

How long until the Star Trek Replicator?

The past, present, and future of 3D printing
(especially the Reprap project)

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Presentation Outline

- 3D Printing (with special mention of the Reprap project)
 - The Past
 - The Present (2010-2012)
 - The Future
 - Social Implications

Note, \$ are \$US unless specifically stated otherwise

The Past

(Mainly the first decade of the 21st Century)

The Big Players

- \$20,000-\$100,000's machines
- Low numbers sold (100's of units per year)
- High Quality prints
- Specific to particular industries with a very specific need e.g. Boeing has historically used the biggest 3D printer in the world to print prototype their jet engines.

The Big Players



- Stratasys Dimension



- Objet Eden
- Multiple materials



- Z-Corp 3D Printer

The Big Players

- 3 main types of printer materials: plastics, ceramics, metals.
- Normally can't mix and match different types of materials in the same printer
- Most take a bunch of powder and apply heat to melt small pieces into bigger pieces.
- Some may take a liquid and change it to to be solid in certain places. Normally UV light focused on a photo-polymer liquid.
- Scott Summit talk 10:40-12:00 Digital Fabrication

The Reprap Project's Humble Beginnings

- Dr Adrian Bowyer had a good idea, made a wiki, blog and email list and issued a press release 2nd Feb 2004
- If we can create a 3D printer that can print its own parts, the cost will come down to the cost of the raw materials.
- Oh, and if you have one you can print two for friends and we can have exponential growth.
- Oh, and if anyone can print one we may as well make the design open which just happens to lead nicely into letting us use “evolution” to find better designs.

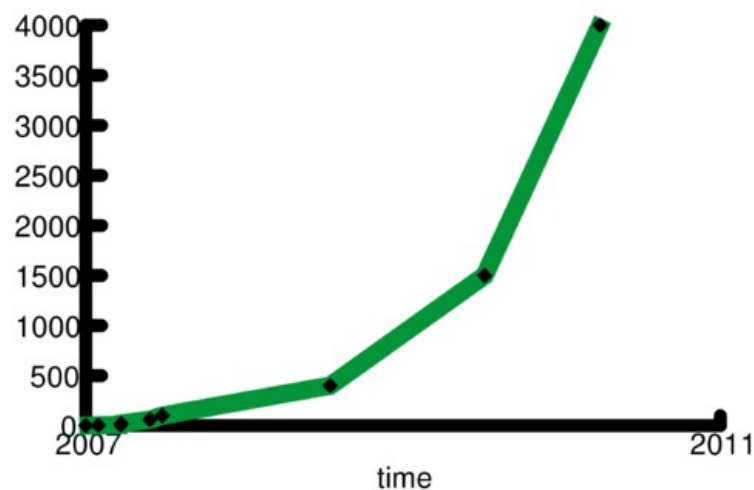
Reprap Video

- General Introduction Video uploaded June 27, 2009 (8 minute video)

Some milestones

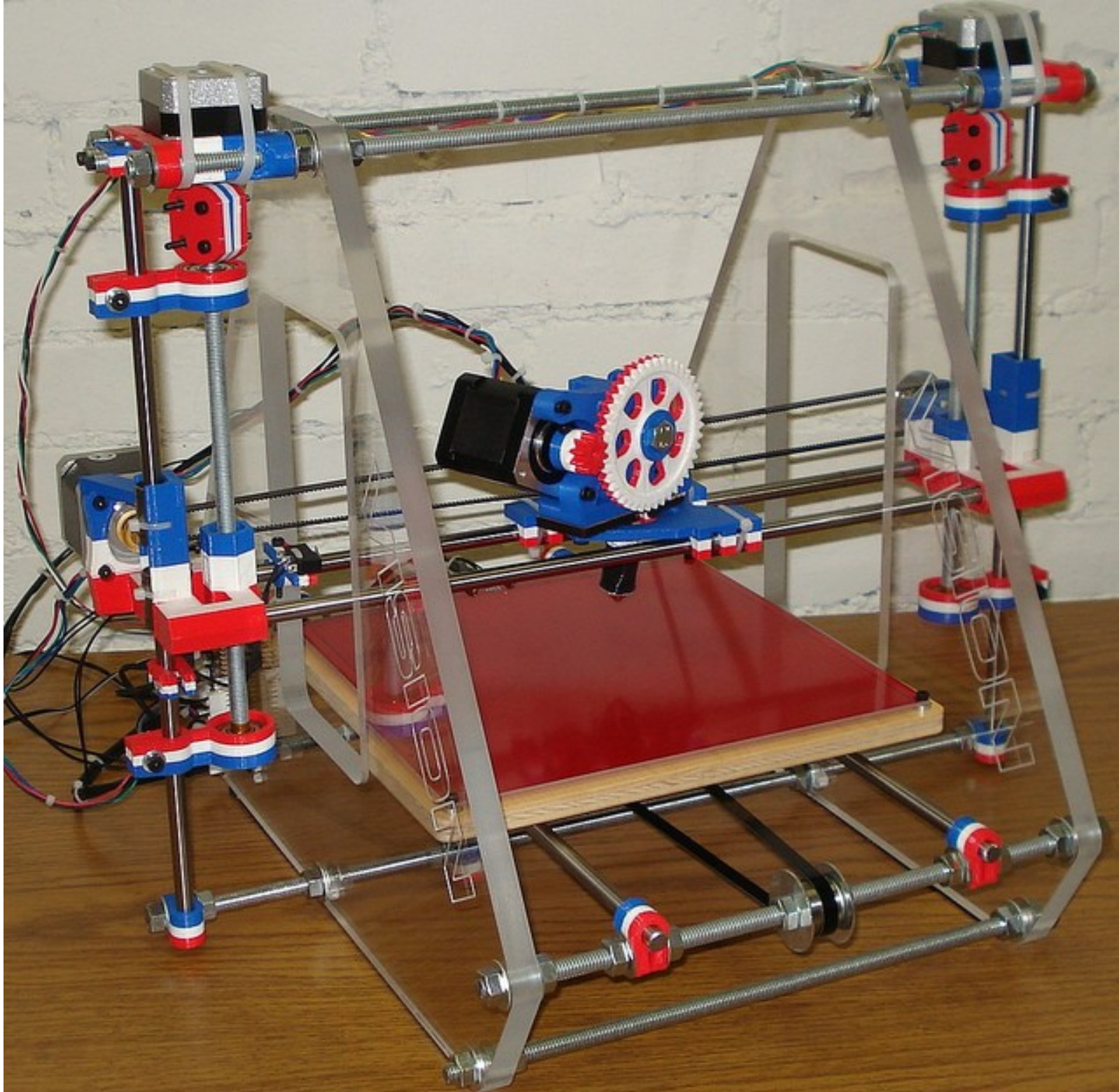
- Spring 2007 – First Reprap Darwin was assembled with parts printed on a Sratasys Dimension
- 29 May 2008 First replication

working repraps over time

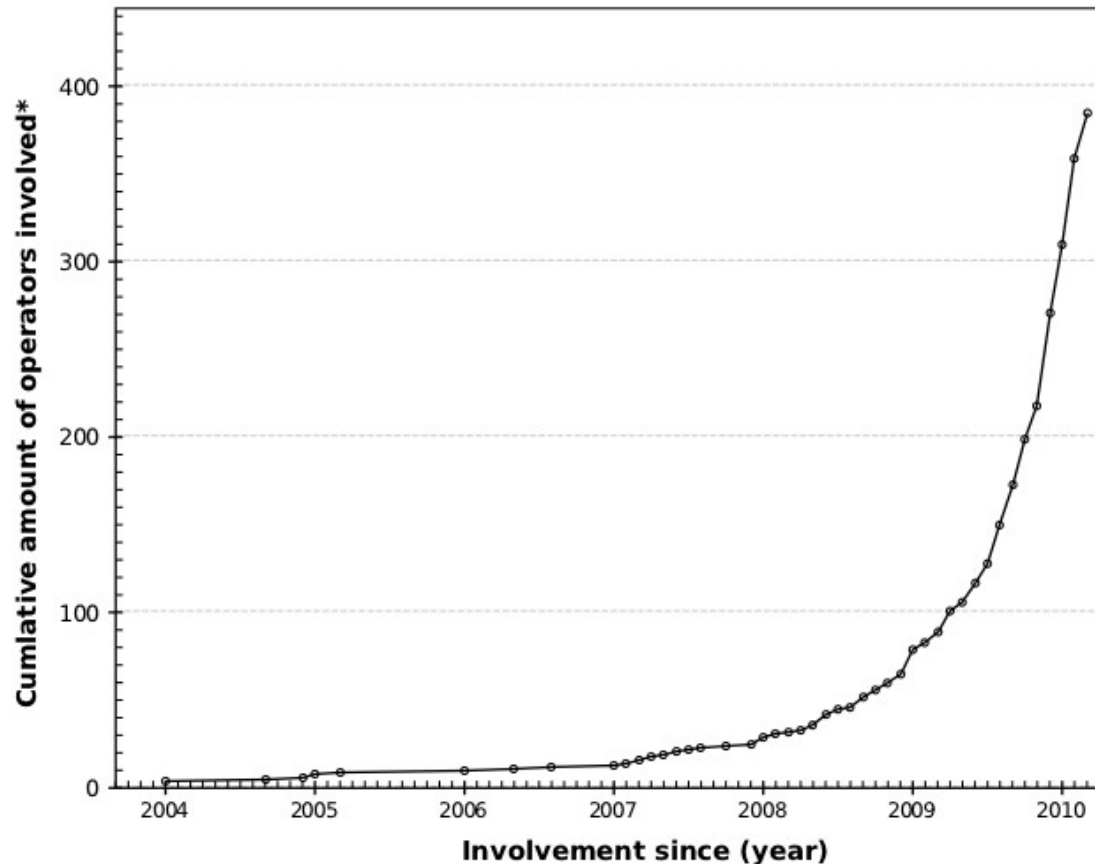


Some estimates (NZ\$)

- 2008 Darwin model: time to print its own parts 40-80 hours, 60% replication + 'vitamin' parts \$800
- 2009 Mendel model: time to print its own parts 30-50 hours, 50% replication + 'vitamin' parts \$700
- 2010 Prusa Mendel variant: time to print its own parts 20 hours, 60% replication + 'vitamin' parts \$600
- 2012 Current Kickstarter project: Vision 3d Printer, modified Prusa Mendel. It supposedly can be built in 1/3 the time with 150+ fewer parts (probably counting each nut). 70 of these (including 8 RP parts) are replaced by 2 acrylic panels.



Estimated Number of Reprappers



* Actual numbers estimated to be 4-5 times higher. Numbers and graph come from a survey conducted by Erik de Bruijn for his Masters thesis "On the Viability of the Open Source Development Model for the Design of Physical Objects - Lessons learned from the RepRap project".

Historically the number of people involved doubling approximately every 6 months!

The Present (2010-2012)

Trends

- The number of big companies is decreasing as they merge with each other
- The cost of the big printers is coming down.
- A high end printer that cost \$100,000 5 years ago can now be bought second hand for \$20,000. And the equivalent printer may be had new for \$80,000.
- Low end commercial printer cost down to \$5,000
- There has been a “Cambrian explosion” of small startups selling hobbyist 3D printers (>30 startups in 2011) \$500-\$5,000.

Worlds smallest 3D printer

- Build Envelope: 20 x 30 x 50 mm
- Layer Thickness: 50 μm (Dimension of one Voxel in Z direction)
- Build Speed: “The 3D micro printer is capable of producing a 1 cm object per hour, independent from the base area.”

Worlds smallest 3D printer



- Show Worlds Smallest 3D printer video (8 minutes – starting at 1 minute mark)

Differentiation in hobbyist designs

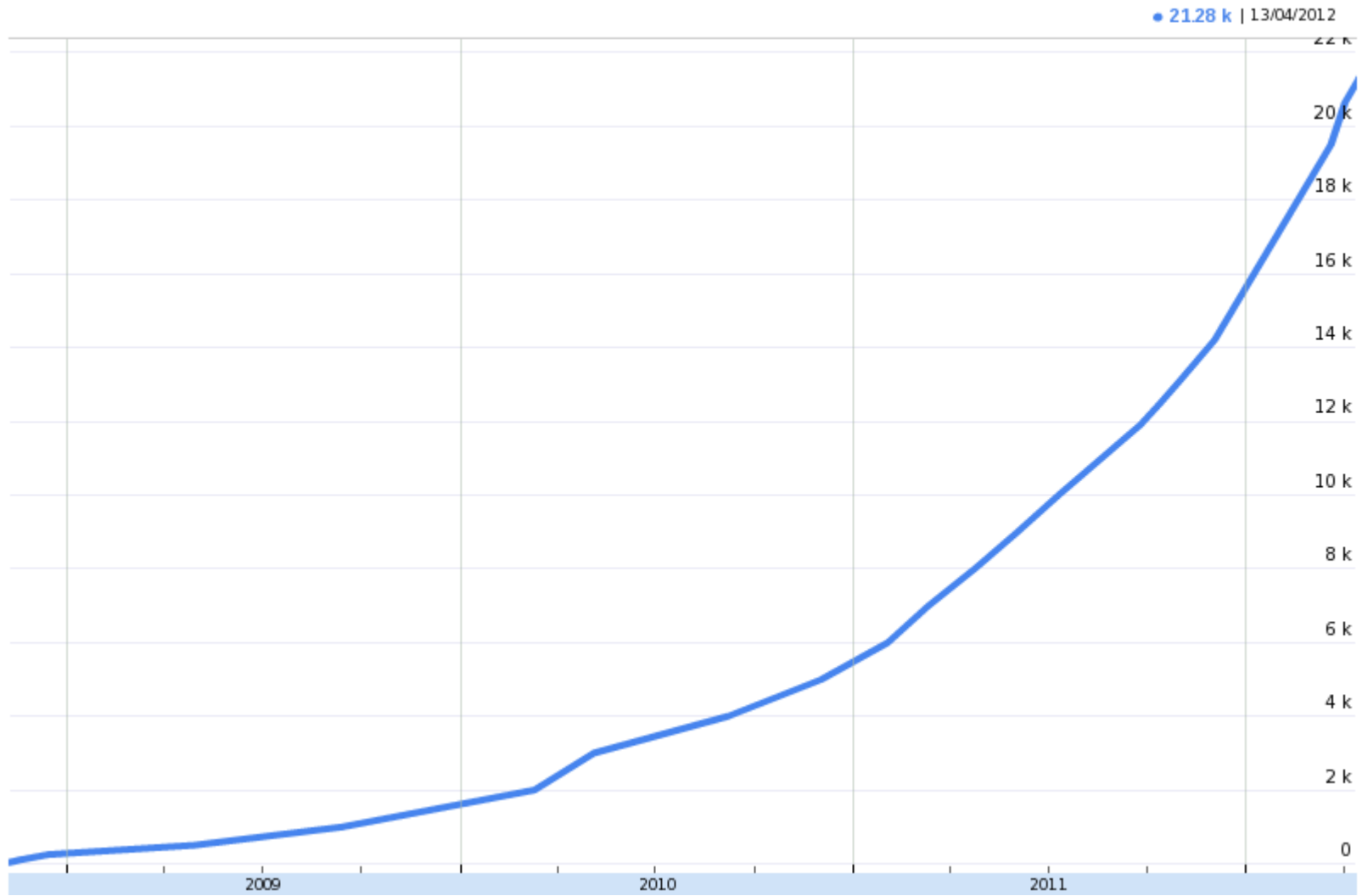
- Some printers can extrude 10x faster
- Some printers can extrude 5x finer detail (starting to measure tolerances in microns not millimetres)
- At least one (Vik Olliver, Auckland) unreleased design has no nuts at all. You just attach everything and hit it with a mallet!

Thingiverse

- OK, so you now have a 3D printer that can print plastic parts. Now what?
- If you have 3D CAD skills you can create a part yourself but if not what can you do?
- Thingiverse was created so that designs can be shared. Now you can search and find what you want to print out that someone else has designed.
- Everything released under open licences so can also create physical mashups.

Number of Things on Thingiverse

Number of objects on Thingiverse ▾



<http://tinyurl.com/cqkj2x7> or <http://dspace.org.nz/2012/05/25/octacon/>

Experimental Biological printing

- Uses Inkjet type technology to place scaffolding material and specific cells in particular places.
- Have been able to print a bladder or blood vessels or other simple organs made from one type of cell in a 3D structure for a decade.
- Experimenting with complex organs such as kidneys with multiple cell types.
- 2011 TED Talk Anthony Atala - Printing a human kidney 7:25-12:00

3D printing starts to appear in mass-media

- One news 2 minute segment

The Future

What we're aiming for

- Star Trek Replicator, “Tea, Earl Grey, Hot” montage video (27 seconds)
- "Twenty years from now, we'll have Star Trek replicators that can make anything." - Neil Gershenfeld, 2006

What we're aiming for

- But he also said this in 2010!
- Nanofactory video 5 minutes
- And/or Past, Present, Future Manufacturing 4 minute video

How do we get there?

- The Interim Personal Manufacturing Gada Prize \$20,000 to be awarded for work done up until the end of 2012:
 - Ability to print at least three different materials, including one that is usefully electrically conductive.
 - Ability to print electronic circuit boards.
 - Total materials and parts cost under \$200 and that 90% of the volume of the printer parts be printed.
 - Build volume of the printer above 300x300x100mm in order to ensure that items of daily utility can be printed.
 - The capacity to print a full set of parts for a complete replica of itself within 10 days unattended save for clearing no more than one printer head jam.
 - Ability to print autonomously without a PC attached.
 - Uses no more than 60 watts of electrical power.
- Possible? Maybe. But its not definite there will be a winner yet.
- There is also a final prize of \$80,000 in 2015 but its not funded yet.

How do we get there?

- More personalisation
- More designs
- More materials
- Better resolution
- Faster printers
- In the hands of more people

Social Implications

(Discuss as I don't have any answers)

Some numbers

- Imagine it takes someone a month to print and put together a 3D printer (theoretically possible today to do it in <40 hours but if we spread that over 4x10 hour weekends we can call it a month).
- If one person makes two printers and passes them on to others who do the same, how long does it take to make one for every person on the planet?
- 30 doublings gets you to 1 billion people, approx 1 per family
- 3 more gets one to everyone.
- At one doubling every month that's less than 3 years!
- Let's be conservative and say it takes 10 years...

What happens when the social changes of the Industrial Revolution are compressed into a decade?

What jobs are destroyed, what jobs are changed beyond recognition, what ones are left alone, and what new ones are created?

<http://www.crnano.org/CTF-Scenario2.htm>

From a working group in 2007

What if you could print 3 meals in a 24 hour period from some dirt, atmosphere, and solar power?

- What happens to farming, agriculture, and the whole food industry?
- Is 3d printing using the atmosphere as feedstock a viable 'carbon sequestering' technique to combat climate change?
- We already have enough food for everyone, the problem is distribution. Does this solve it or just make the politics worse?

- What has value if everything can be duplicated at the molecular level?
- Are expensive pieces of art valuable because they are rare or because they are beautiful?
- Will individual craftsmen become millionaires because they make one-of-a-kind things?
- Current economic theory is built upon the fundamental assumption of scarcity, what happens to economic relationships in a post-scarcity world?

- If we can personalise everything, will we? Clothes are desirable to be fit to our body rather than picking from an arbitrary sizing system but what about furniture, vehicles, houses?
- What happens when the digital revolution that has happened in music, movies, and now books comes to the rest of our possessions? I have got a lot of shelf space back by going digital with my music and movie collections and am currently in the process of doing the same with my books. When we have digital designs for all our favourite possessions, will we just instantantiate possessions when we need them and recycle them when we're finished?
- What about 'physical piracy' and 'physical DRM'?

- If we can duplicate food, what about the ethics of trying to duplicate living animals and humans? What if the only available 3d scanning techniques are destructive i.e. to duplicate a living organism you have to kill it in the process?

Extra if time permits

- Show Open Source Ecology video (4 minutes)