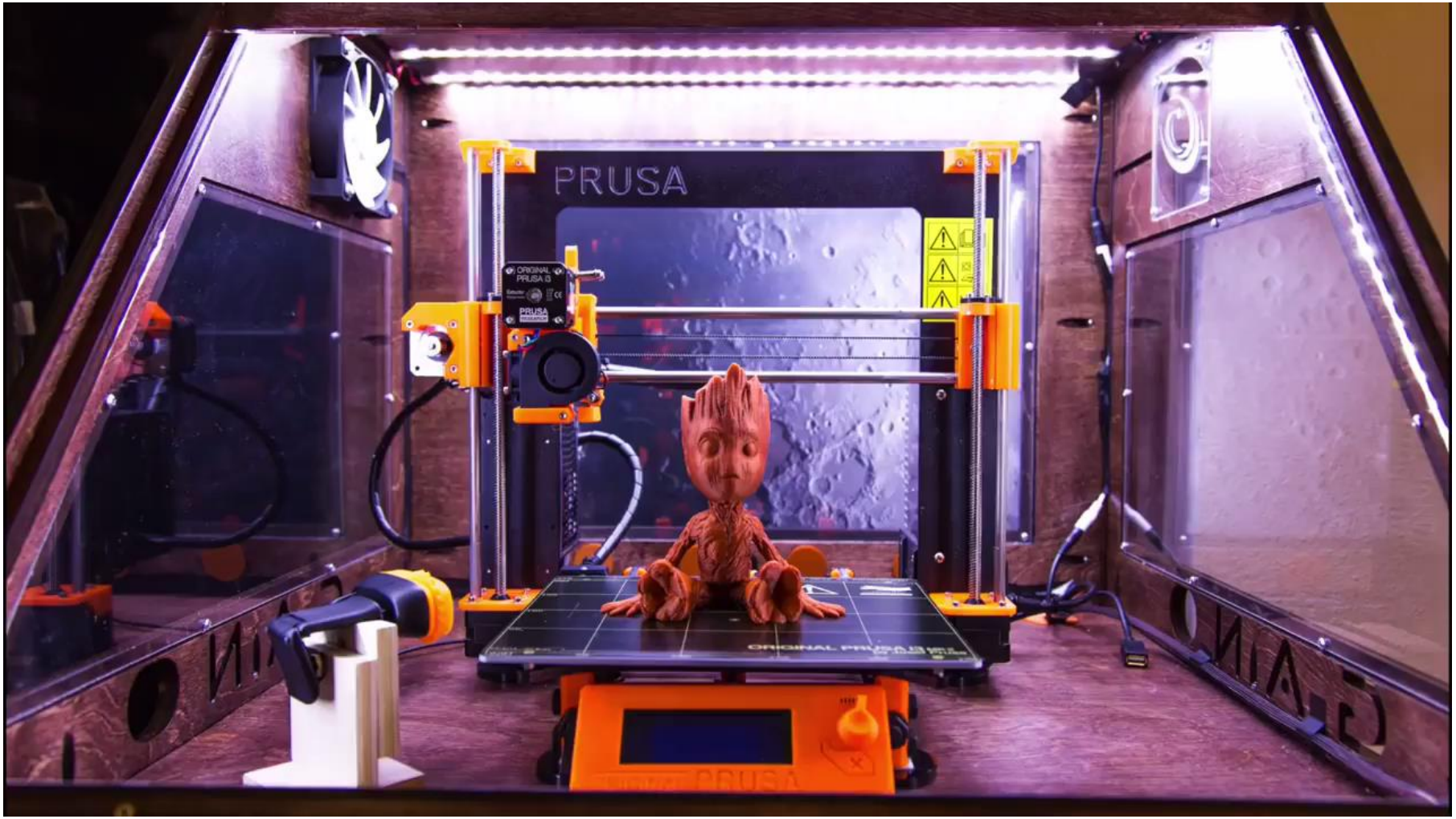
U3A 13/7/18

Today's Presentation

- **Safety:**
  - Reminder to be aware of emergency alert and evacuation alarms
- **I expect to take about 90 minutes**
  - Please ask questions as they arise
- **I expect that at the end of the prese**
  - if 3D printing is likely useful to you e
  - You will have some information as to
- **Was the Media hype real?**
  - Democratising Manufacturing
  - Industrial Revolution 2.0
- **What is 3D printing?**
  - Commonest 3D print process
  - What does a printer cost?
  - Some real prints



3D Printing Time Lapse



https://www.youtube.com/watch?v=m_QhY1aABsE

3D printing is:

- Not new (printers existed in the 1980's)
- Technologies:
  - Selective Laser Sintering (SLS) / Selective Laser Melting (SLM)
  - Electron Beam Melting (EBM)
  - Laminated Object Manufacturing (LOM)
  - Digital Light Processing(DLP)/ Stereo Lithography(SLA)
  - **Fused Deposition Modelling (FDM) / Fused Filament Fabrication (FFF)**
    - **A form of Computer Numerical Control Machining**
    - **Molten plastic is built up layer by layer**

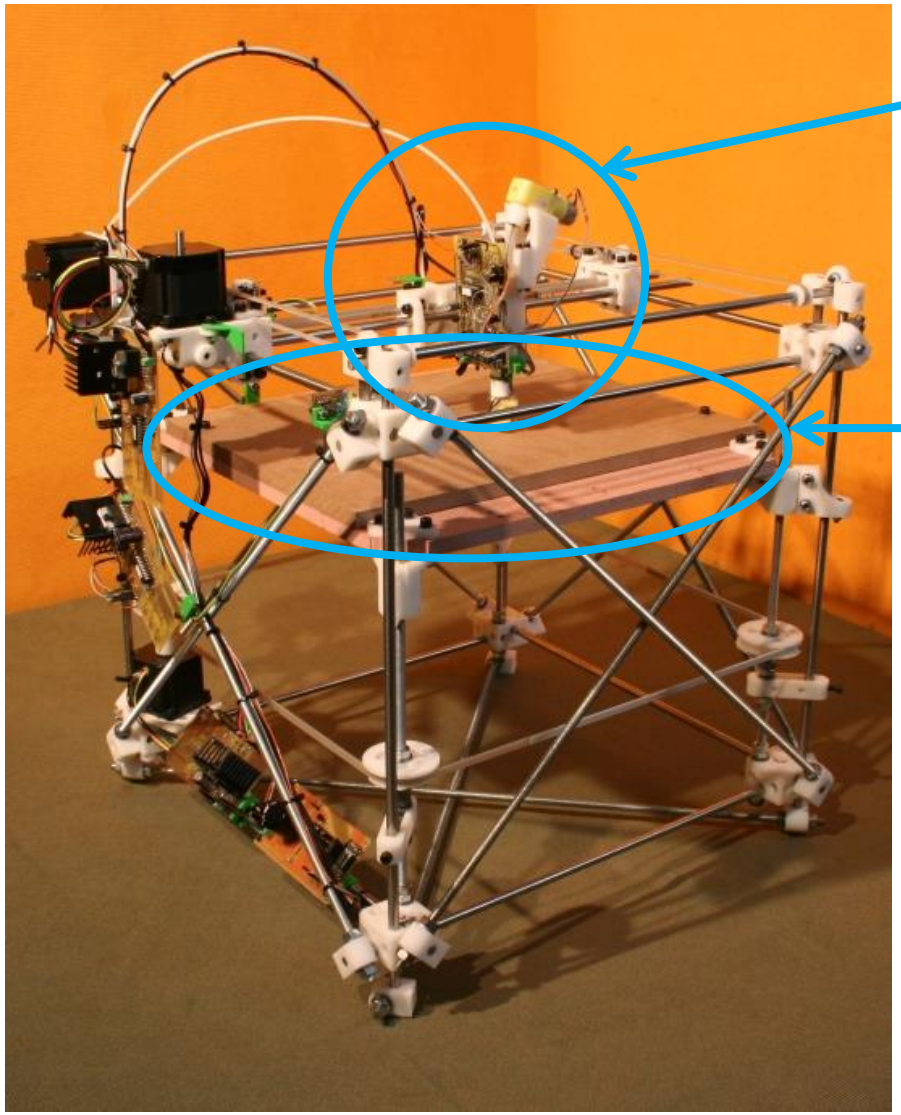
Origin of Home 3D Printing

- RepRap (Replicating Rapid Prototyper) Project
  - Started in 2005 by Dr Adrian Bowyer at the University of Bath
  - Triggered by patent expiries

RepRap work is "open source" with no restrictions on usage except for attribution

- The aim was to make a machine which could make itself

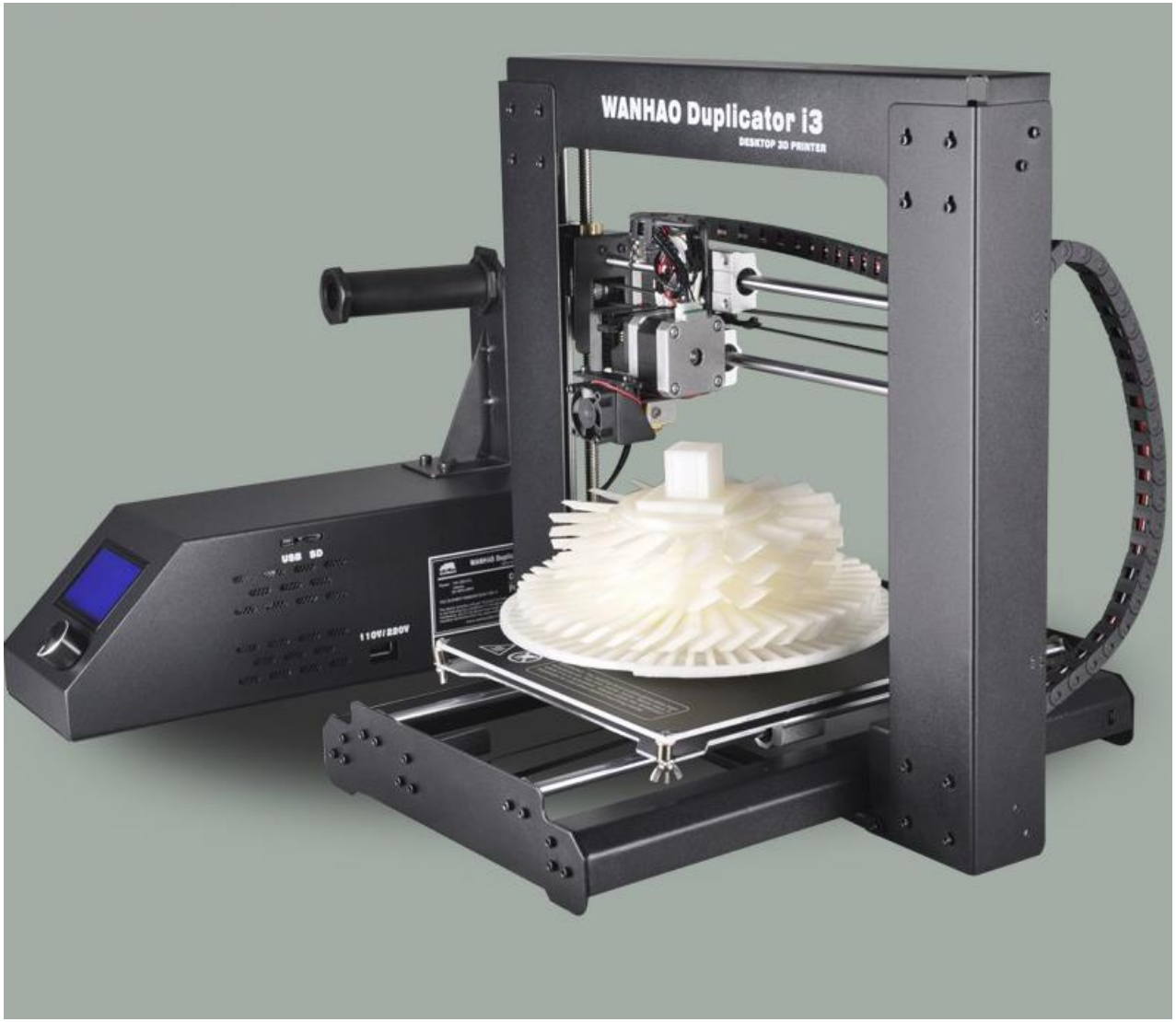
RepRap Darwin - First Device



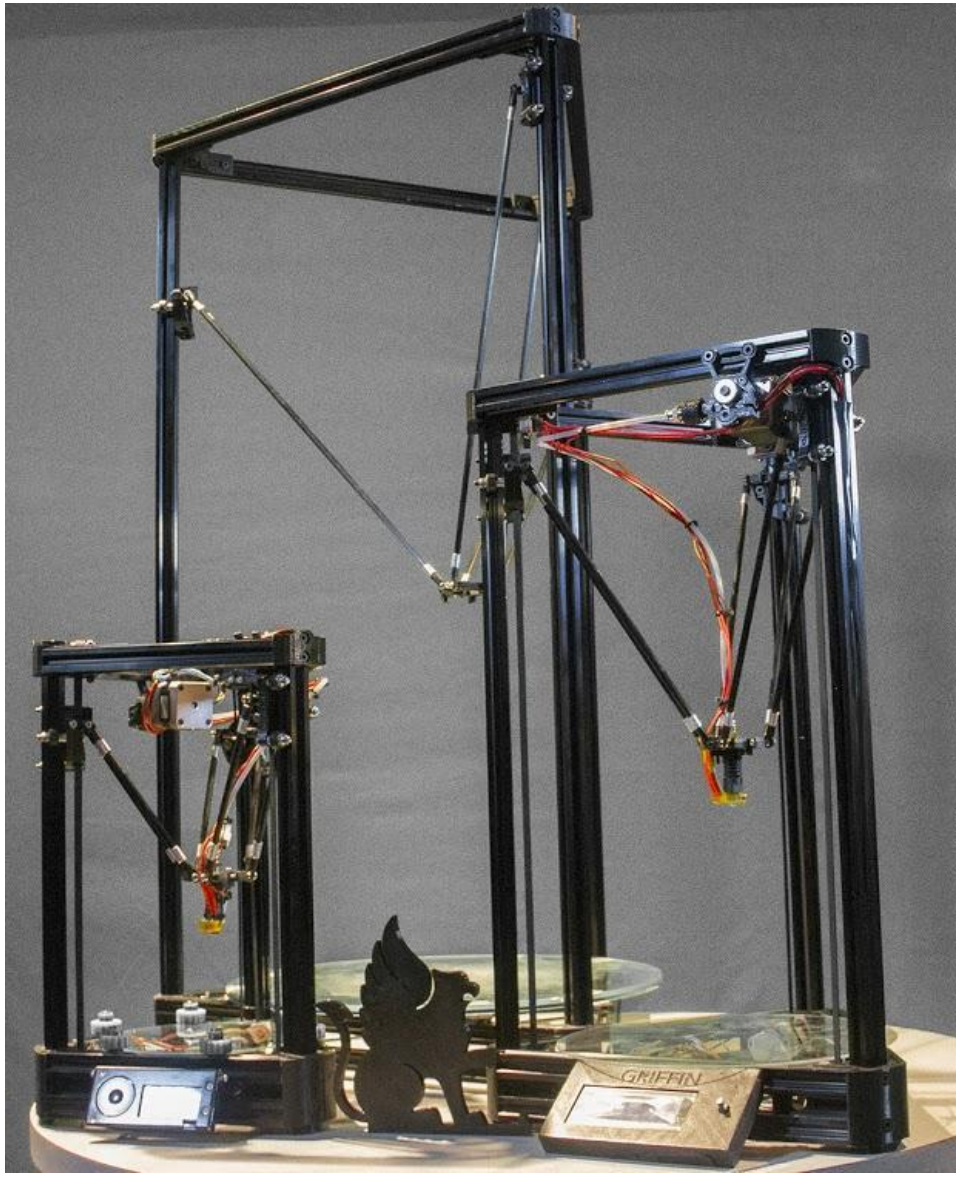
- Hot end
  - "Hot Glue Gun on Steroids"
- Build plate
  - object grows here

The majority of printers since are improvements on this idea

Typical Contemporary Mid-Cost Printer



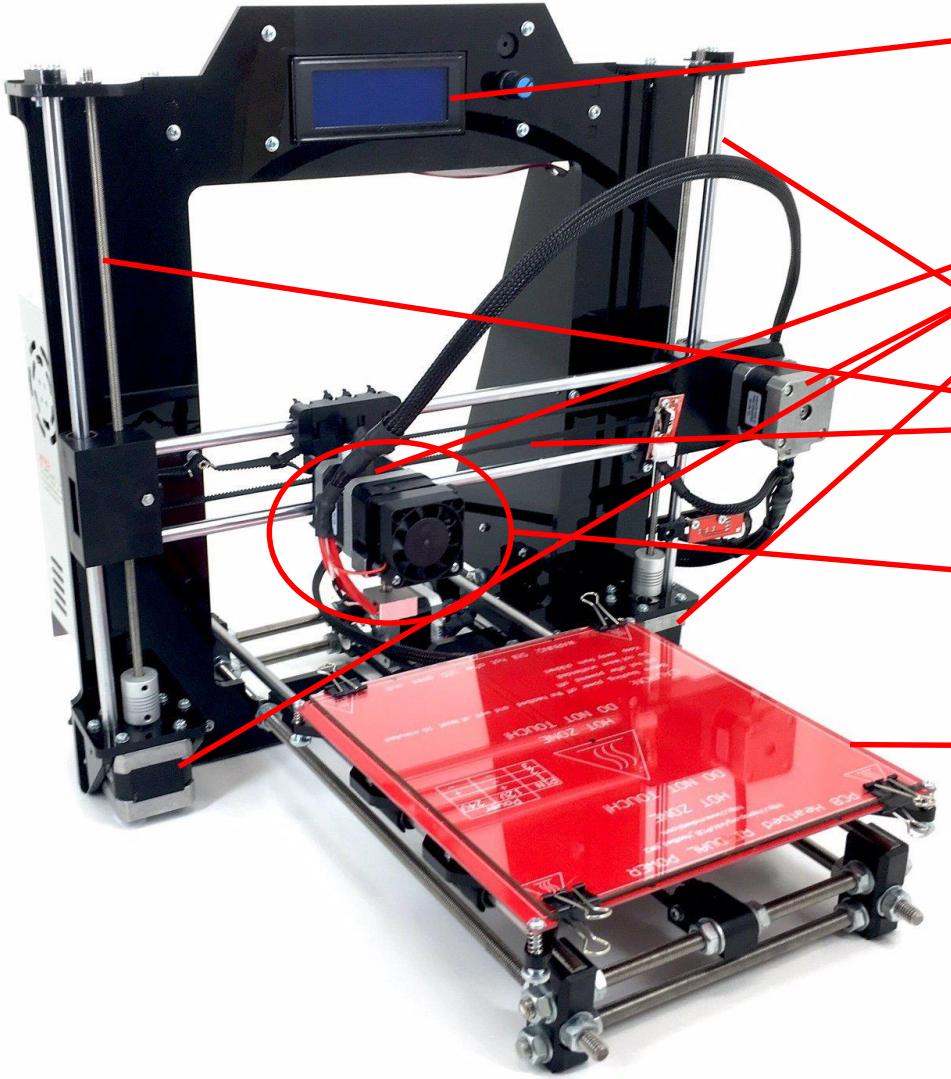
Typical Delta Type 3D Printers



Typical Commercial 3D Printer

3D Printer Drive Mechanism

3D Printer Drive Mechanism



Control Electronics
Usually 8 bit Arduino Based

Several Stepper Motors

Motor rotation converted to movement by belts and threaded rods

Hot end assembly

Heated bed

https://www.amazon.com/RepRap-Guru-prusa-3D-Printer/dp/B077Q7BJPR

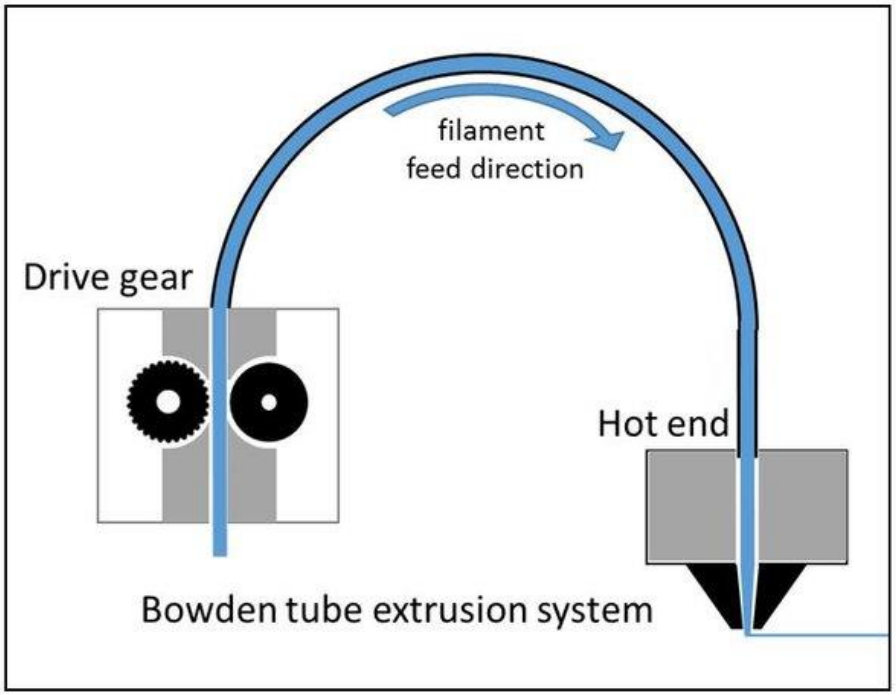
Hot End Types

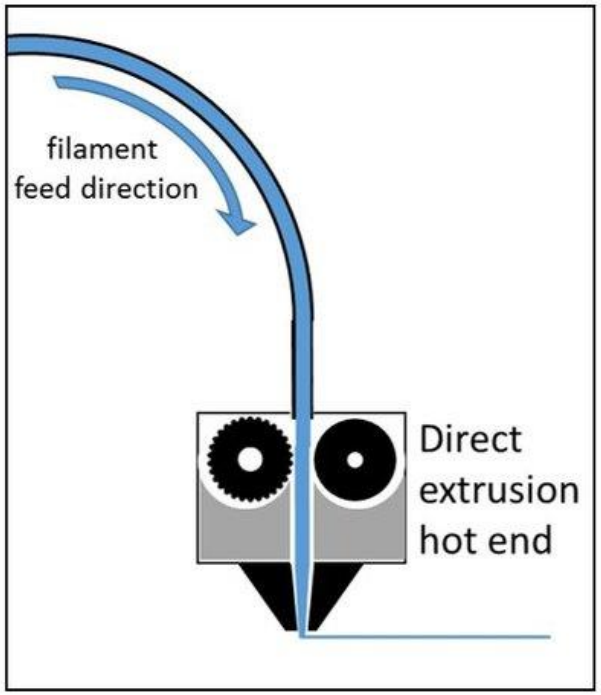
Bowden drive

- Drive hardware is remote
- Lower mass to move
- Less direct

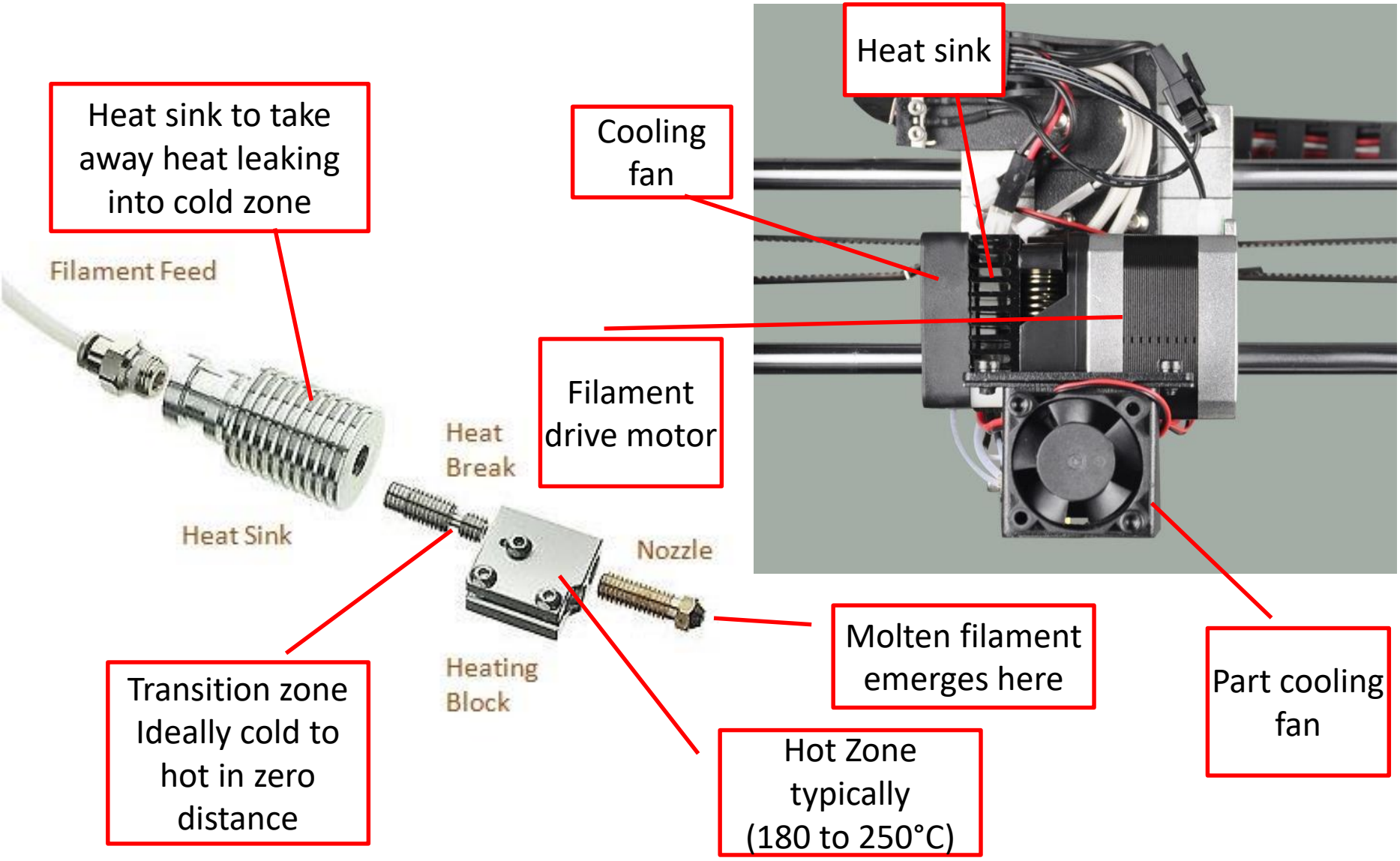
Direct drive

- Drive hardware on top
- Larger mass to move
- Very direct





Parts of Typical Hot Ends



https://3dprint.com/55647/e3d-lite6-hotend/
https://www.google.com/search?client=firefox-b&biw=1280&bih=671&tbm=isch&sa=1&ei=mP8iW4SKMoz-8gWTrIXACA&q=wanhao+3d+i3+hot+end+photos&oq=wanhao+3d+i3+hot+end+photos&gs_l=img.3...50480.53157.0.53433.7.7.0.0.0.0.217.1348.0j6j1.7.0....0...1c.1.64.img..0.0.0....0.jb-bPM61K9A#imgrc=VxmPaiv-94AFDM:

Time Lapse Print

https://www.youtube.com/watch?v=uVwmVUdy-iY

SoHo Printers Range in Price & Quality

Source form	Supplier	Cost	Effort	Support	Overall
Kit	eBay/ AliExpress	<300 USD	Assemble and align it yourself	Look in the mirror (or YouTube)	Experienced only
Assembled	eBay/ AliExpress	<400 USD	Fix assembly and align yourself	Look in the mirror (or YouTube)	Experienced only
Major cloner (eg Wanhao/ Cocoon Create)	On-line/Retailer	<600 USD	Likely works out of the box	Manufacturer/ Many support groups	Decent starting experience
Prusa	Prusa	Kit/Assembled <800 / <1000 USD	Likely works out of the box	Manufacturer/ Many support groups	Good starting experience
Commercial printer	Too many to list	> 1000 USD	Plug and play	Manufacturer/ some support groups	Varies: Excellent to disappointing

Notes:

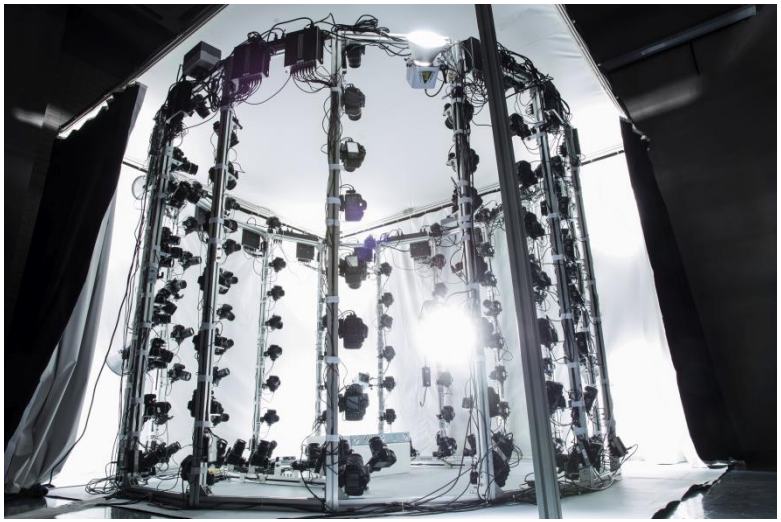
- Restricted to heated bed metal framed 3D printers only with build volumes about 200x200x200mm
- You can always find a cheaper one! Prices shown are for guidance only
- Caveat emptor: Buyers remorse common in this space. Best to buy tomorrow!

3D Scanners

- **Small scale Photogrammetry**
  - Use a digital camera to take lots of photos and then software combines them
    - 3DF Zephyr
    - AGISoft Photoscan Professional
    - Autodesk Recap

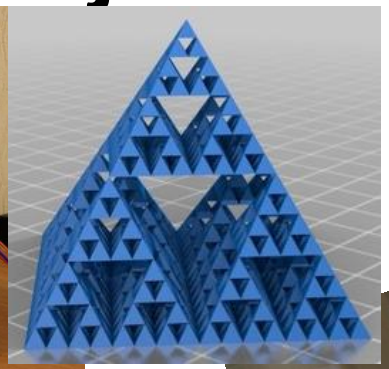
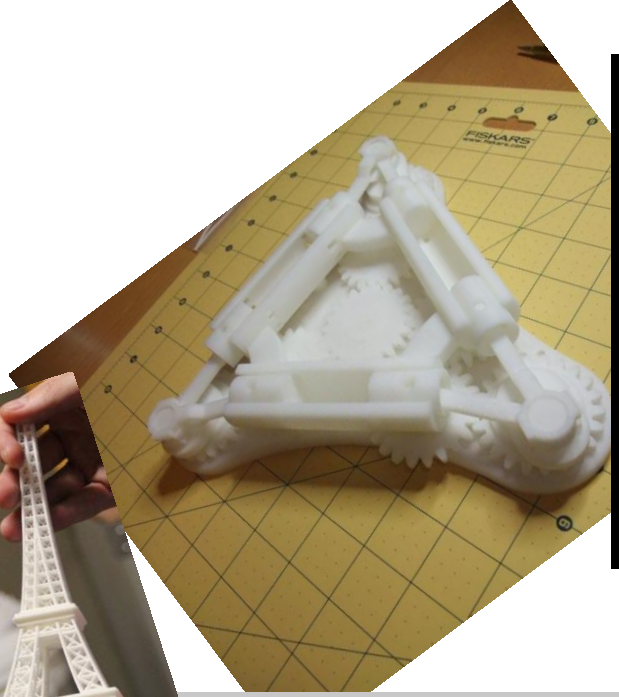
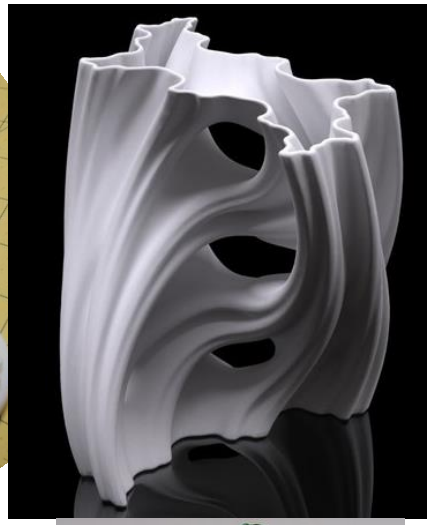
- **Structured Light Scan**
  - Typically small object on turntable
  - Laser/projector throws patterns of light onto object

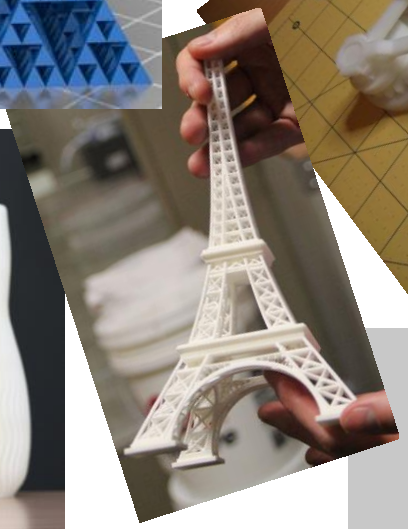
- **Multi-camera Scanners (body scanners)**
  - Really industrial scale Photogrammetry
  - Typically uses custom software

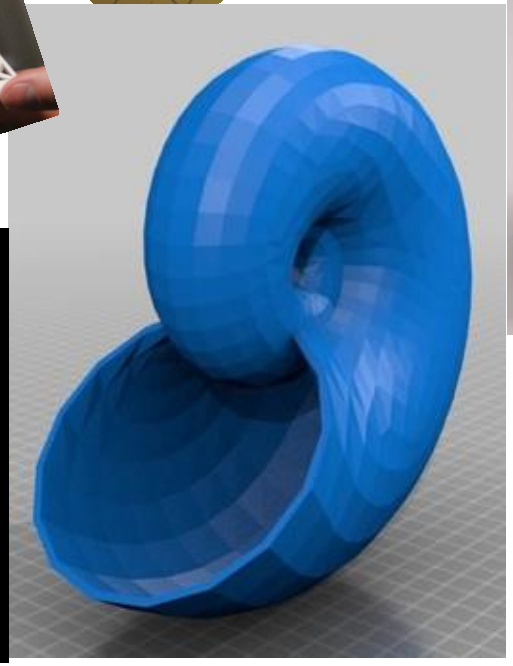
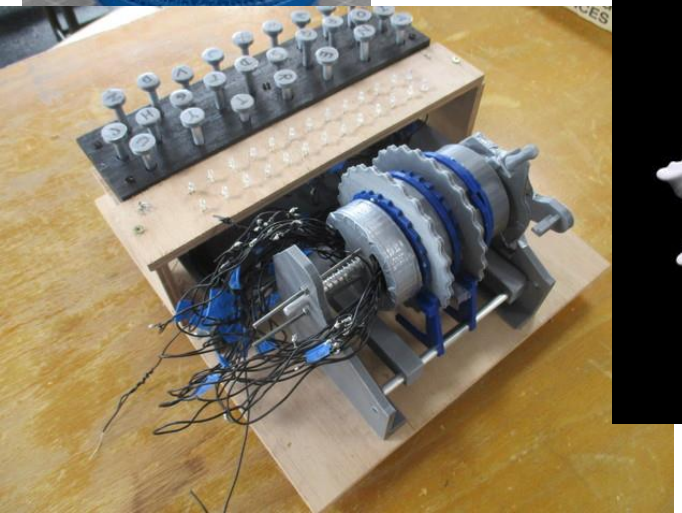


- **Scanned results has problems**
  - shiny/dark areas hard to scan
  - uniform areas scan badly
  - holes have depth problems
  - obscured areas not scanned at all
- **Combined printer / scanners exist**

Existing Objects

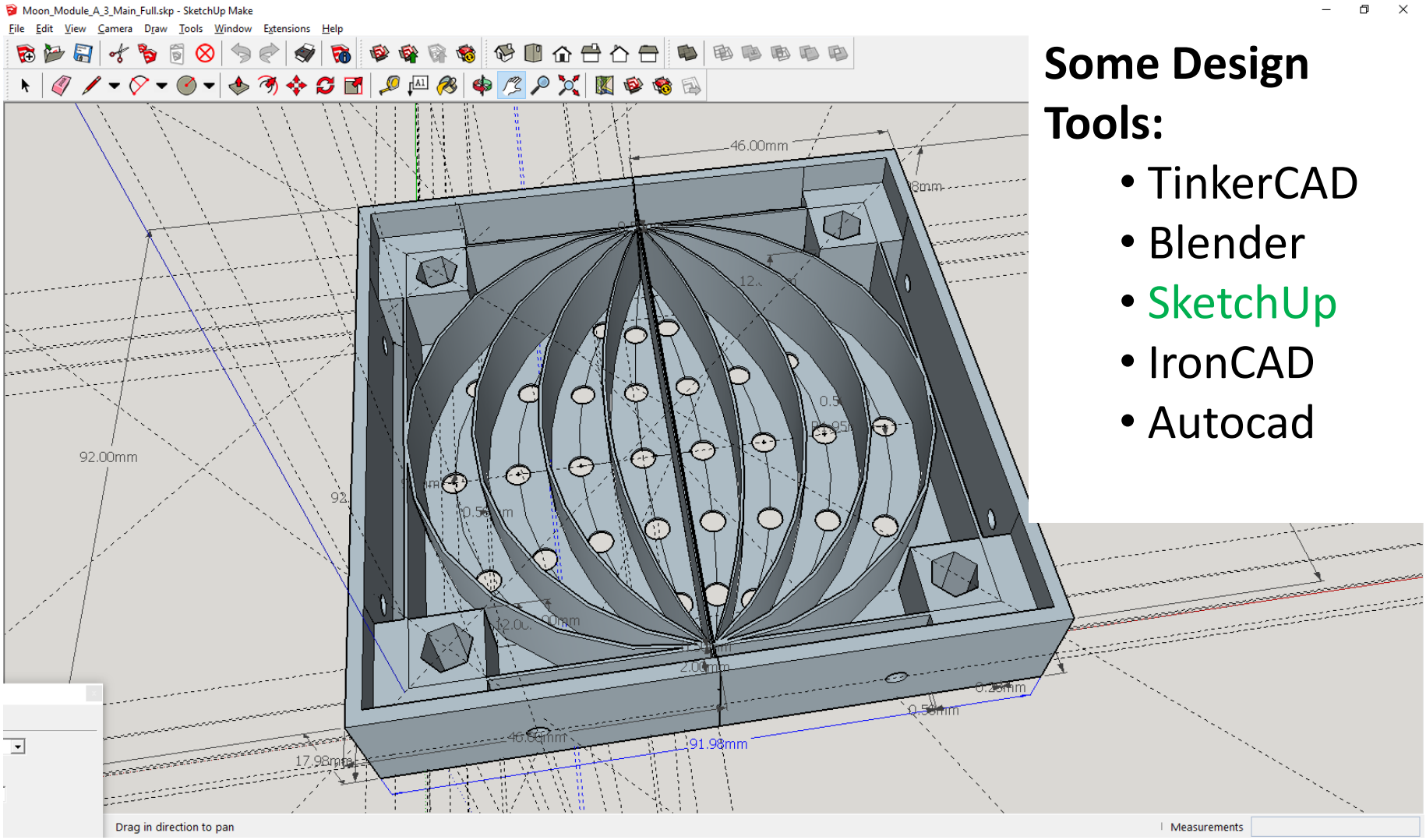



“Custom Designed Engineered” parts

- **Significant design effort and intellectual input**
  - Form follows function
  - Significant effort to measure
  - Must be designed to be printed
  - Comparatively easy to create an unprintable part
  - Be prepared to prototype
- **Can be functional**
- **Strong enough – not as good as moulded**
- **Parts are both:**
  - **Accurate** (Close to the designed value) and
  - **Repeatable** (Parts made at different times will measure the same)

Example Part in Design Phase



Some Design Tools:

- TinkerCAD
- Blender
- SketchUp
- IronCAD
- Autocad

3D Printing Workflow is complex

Find Existing Object

Scan Object

Design Object

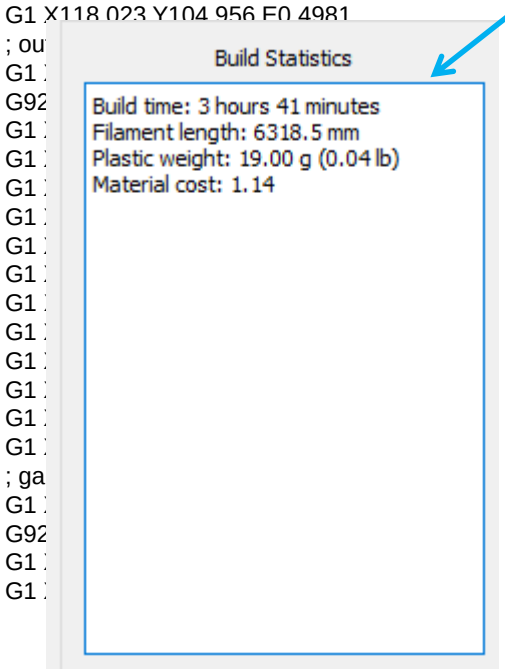
Files are .stl type

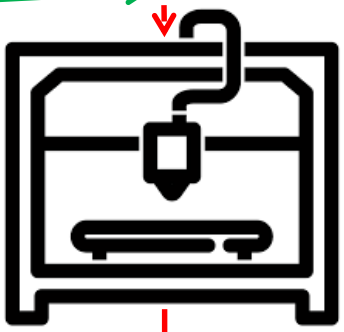
Repair tools:
- Windows 3D Builder
- Meshmixer
- Blender

‘Fix’ STL

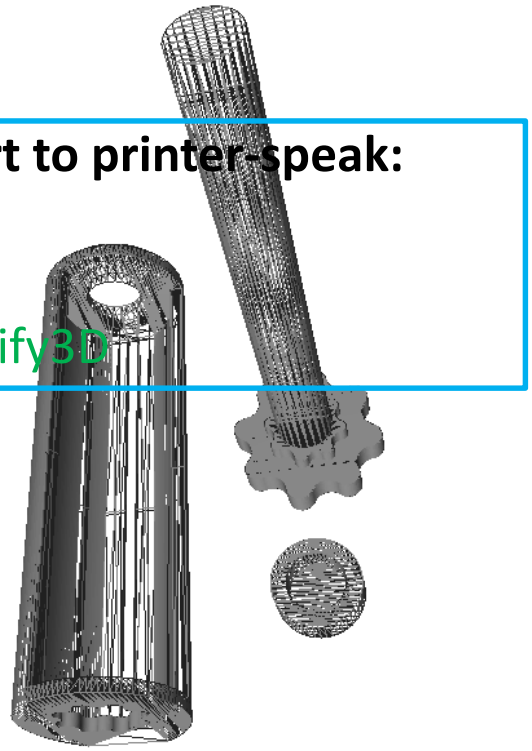
Slice Model

Output from slicer is a gcode file





Convert to printer-speak:
- Cura
- Slic3r
- Simplify3D



Resources

Repositories

- Thingiverse
- My MiniFactory
- Just search with Google

Scanners

- 3D Zephyr
- Autodesk Recap
- Agisoft Photoscan

Design tools

- TinkerCAD
- Blender
- SketchUp
- IronCAD
- Autocad

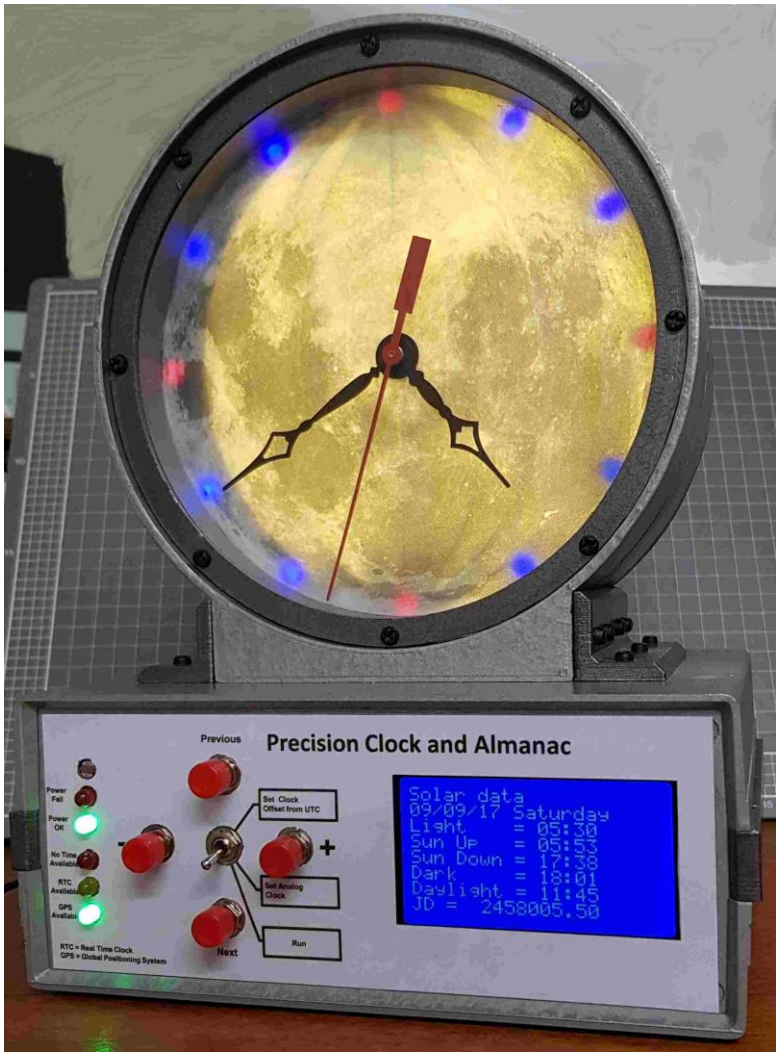
- Windows 3D Builder
- Meshmixer

Slicing Tools

- Cura
- Slic3r
- Simplify3D

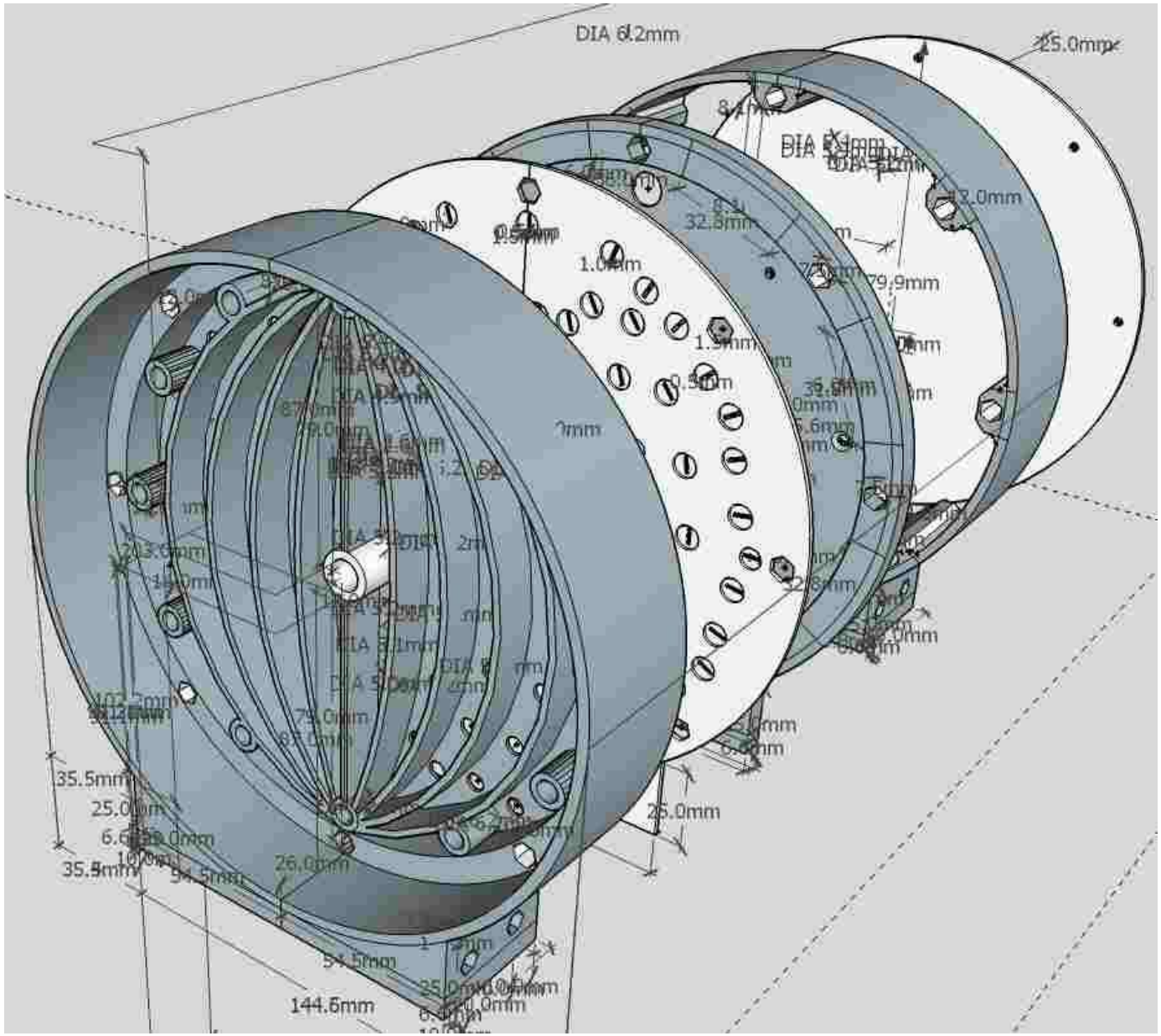
Highly 3D Printed Finished Objects

Version 2.0



Version 3.0

Overall layout – Head of 3.0

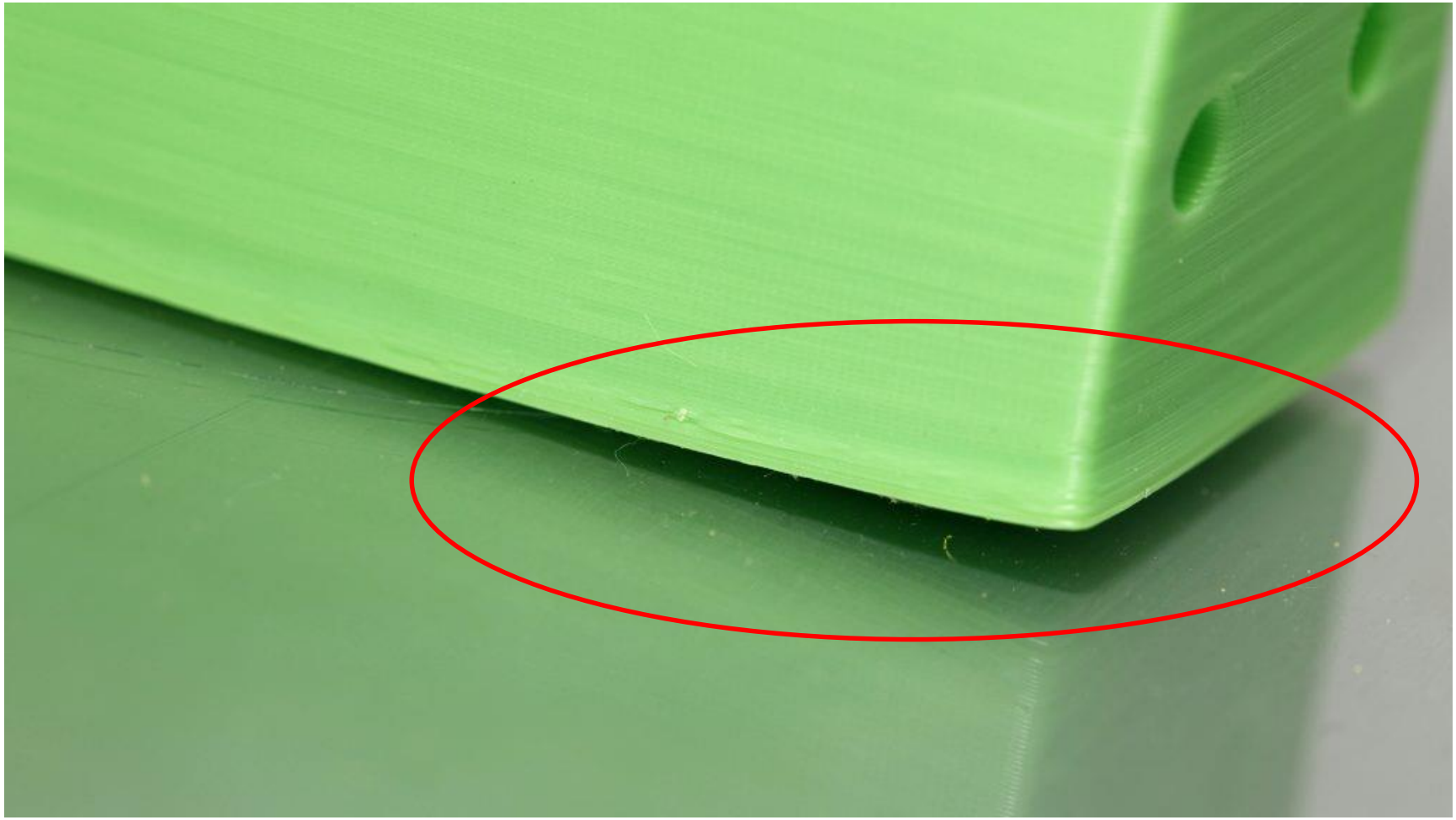


Fabrication Materials

Material	Printability	Advantages	Limitations
PLA (Poly lactic acid)	Excellent	Good range of colours, not toxic. Bed need not be heated	Models distort if left in a hot car
ABS (Acrilonitrile Butadiene Styrene)	Problematic	Model is heat tolerant	Warping and splitting common. Heated bed essential, heated enclosure desireable
PETG (Polyethylene Terephthalate Glycol)	**Good**	**Model is strong, heat tolerant. Food grade plastic**	**Stringing and blobbing on model**
Flexible materials (Too many to nominate)	Problematic	Model is flexible	Can be almost impossible to extrude
Nylons (too many to nominate)	Problematic	Model is strong, heat tolerant	High extruder temperatures required
HIPS (High Impact Polystyrene)	Problematic	Can be used as support material but produces high quality models	Warping and splitting common. Heated bed essential, heated enclosure desirble
PVA Poly Vinyl Acrylic	Dissolves in water	Can be used as support material	Requires dual extruder

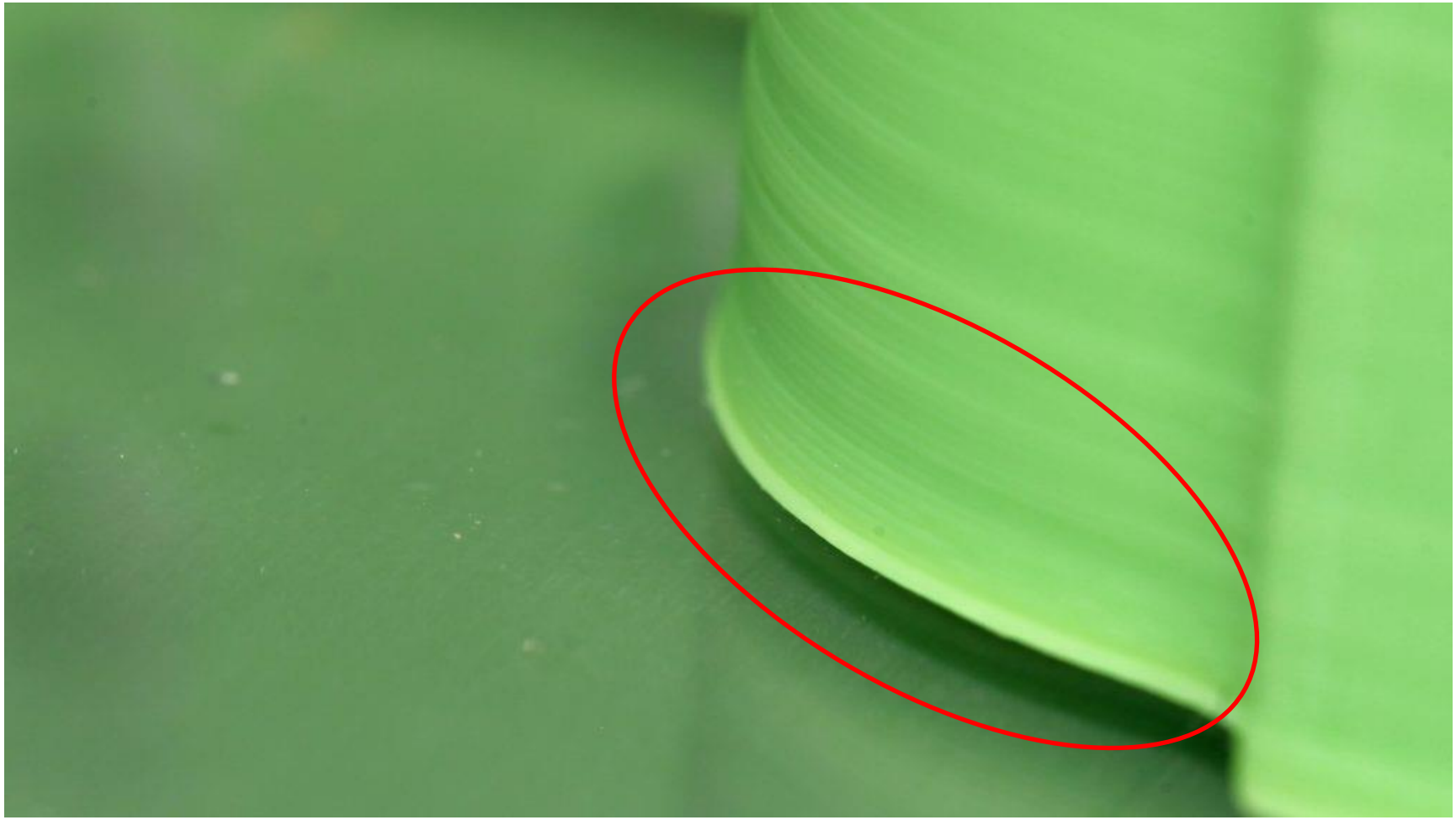
Common print problems

Warping off the print bed



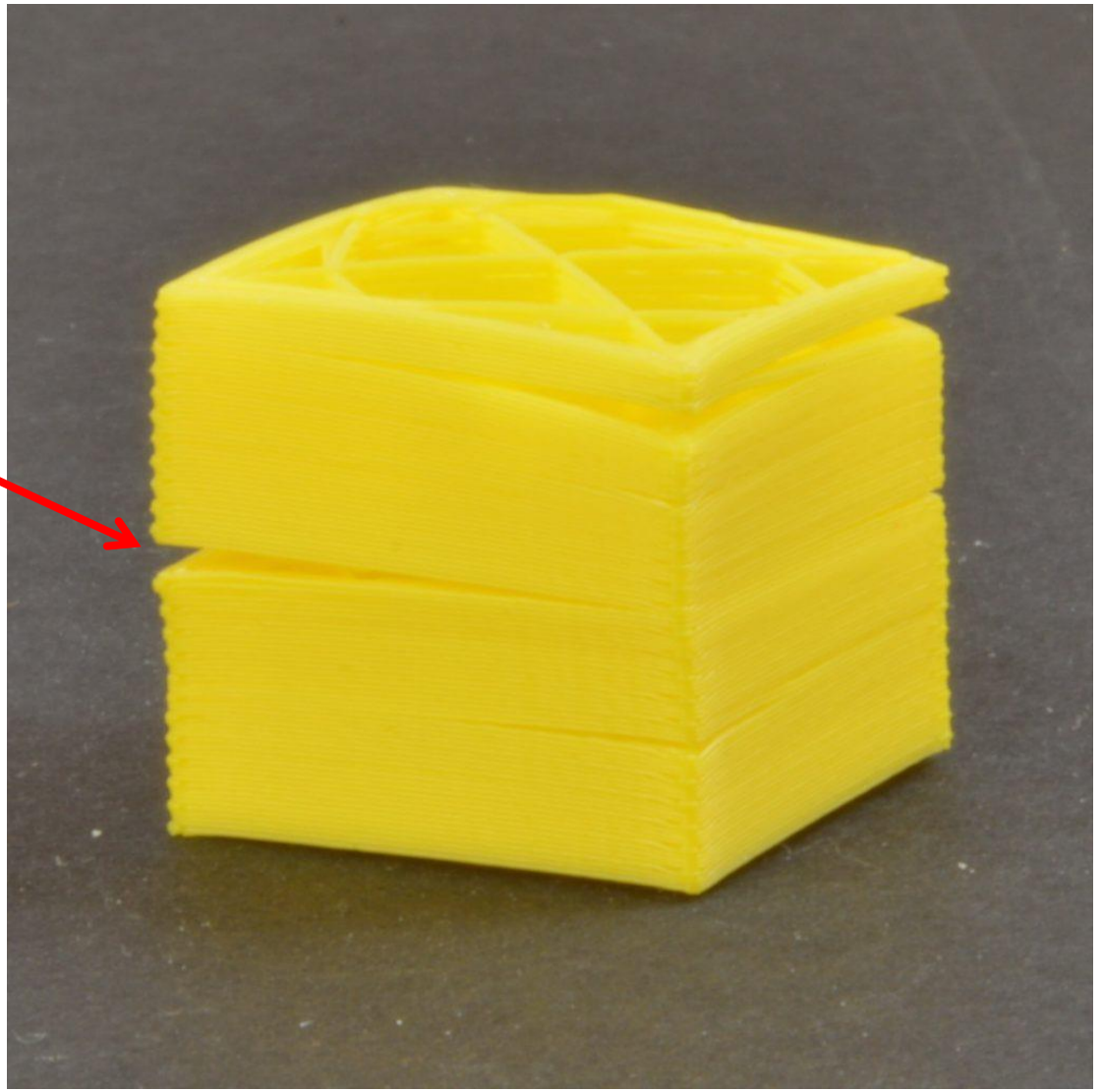
Common print problems

Elephant’s foot



Common print problems

Tall objects crack
Worse for
ABS/HIPS
especially if no
enclosure



Common print problems

First layer does not adhere to the print bed

Finishing Objects

- Objects look quite good “off th
- Trimming edges is a plan
- Sand paper (“wet and dry” and are your friend)
- Filler primer is useful for a good surface
- “Hammer tone” finish hides blemishes

So Is the Star Trek Replicator Close?

What isn’t quite right

- Premade objects seldom ”just what you want”
- It takes forever to design an object
- It often takes several iterations to get it right – the right object and a printable object
- It takes hours to print – a typical object of any reasonable size takes 14 to 20 **hours, sometimes longer**
- The print may fail for any number of reasons
  - The power might fail
  - The printer filament feed could jam
  - Filament could run out
  - Filaments tangle
  - First layer problems

But when it works

(at least 75% of the time)

You are presented with models which:

- Work as engineering parts
- Are the size you designed
- Often could not be made any other way
- Can be “finished” to look good
- You can have more without effort

And it can only get better:

- The competition is still ferocious
- New 3D printer every day.
- Racing to the bottom in cost

So is this a revolution or not?

Media hype a couple of years ago unjustified

- Technology not ready – printers were not plug and play
- Design is not for everyone – exacting and demanding work
- Limited to plastic for home users
- Plastics tricky to use, Ideal plastic still coming
- Parts of limited strength
- Slow printing unsuited to media attention span

So Industrial Revolution 2.0 didn't really arrive on cue

Media now saying technology is "dead" - also wrong

- Technology is better – good plug and play printers exist
- Design tools are better and "friendlier"
- Still limited to plastic for home users, but a greater range of plastics
    - Some users are casting metal using "lost plastic" or lost wax
- Parts still limited in strength
- Still slow. Speed is limited by materials and method

Result: Entirely practical for prototypes and small production

Useful Resources

The following YouTubers are worth looking at:

Channel	Link
Thomas Sanladerer Germany	https://www.youtube.com/user/ThomasSanladerer
Makers Muse (Angus Deveson) - Australia	https://www.youtube.com/user/TheMakersMuse
CHEP Chuck Hellebyuck - USA	https://www.youtube.com/user/beginnerelectronics
3D Printing Nerd Joel Telling - USA	https://www.youtube.com/channel/UC_7aK9PpYTqt08ERh1MewlQ
CNC Kitchen Stefan Hermann - Germany	https://www.youtube.com/channel/UCiczXOhGpvoQGhOL16EZiTg
SexyCyborg (Naomi Wu) – China	https://www.youtube.com/channel/UCh_ugKacslKhsGGdXP0cRRA

Not exhaustive by any means but will get you started

Questions??