

Printing a Penguin

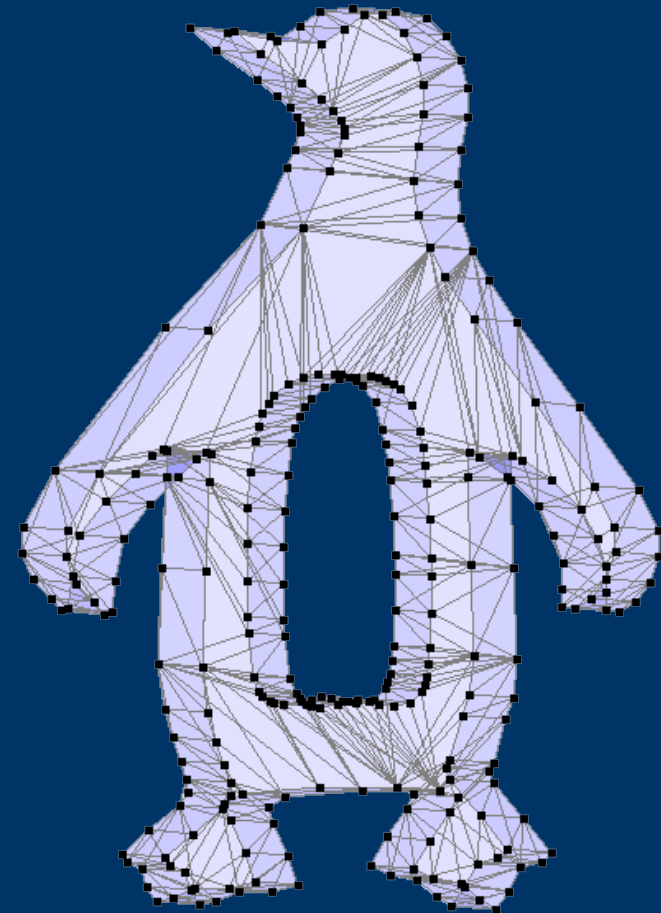
- or How I learned to Love The Replicators

by Vik Olliver

The RepRap Project

University of Bath

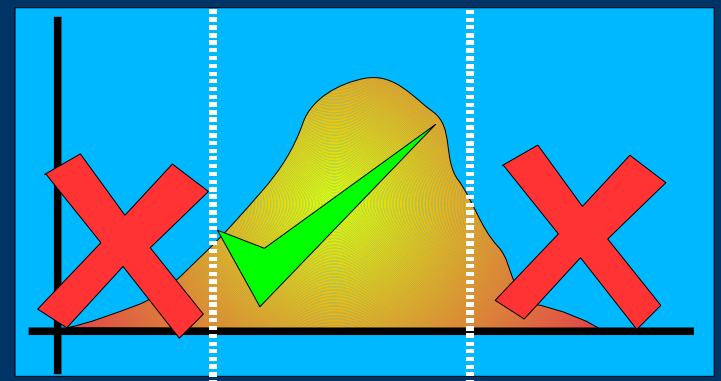
<http://reprap.org>



In last year's episode

- ◆ Why hardware sucks.
 - ◆ What the heck is a RepRap?
 - ◆ Why the funny name?
 - ◆ Won't replicators take over the world?
 - ◆ Who are these mad people anyway?
-
-

Why Hardware Sucks



- ◆ It's mass-produced for the "average" user.
- ◆ Its primary purpose is to turn profit ...
- ◆ ... or act as a vehicle to sell more stuff.
- ◆ You can't really change it.
- ◆ Increasingly, you can't fix it either.

If only hardware was like Open Source.

What The Heck Is A RepRap?

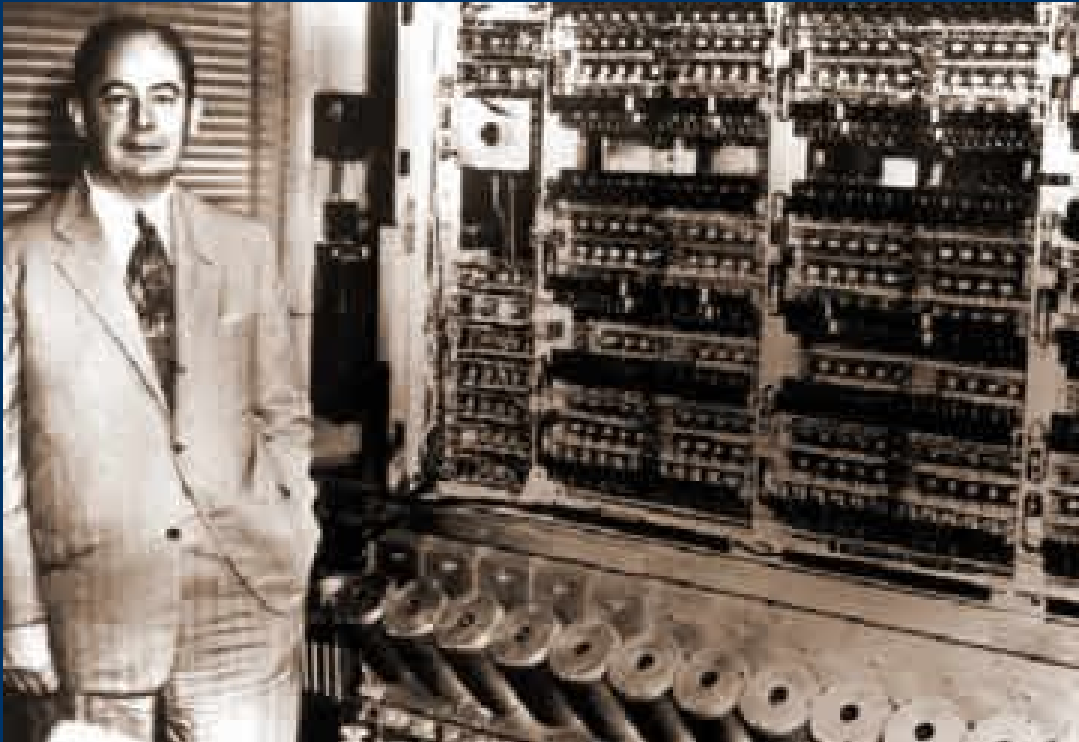
The RepRap is a practical hardware implementation of a Von Neumann Universal Constructor, explicitly designed to be subject to Darwinian evolution.

What The Heck Is A RepRap?

Duh ?!?

OK, lets take a few steps back...

Quick History Lesson – Von Neumann



John von Neumann with ENIAC

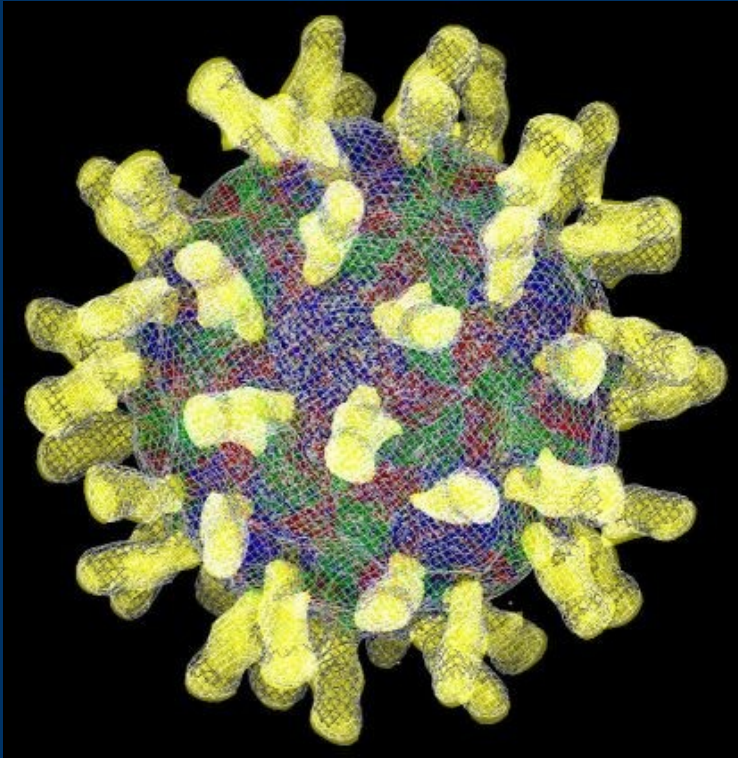
John von Neumann:

Universal Constructor
(1950s)

A Universal Constructor would be a computer linked to a manufacturing robot.

The combination would be able to copy themselves.

Simple biological replicators get complicated replicators to do the assembly.



Rhinovirus



H. sapiens



We provide the simple, readily obtainable materials and it builds parts from them:

- ◆ Nuts, bolts, screws
- ◆ Plastic feedstock
- ◆ Metal feedstock
- ◆ Motors and bushings
- ◆ Power supply, 12V
 - wall-wart, solar, wind, etc.
- ◆ Chips & discrete components
- ◆ Wire
- ◆ Grease
- ◆ PCBs



As the design is improved, the RepRap can make more of its own parts and the list shrinks:

- ◆ Screws
- ◆ Metal feedstock
- ◆ Motors and bushings
- ◆ Power supply, 12V
 - wall-wart, solar, wind, etc.
- ◆ Chips & discrete components
- ◆ Grease



As the design is improved, the RepRap can make more of its own parts and the list shrinks:

- Screws
- Metal feedstock
- Bushings

- Chips



The whole thing is Open Sourced, so

- ◆ People have the tools to improve it,
- ◆ A way of making anything to their design,
- ◆ The information to do so, and
- ◆ They can make as many of these as they like.

...and all the improvements get ploughed into the next generation of machines.



Hang on, what about "Grey Goo" ?

<TinfoilHat>

Self-replicating machines will take over the world!

</TinfoilHat>

Actually, they already have.

Humans are mass produced from self-replicating raw materials by unskilled labour – usually without a manual.

So we'll use humans to put **RepRaps** together.

So, A RepRap:

- ◆ Is a **Replicating Rapid** Prototyper - RepRap
- ◆ Self-replicates, but doesn't self-assemble (like a virus)
- ◆ Exists symbiotically with people, giving them goods in return for being helped to replicate (like flowers)...
- ◆ Improves and evolves with each successive generation – and V1.x machines can build V1.(x+1)

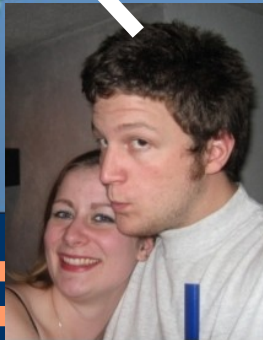
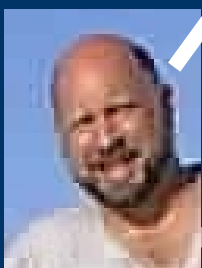
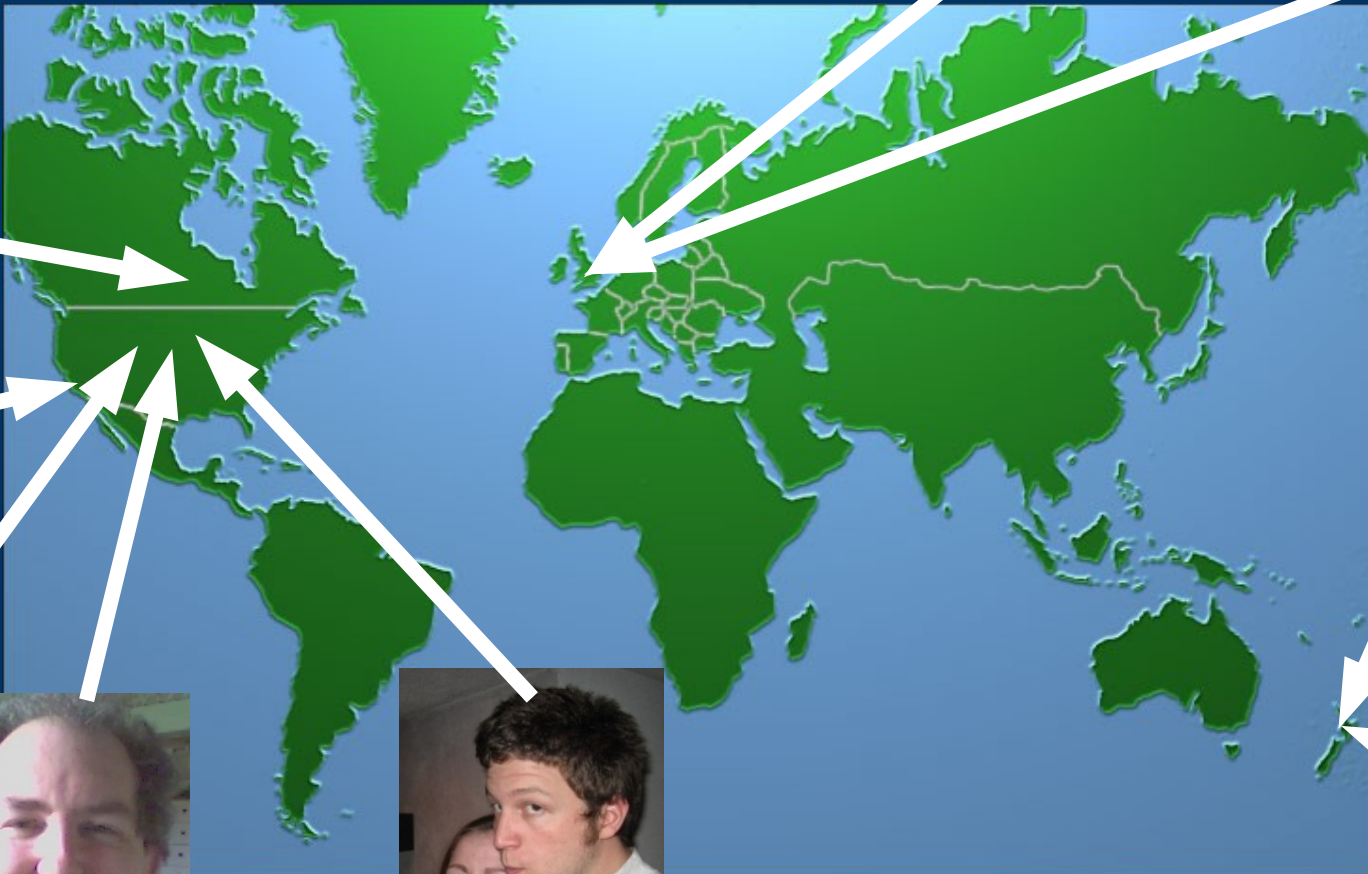
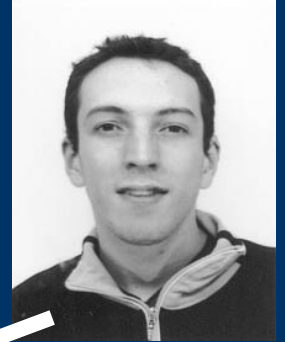
What would you build with one?

The logo for RepRap, featuring a green teardrop icon to the left of the text "RepRap" in a bold, green, sans-serif font, all contained within a white rectangular box.

RepRap

The Team and Our Supporters

- ◆ Nuffield Foundation
- ◆ EPSRC
- ◆ Bath University IMRC
- ◆ The Open Source Community



How can RepRapping be done?

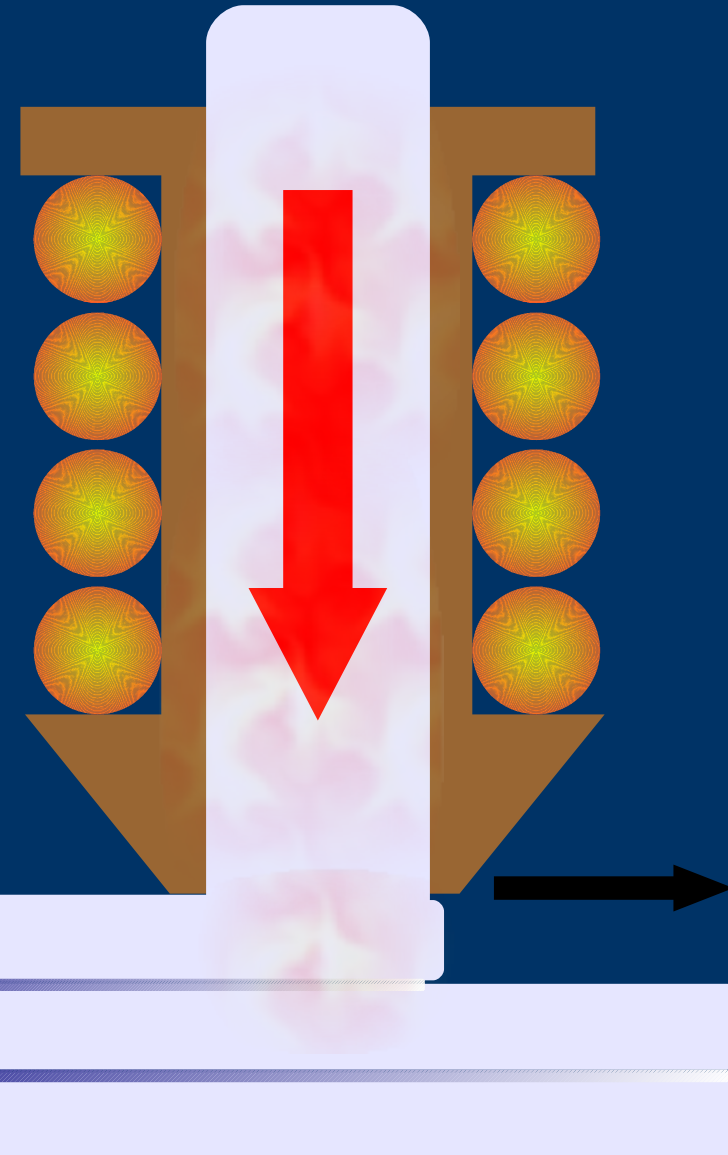
- ◆ Squirt stuff out.
- ◆ Move things around and catch it.
- ◆ Some kind of hardware interface.
- ◆ Clever software to synchronize it all.

Open Source all the way.

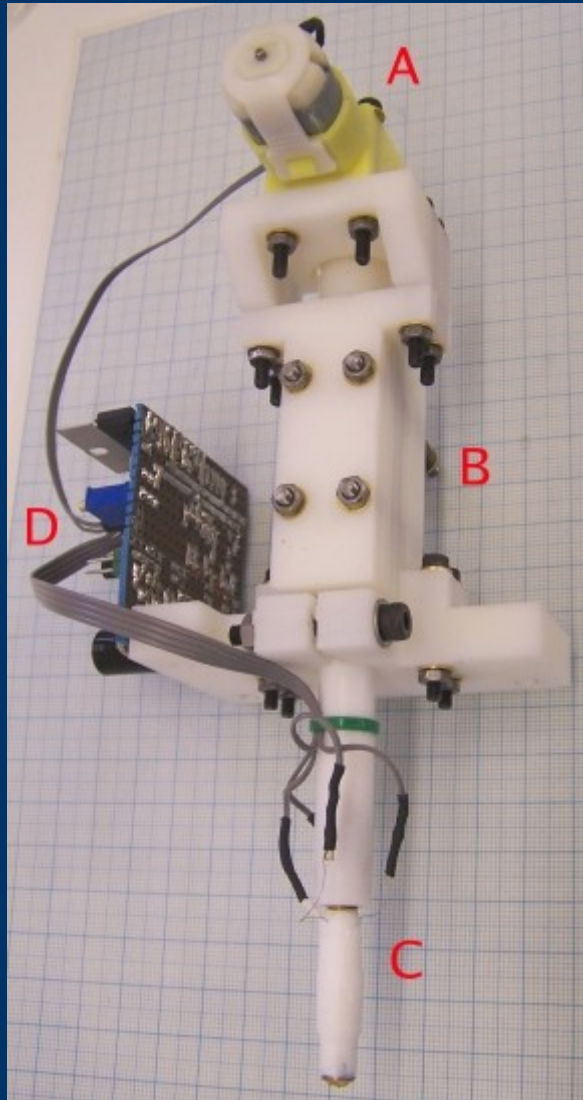
Squirting stuff out

– it's harder than you think.

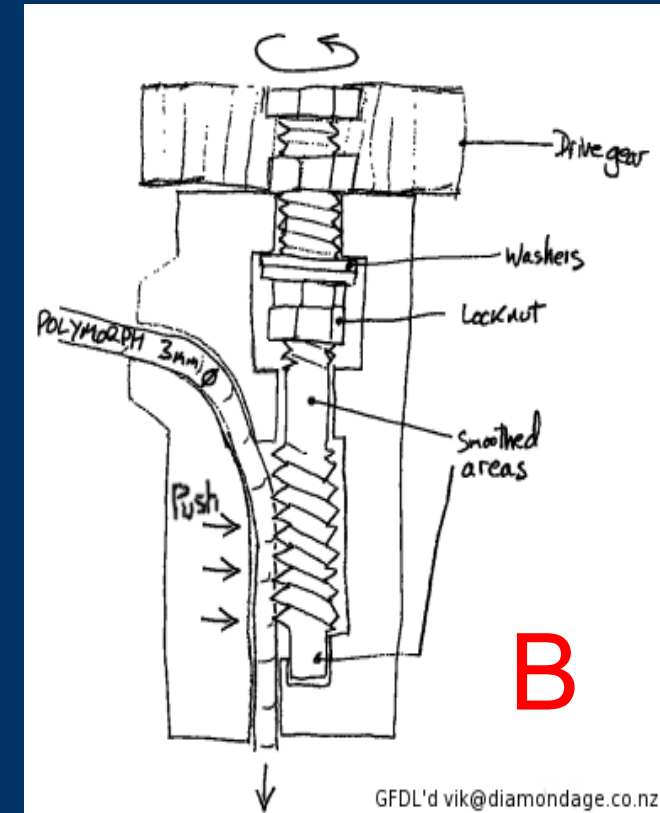
- Additive fabrication puts less stress on the moving parts.
- Some materials like DIY filler & molten metal squeeze from a syringe.
- FDM - Heat from the nozzle fuses the layers of polymer together.
- But it needs accurate feedstock – we started with 2.7-3.0mm



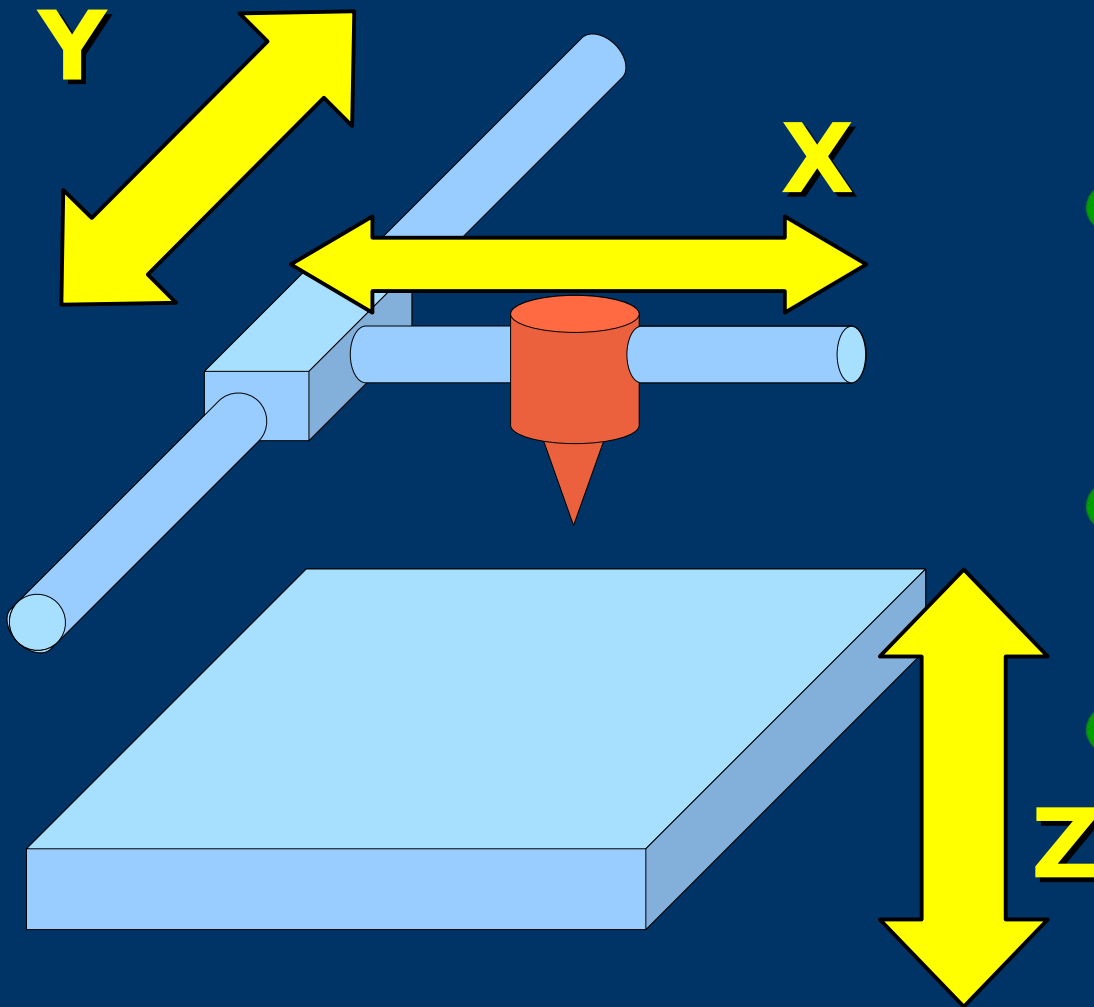
Rapid-prototyped FDM write-head - The trusty Mk2



- A** – geared motor
- B** – screw drive
- C** – heated extruder
- D** - electronics

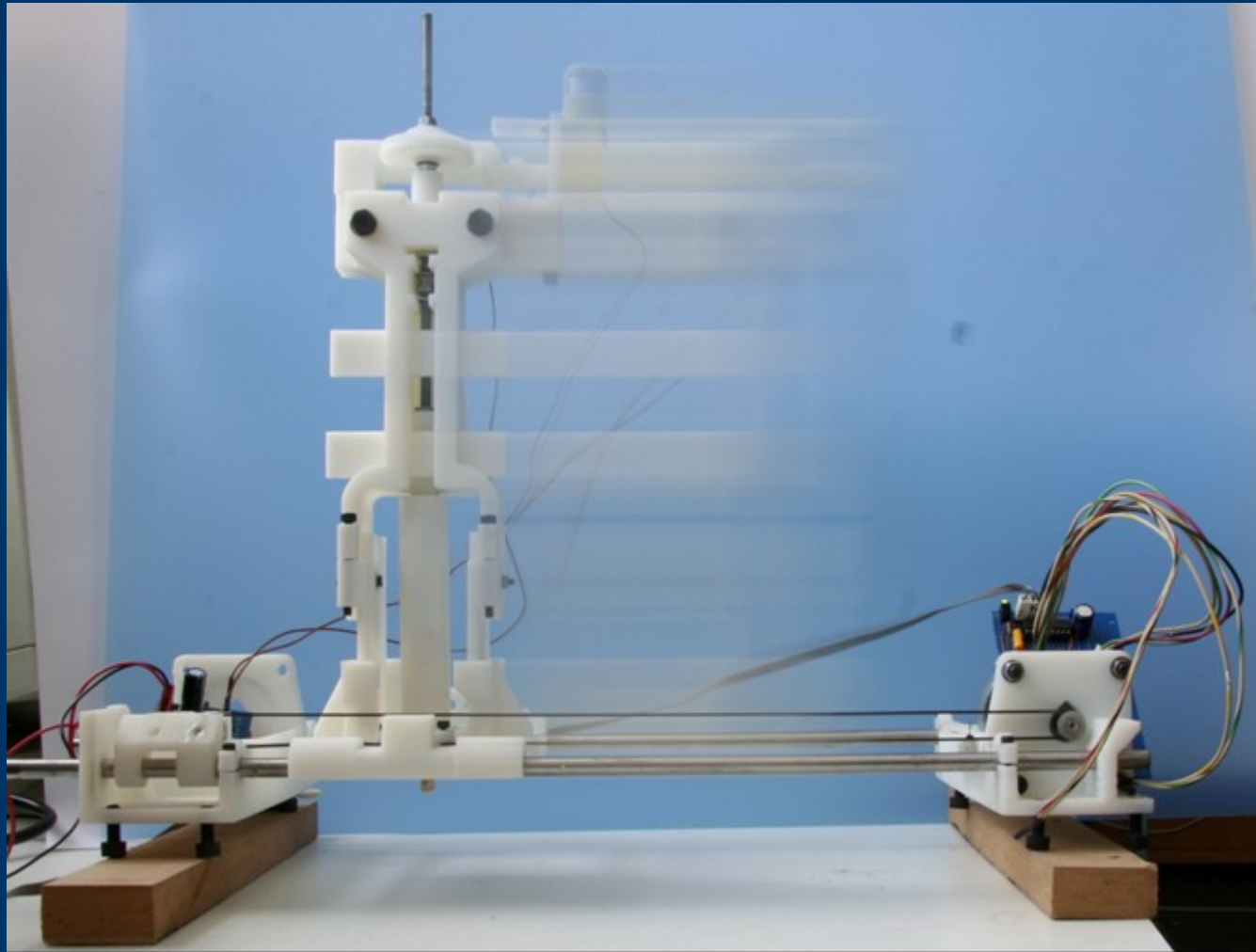


Moving things around



- Stepper motors are reliable and self-calibrating.
- Moving the print head in X & Y preferred to moving the stage.
- Belts move X & Y quickly.
- Screw threads ratchet the Z axis and give mechanical advantage.

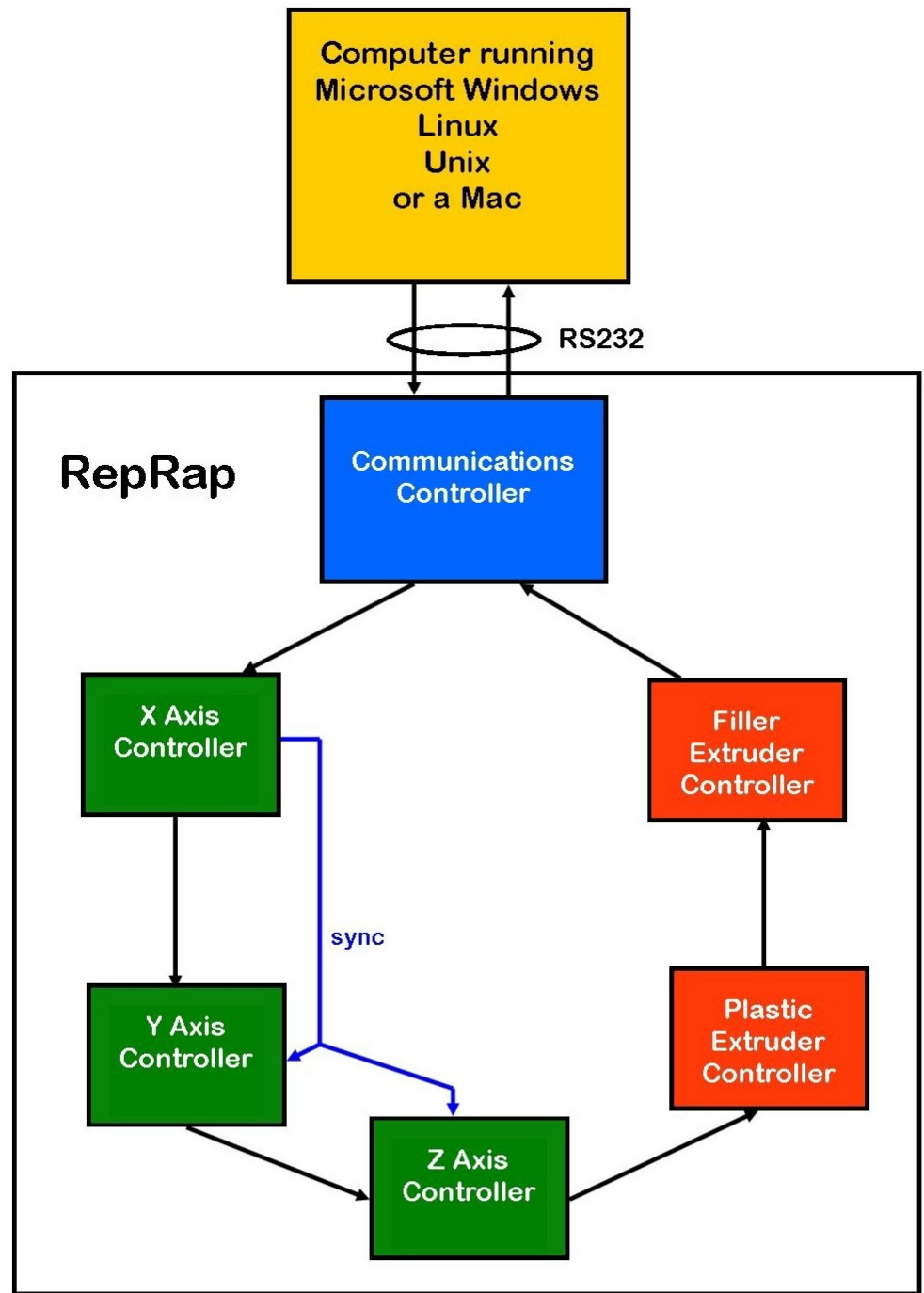
Moving things around



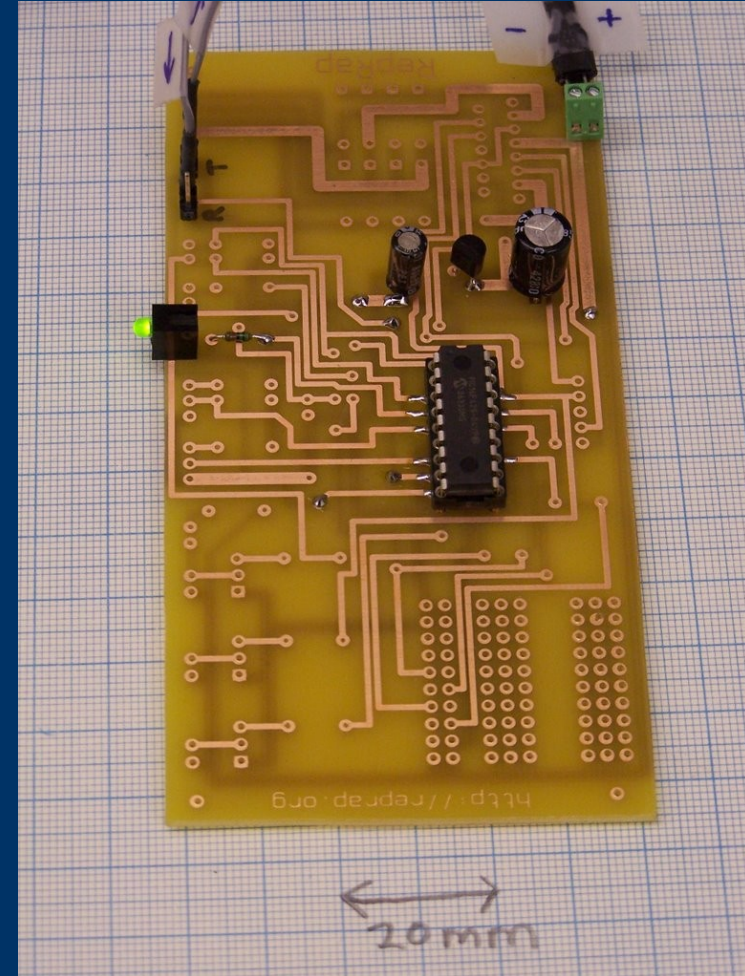
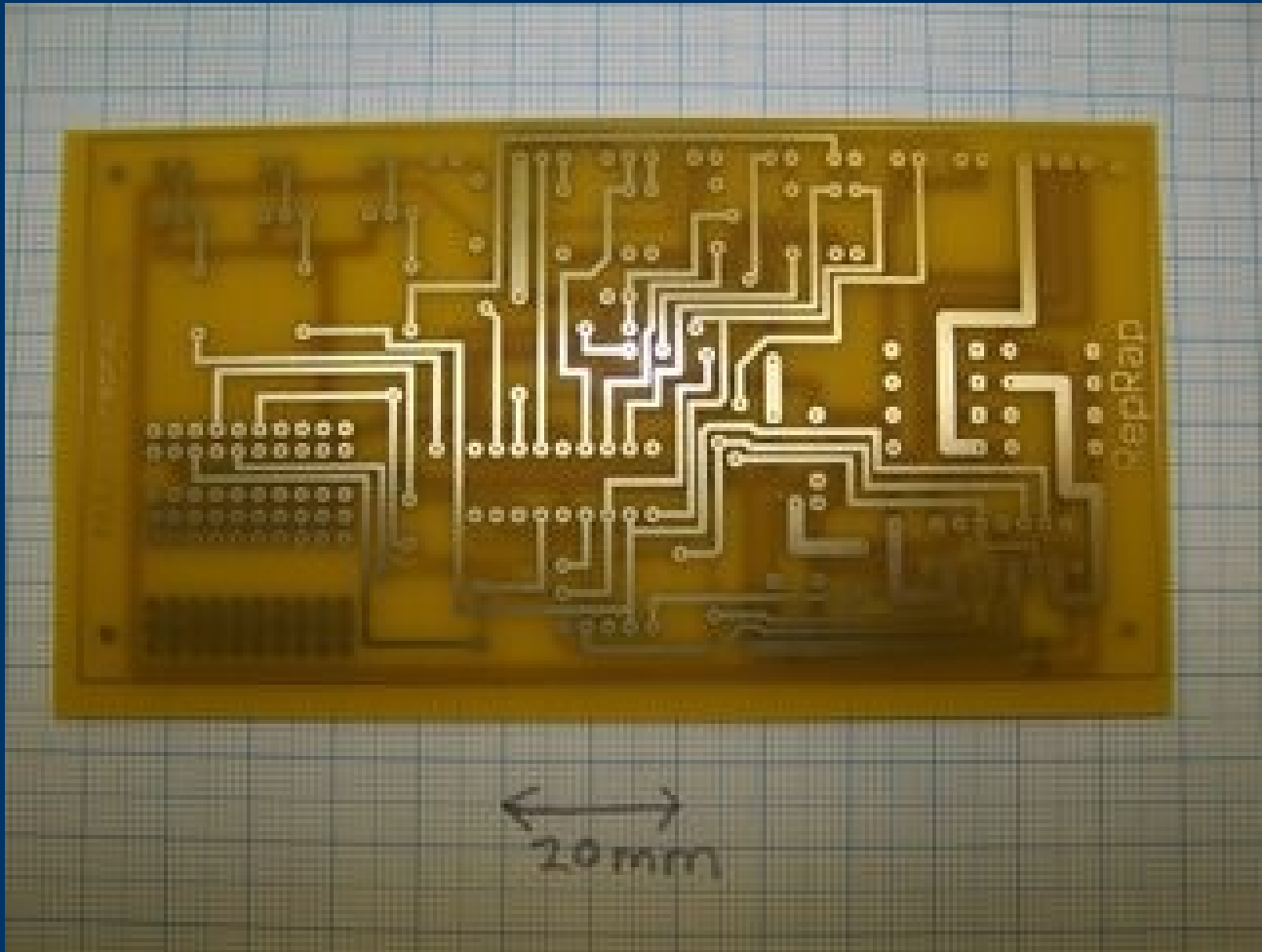
Belt-driven axis shown moving a filler deposition head.
The white parts are made on a Stratasys FDM machine.

Driver hardware and software

- Communications work in a ring.
- Only 2 kinds of PCB – controller, and driver.
- Synchronization signal wires used.
- RS232 works for us. USB in development.
- PC Software in Java takes STL files as input.



Latest "universal" PCB, hot out of the vat

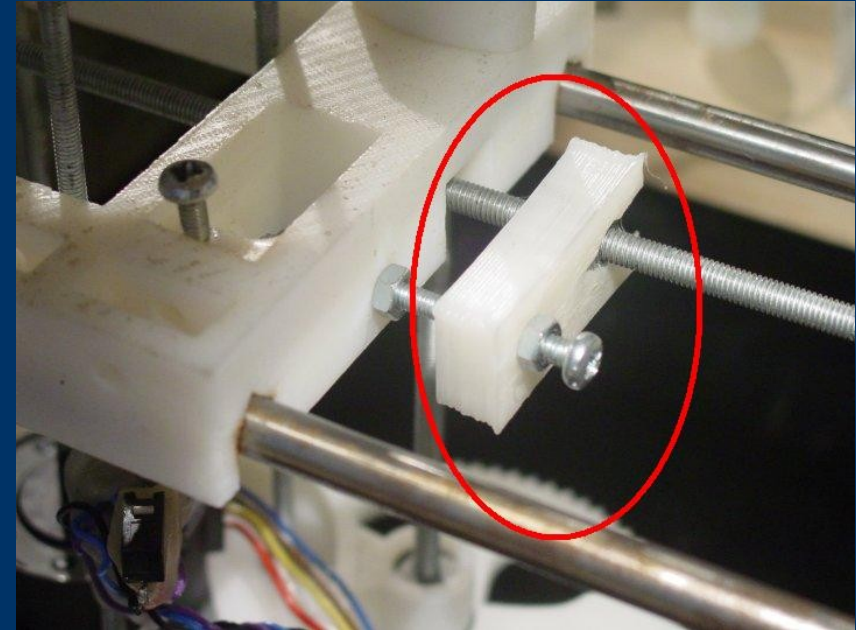


Uses a PIC16F628A micro & either L298 drivers or power transistors

Stick it all together - does it work?



Testbed machine



13 September 2006

What worked, and what didn't

YES

Screw thread extruders

Polycaprolactone

Depositing on wood

Cooling the output

Java GUI

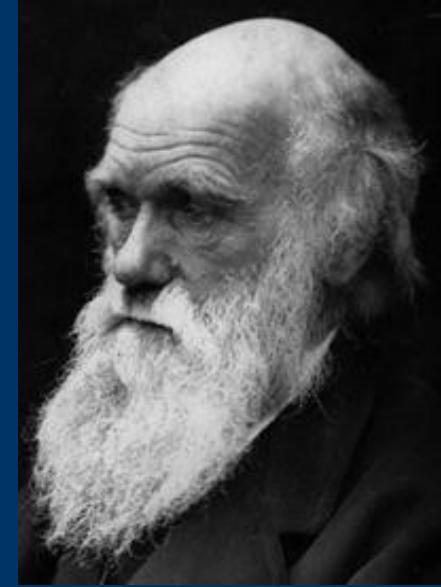
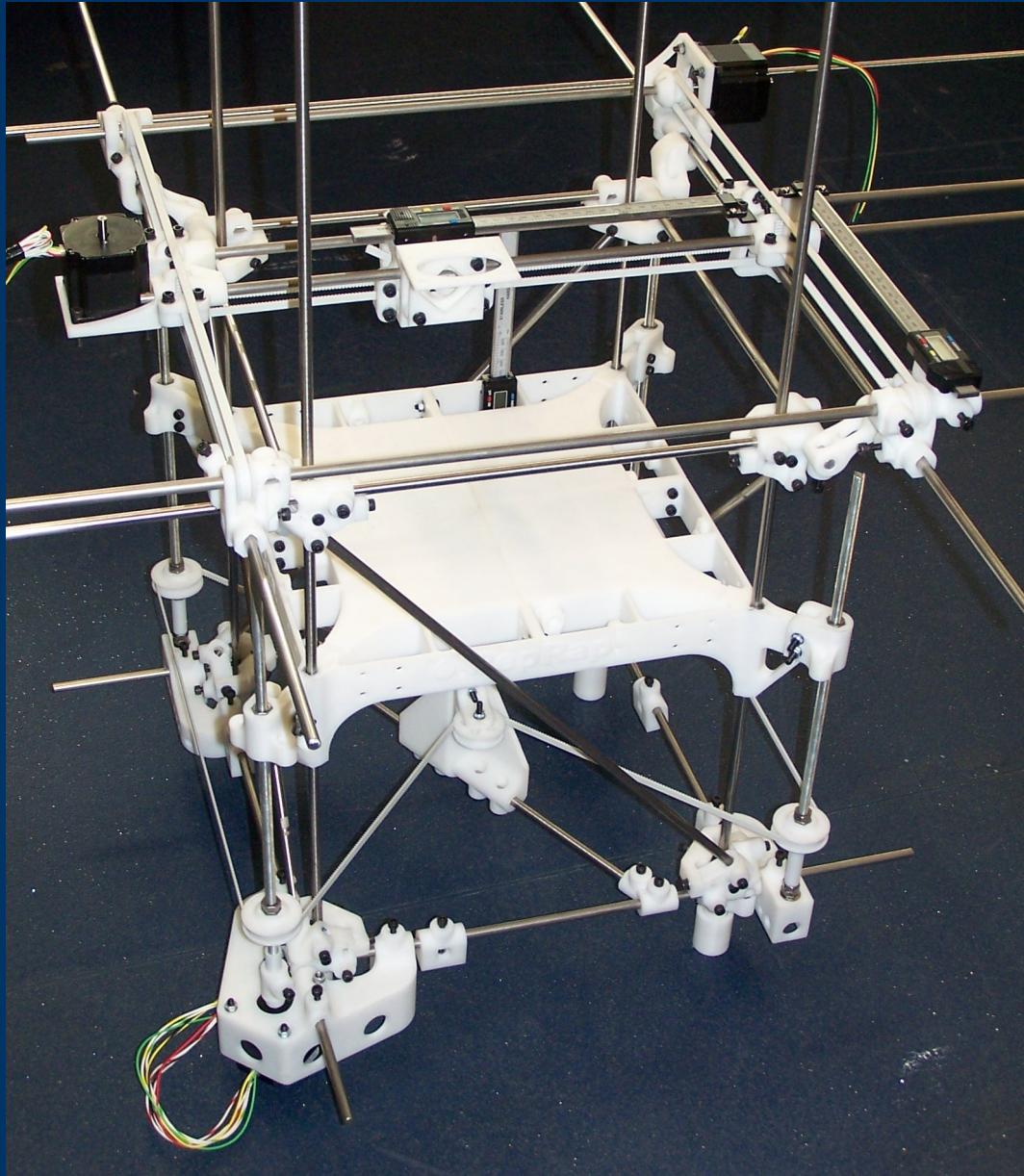
NO

Icing as support

Concrete nozzles

Depositing on glass

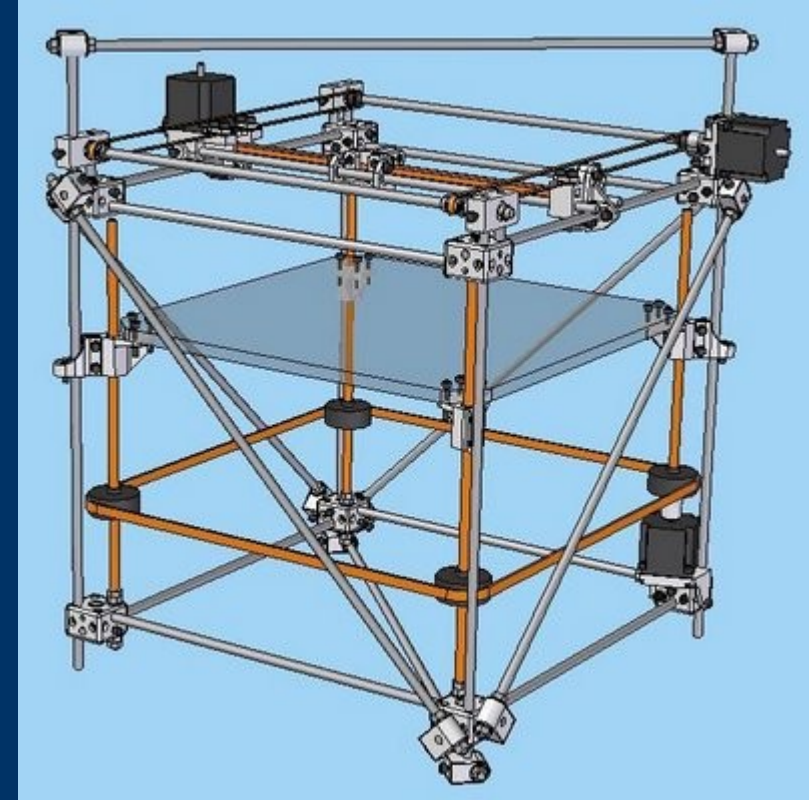
V1.0 alpha – "Darwin", best guess:



< ARNIE – a testbed for the Darwin design.

V1.0 alpha – "Darwin", the specs.

- ◆ Working volume: adjustable, but nominally a 300 mm cube
- ◆ Working materials: Polycaprolactone and filler/support
- ◆ 3-axis Cartesian drive using stepper motors
- ◆ Computer interface: RS232@19200
- ◆ Two fixed material deposition heads, user exchangeable
- ◆ Power supply needed: 8A at 12V
- ◆ Driving computer and operating system needed: Microsoft Windows, Linux, Unix, or Mac.



Parts cost: US\$400

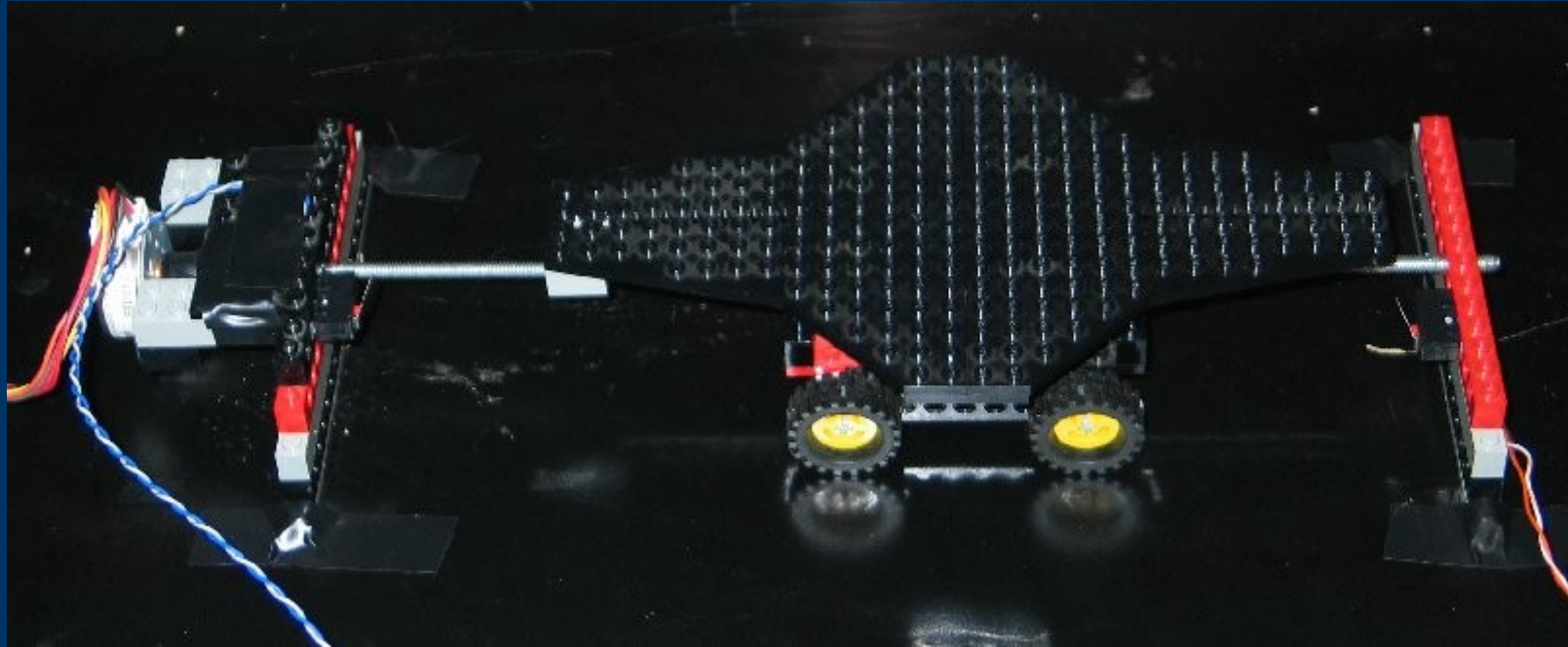
Building RepRaps around the world – the RepStrappers.

Two goals major goals have already been met:

- A RepRap has made its own parts.
- The design has started to evolve beyond our original conceptions.

Other people are picking up the idea and running with it...

Building RepRaps around the world – the RepStrappers.



... with Lego ...

Building RepRaps around the world – the RepStrappers.



Philip Tiefenbacher at Metalabs, Vienna

... Meccano™ ...

Building RepRaps around the world – the RepStrappers.

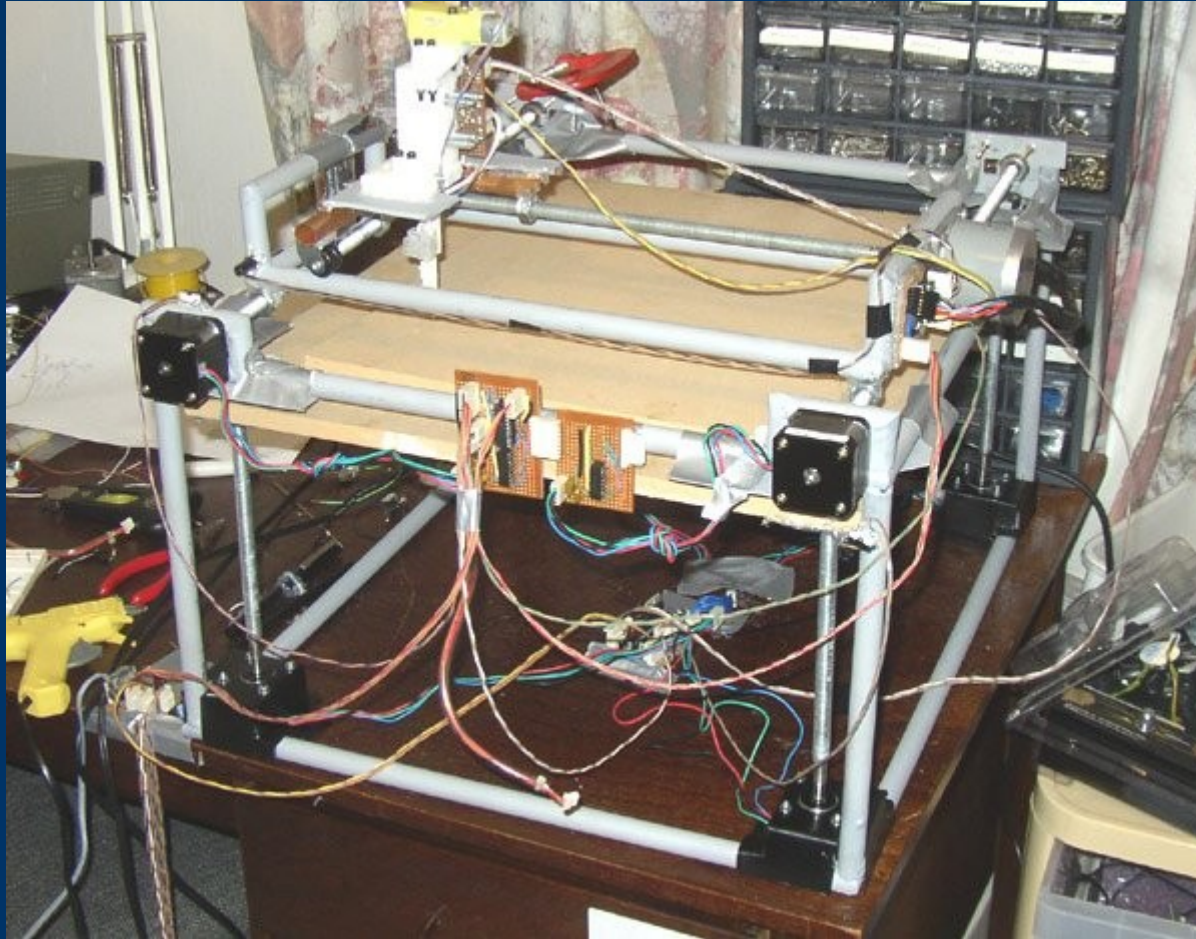


... wood ...

Forrest Higgs

Jim Wilkins

Building RepRaps around the world – the RepStrappers.



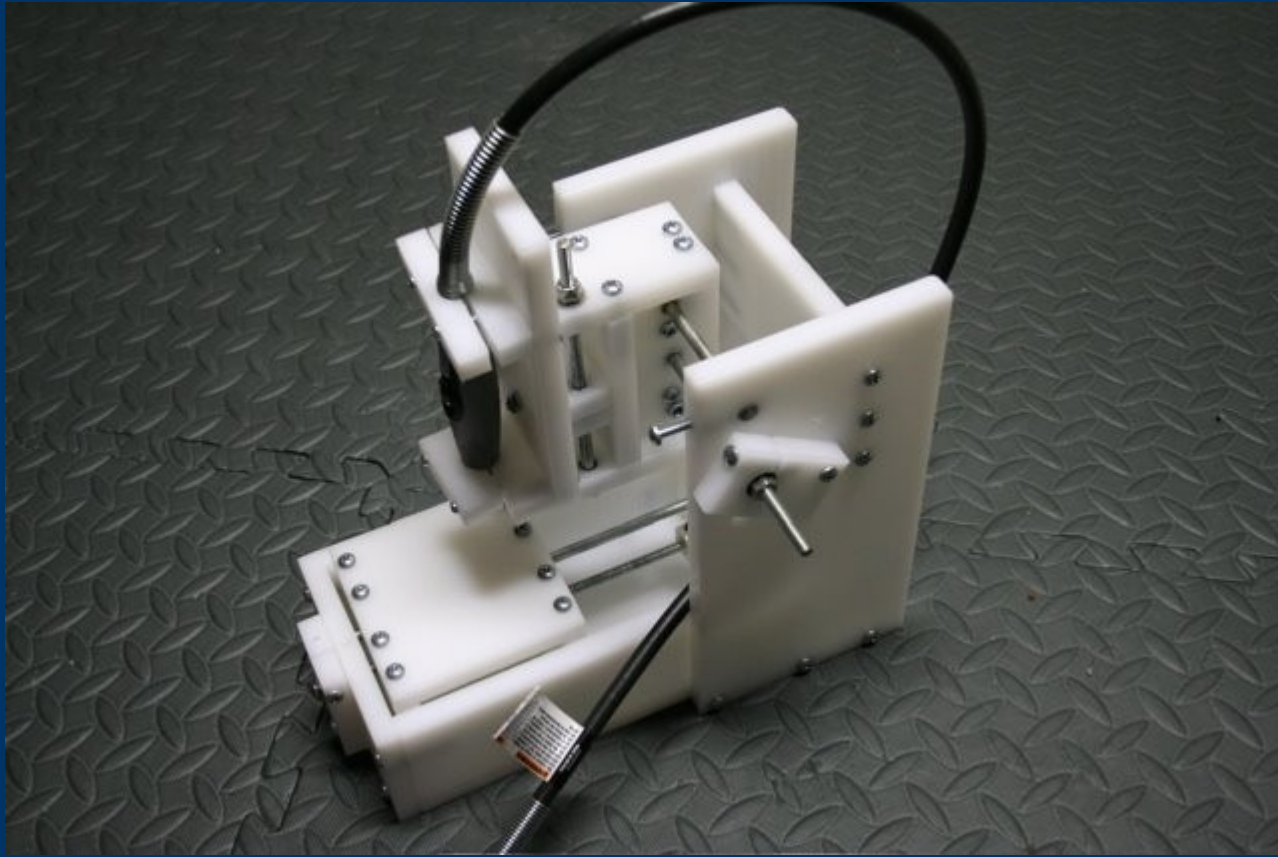
... metal pipe ...

Building RepRaps around the world – the RepStrappers.



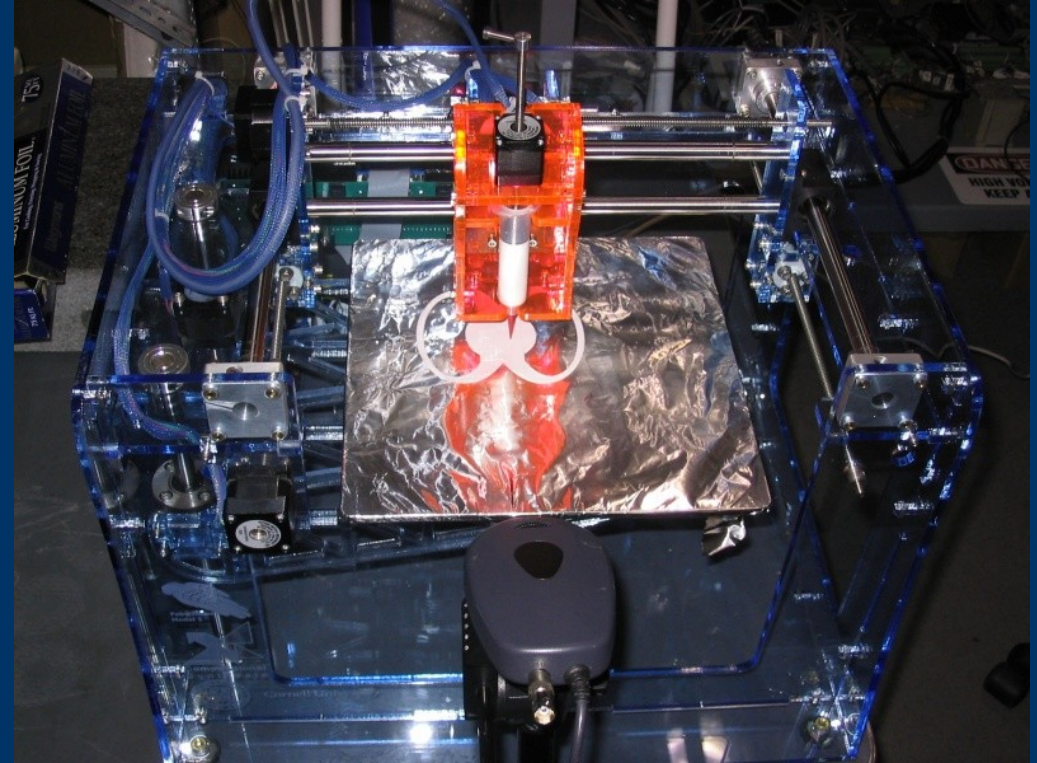
... syringes ...

Building RepRaps around the world – the RepStrappers.



... and hacked up pieces of chopping board.

Honourable mention - FAB@Home



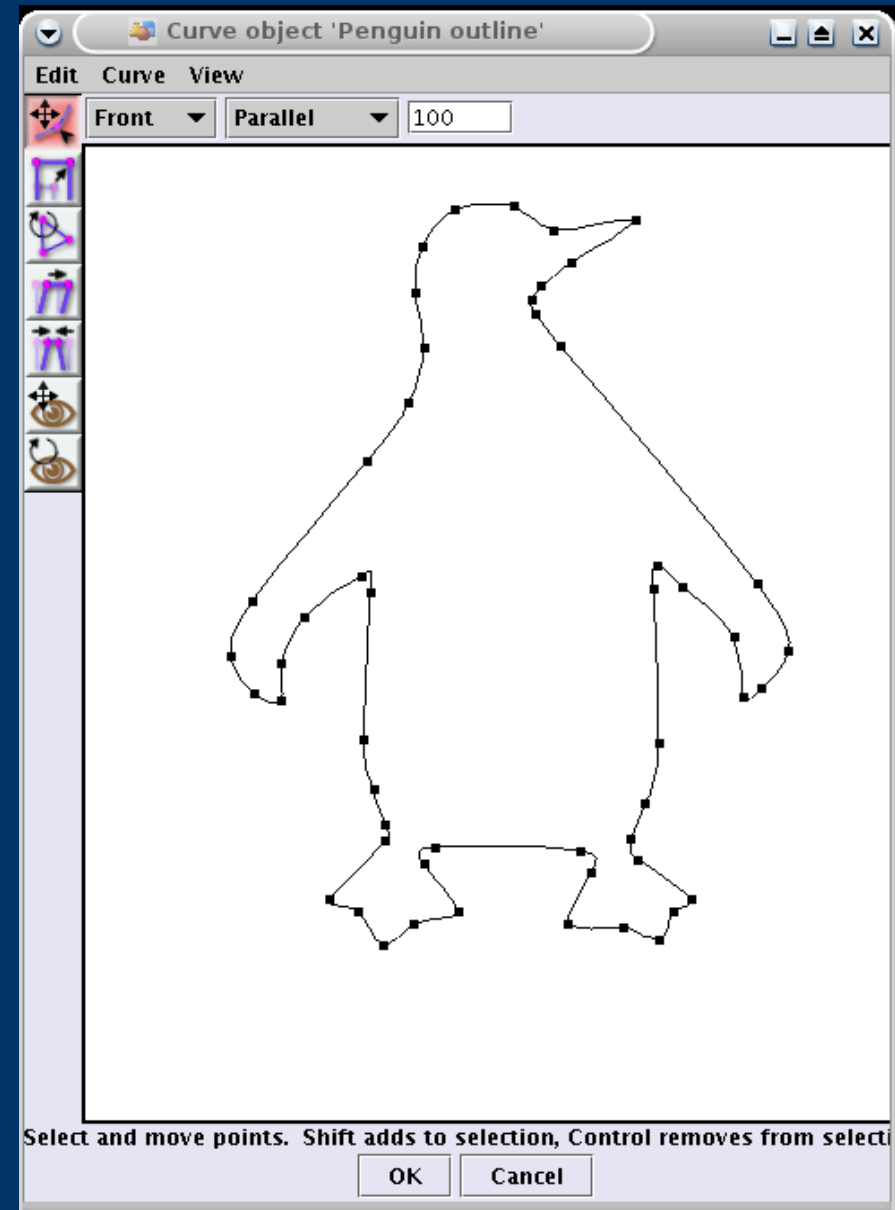
Open Source licence undecided. Not self-replicating. Materials cost US\$2,400 including \$400 of acrylic sheet. Model on left used as a device for biochemical analysis.

Penguin Printing HOWTO

ArtOfIllusion

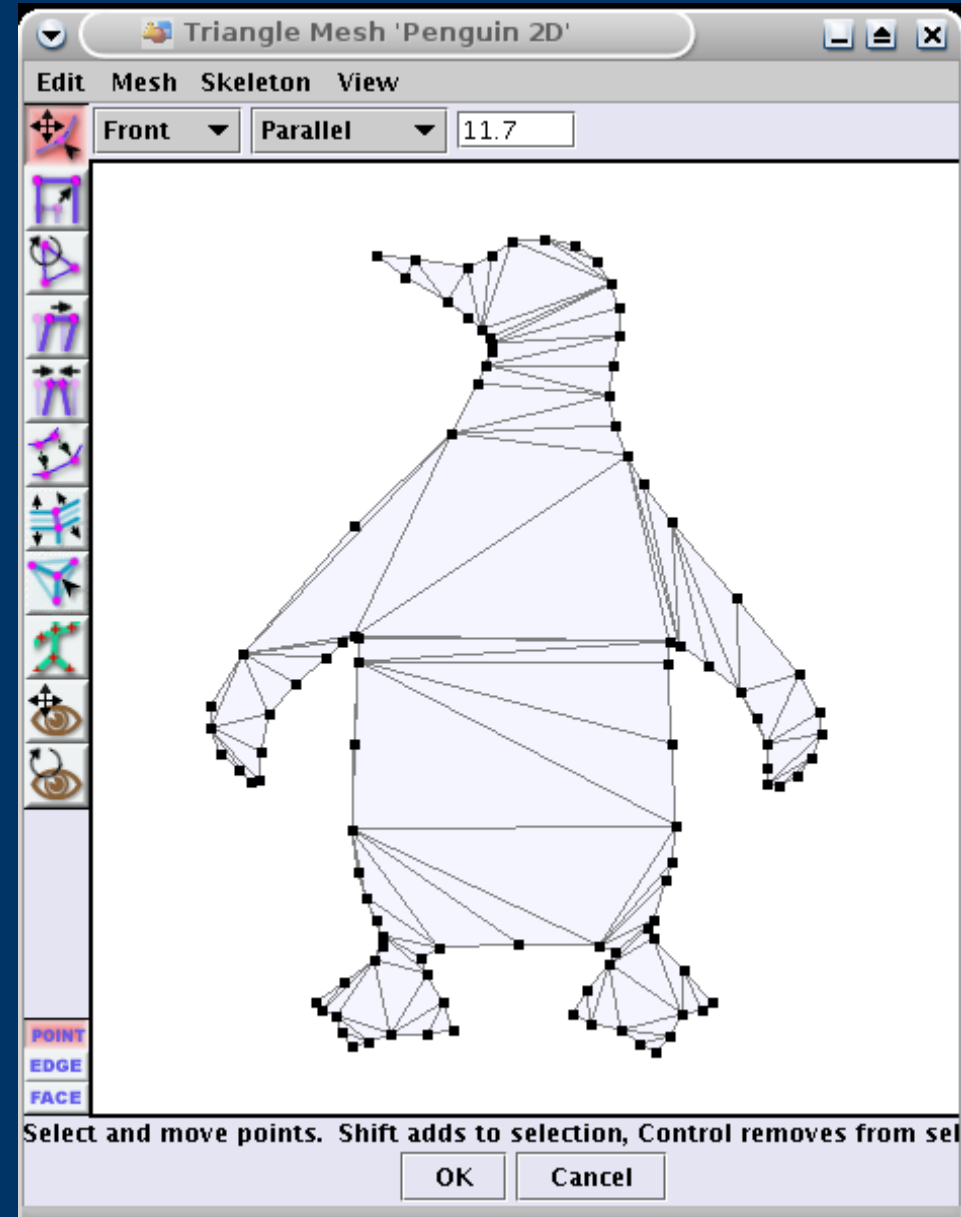
<http://www.artofillusion.org> is meant as a modeling tool, but has an easy GUI and outputs STL files.

Start by drawing the outline:



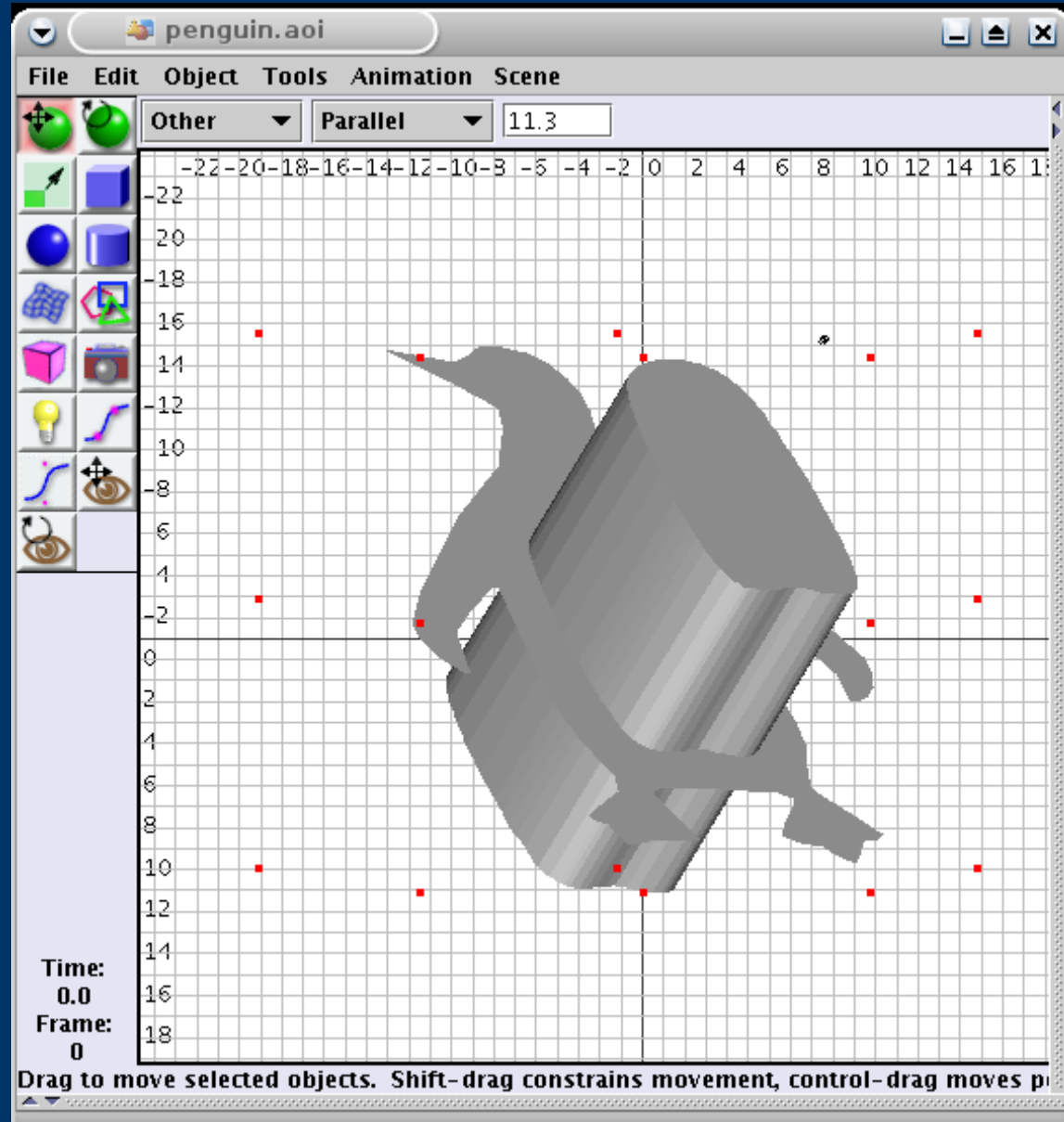
Penguin Printing HOWTO

Convert the outline to a 2D triangle mesh



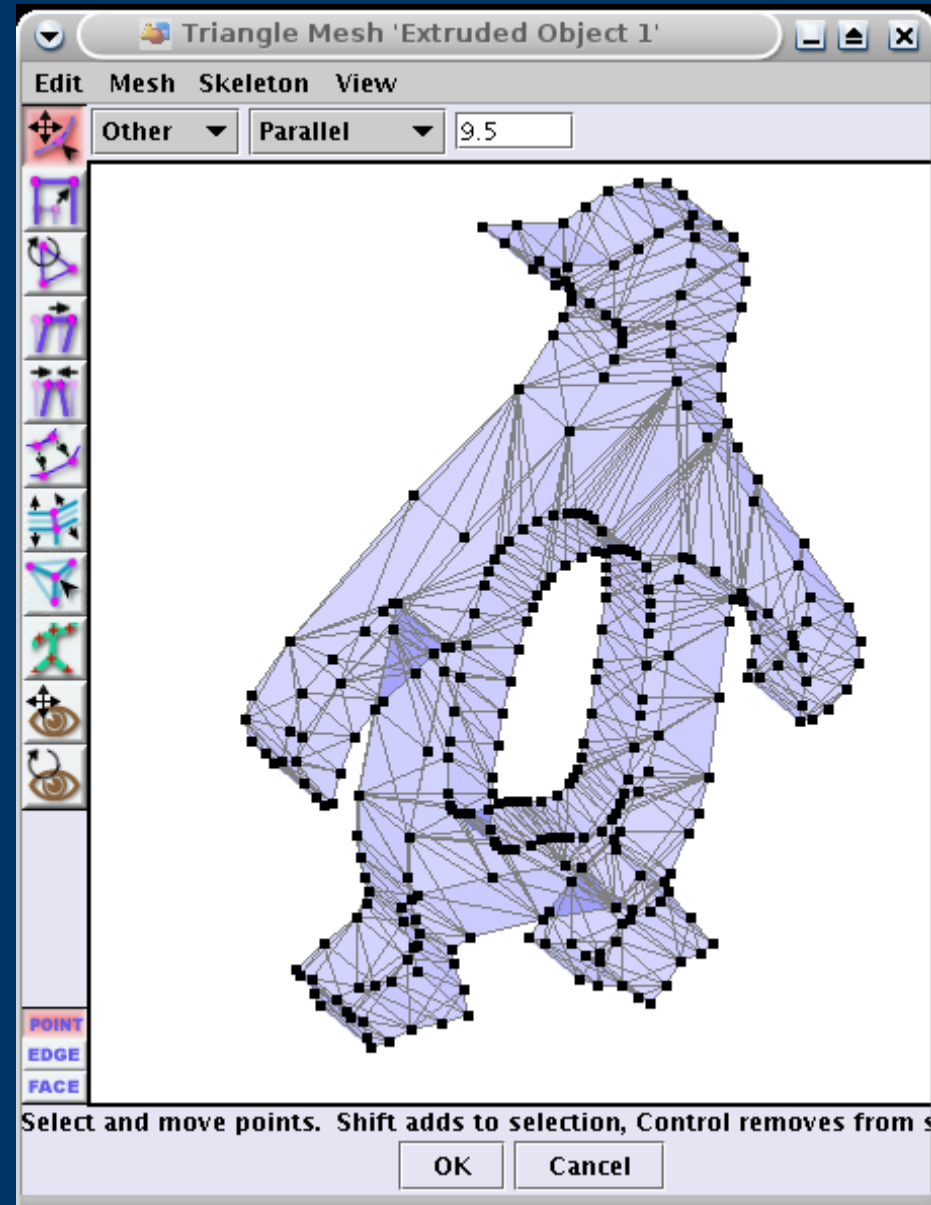
Penguin Printing HOWTO

Chop any desired hollow bits out using a boolean modeling tool



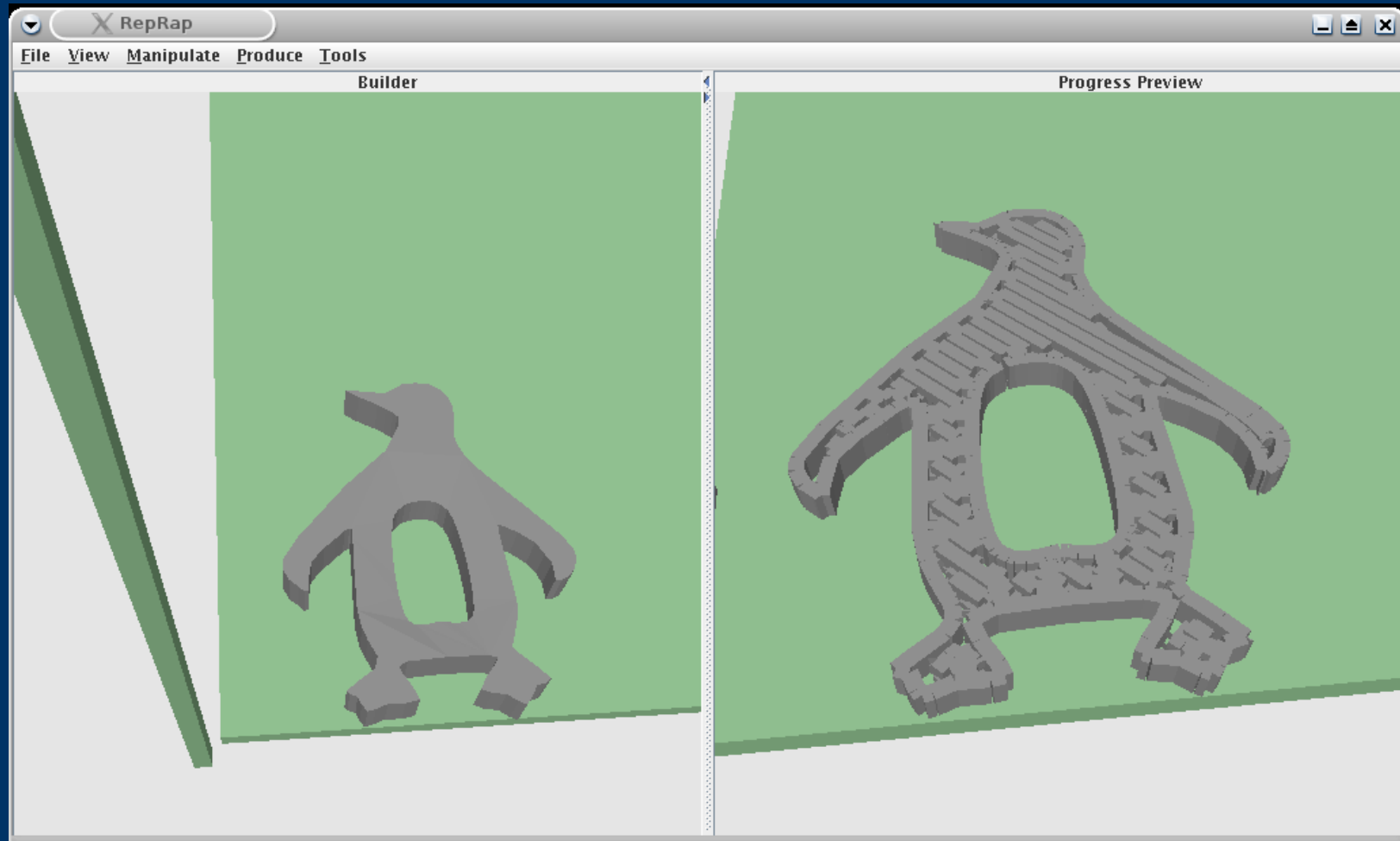
Penguin Printing HOWTO

Extrude the 2D model like toothpaste, into a 3D shape.



Penguin Printing HOWTO

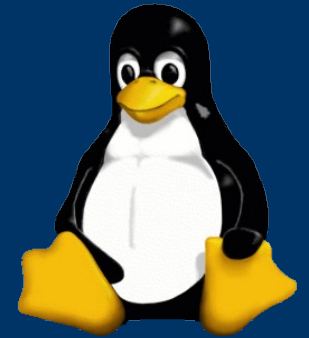
Export the 3D as an STL file and import it into the RepRap GUI.



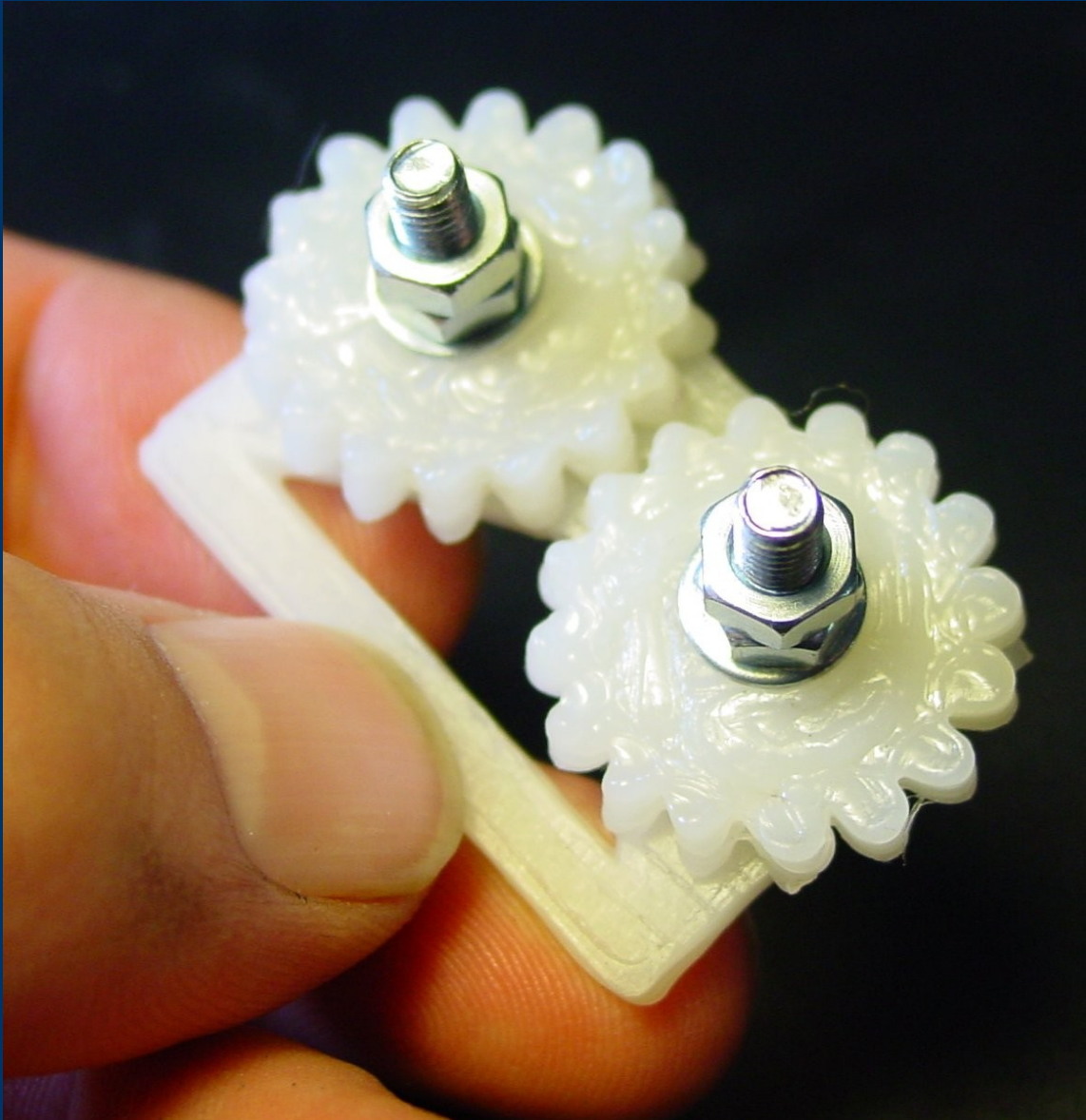
Penguin Printing HOWTO

Watch it print...

(This one is done with a loose fill to demonstrate the crosshatching)



Other bits we've made:



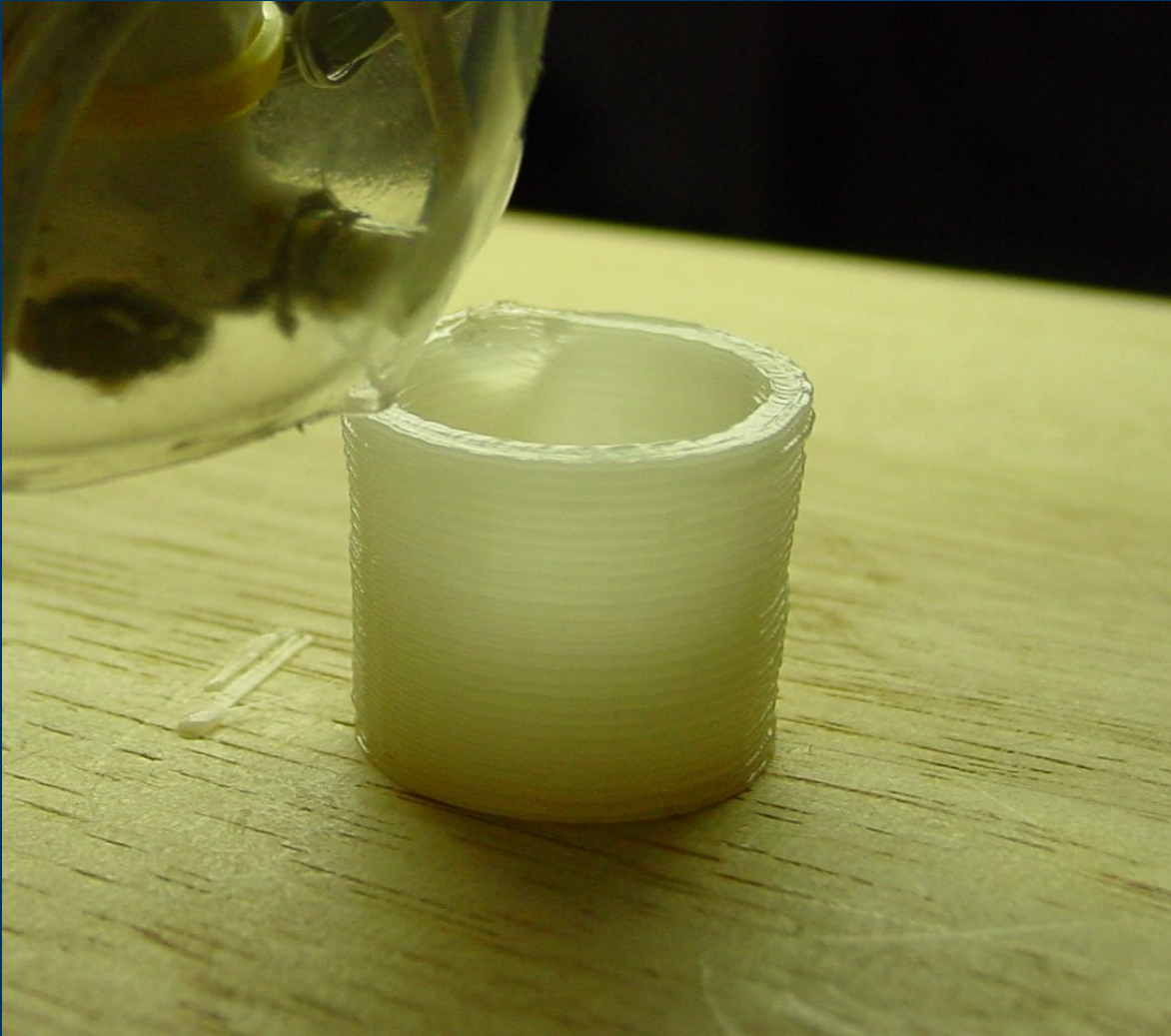
A Working gear train
and supporting
bracket.

Other bits we've made:



It made a name for itself...

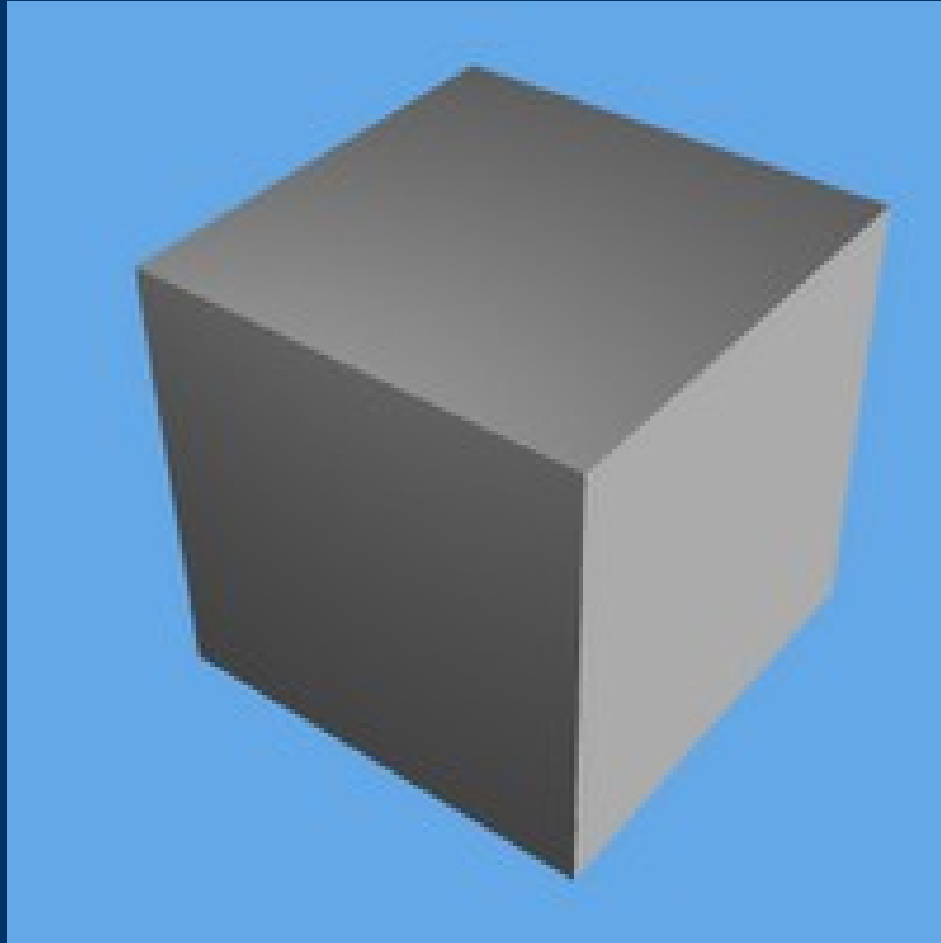
Other bits we've made:



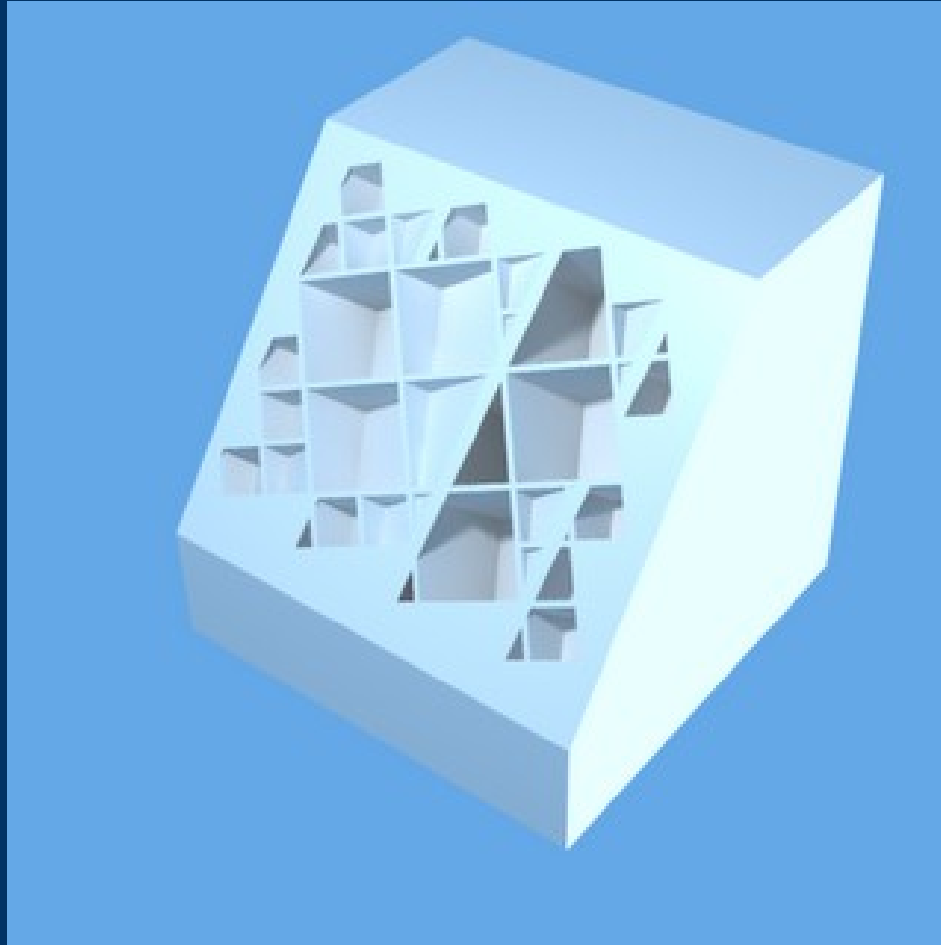
.. and a fully functional, waterproof, alcoholproof, gently tapering shot glass.

Cheers!

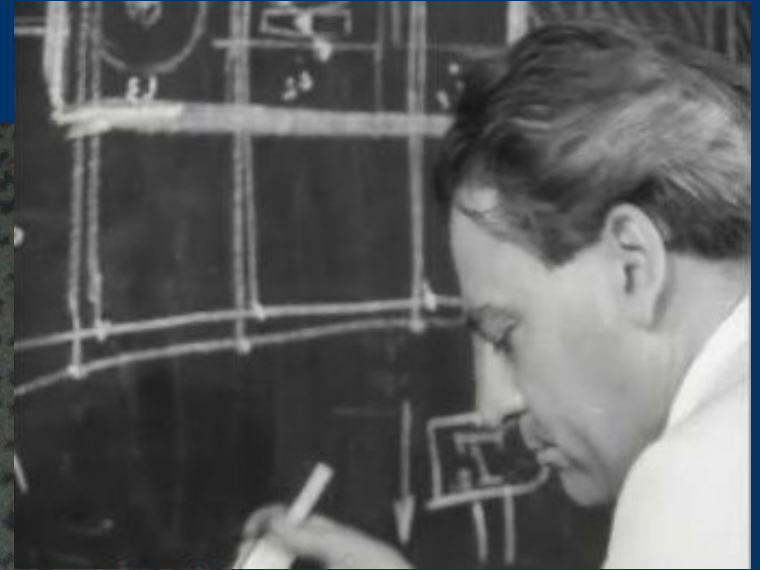
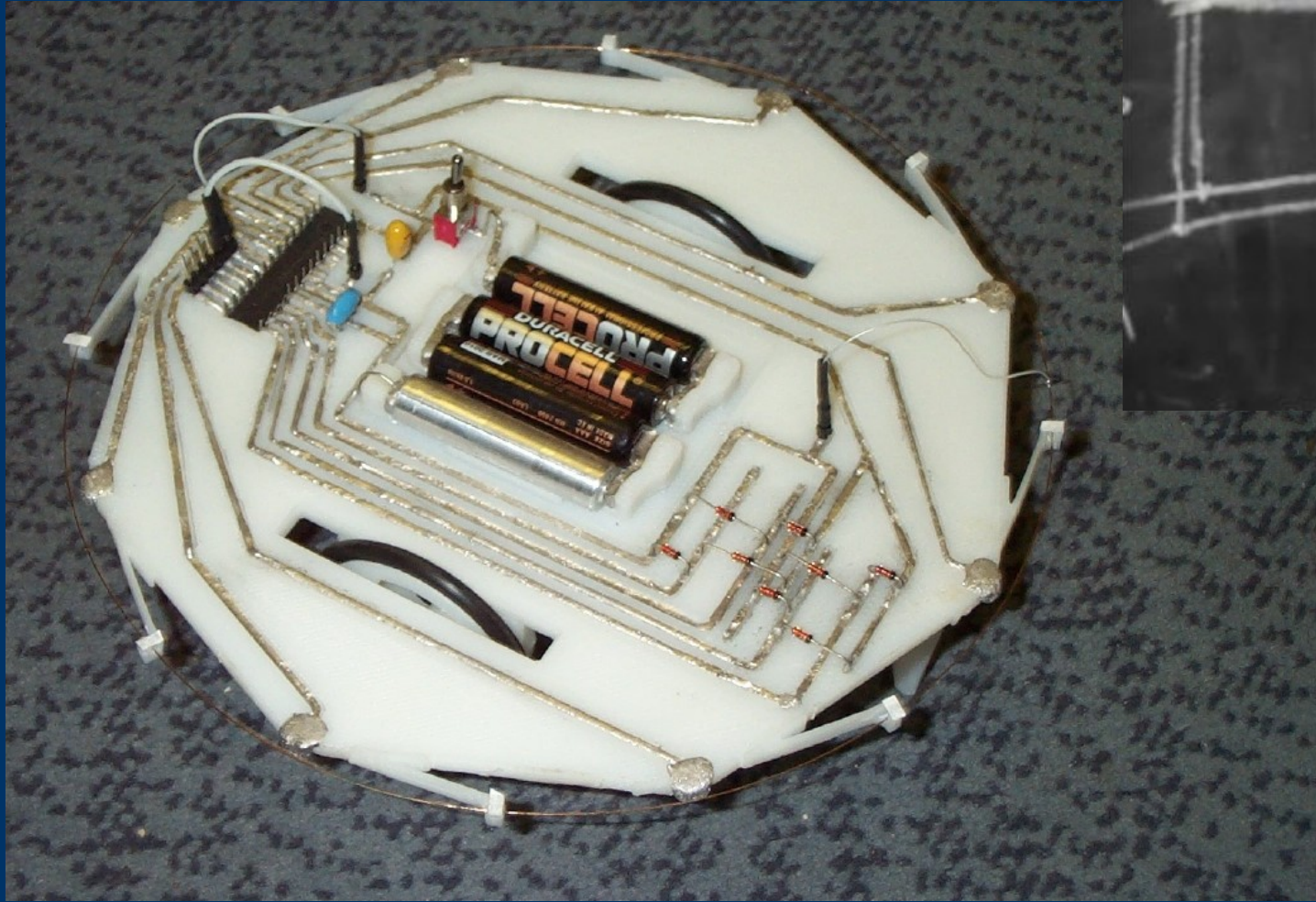
Our latest creation:



Our latest creation:



Rapid-prototyped electric circuits



John Sargrove

The Future: V2.0 – "Mendel"

- ◆ Use of PLA as main plastic feedstock.
- ◆ Metal deposition head.
- ◆ Capable of manufacturing own electronics.
- ◆ Automated exchangeable head mechanism.
- ◆ USB Interface.
- ◆ DC Servos instead of stepper motors.

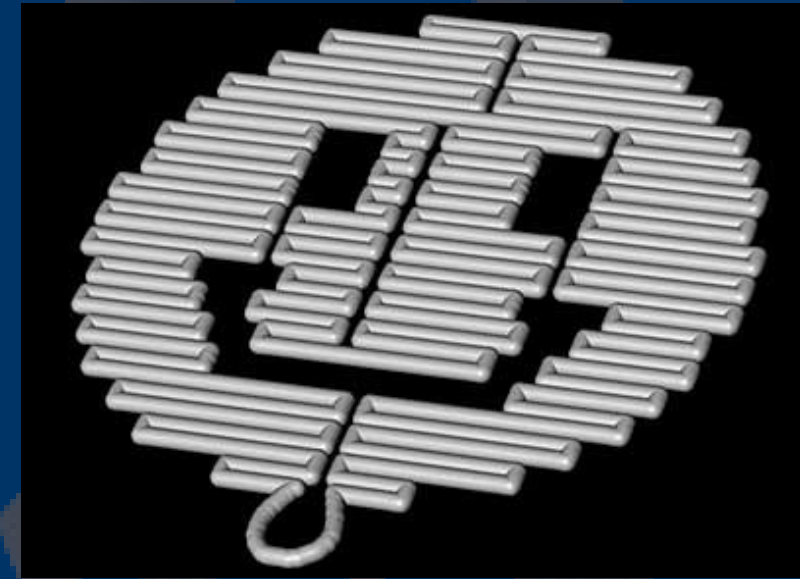
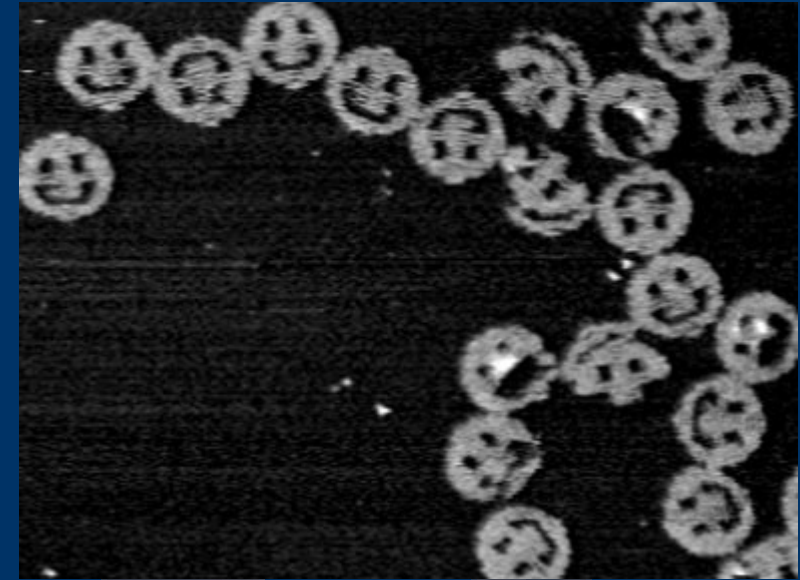


Far In The Future

RepRap-like solutions on the micro- and macroscale.

RepRap isn't nanotechnology, but it has similar problems and may be one of the tools used in its creation.

Could a RepRap design be made using naturally forming crystalline components held together with cunningly folded DNA?



Nearer In The Future?

- ◆ V3.0? V9.0? How long until there is a RepRap in every home?
- ◆ RepRaps making chemical factories for medicines, plastics, organic semiconductors...
- ◆ RepRap-like solutions on the micro- and macroscale.

What will you build with yours?

Project website:

<http://reprap.org>