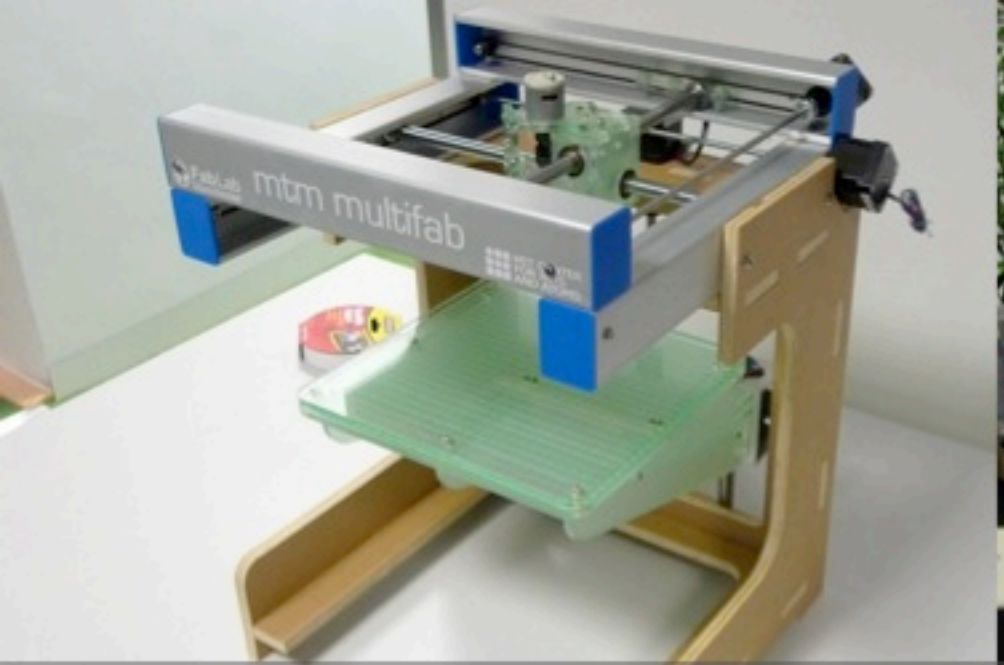
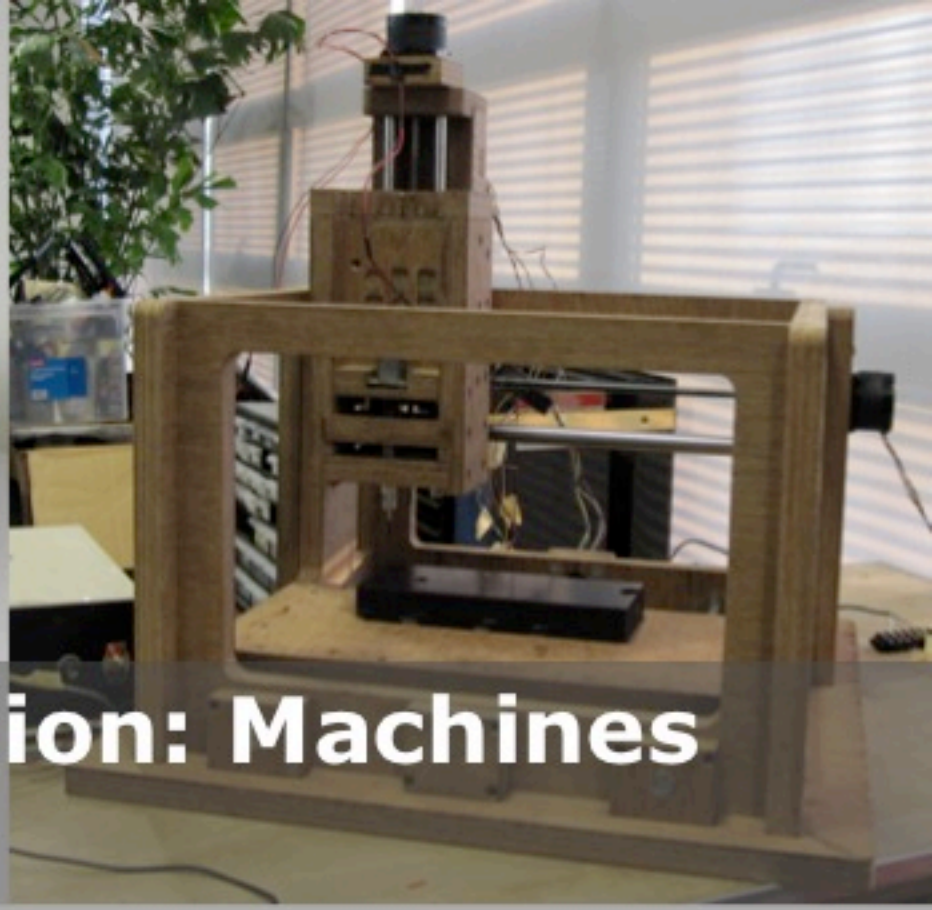




The Digital Revolution: Machines That Make

Ilan Moyer – CTMTM Co-Founder
Natan Linder – MIT Media Lab

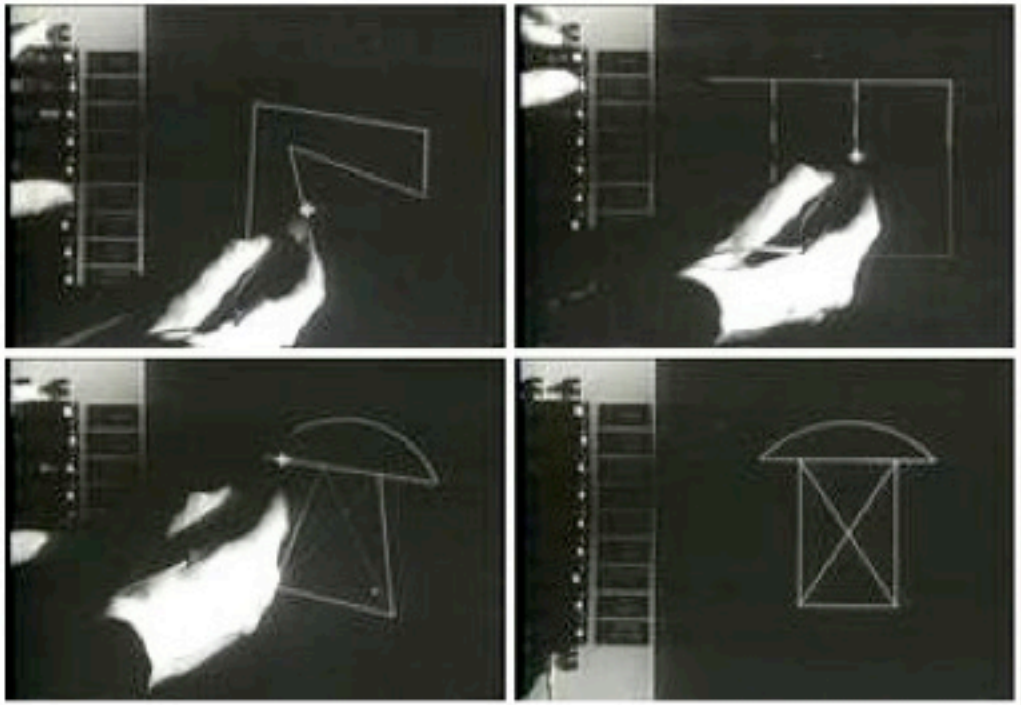
THE CENTER FOR BITS AND ATOMS
Massachusetts Institute of Technology

Fluid
INTERFACES GROUP
MIT MEDIA LAB

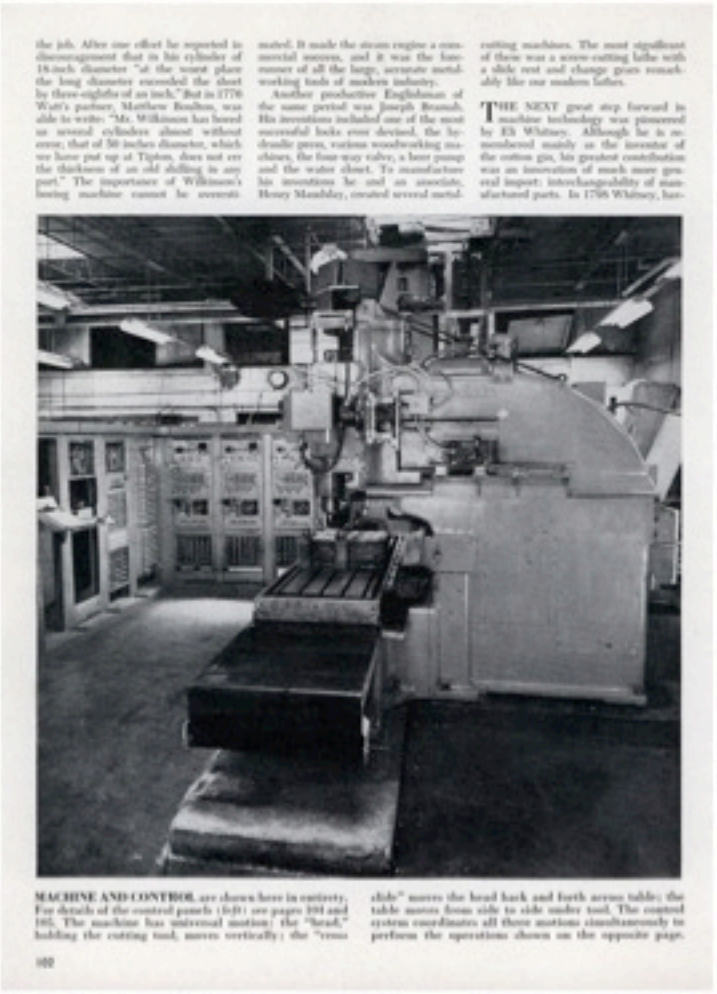
Agenda

- Digital FAB Overview
- CBA MTM Project
- How make something with MTMs

From CNC to FABLAB



Ivan Sutherland, 1963
Sketchpad



the job. After one effort he reported in discouragement that in his cylinder of 18-inch diameter "at the worst place the long diameter exceeded the short by three-eighths of an inch." But in 1776 Watt's partner, Matthew Boulton, was able to write: "Mr. Wilkinson has bored us several cylinders almost without error, that of 50 inches diameter, which we have put up at Tipton, does not err the thickness of an old shilling in any part." The importance of Wilkinson's boring machine cannot be overestimated. It made the steam engine a commercial success, and it was the forerunner of all the large, accurate metal-working tools of modern industry.

Another productive Englishman of the same period was Joseph Bramah. His inventions included one of the most successful locks ever devised, the hydraulic press, various woodworking machines, the four-way valve, a beer pump and the water closet. To manufacture his inventions he and an associate, Henry Maudsley, created several metal-cutting machines. The most significant of these was a screw-cutting lathe with a slide rest and change gears remarkably like our modern lathes.

THE NEXT great step forward in machine technology was pioneered by Eli Whitney. Although he is remembered mainly as the inventor of the cotton gin, his greatest contribution was an innovation of much more general import: interchangeability of manufactured parts. In 1798 Whitney, bar-

MACHINE AND CONTROL are shown here in entirety. For details of the control panels (left) see pages 100 and 101. The machine has universal motion: the "head," holding the cutting tool, moves vertically; the "cross slide" moves the head back and forth across table; the table moves from side to side under tool. The control system coordinates all three motions simultaneously to perform the operations shown on the opposite page.

William Pease, 1950
"Card-a-matic Milling Machine"

THE CENTER FOR BITS AND ATOMS
Massachusetts Institute of Technology

Ghana, South Africa, India, Costa Rica, Boston, Norway, …

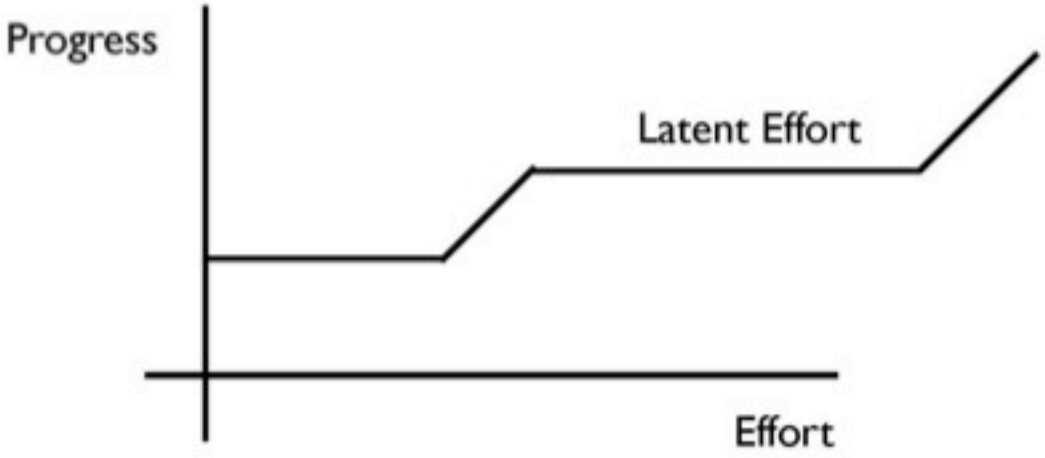
Fab Labs

fabrication and instrumentation divide

Rapid prototyping?

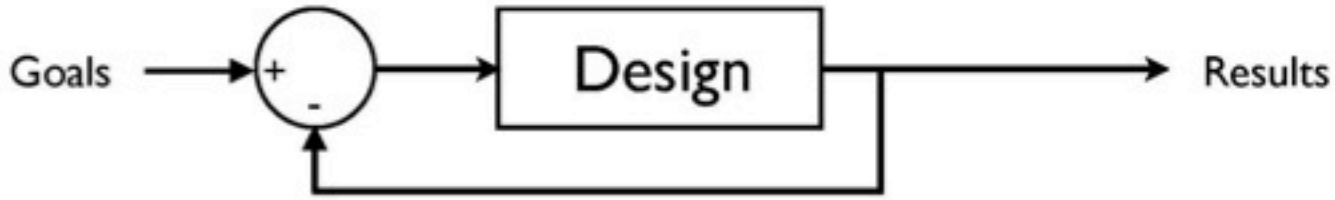
- Rapid prototyping (industrial design)
- Scalability (parametric designs)
- Object (or manufacturing) for one person

Rapid prototyping?

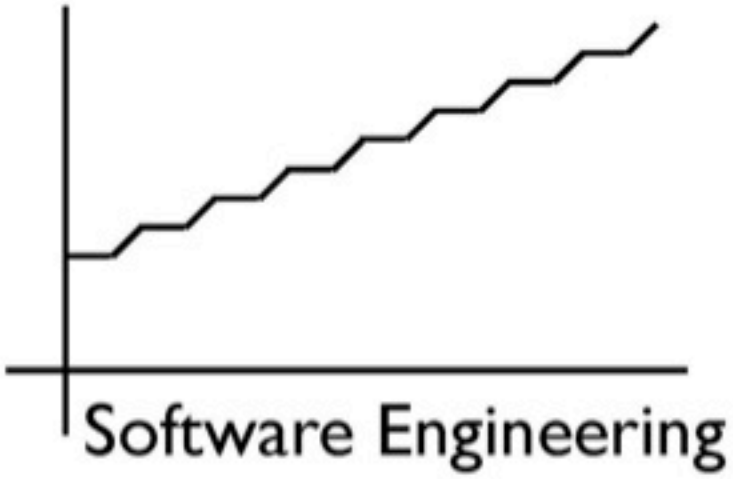


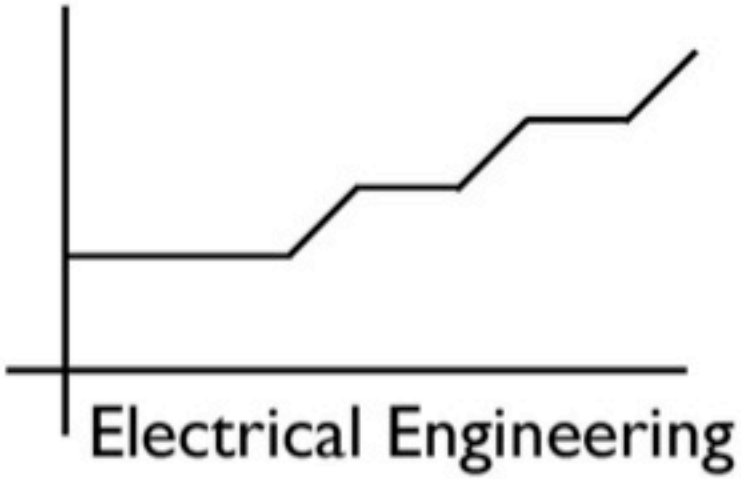
Progress is a state change.

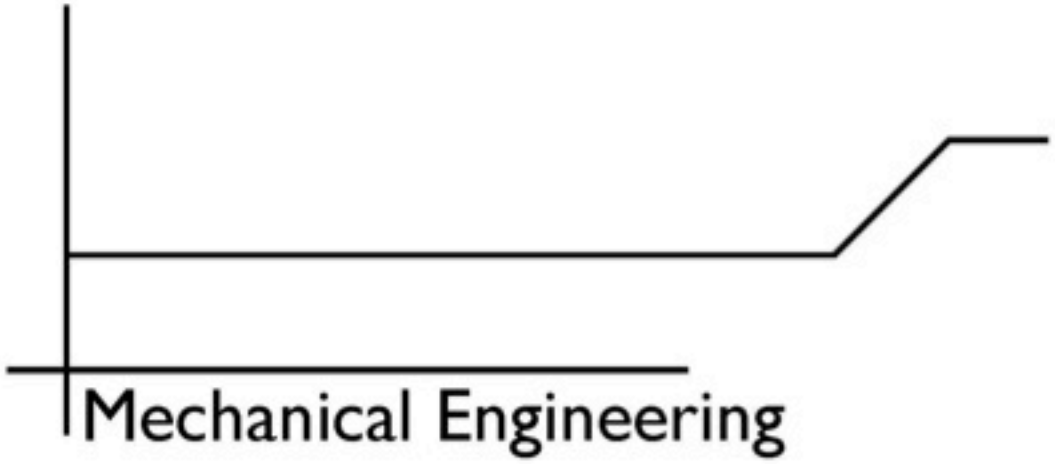
Rapid Prototyping is closed loop.



Rapid prototyping?







Techniques

Additive

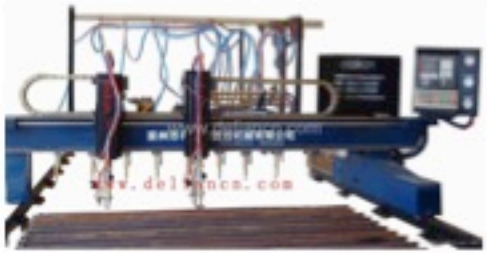
Subtractive

Subtractive

Waterjet

Milling Machine

Beam Laser Cutter



Plasma Cutter

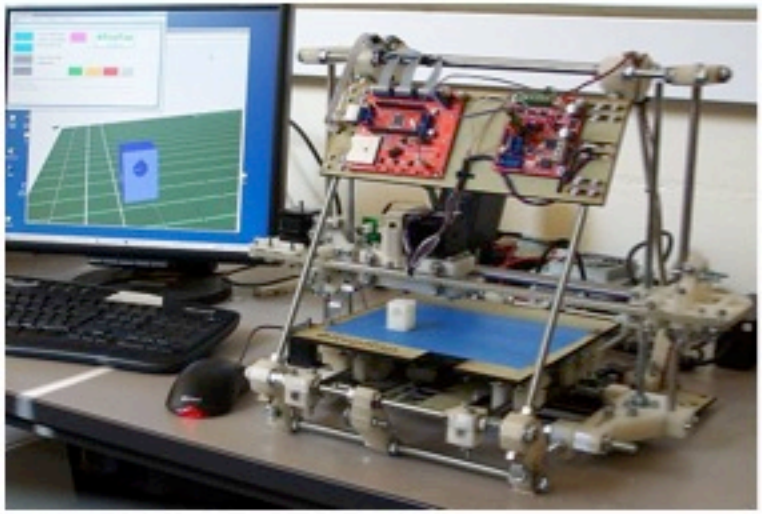
Additive

- **Selective laser sintering (SLS):** Thermoplastics, metals, sand
- **Fused Deposition Modeling (FDM):** Thermoplastics
- **Stereolithography (SL):** Photopolymer
- Electron Beam Melting (EBM): Titanium alloys
- 3D Ceramic Printing: Various clay and ceramic materials

ZCOPP

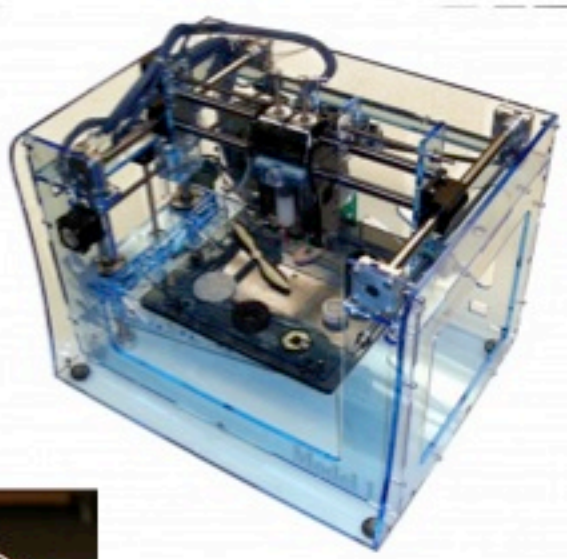
Dimension

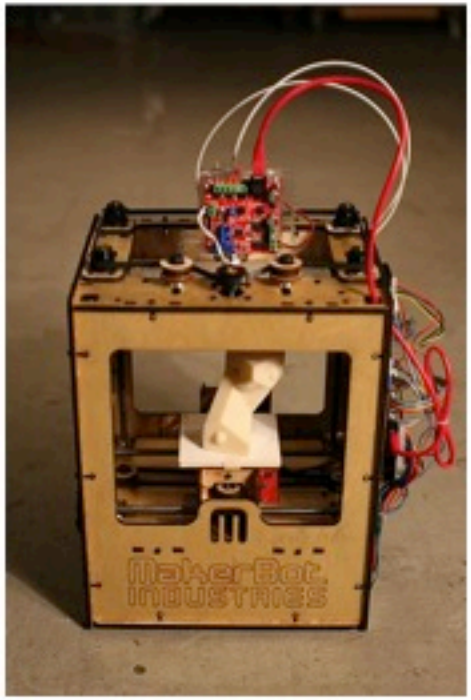
Personal Fabrication & DIY



RepRap

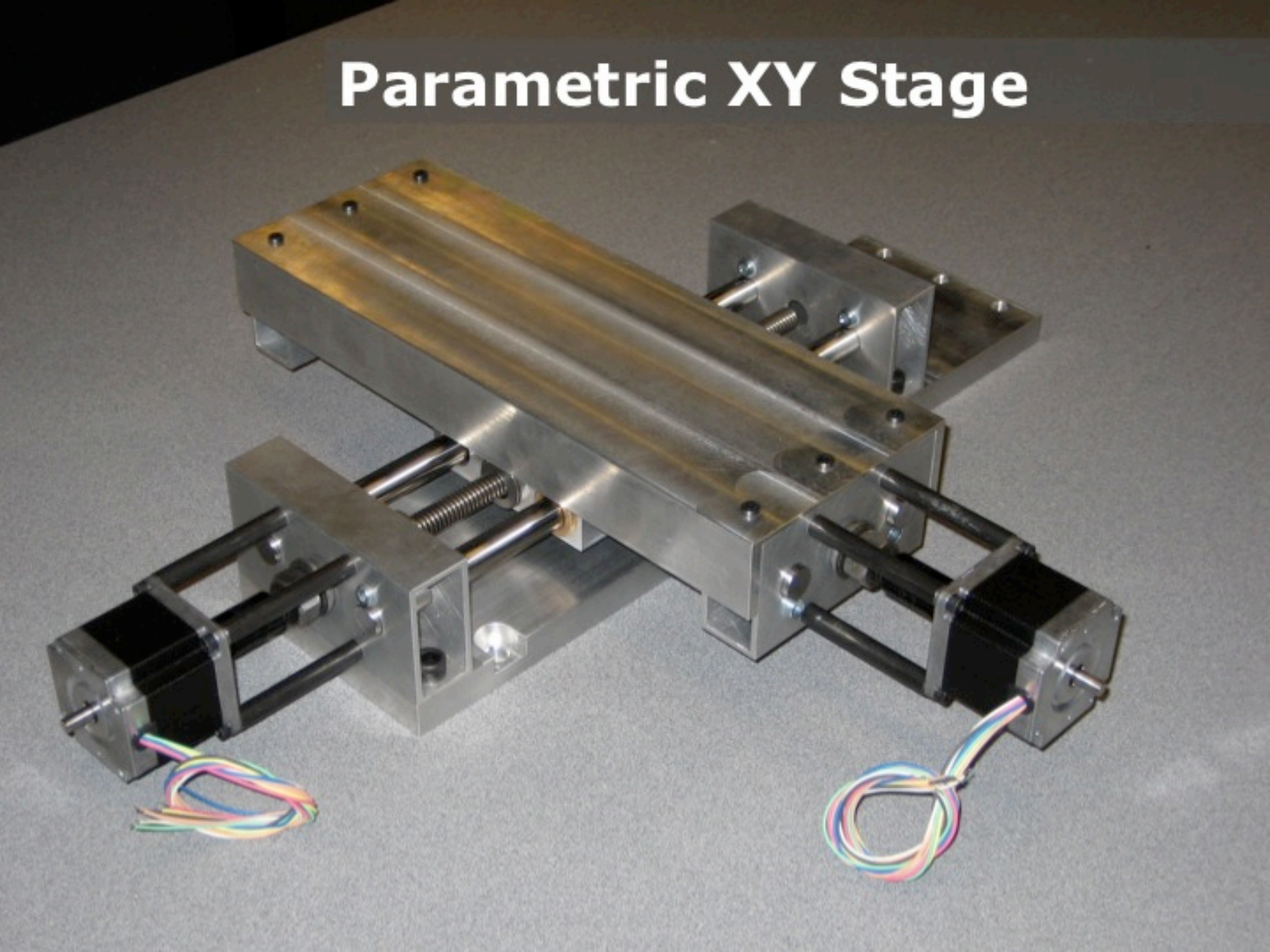
Fab@Home



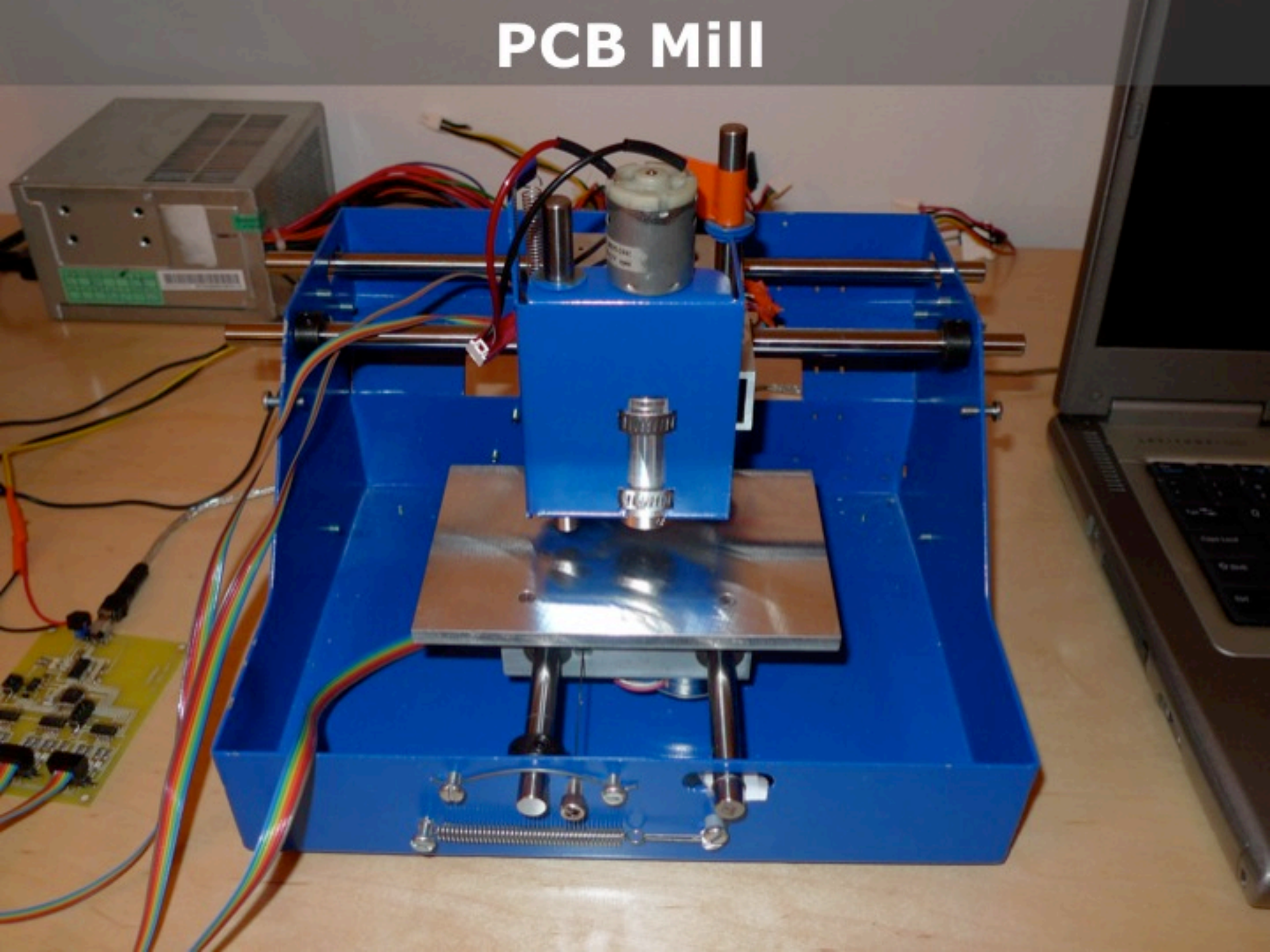


MakerBot INDUSTRIES

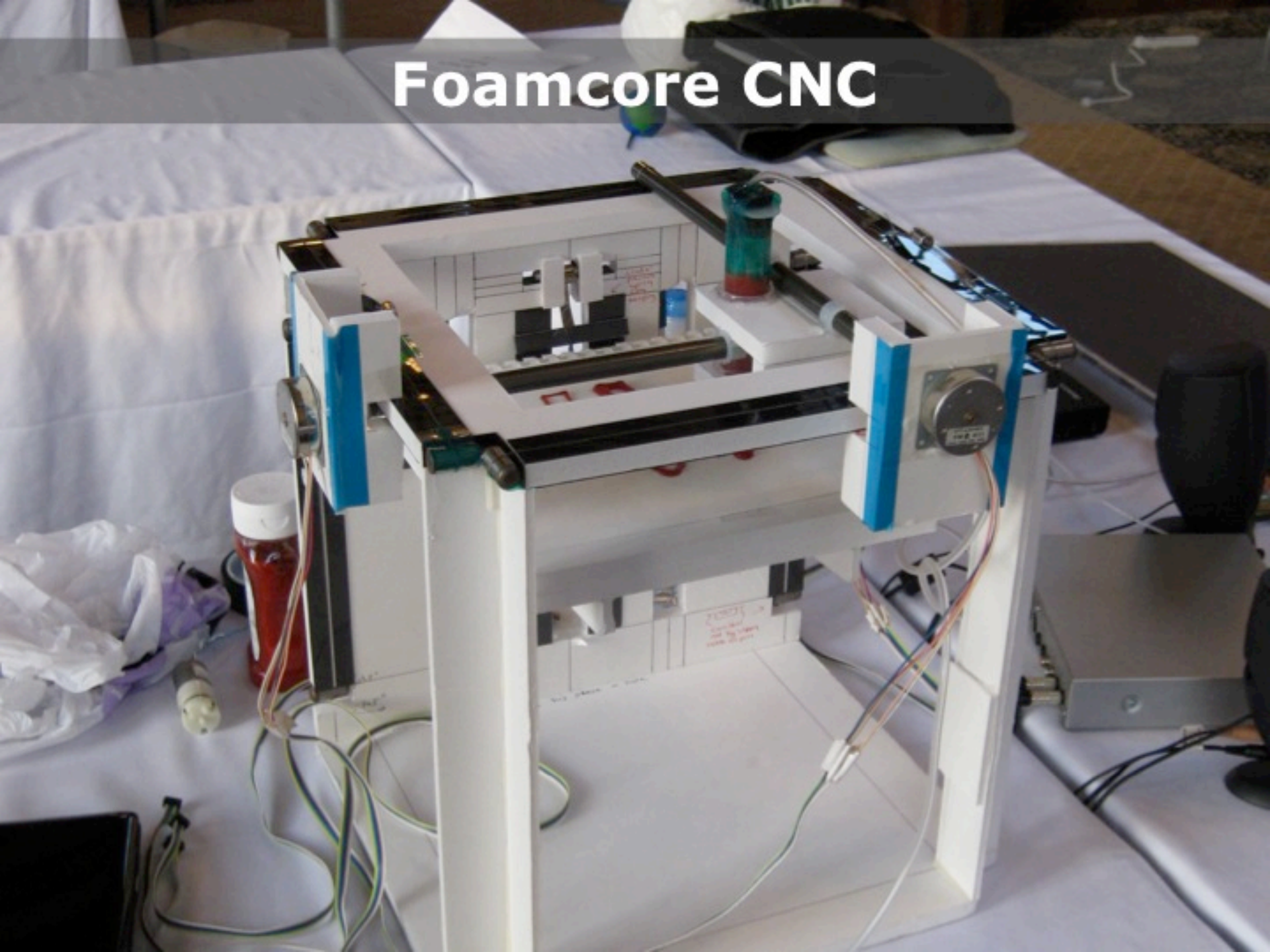
Parametric XY Stage



PCB Mill

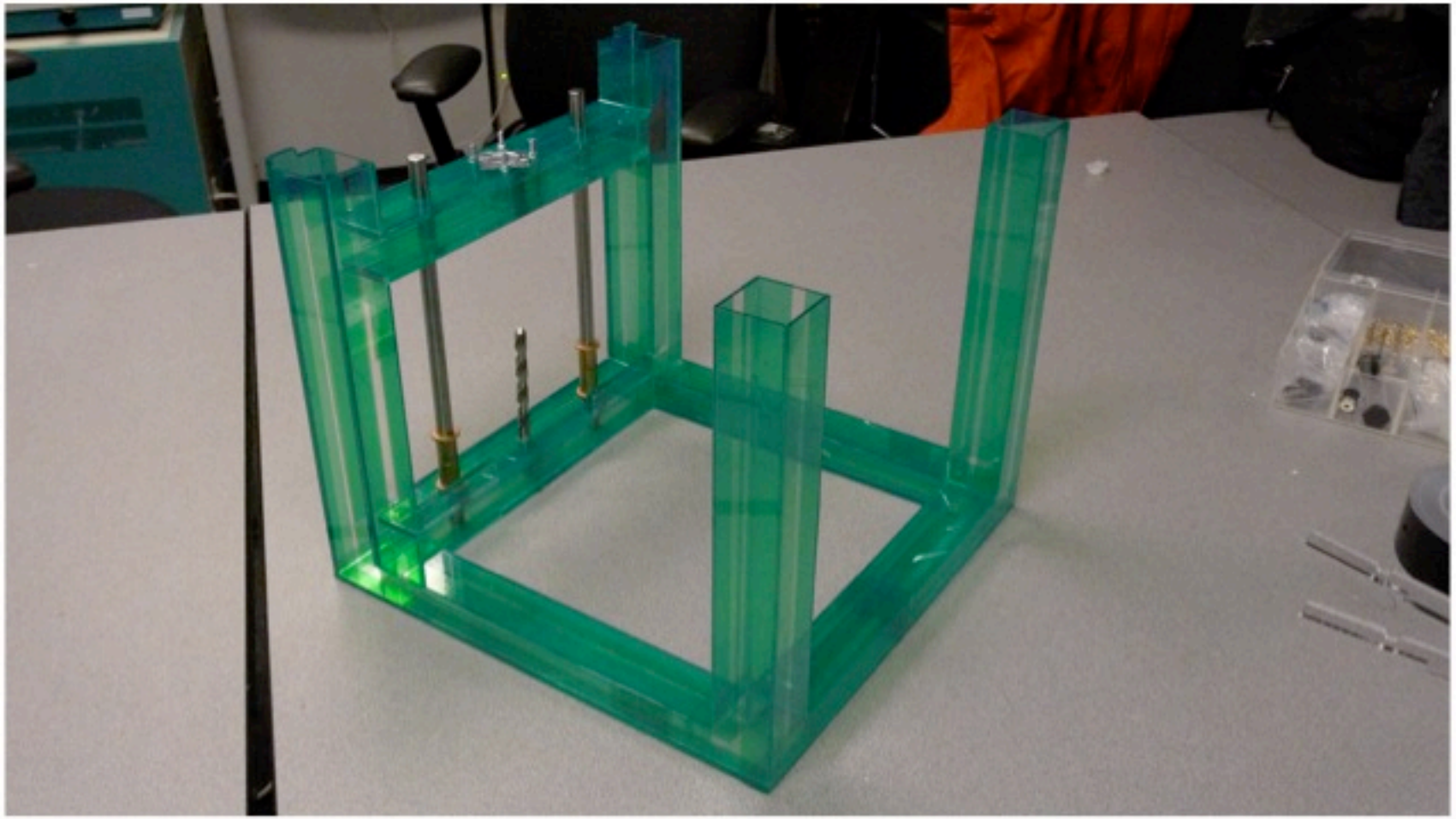


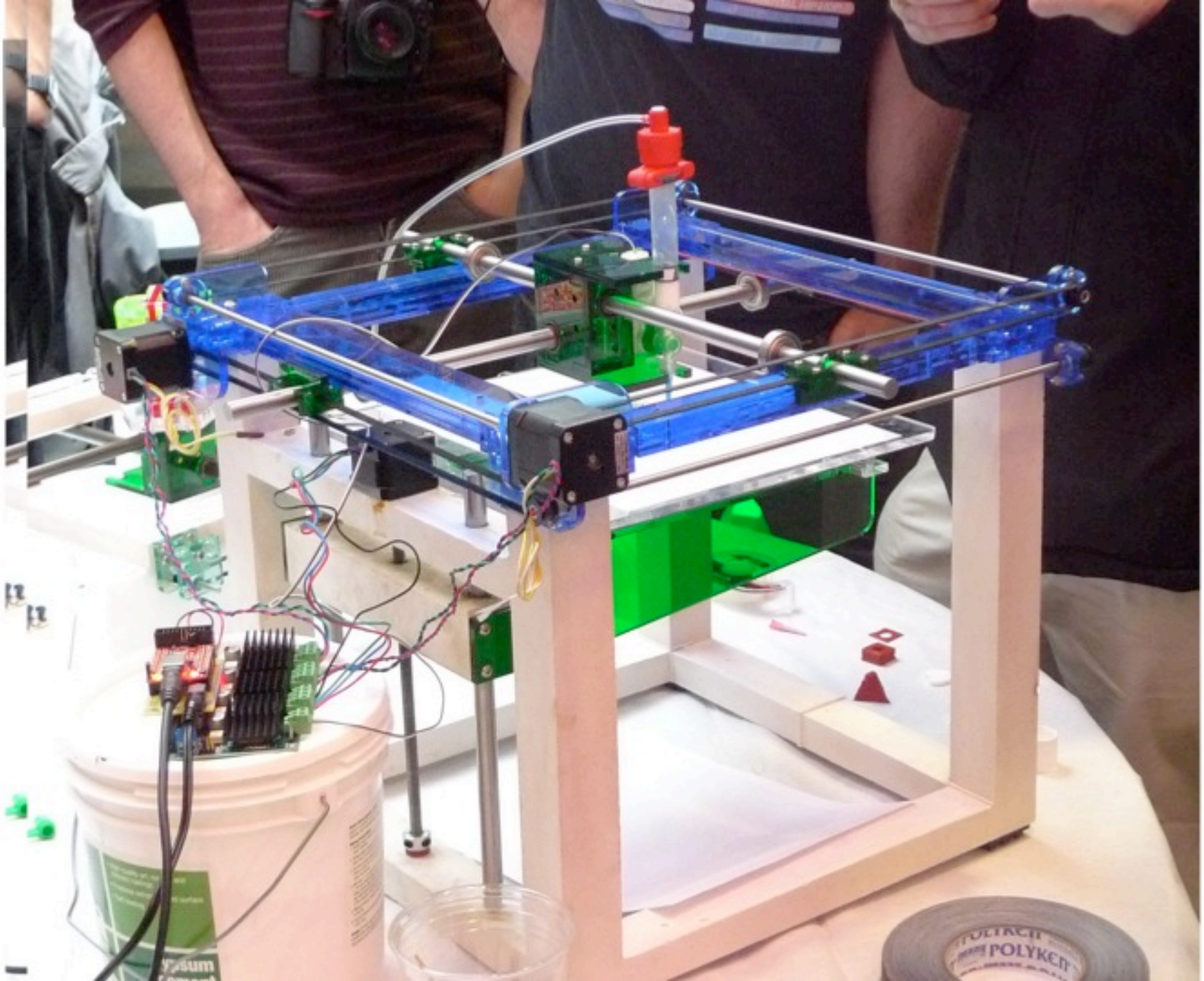
Foamcore CNC



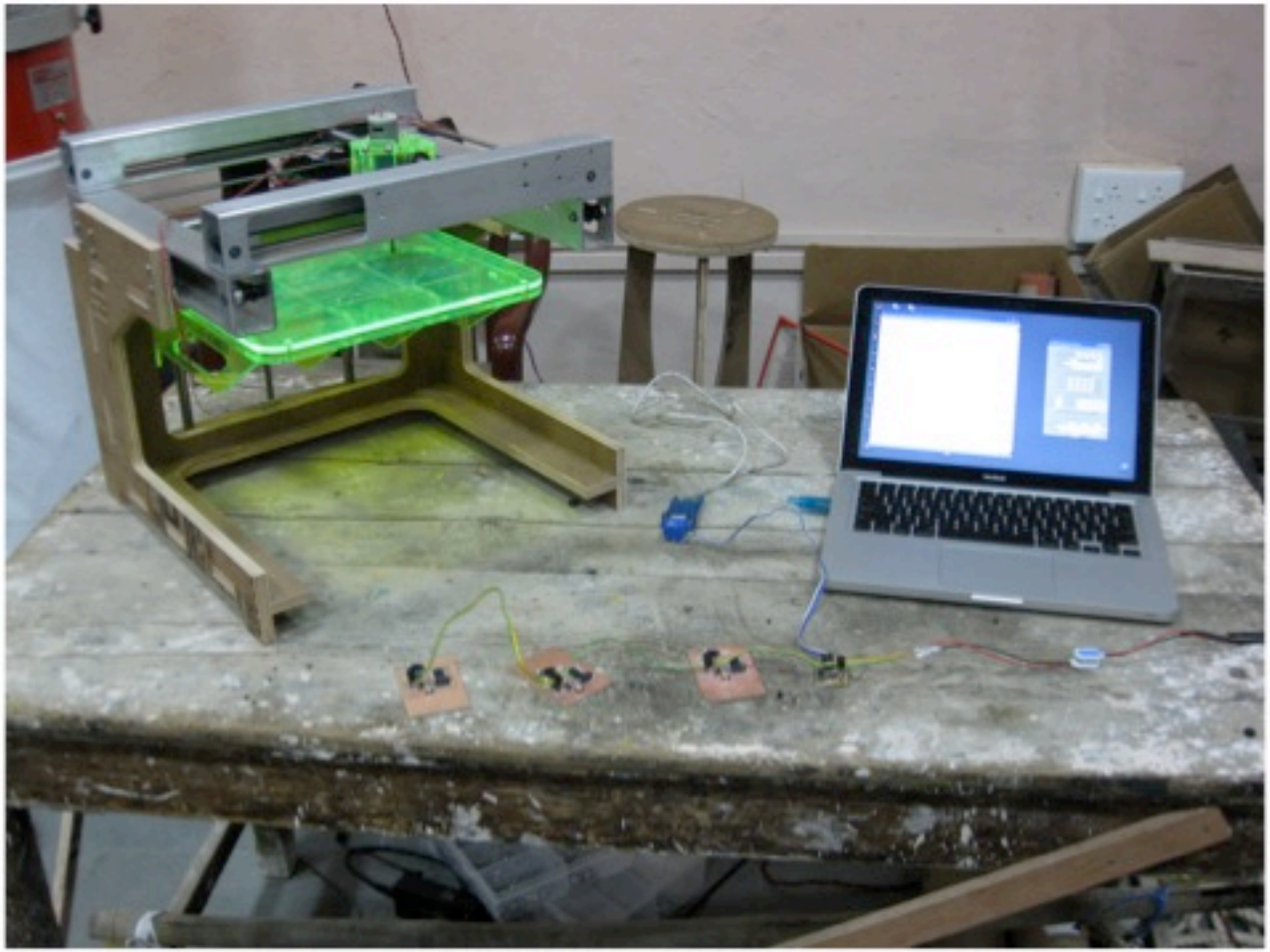
Plaster Disaster

Plaster Disaster





Made in India



Machines That Make | MtM | An MIT Center for Bits and Atoms Project

http://mtm.cba.mit.edu/

machines that make

themselves • other machines • functional parts • fun stuff

MACHINES

MtM A-Z

DIY Vinyl Cutter

$100 Mantis CNC Mill

TOOLHEADS

Spindle

Low Cost Spindle

CONTROL

Virtual Machines

Internet Zero

Simple Stepper

PEOPLE

Jonathan Ward

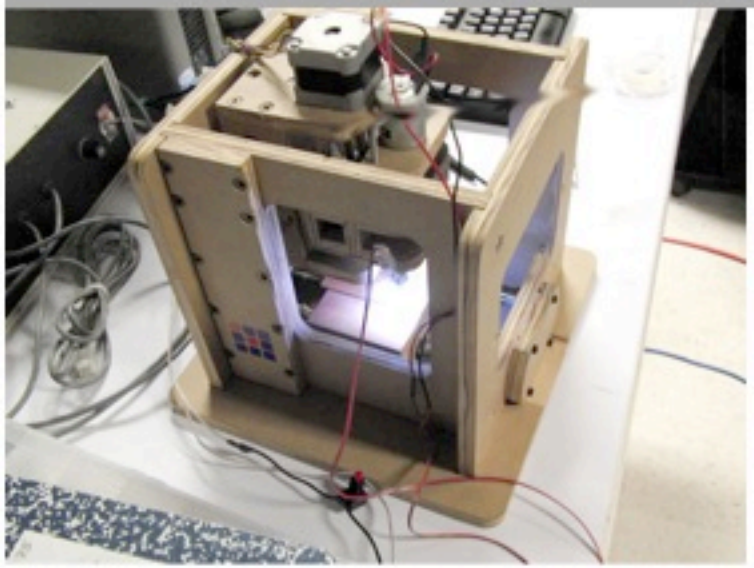
Maxim Lobovsky

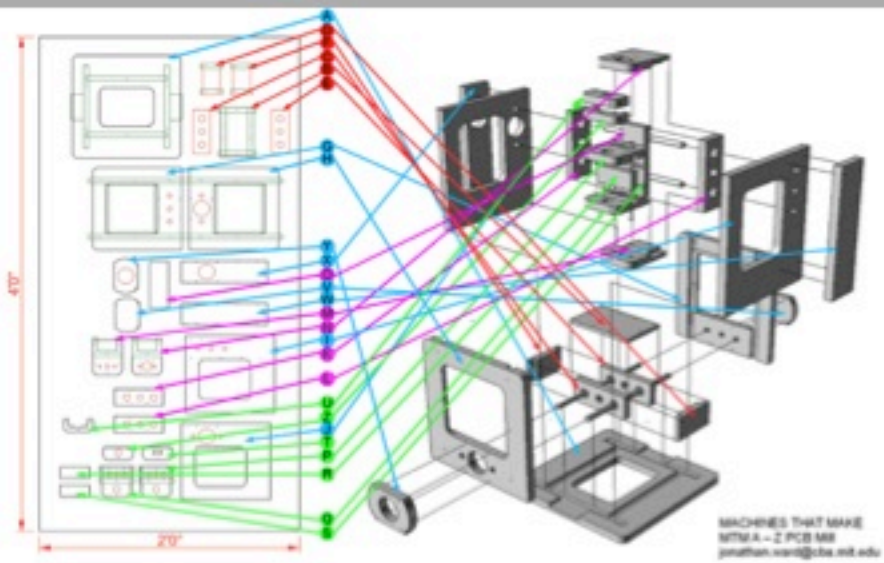
Steffen Reichert

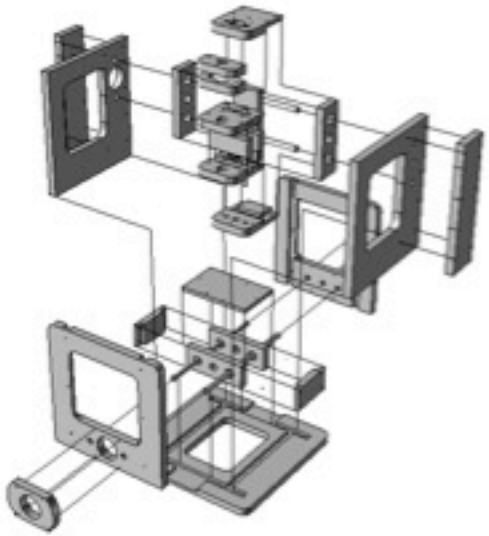
MTM

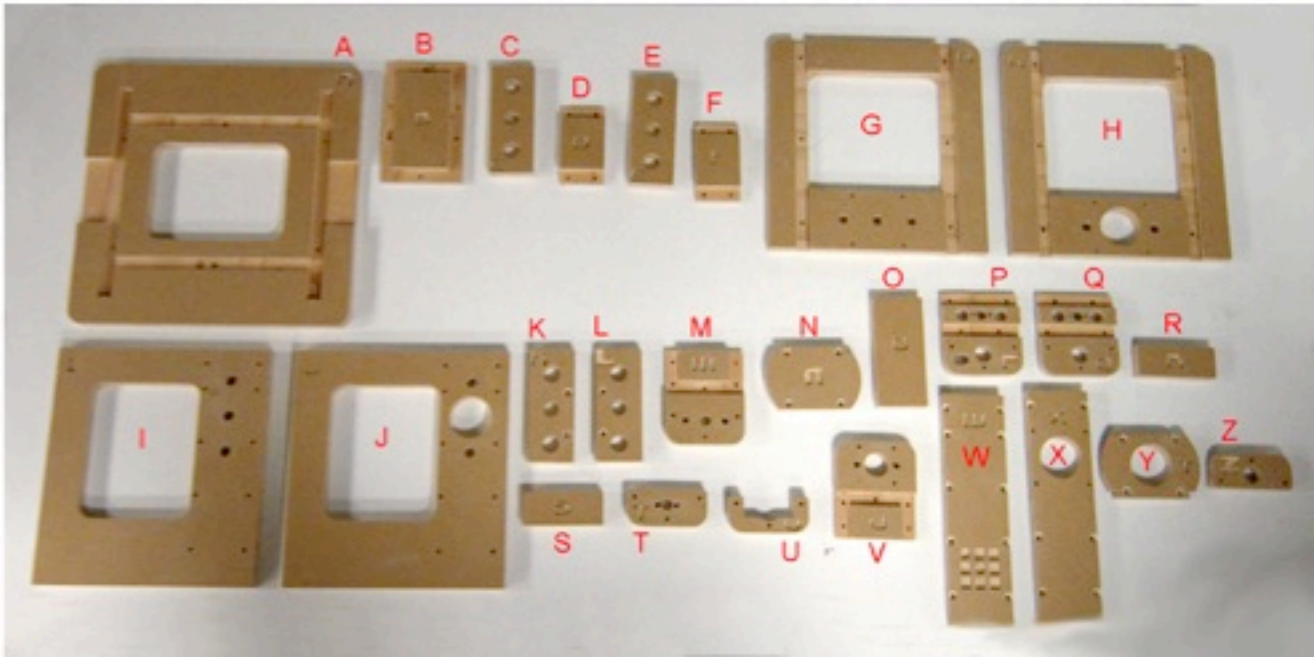
- Multifab machines – multi-functions
- Open source
- Networked
- Low cost
- Exploring different materials and form factors

MTM AZ – Jonathan Ward

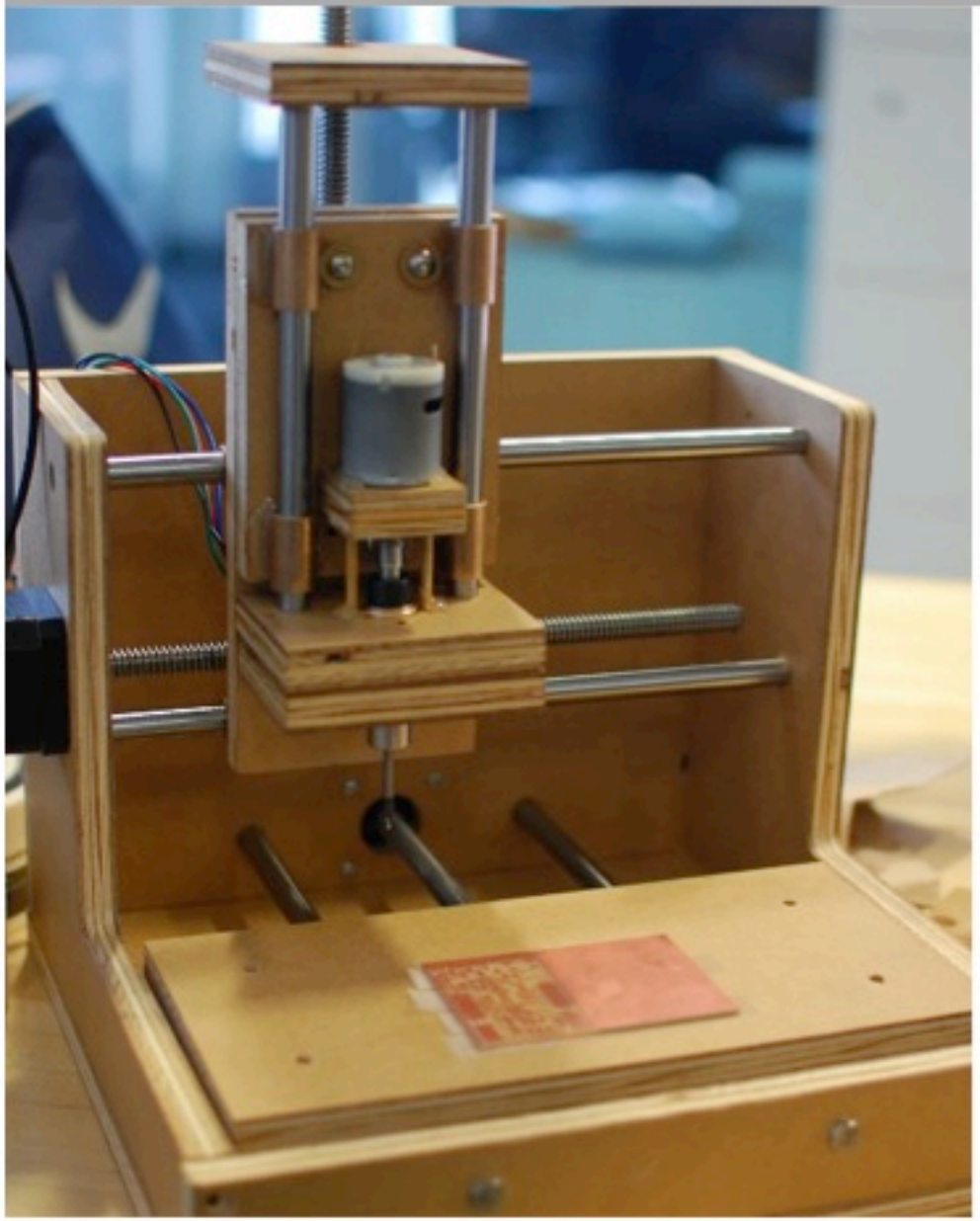


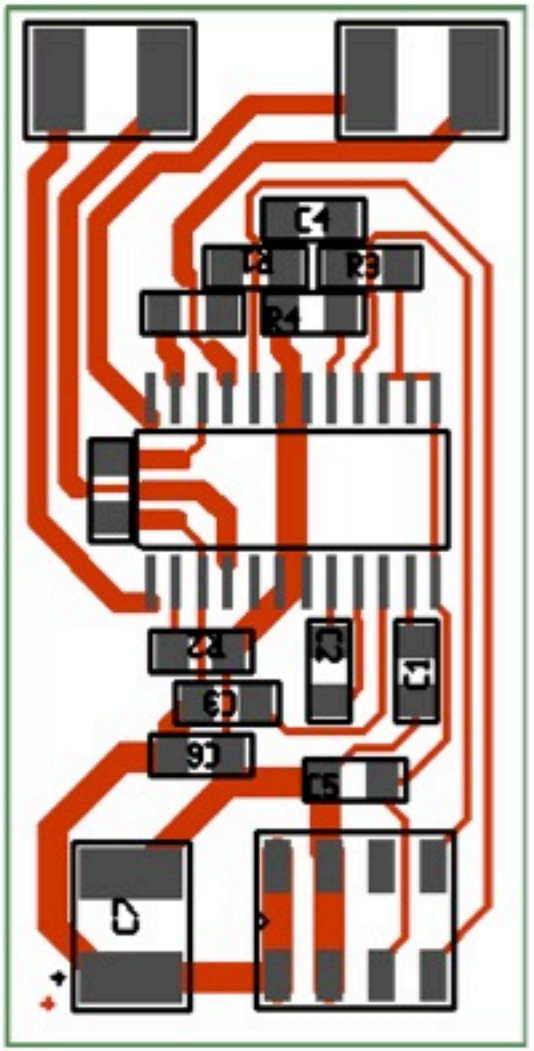






Mantis < $100 ! – David Carr



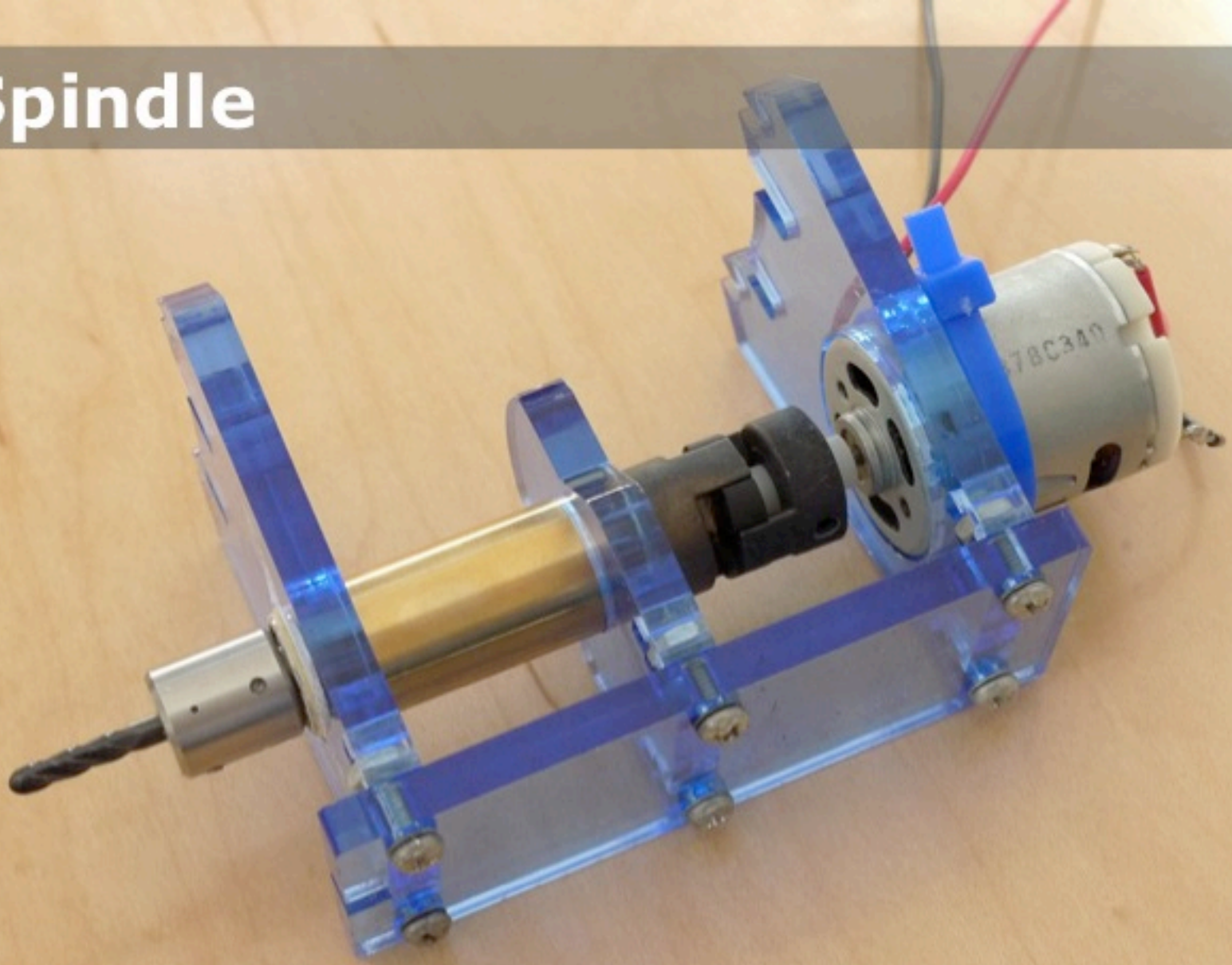


http://makeyourbot.org/

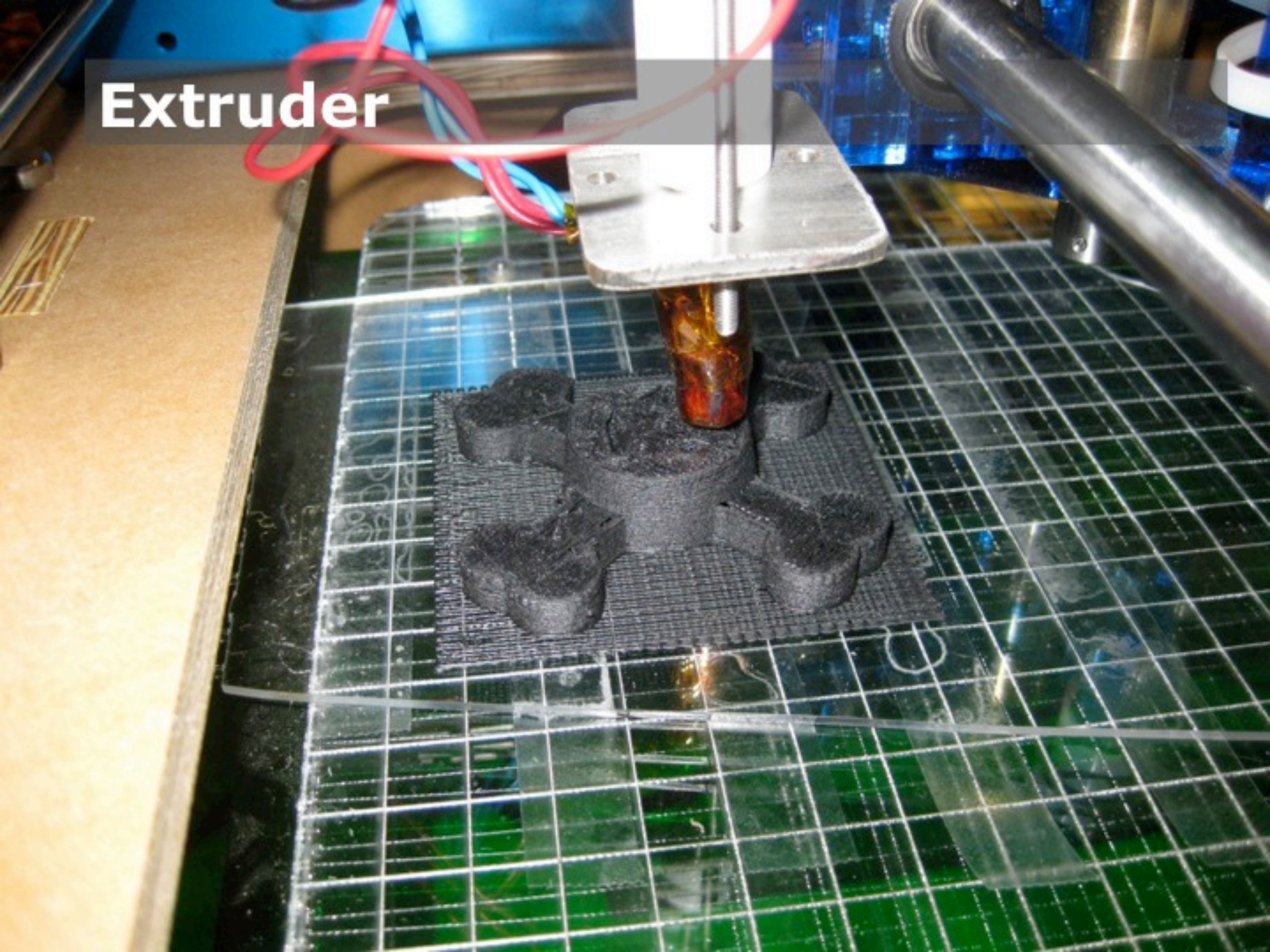
Casting & Molding – David Carr

MTM Multifab – Ilan Moyer

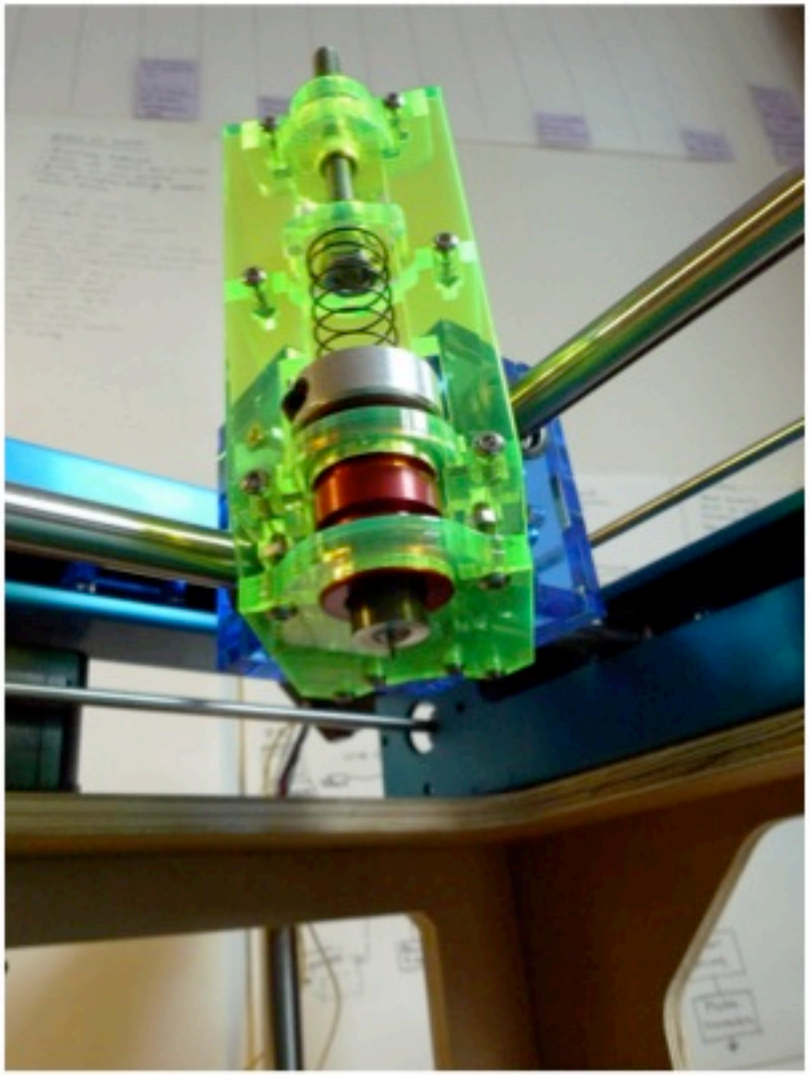
Spindle



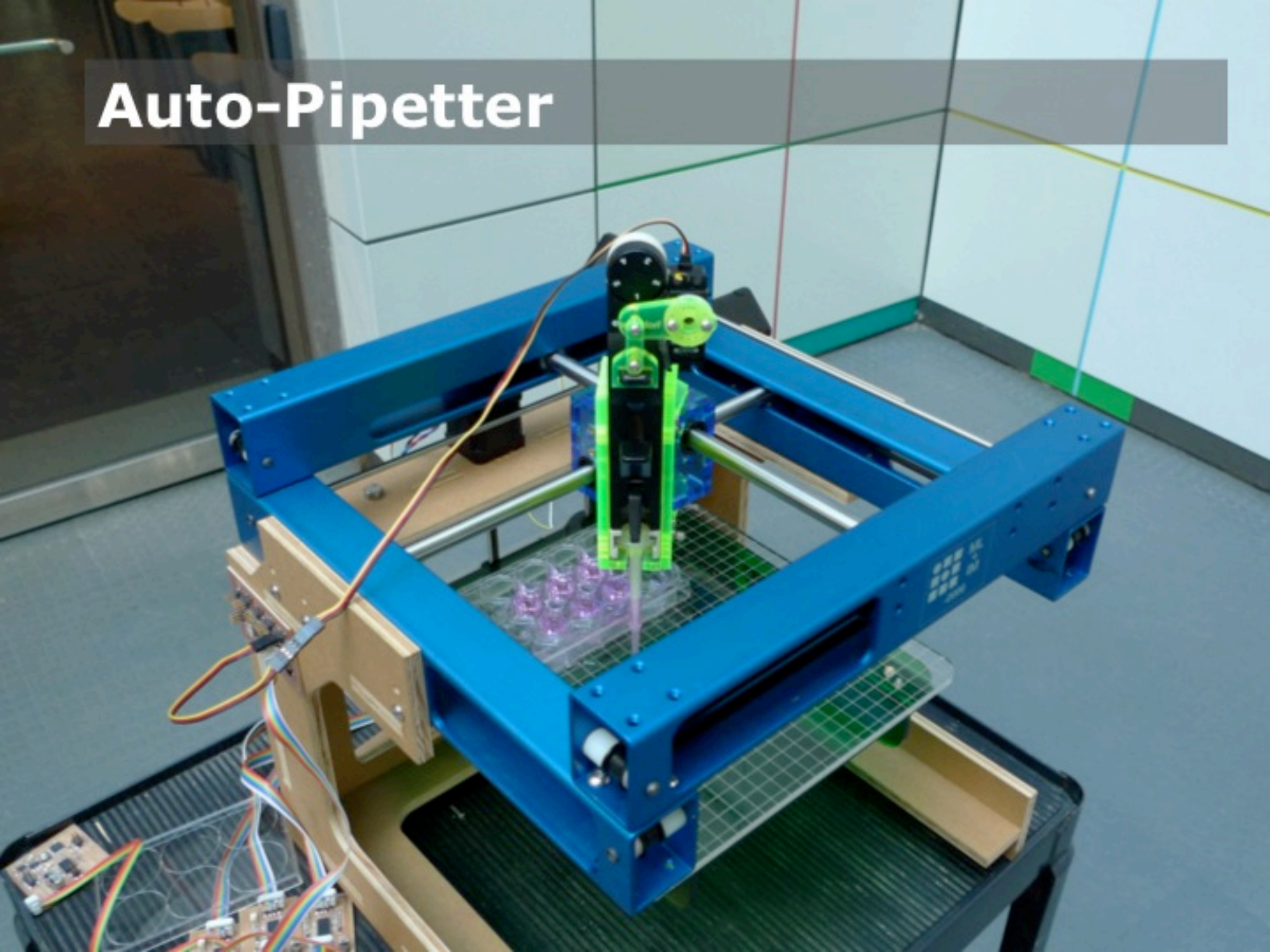
Extruder



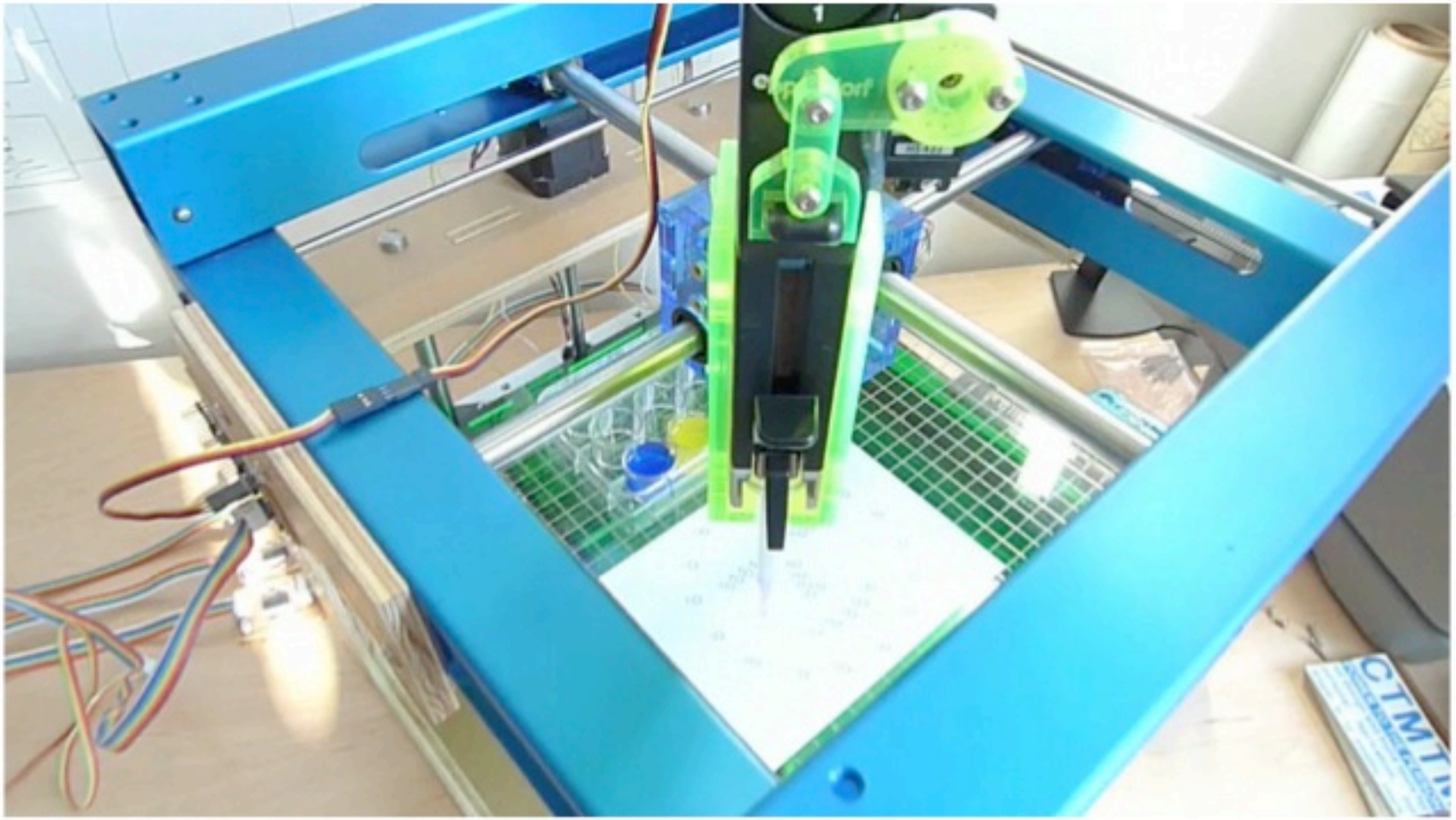
Vinyl Cutter



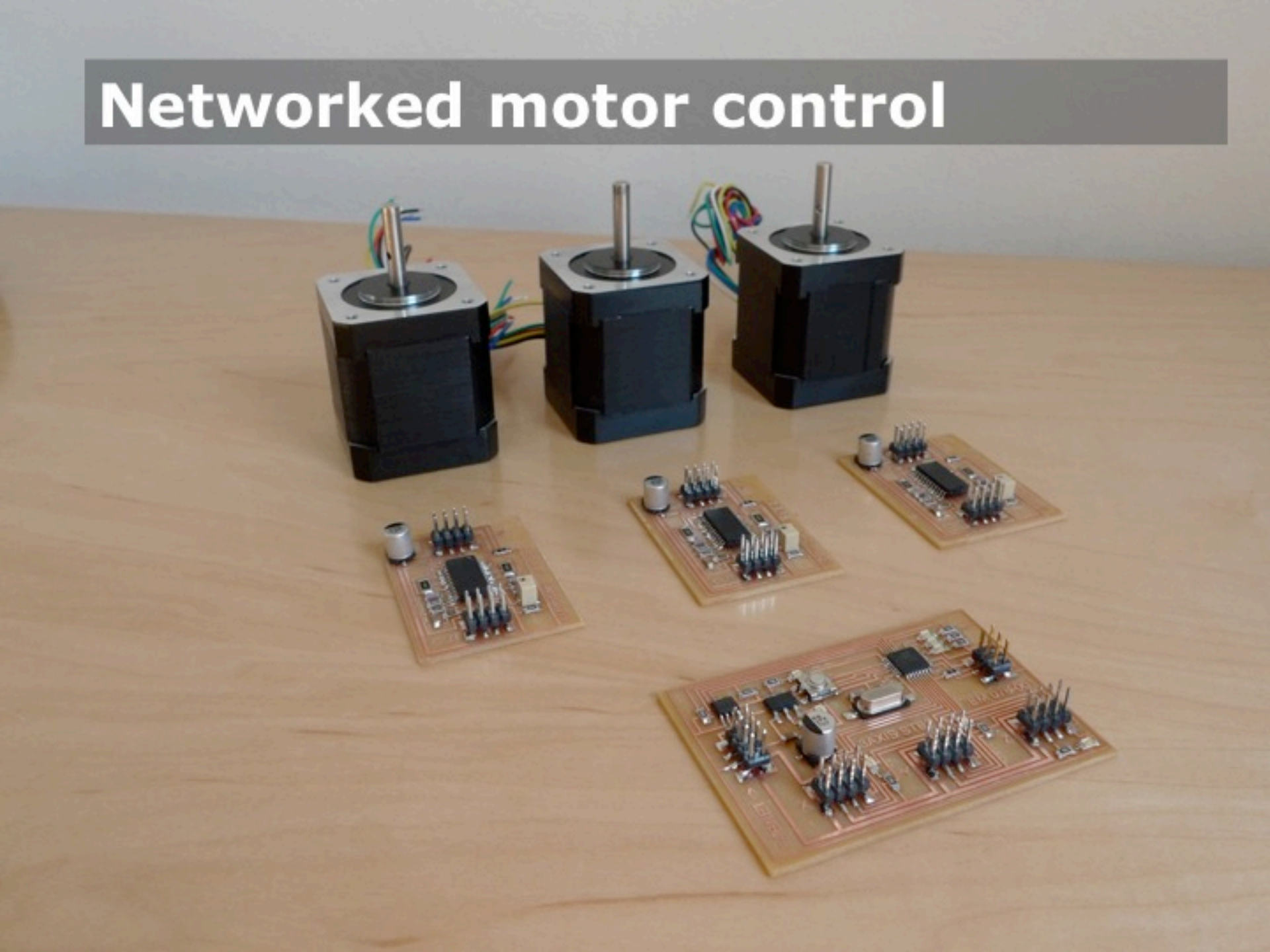
Auto-Pipetter



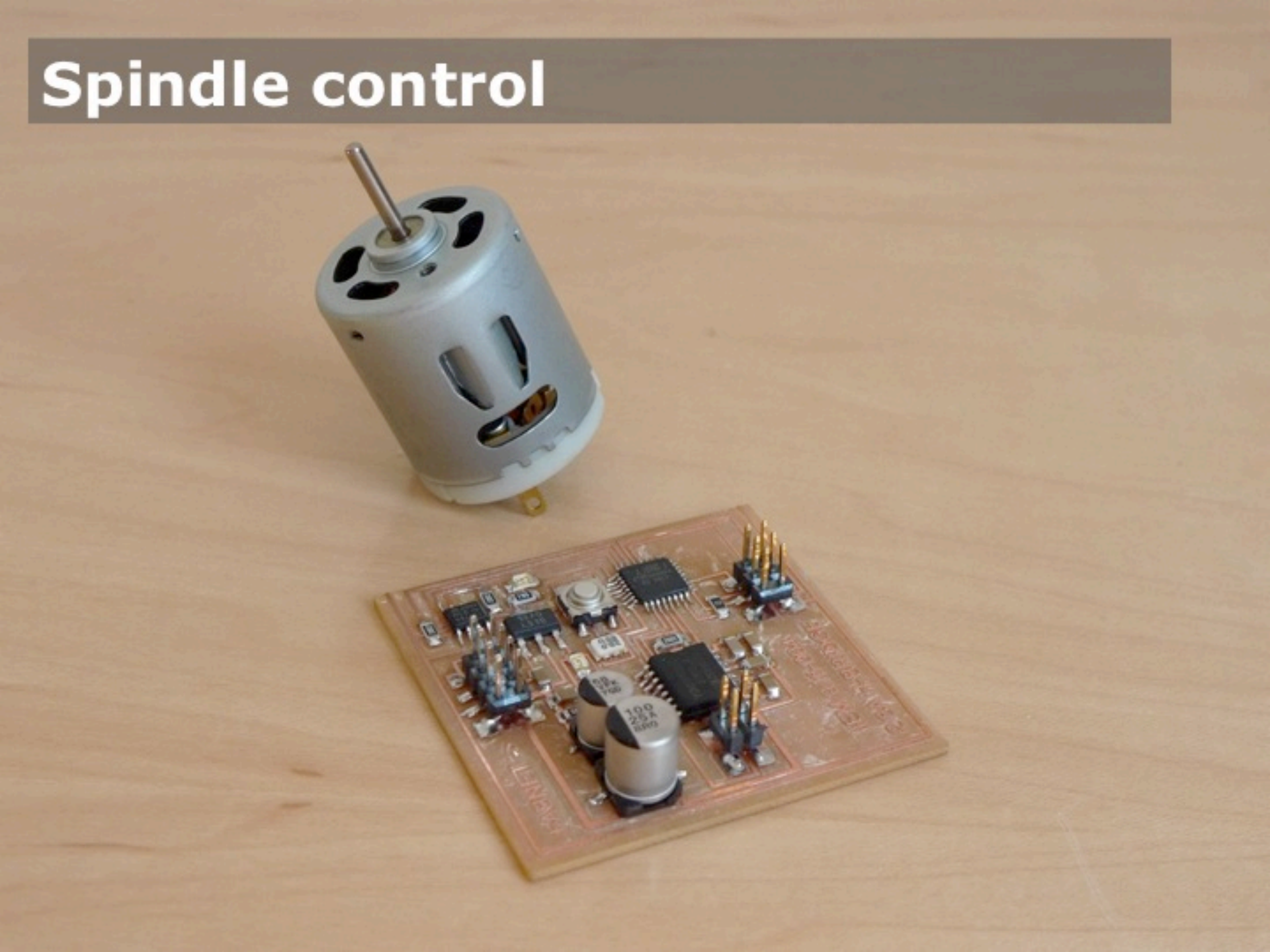
Auto-Pipetter



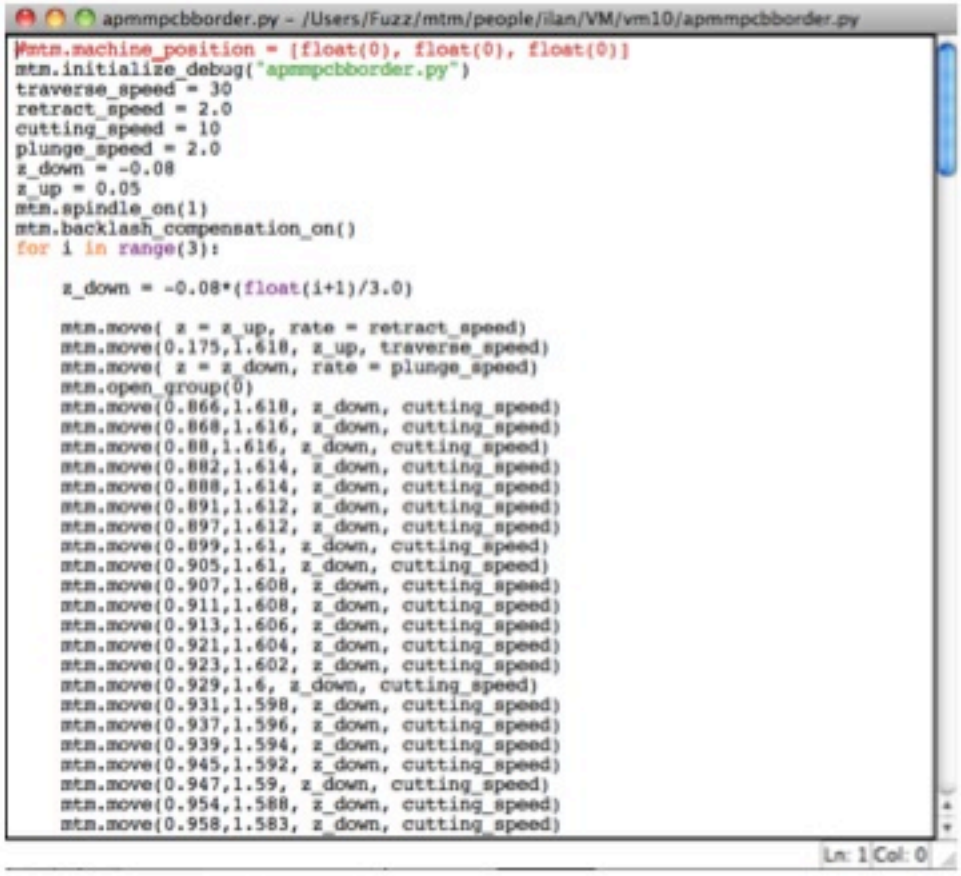
Networked motor control

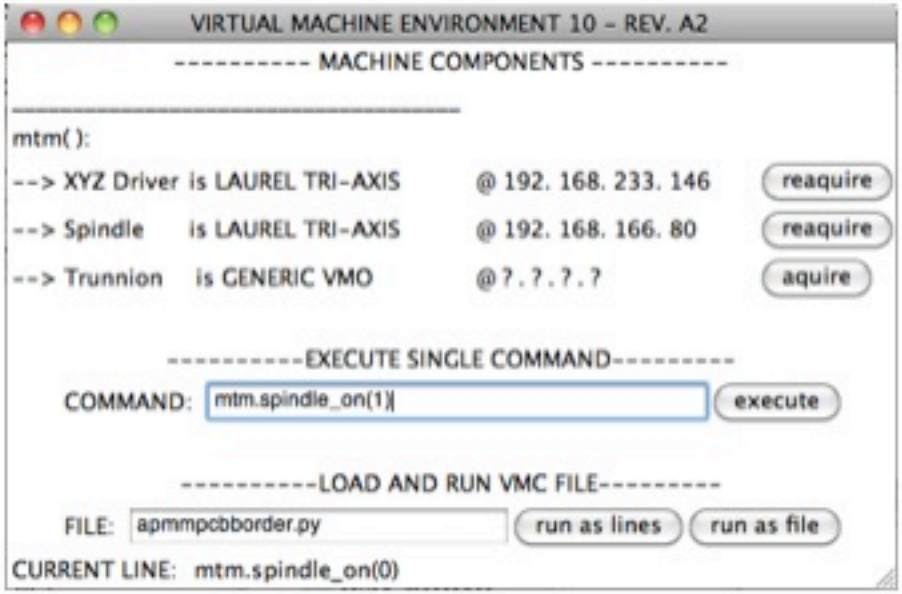


Spindle control

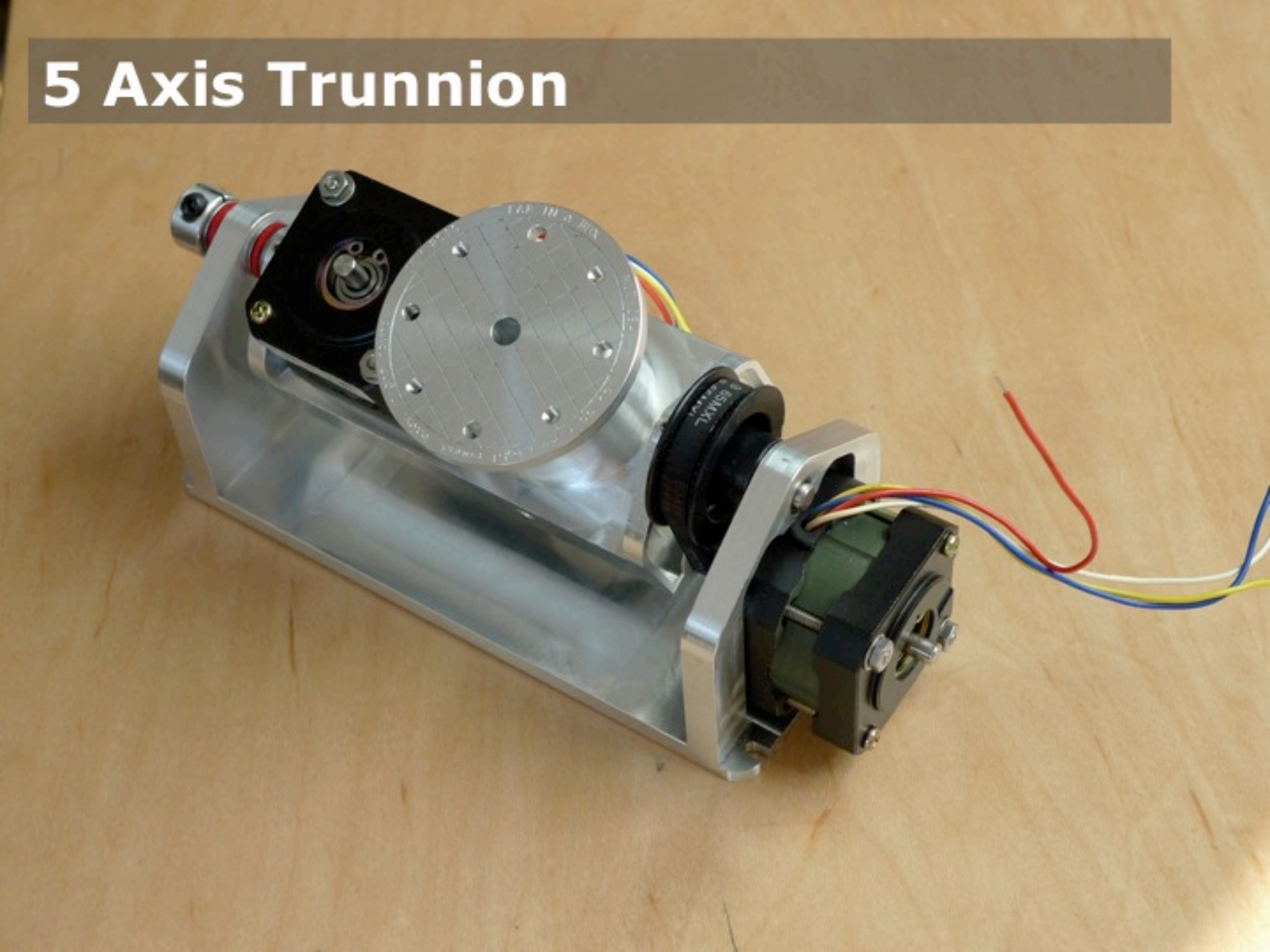


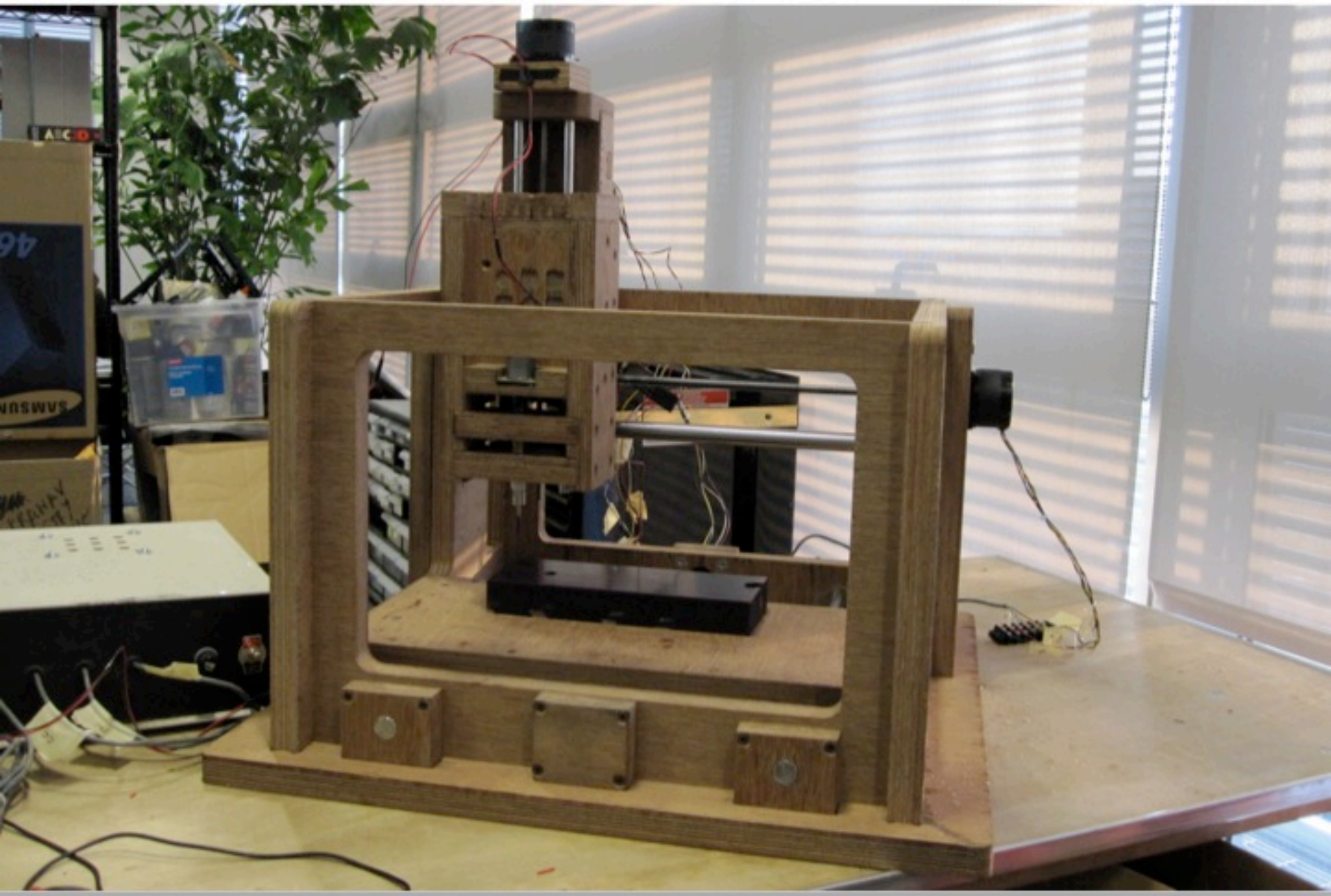
Virtual Machines Control



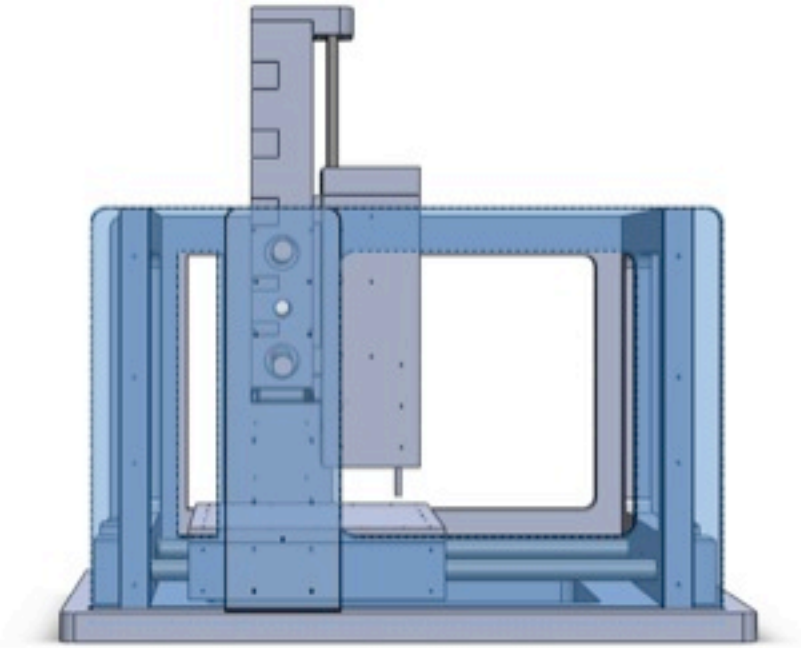


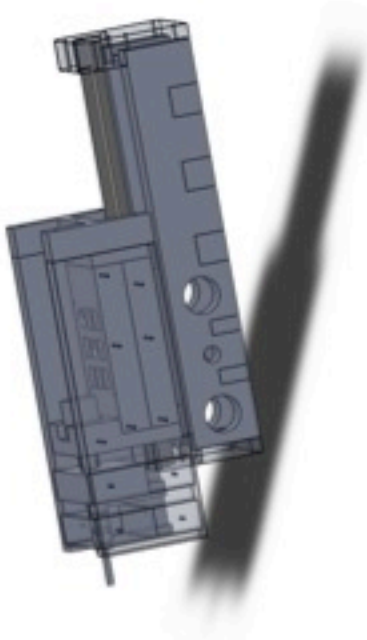
5 Axis Trunnion

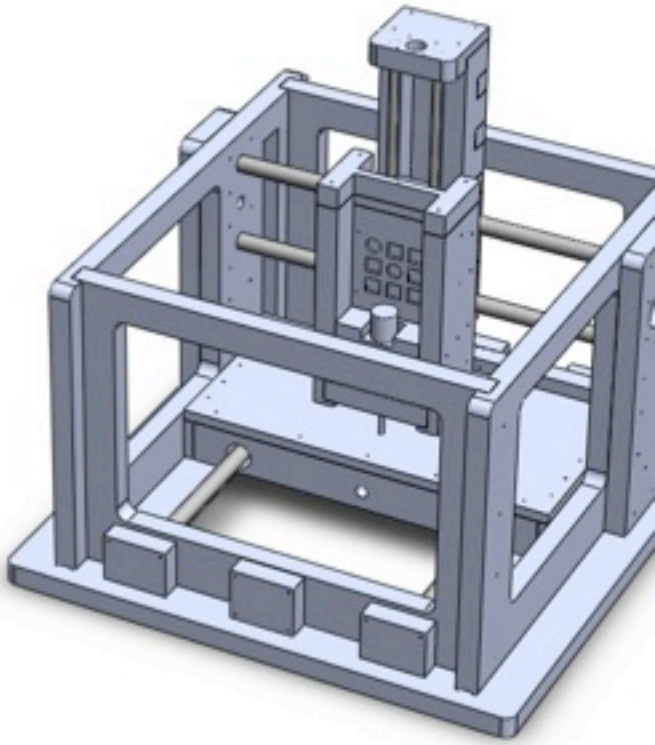




MTM Little John

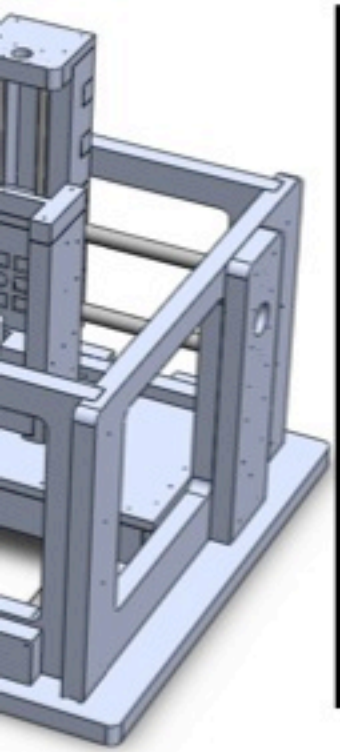


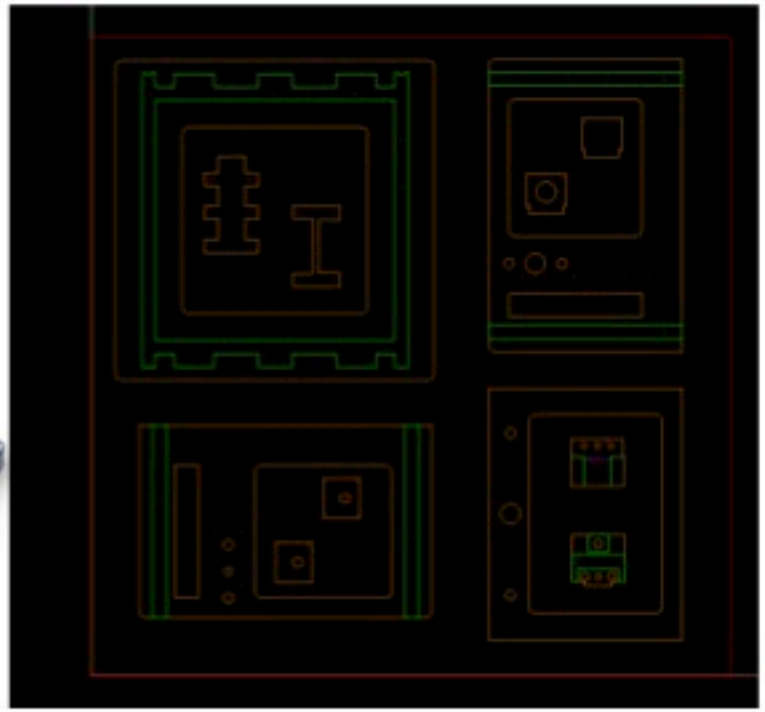


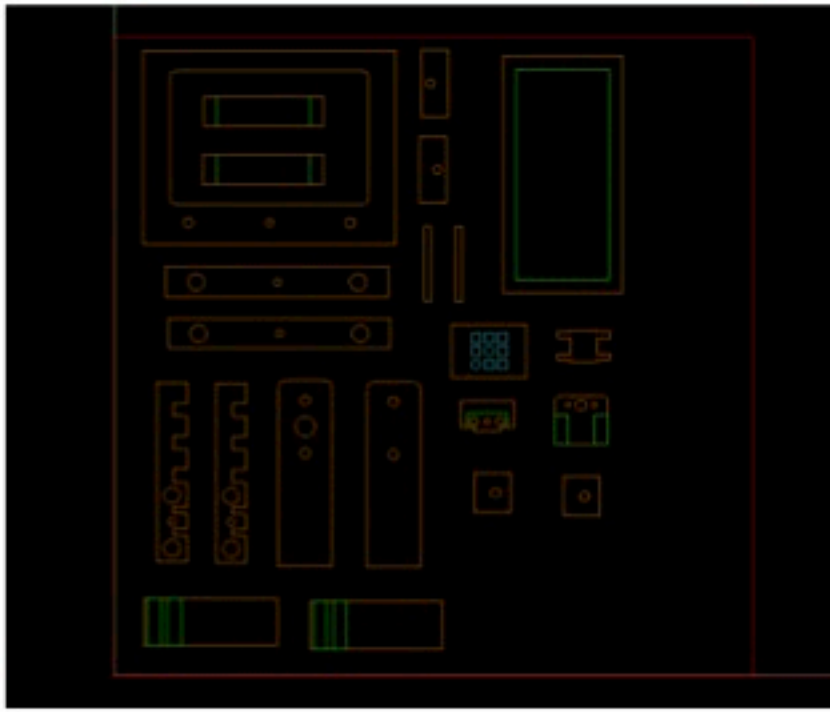


Overview

MTM "Little John" is a multi-purpose mid-size rapid prototyping machine that which has the goal of being a personal fabricator capable of performing a variety of tasks (3D printing, milling, scanning, vinyl cutting, etc.) at a price point in the hundreds rather than thousands of dollars.

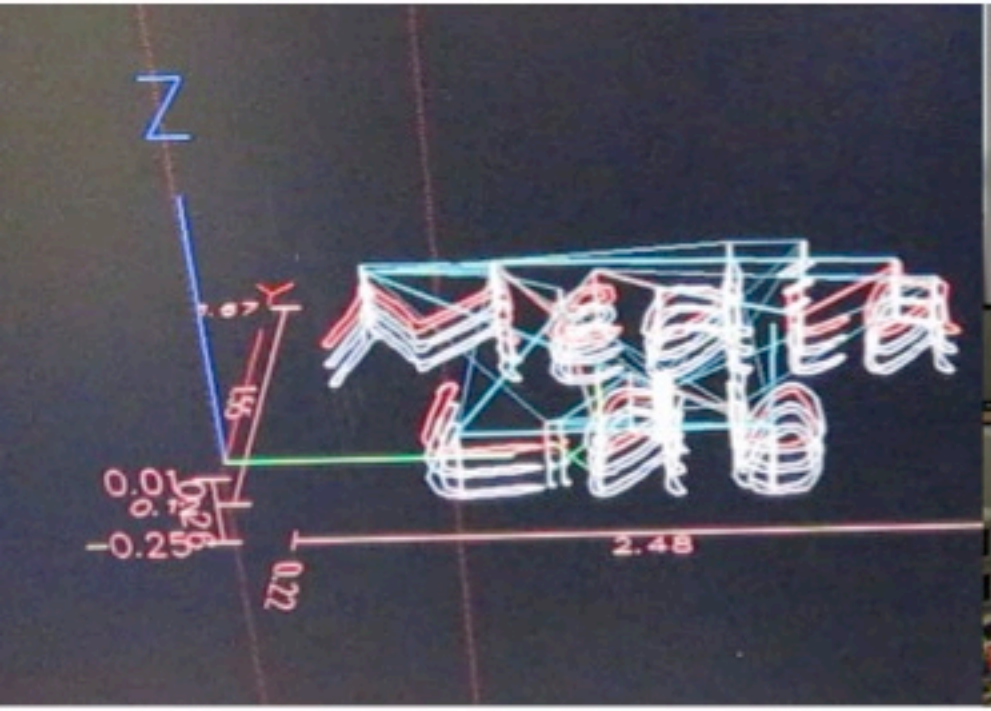






Open-Source Plans (http://mtm.cba.mit.edu/machines/mtm_lj/Site/MTM_Little_John.html)

All the MTM-LJ parts are currently using two 4' x 4' x 1" sheets. Parts layout is using spacing for cutting with a 0.25" straight end-mill. Pilot holes should be cut first using a 0.125" straight end-mill, see Fabrication section for detailed screenshots. To make tool-path generation the DXF & Rhino files below are using layers.



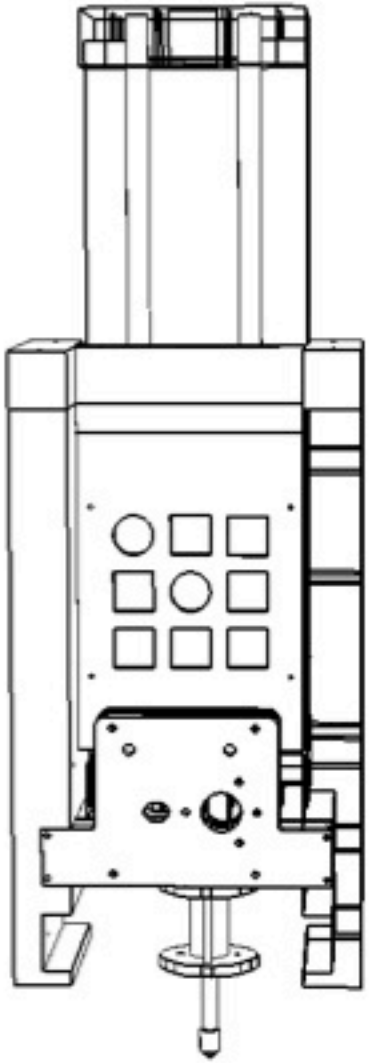
Specifications / Key Features:

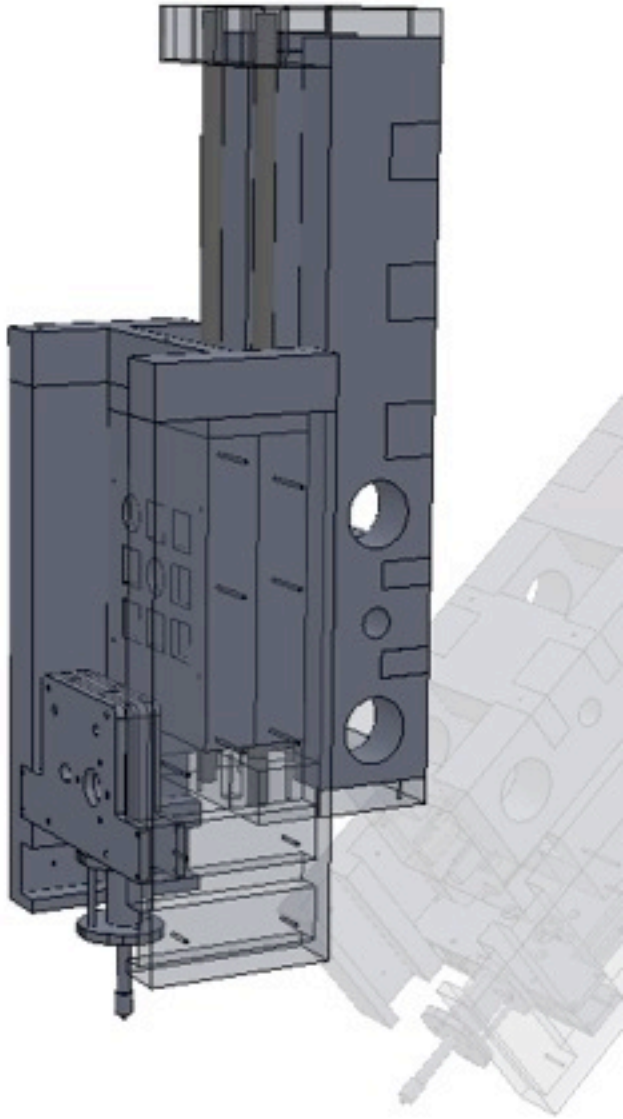
Dimensions: 2’x2’x14.5”
Working envelope: 9”x18”x5.5”
Interchangeable tool interface, multiple heads
I0 Networked motor control (unipolar+bipolar support)
Open-source H/W + S/W Linux RT + EMC2

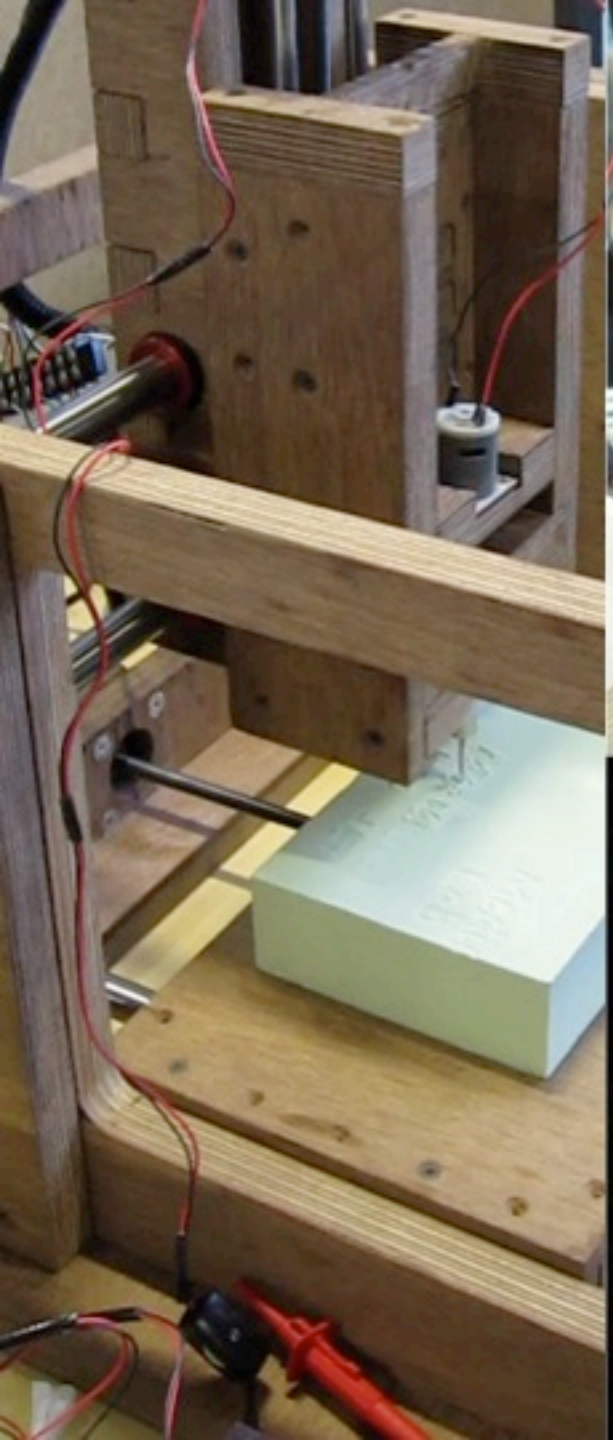
Multifab Toolinterface

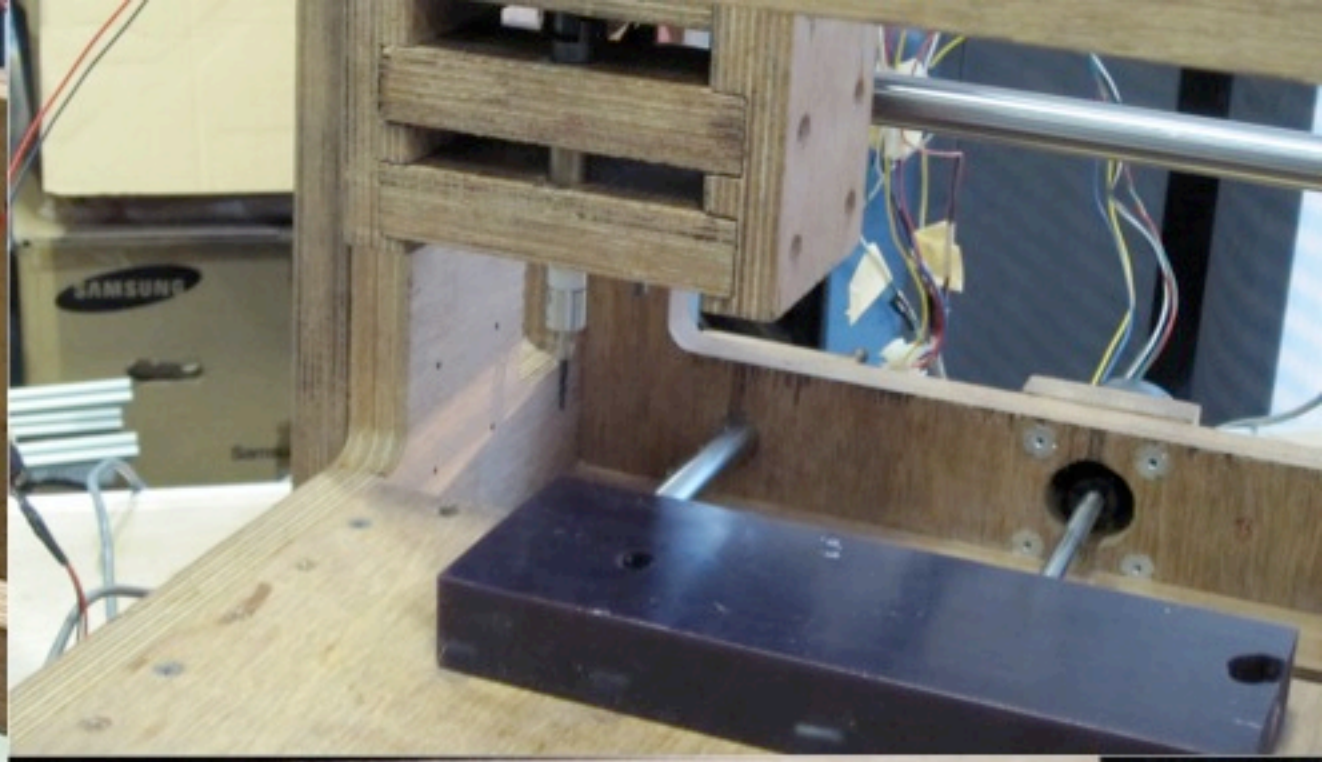
MTM Little John tool interface is designed to support multiple tools-heads. Example tools can be a combination of plastic extruders, printing/plotting, milling, scanning.

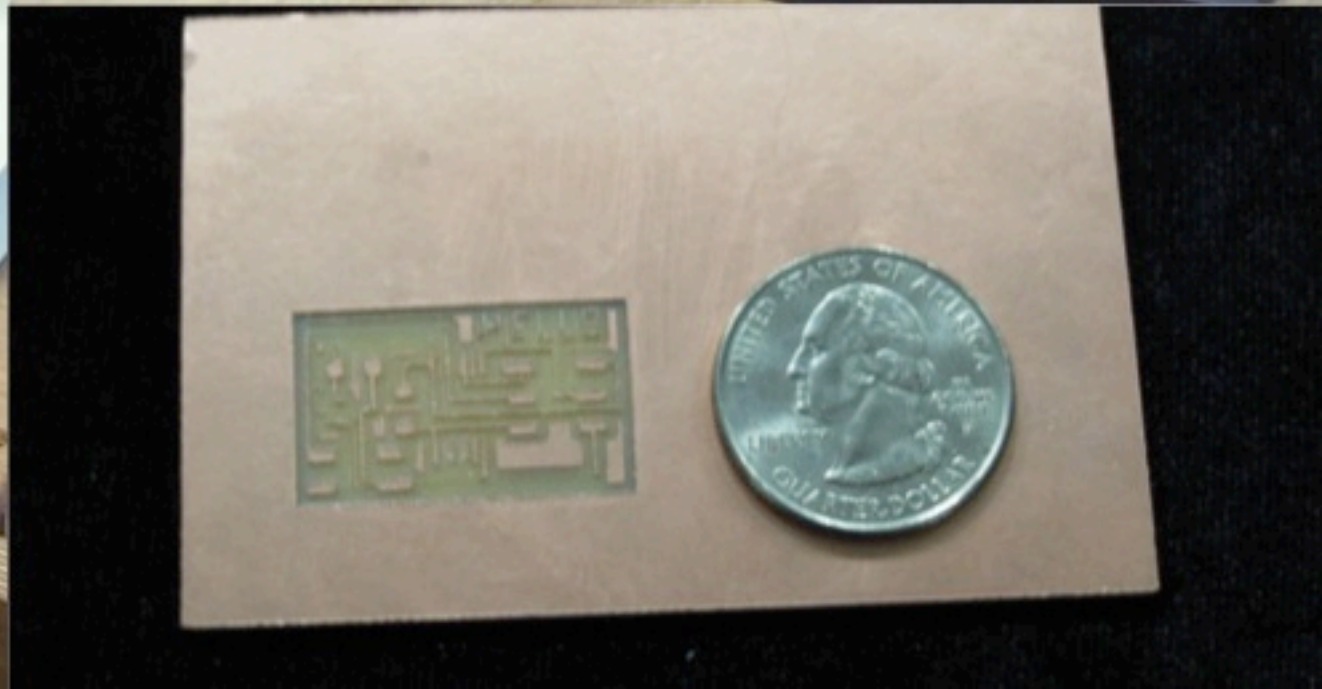
Plastruder





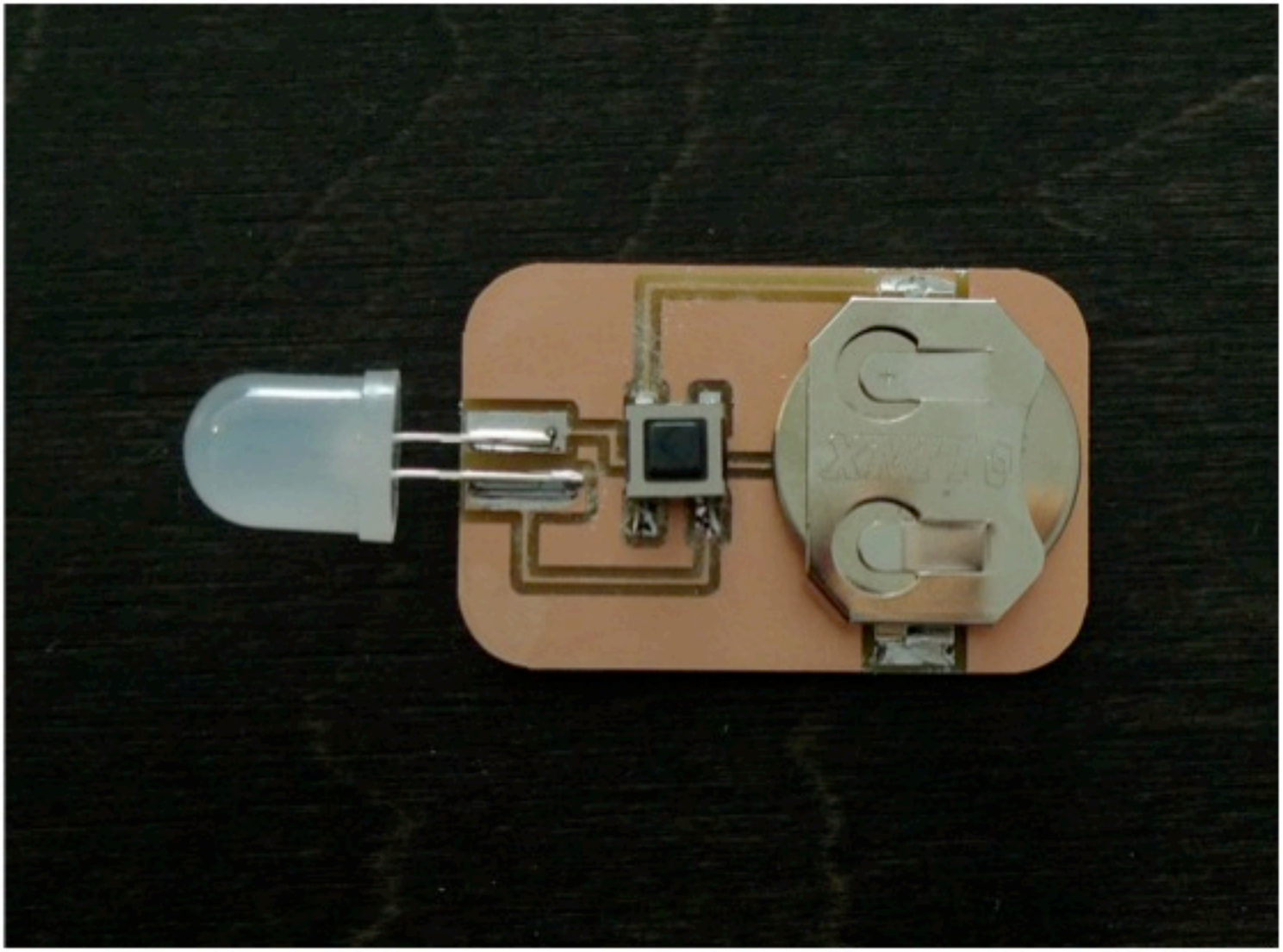


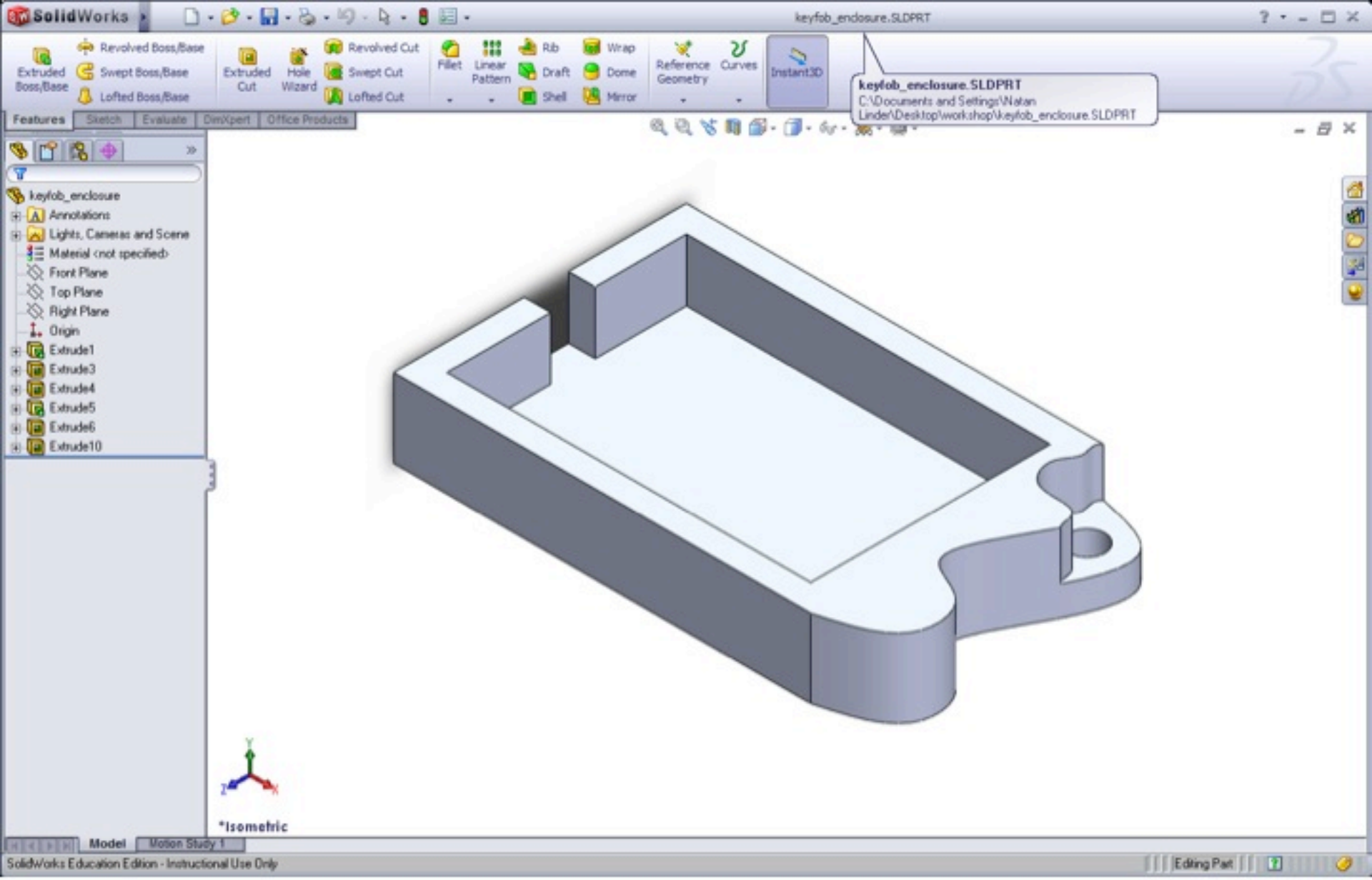

SAMSUNG


UNITED STATES OF AMERICA
QUARTER DOLLAR

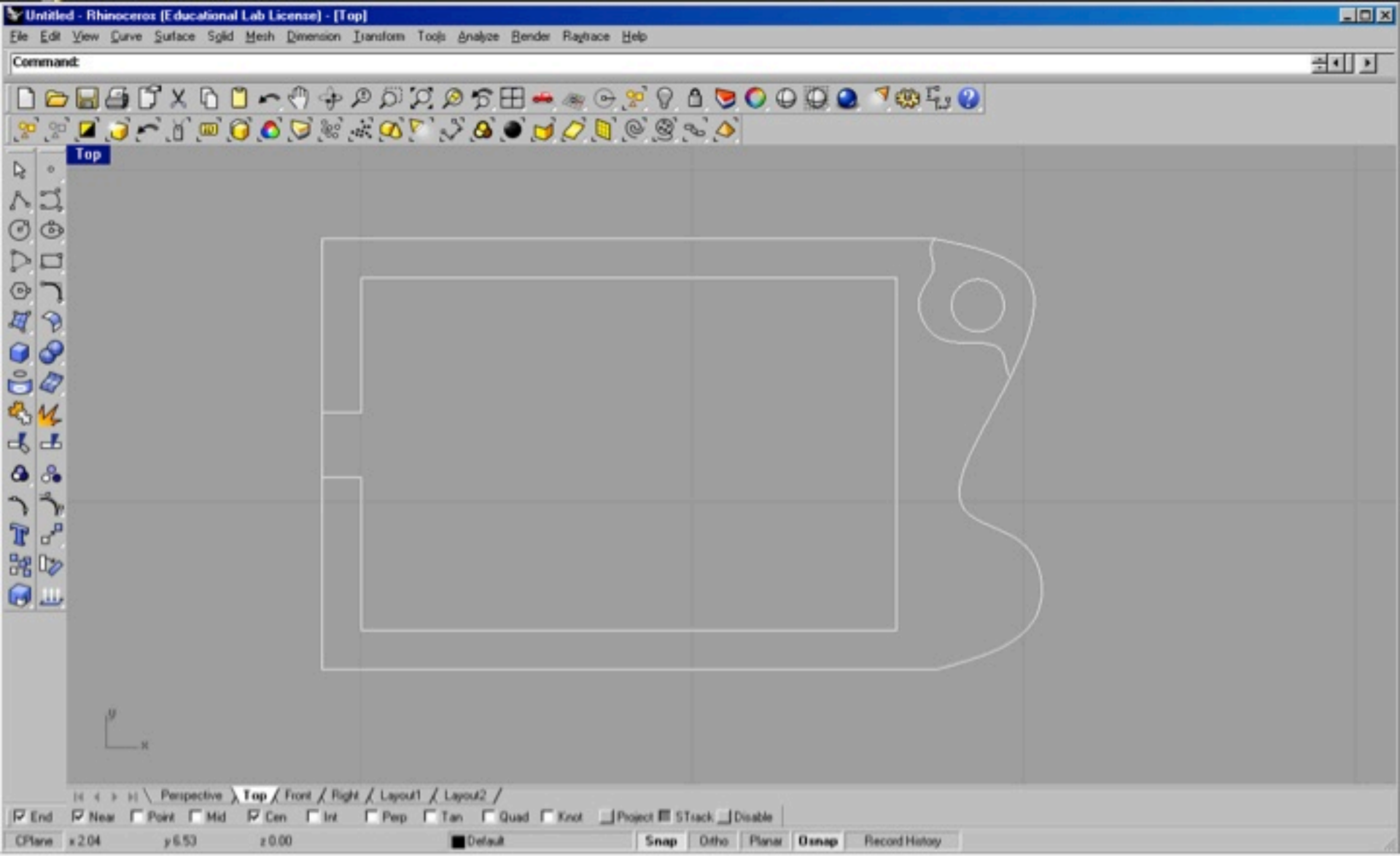
How make something with MTMs

Keychain Flashlight

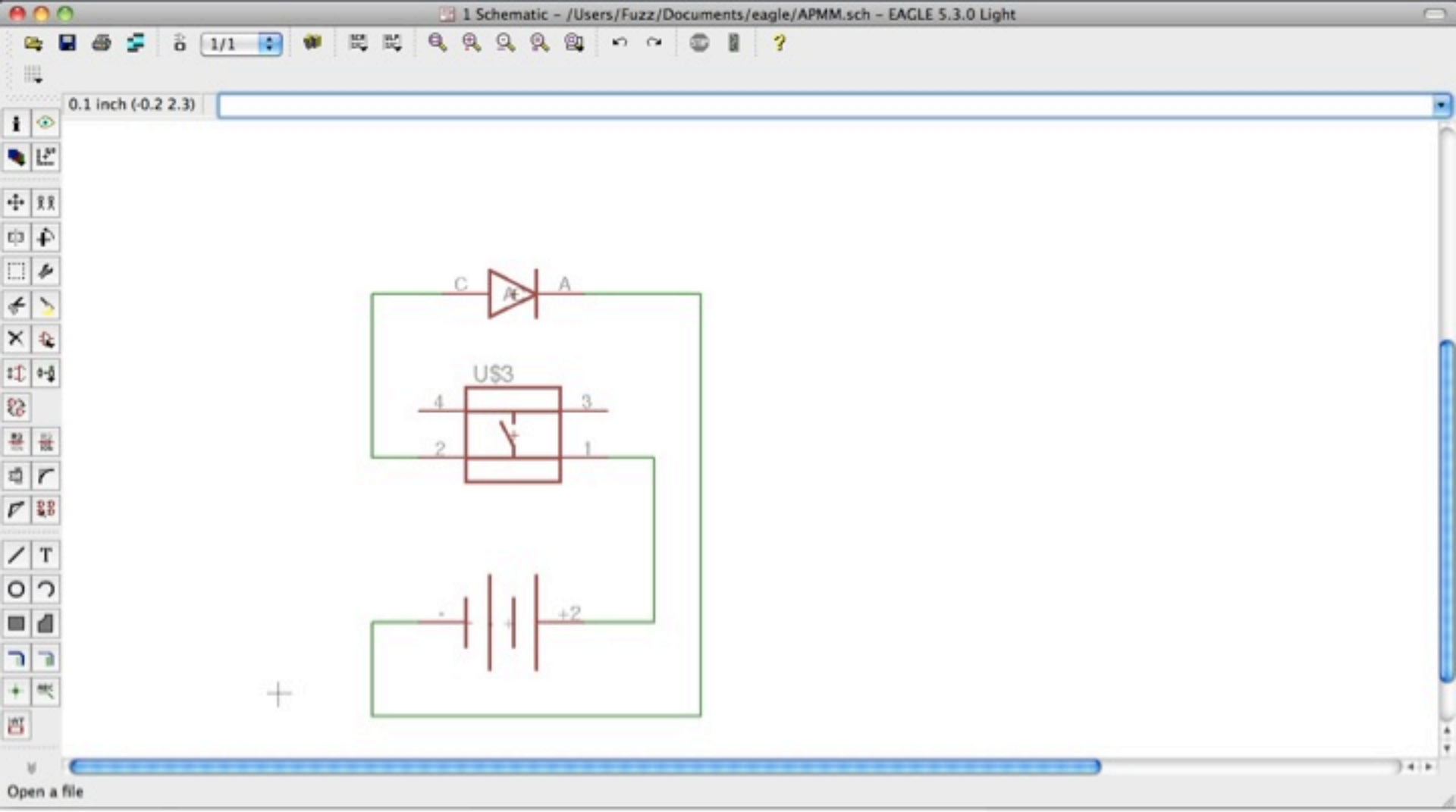




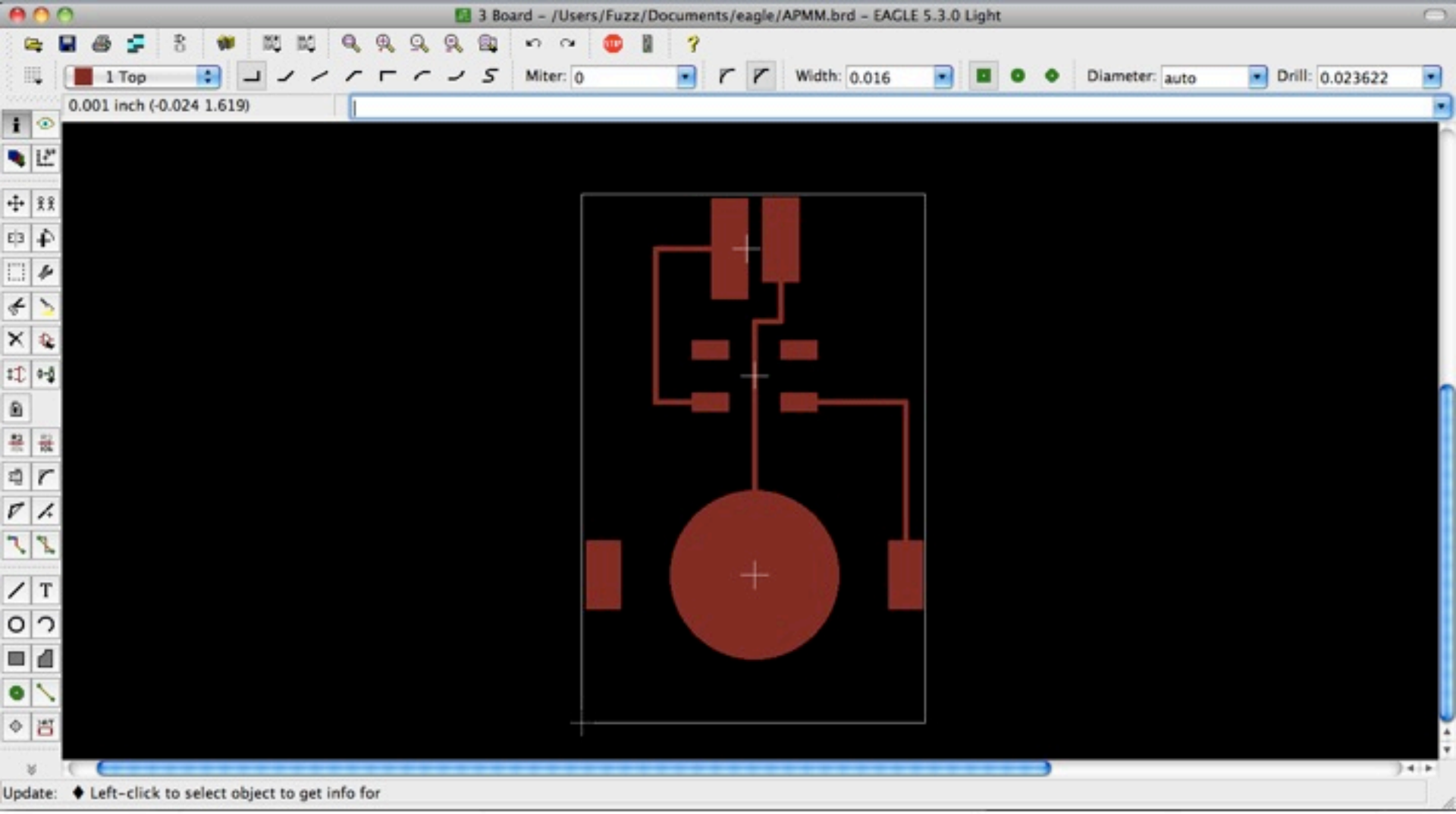
CAD – Solidworks



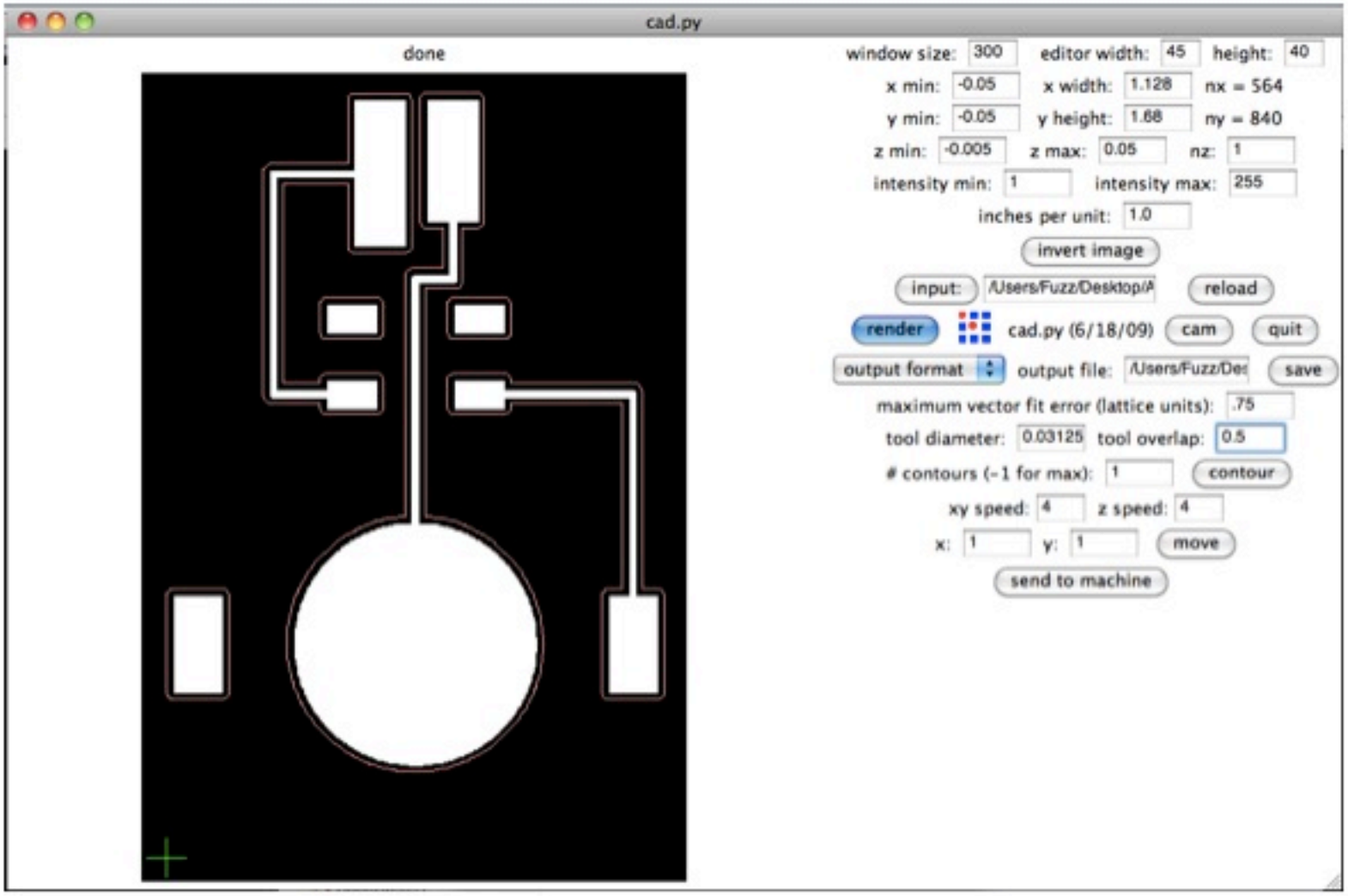
Top projection → DXF - Rhino



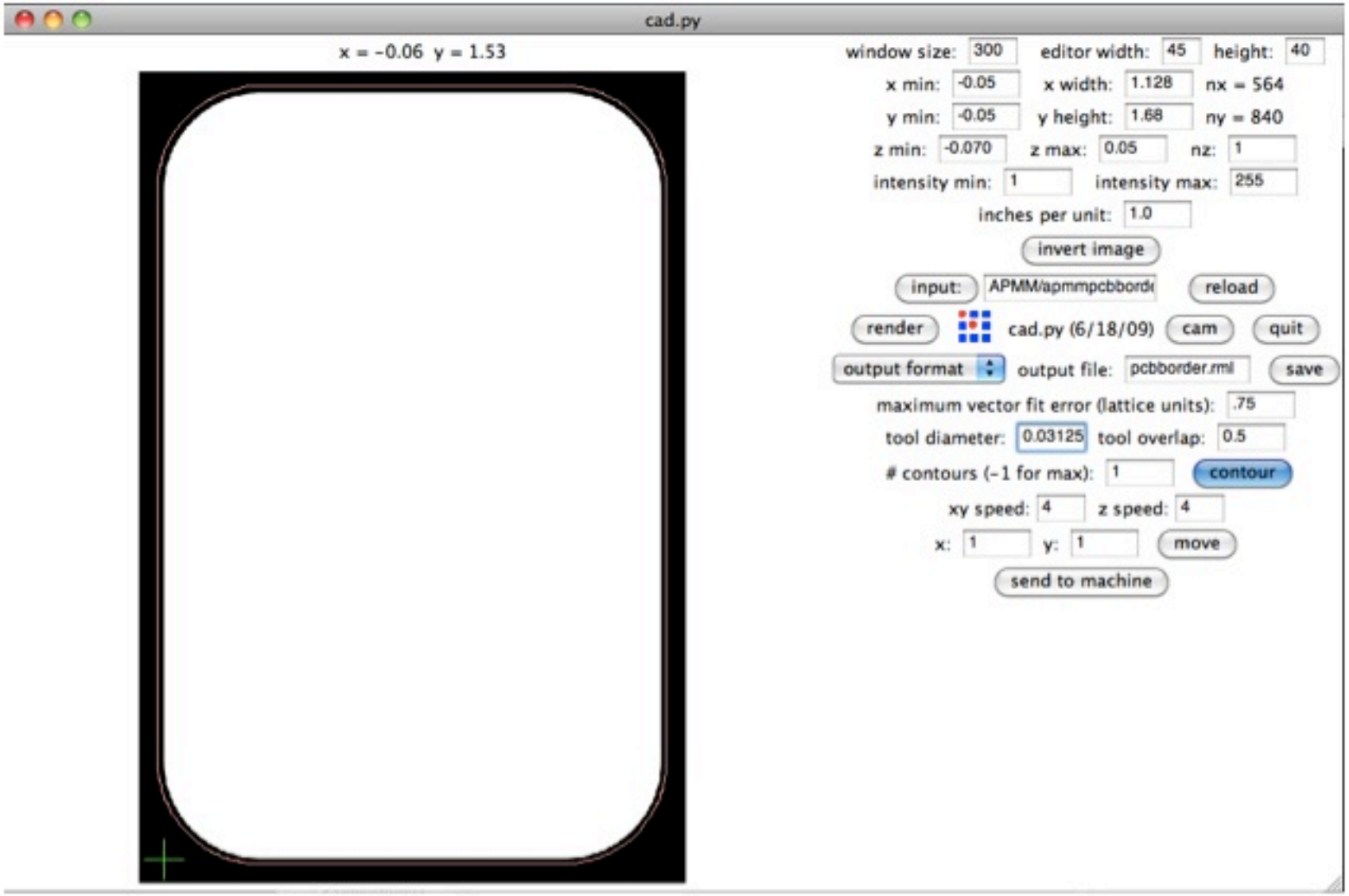
Schematics & PCB Layout – Eagle



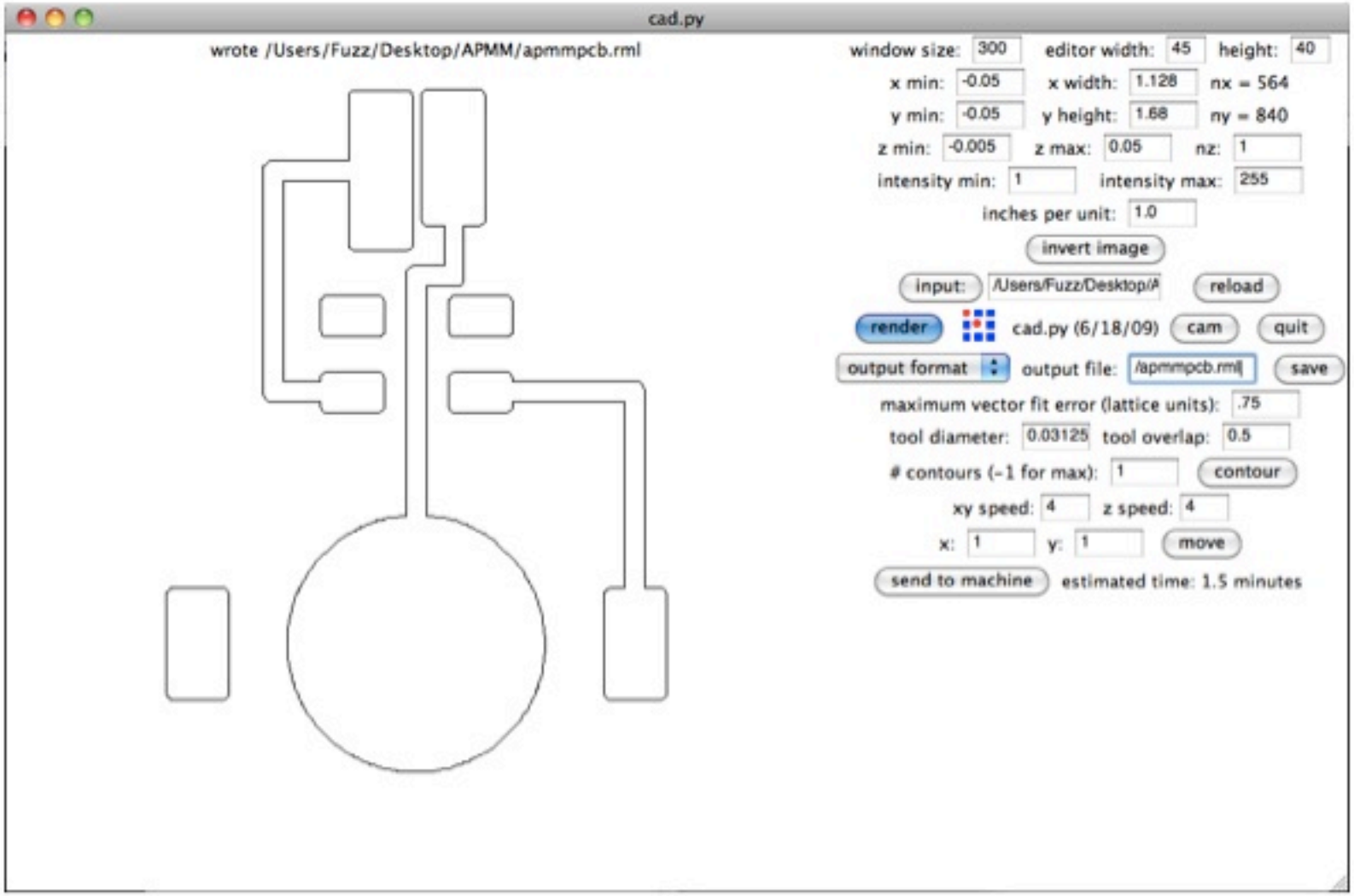
Schematics & PCB Layout – Eagle



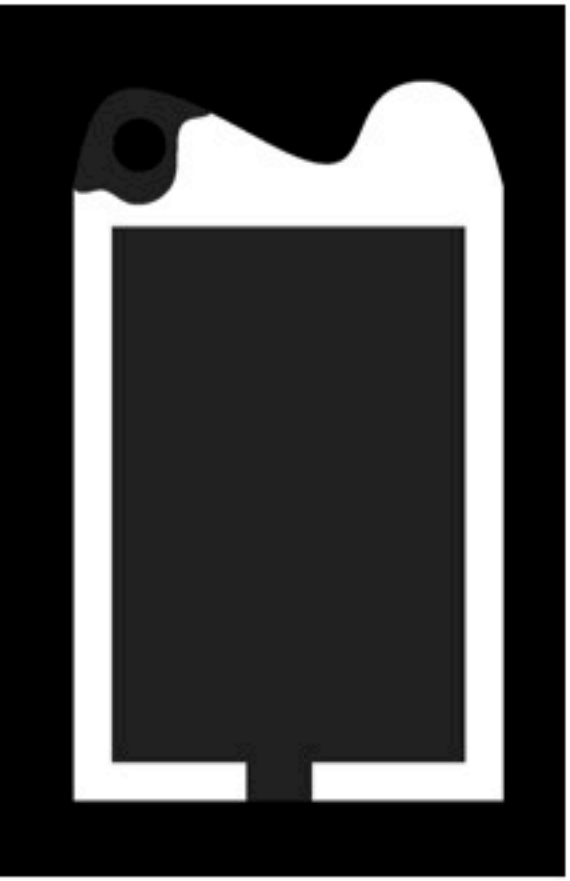
Cad.py – PCB layout

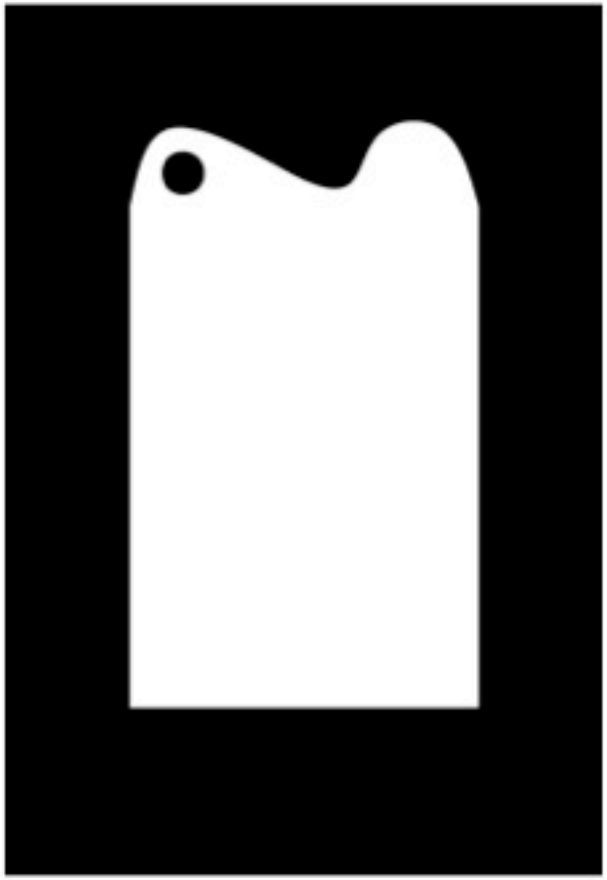


Cad.py – Border layout



Cad.py – Toolpath





Keyfob enclosure toolpath

keyfob_enclosure_unified.ngc - AXIS 2.3.0 on mtmadam

File Machine View Help

Manual Control [F3] MDI [F5]

Axis: X Y Z

Continuous

Home Axis Touch Off

Spindle:

Preview DRO

X: 0.0000
Y: 0.0000
Z: 0.0000
Vel: 0.0000

Feed Override: 100 %
Spindle Override: 100 %
Jog Speed: 5.8 in/min
Max Velocity: 30 in/min

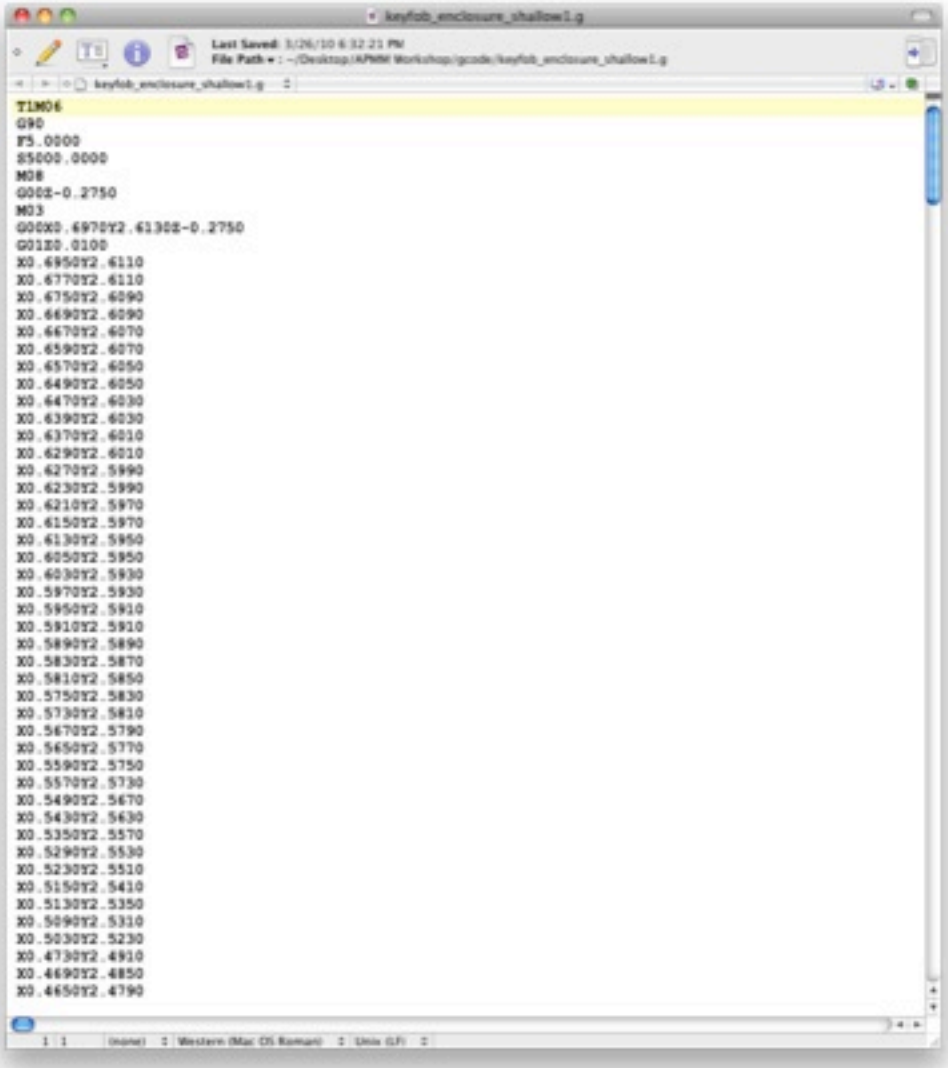
```
1: T1M06
2: G90
3: F5.0000
4: S5000.0000
5: M08
6: G00Z0.0500
7: M03
8: G00X0.7230Y2.6150Z0.0500
9: G01Z0.0500
```

ESTOP | No tool | Position: Relative Actual

Applications Places System

Natan Linder Sat Mar 27, 1:04 PM

keyfob_enclosure_un...


keyfob_enclosure_shallow1.g
Last Saved: 3/26/10 6:32:21 PM
File Path: ~/Desktop/APMM Workshop/gcode/keyfob_enclosure_shallow1.g
T1M06
G90
F5.0000
S5000.0000
M08
G00Z-0.2750
M03
G00X0.6970Y2.6130Z-0.2750
G01Z0.0100
X0.6950Y2.6110
X0.6770Y2.6110
X0.6750Y2.6090
X0.6690Y2.6090
X0.6670Y2.6070
X0.6590Y2.6070
X0.6570Y2.6050
X0.6490Y2.6050
X0.6470Y2.6030
X0.6390Y2.6030
X0.6370Y2.6010
X0.6290Y2.6010
X0.6270Y2.5990
X0.6230Y2.5990
X0.6210Y2.5970
X0.6150Y2.5970
X0.6130Y2.5950
X0.6050Y2.5950
X0.6030Y2.5930
X0.5970Y2.5930
X0.5950Y2.5910
X0.5910Y2.5910
X0.5890Y2.5890
X0.5830Y2.5870
X0.5810Y2.5850
X0.5750Y2.5830
X0.5730Y2.5810
X0.5670Y2.5790
X0.5650Y2.5770
X0.5590Y2.5750
X0.5570Y2.5730
X0.5490Y2.5670
X0.5430Y2.5630
X0.5350Y2.5570
X0.5290Y2.5530
X0.5230Y2.5510
X0.5150Y2.5410
X0.5130Y2.5350
X0.5090Y2.5310
X0.5030Y2.5230
X0.4730Y2.4910
X0.4690Y2.4850
X0.4650Y2.4790

gcode

DEMO