Cornell University

Computational Synthesis

Fab@Home

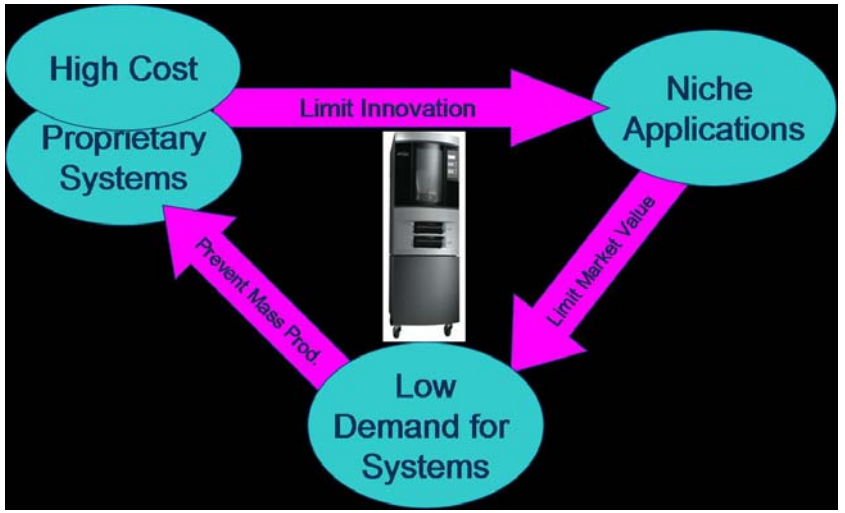
The Personal Desktop Fabricator Kit

Evan Malone, Hod Lipson, Max Lobovsky, Dan Periard, Jennifer Yao, etc.

The Fab@Home Project

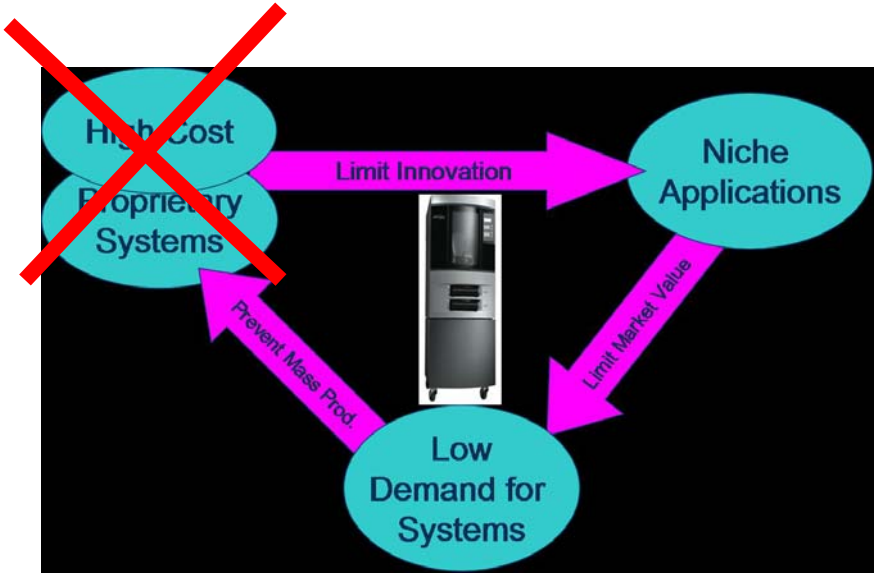
The Challenge:

How to break SFF/RP free of the high-cost/niche application trap, and help to realize the potential of personal fabrication?

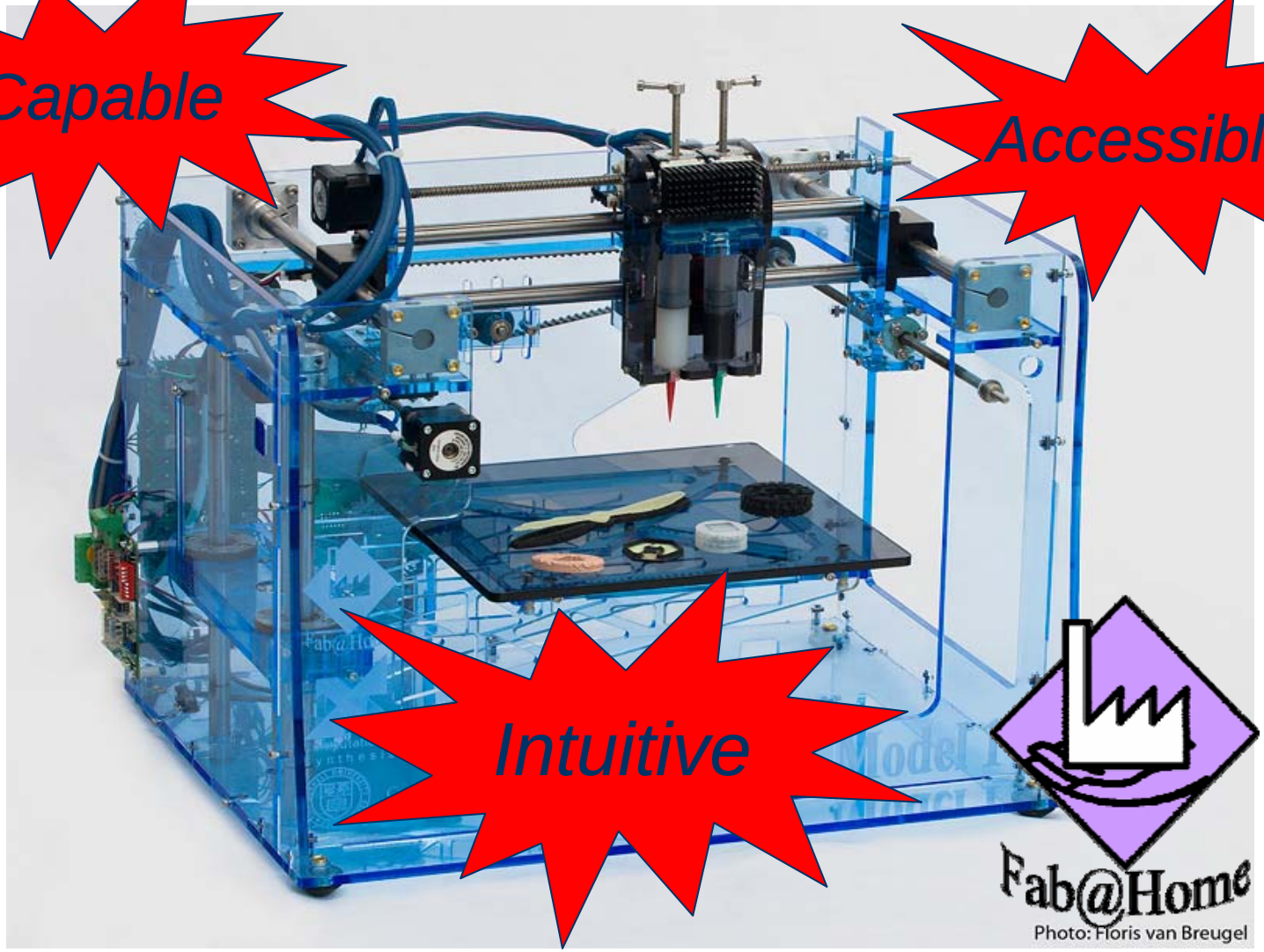


The Fab@Home Response:

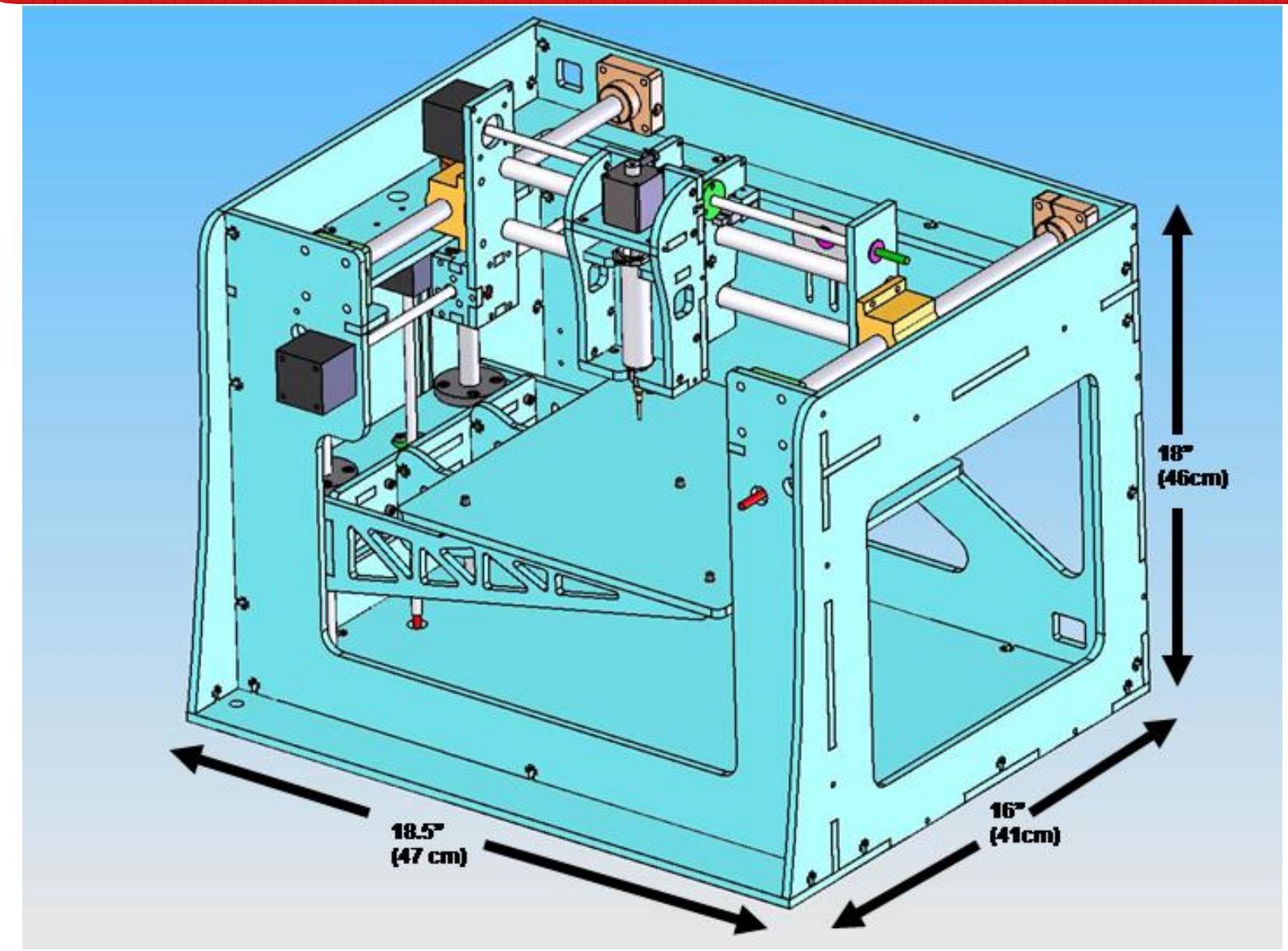
Put cheap, open-architecture "fabbers" into the hands of hobbyists and hackers, and let them improve the technology and invent applications!



Philosophy

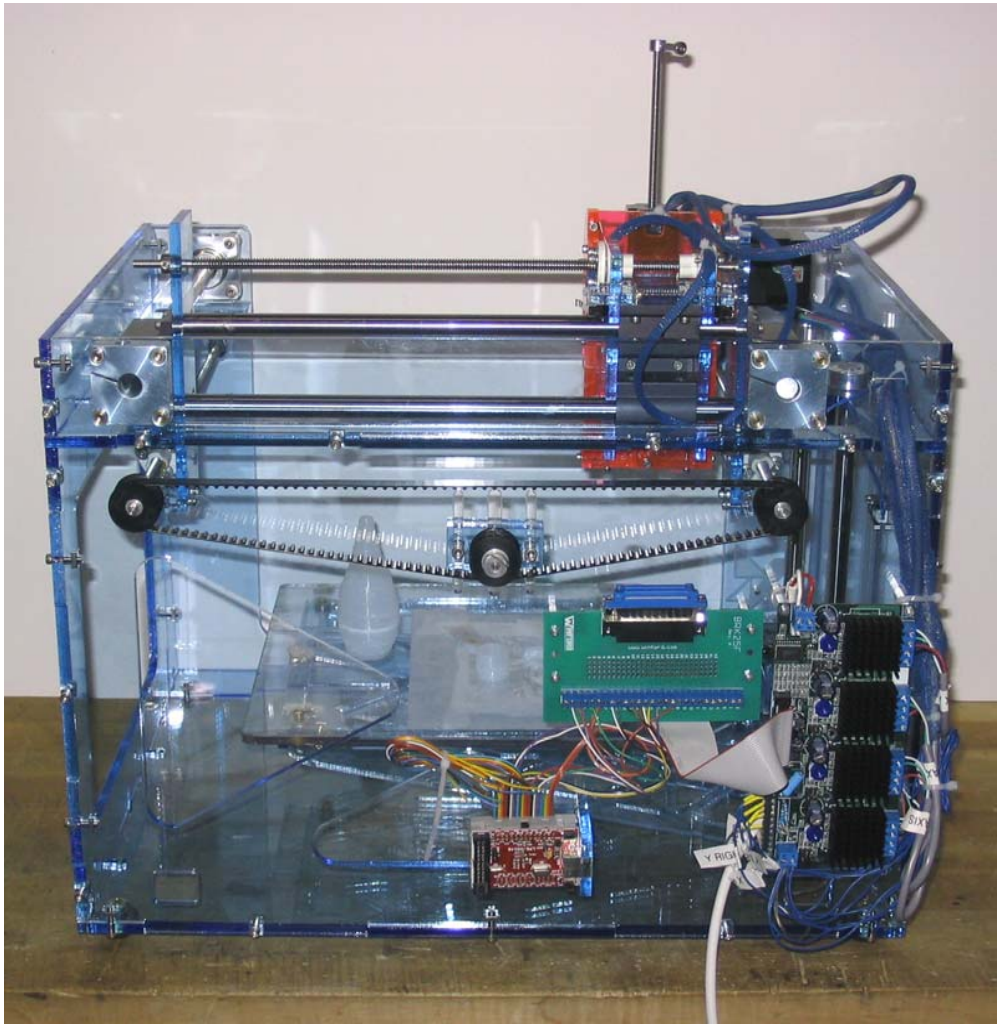

Capable
Accessible
Intuitive
Fab@Home
Photo: Floris van Breugel

Technical Details - Mechanical



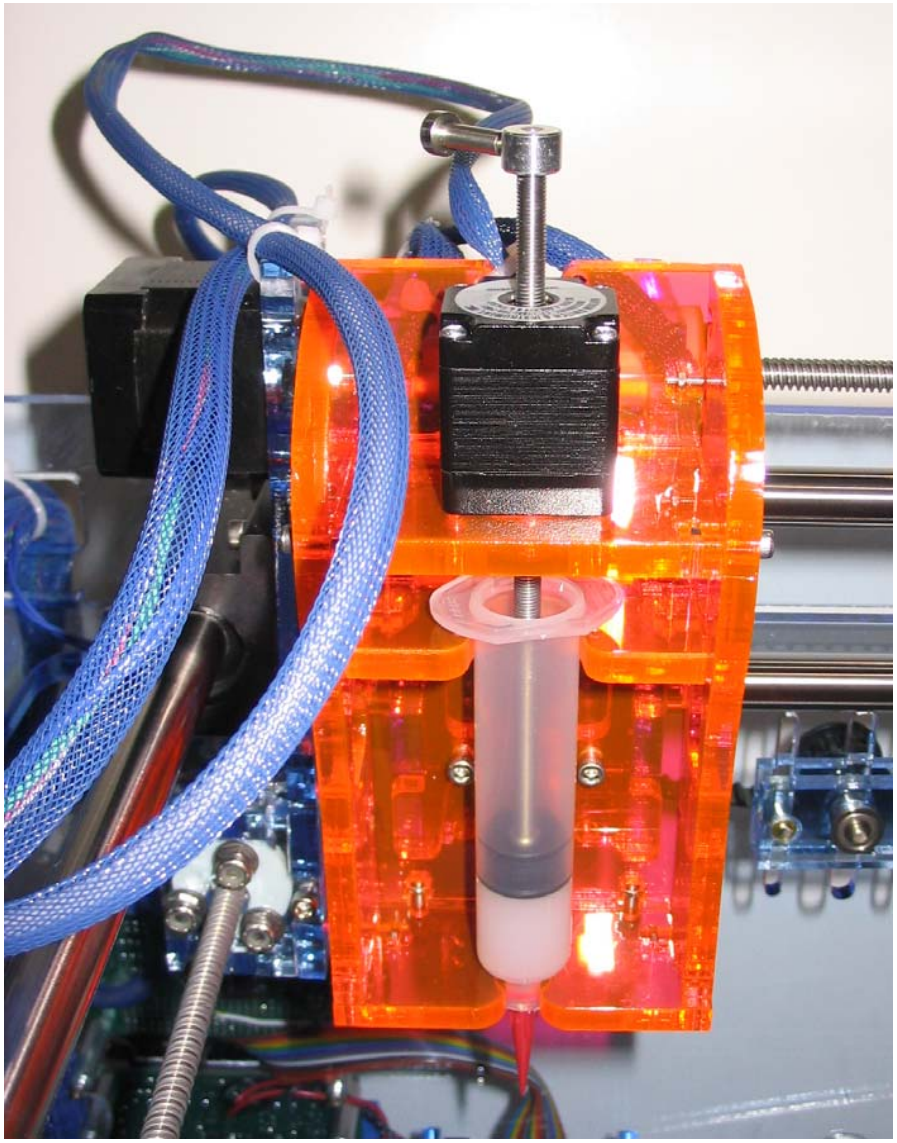
Technical Details - Mechanical

- XY Gantry, Z Table – Cartesian
  - Low XY inertia
  - Minimize object accel.
- 3 BP step motors with integrated lead screws (HSI Inc.)
  - Easy assembly
  - Expensive
- Timing belt couples X-slave axis
- Snap-together acrylic frame
  - Readily available
  - Brittle
- Sized for desktop
  - ~12 kg
  - ~0.5 m (L, W, H)
  - Mix of SI and Imp. units



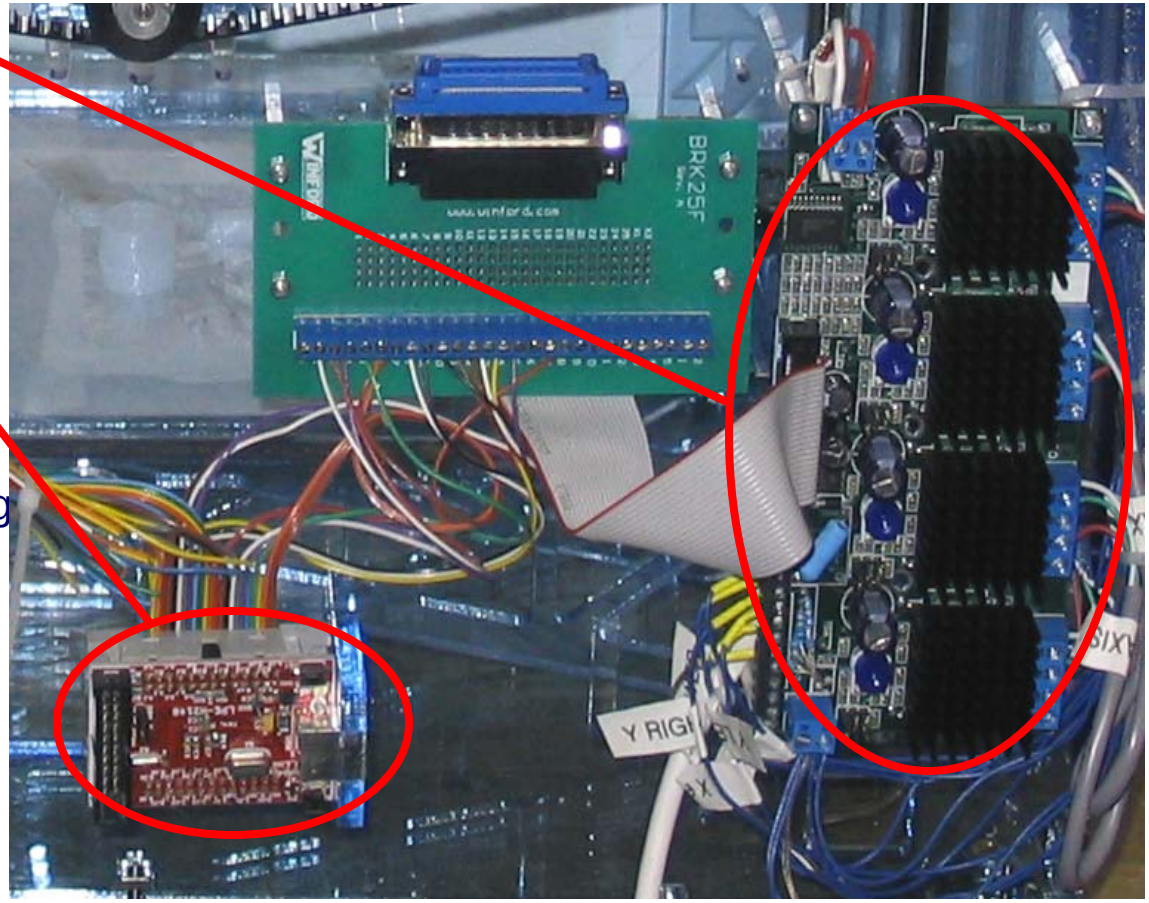
Technical Details – Deposition Tool

- Motorized syringe-pump(s)
  - HSI non-captive BP stepper
  - ~60PSI/~400kPa max
  - threads into nut in piston
- Plastic syringe barrels
- Quick “snap-in”
- Positive displacement reduces viscosity + friction senstivity -> “Any material”
- Syringes too small for large jobs

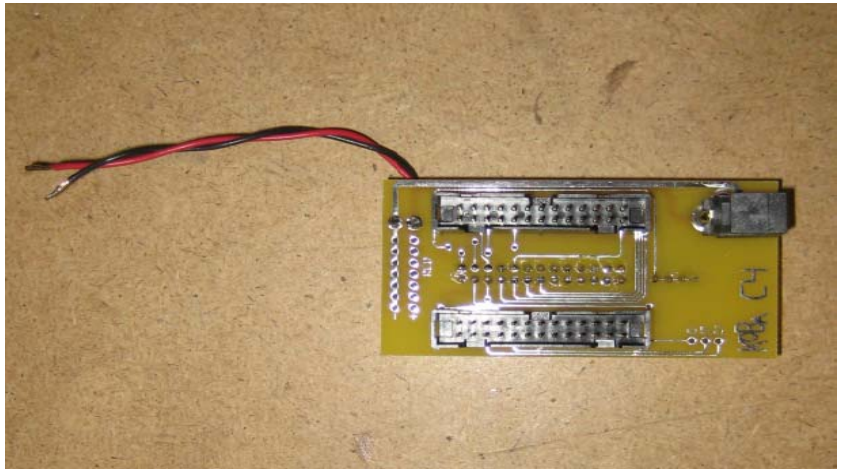


Technical Details - Electronics

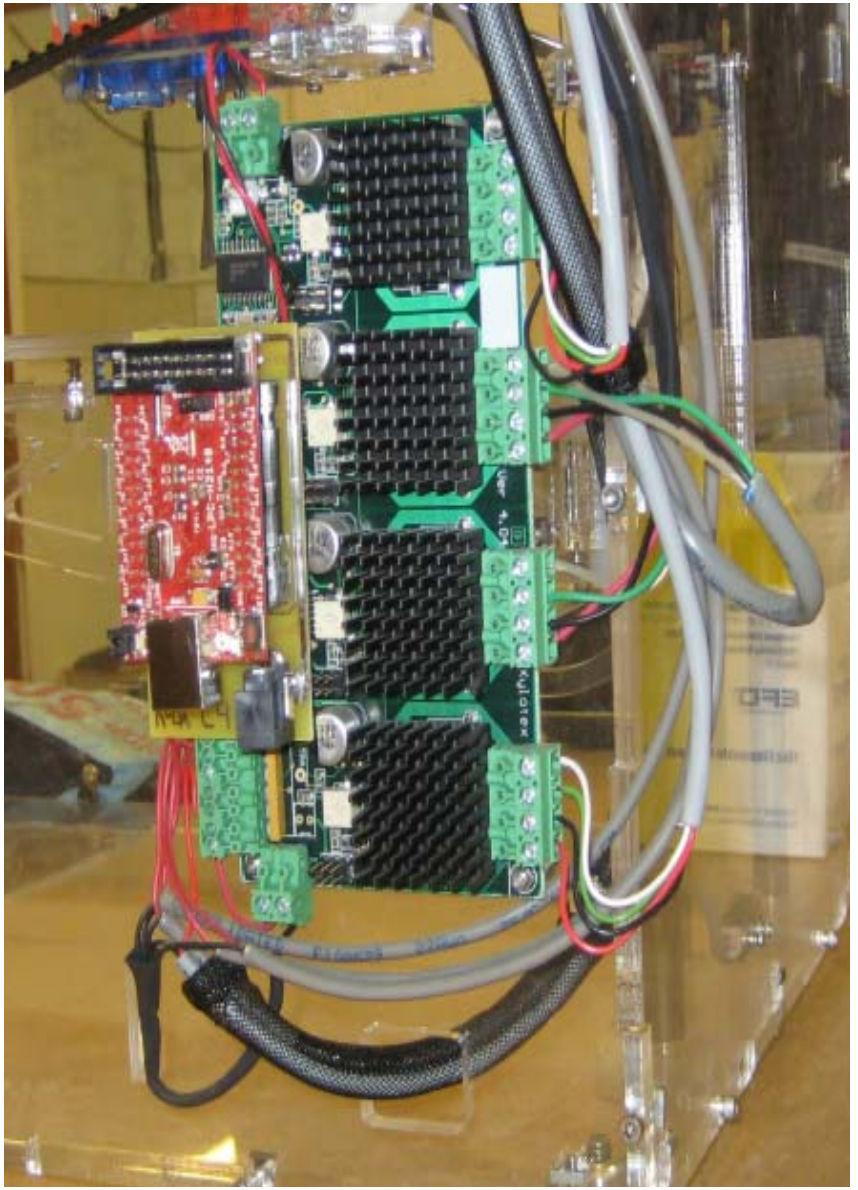
- Stepper amplifier
  - 4 axes
  - Bipolar
  - 1/8 stepping
  - 35V, 2.5A/ph max
- Microcontroller
  - ARM7 RISC
  - USB interface
  - A/D, D/A, SPI, etc.
  - JTAG programming
- Screw terminals
- Break-out board
- 24VDC / 30W global PS
- Strip & tin & screw assembly
- Wiring errors common



Electronics Improvements

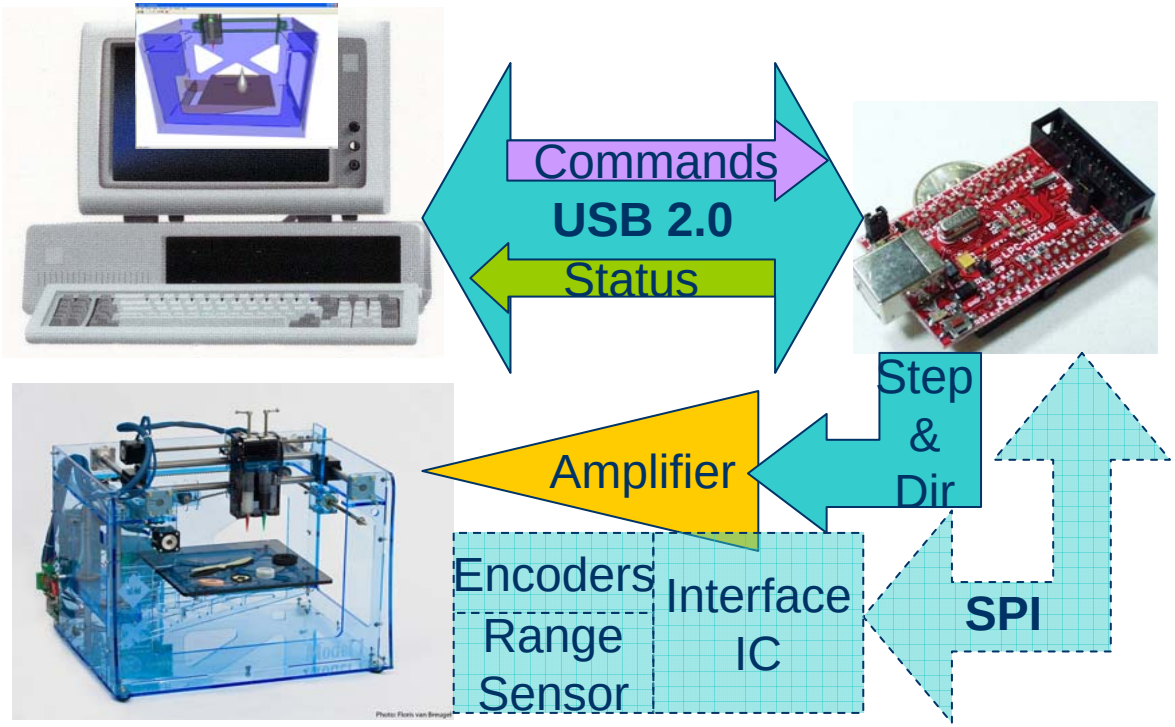


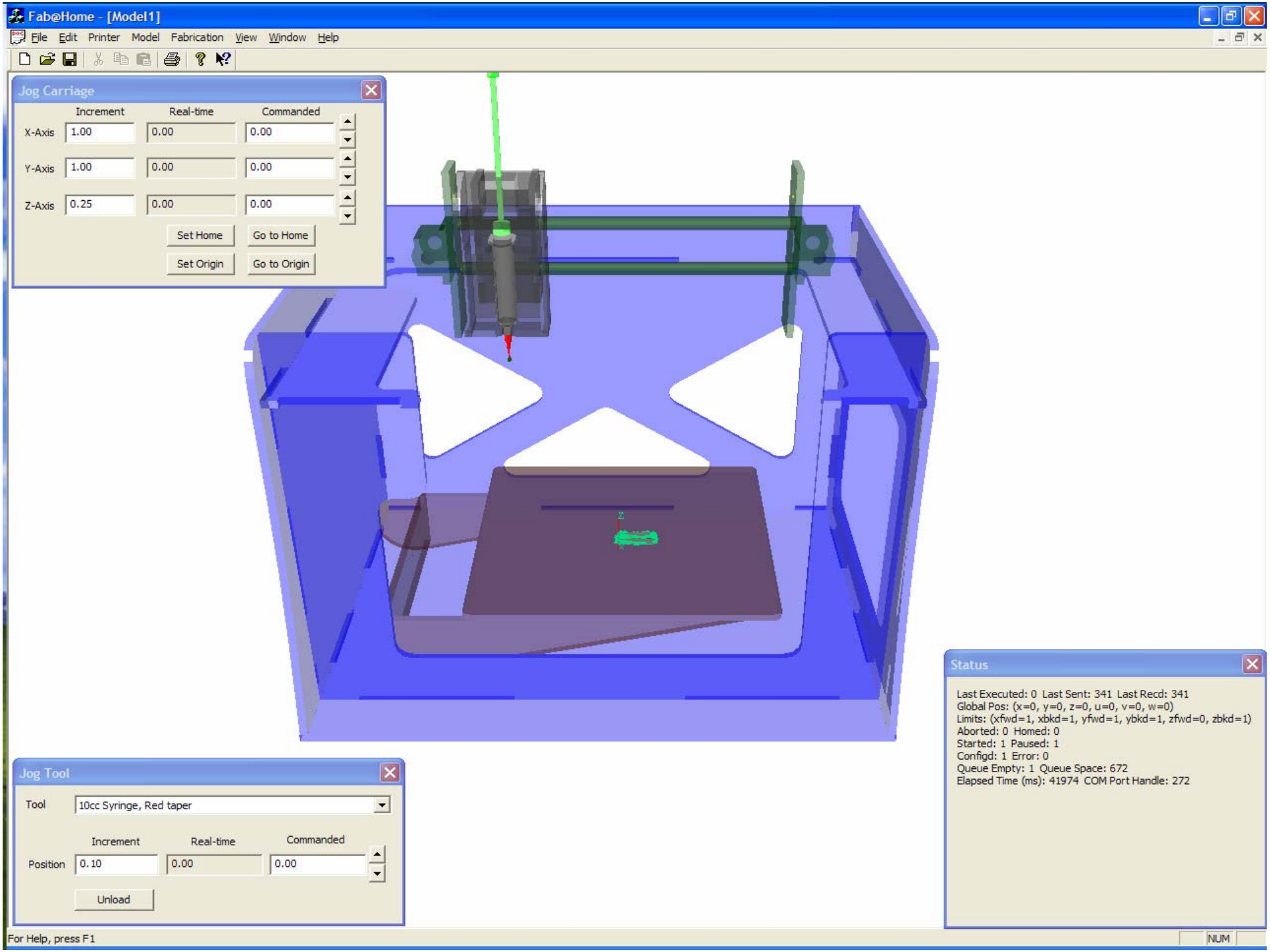
- Eliminate ribbon cables and breakout board
- Use power supply connector rather than cutting off
- Needs improved mechanical attachment
- USB noise sensitivity -> need electronics box
- Connectorize for 8P8C (LAN) cables?

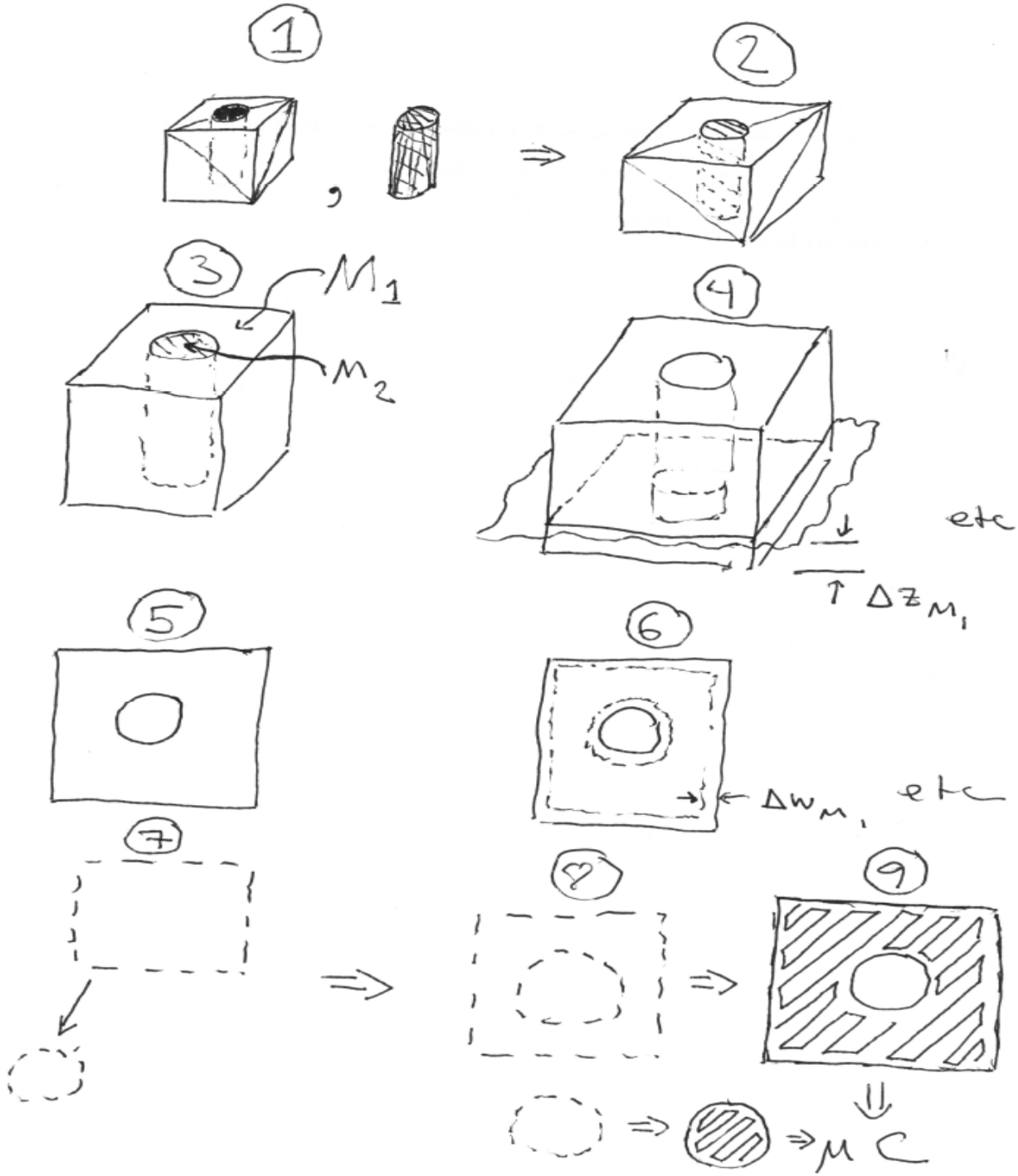


Control

- PC application
  - Win PC target
  - OpenGL GUI ~ WYSWYG
  - Intuitive operation and GUI
  - Import and process STLs
  - Multi-material assembly
- Firmware
  - Bidirectional packet USB2.0 comms
    - Status + commands
  - Queued and immediate commands
  - Queue ~ 700 6 dimensional path segments
  - Open loop steppers

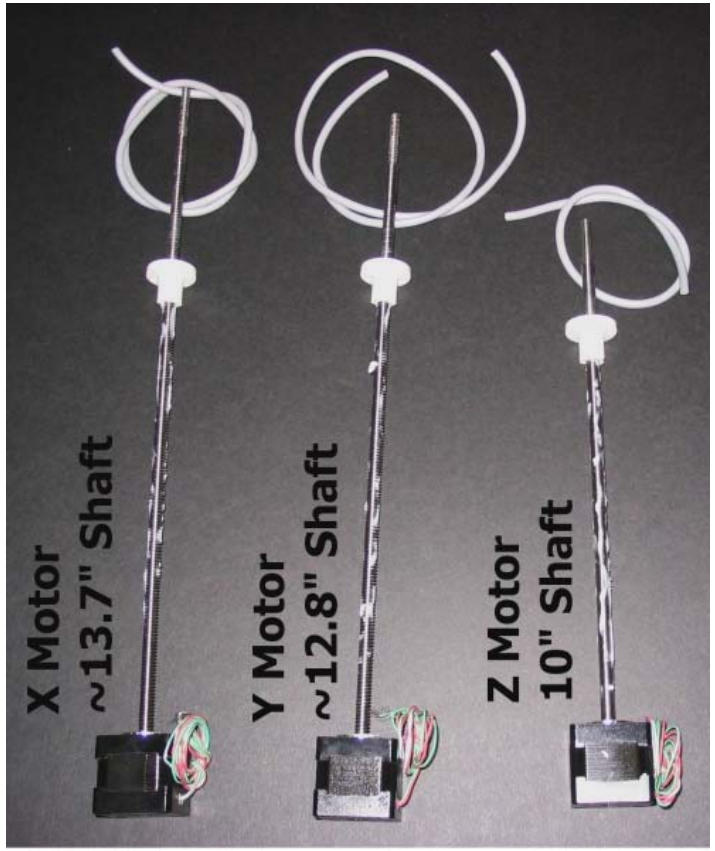


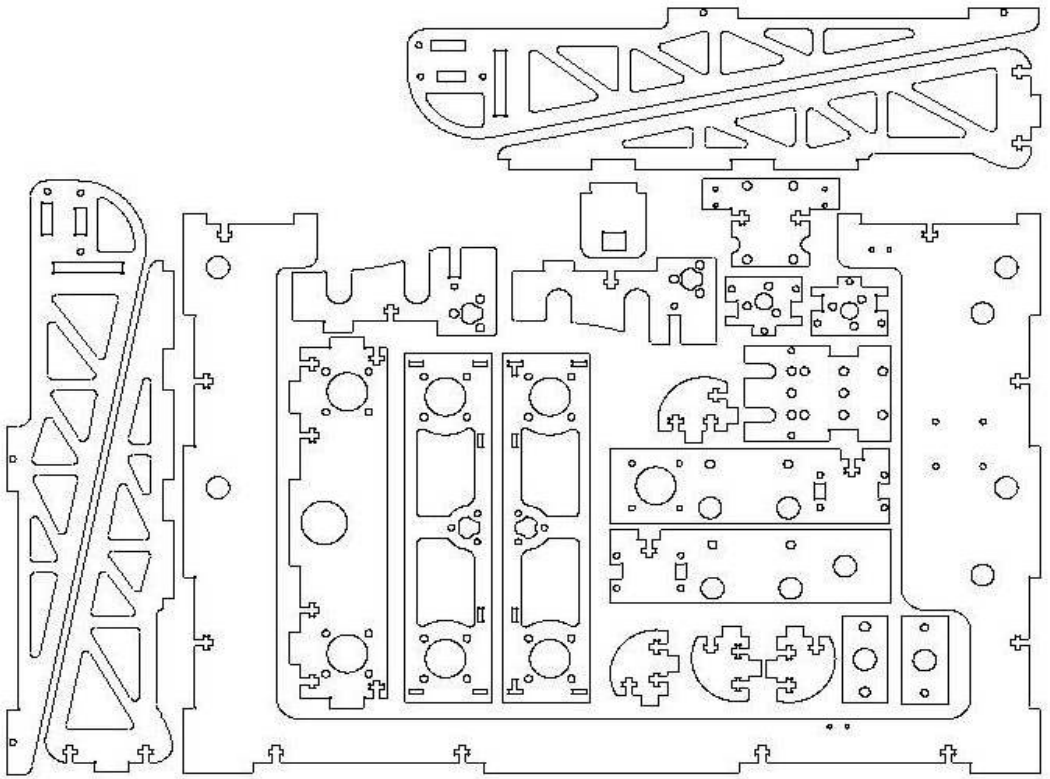

Fab@Home - [Model1]
File Edit Printer Model Fabrication View Window Help
Jog Carriage
Increment Real-time Commanded
X-Axis 1.00 0.00 0.00
Y-Axis 1.00 0.00 0.00
Z-Axis 0.25 0.00 0.00
Set Home
Go to Home
Set Origin
Go to Origin
Jog Tool
Tool 10cc Syringe, Red taper
Increment Real-time Commanded
Position 0.10 0.00 0.00
Unload
Status
Last Executed: 0 Last Sent: 341 Last Recd: 341
Global Pos: (x=0, y=0, z=0, u=0, v=0, w=0)
Limits: (xfwd=1, xbkd=1, yfwd=1, ybkd=1, zfwd=0, zbkd=1)
Aborted: 0 Homed: 0
Started: 1 Paused: 1
Configd: 1 Error: 0
Queue Empty: 1 Queue Space: 672
Elapsed Time (ms): 41974 COM Port Handle: 272
For Help, press F1
NUM



1. Import STL(s)
2. “Model”
3. Apply Materials
4. Slice STL(s) w. mat. params
5. “Layer” boundaries
6. Offset boundaries -> region edges
7. Nest edges in tree
8. “Region”
9. Create Region paths

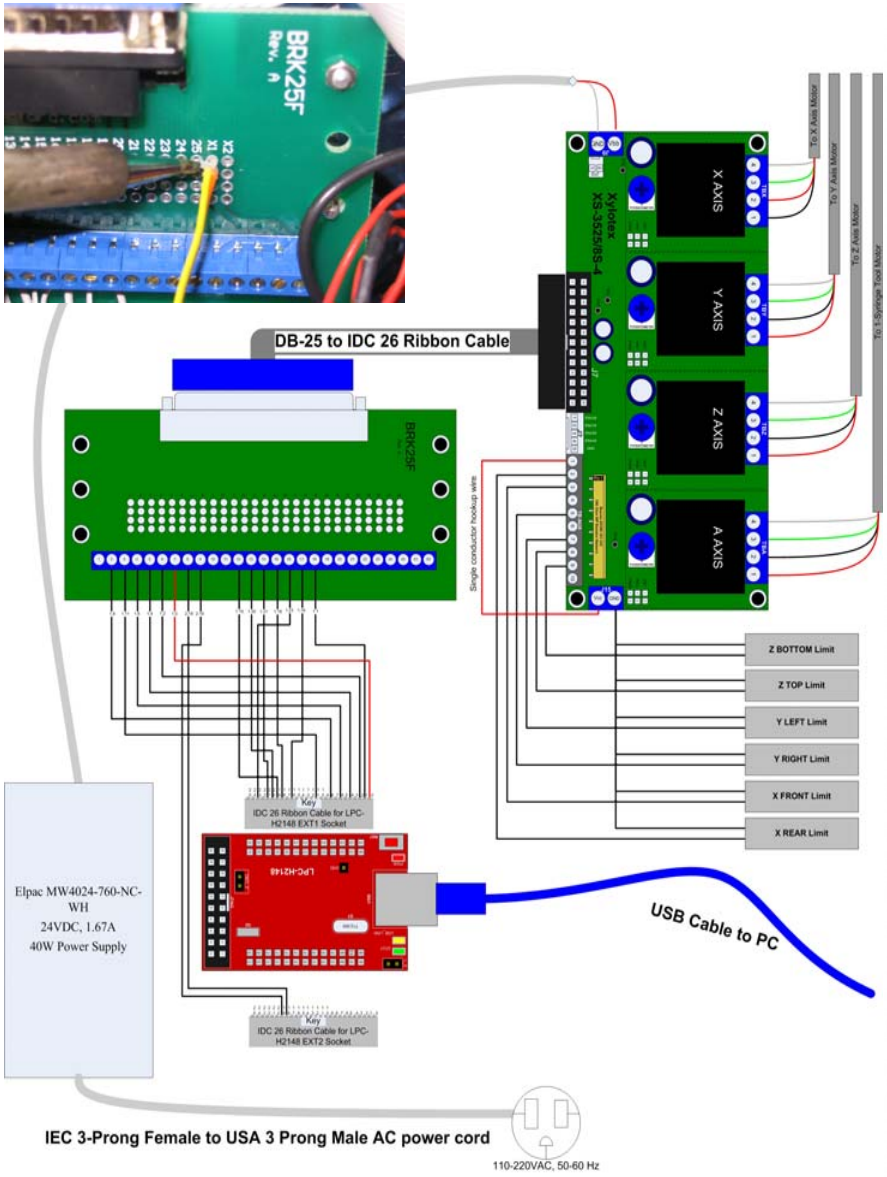
Purchasing / Vendors



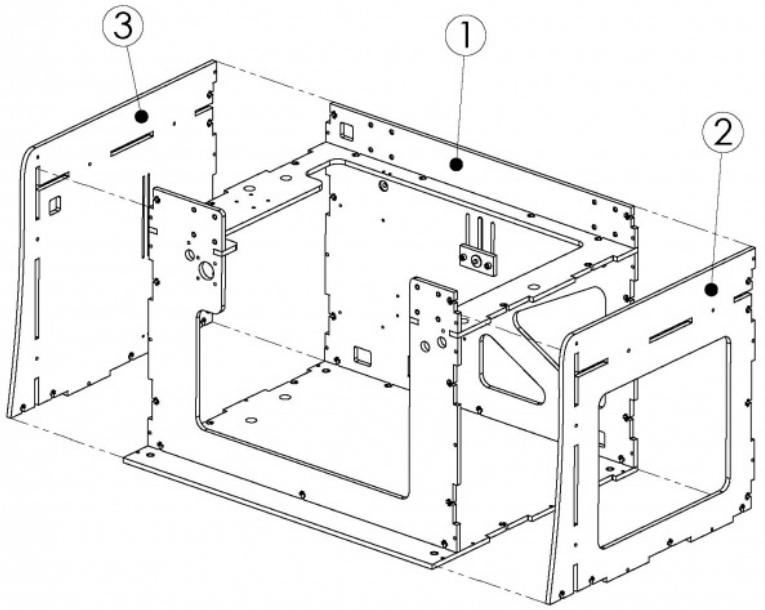


- Most parts off-the-shelf w. pre-filled web orders
- Motors semi-custom “kit” incl. prepared shafts and cables
- Complete kits and assembled machines comm. available

Example Assembly Instructions



Base
Assembly Step 9



ITEM NO.	PART NUMBER	QTY.
1	Base-Step 8	1
2	Base Side Panel, Left, 0.236" THK Laser-cut Acryli	1
3	Base Side Panel, Right, 0.236" THK Laser-cut Acryli	1

Documentation and Collaboration

Fab@Home.org
Project explanation
HW Design docs
BOM/Vendors
Assy. Inst.
User manuals
FAQ/Contacts

SourceForge
App. source
Firmware source
Driver source
Bug tracking
Feature reqs.
Developer Forums

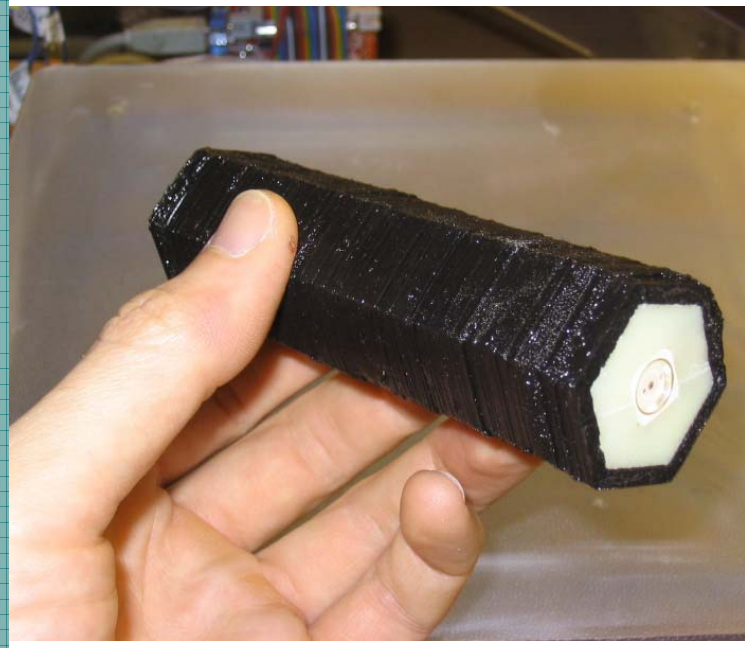
GoogleGroup
Group purchasing
Brainstorming
User-user Q/A

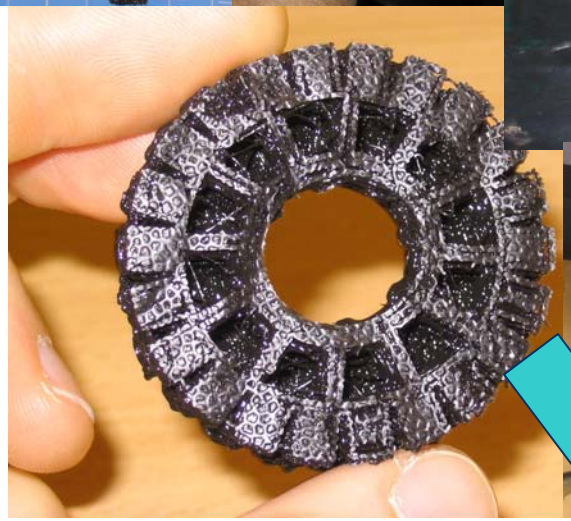
FabAtHome.org:
- Documentation
- Downloads
- Images & Video

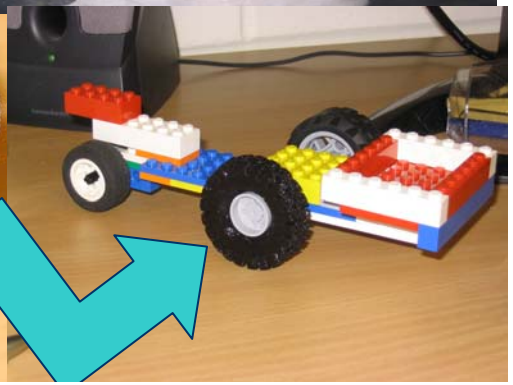
SourceForge.net:
- Collaborative Software Development

GoogleGroups:
- Discussion forum for Users

Rubber and Epoxy Products



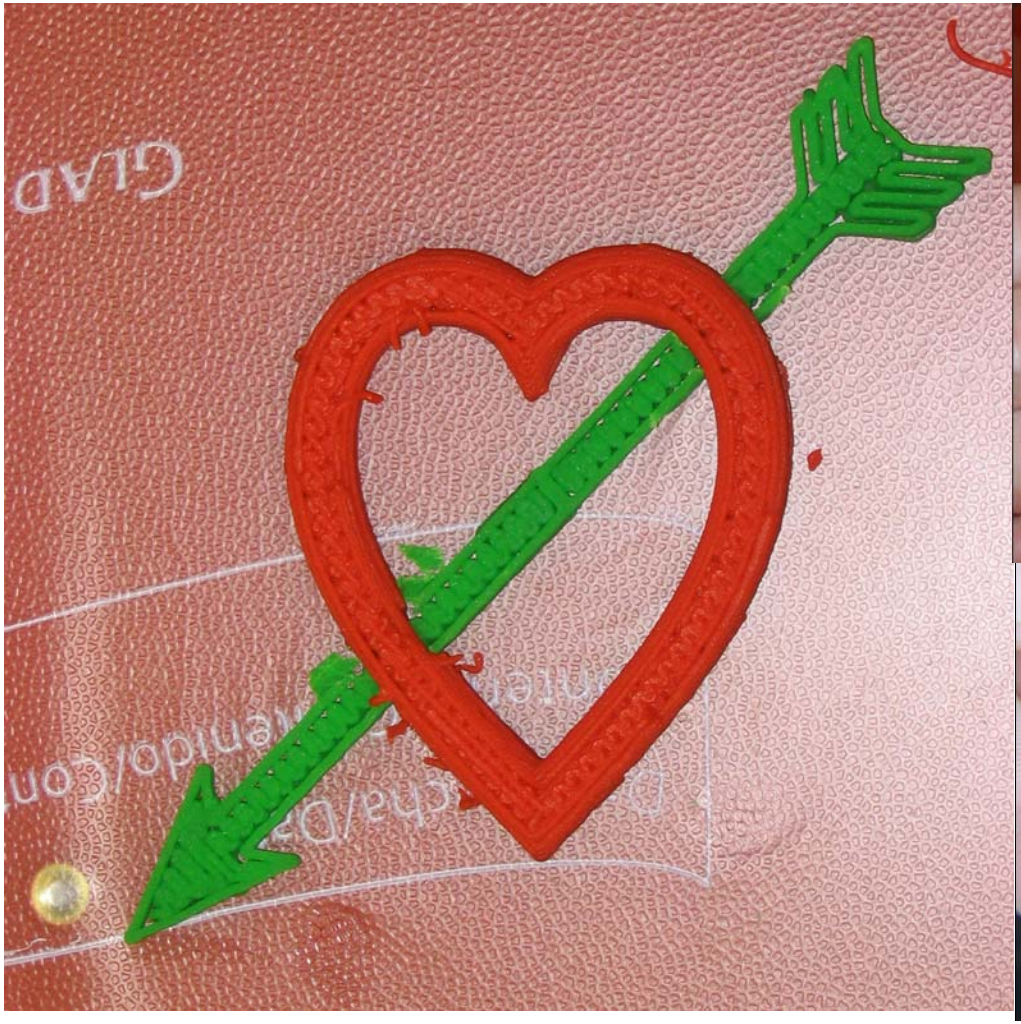




Clockwise from above:

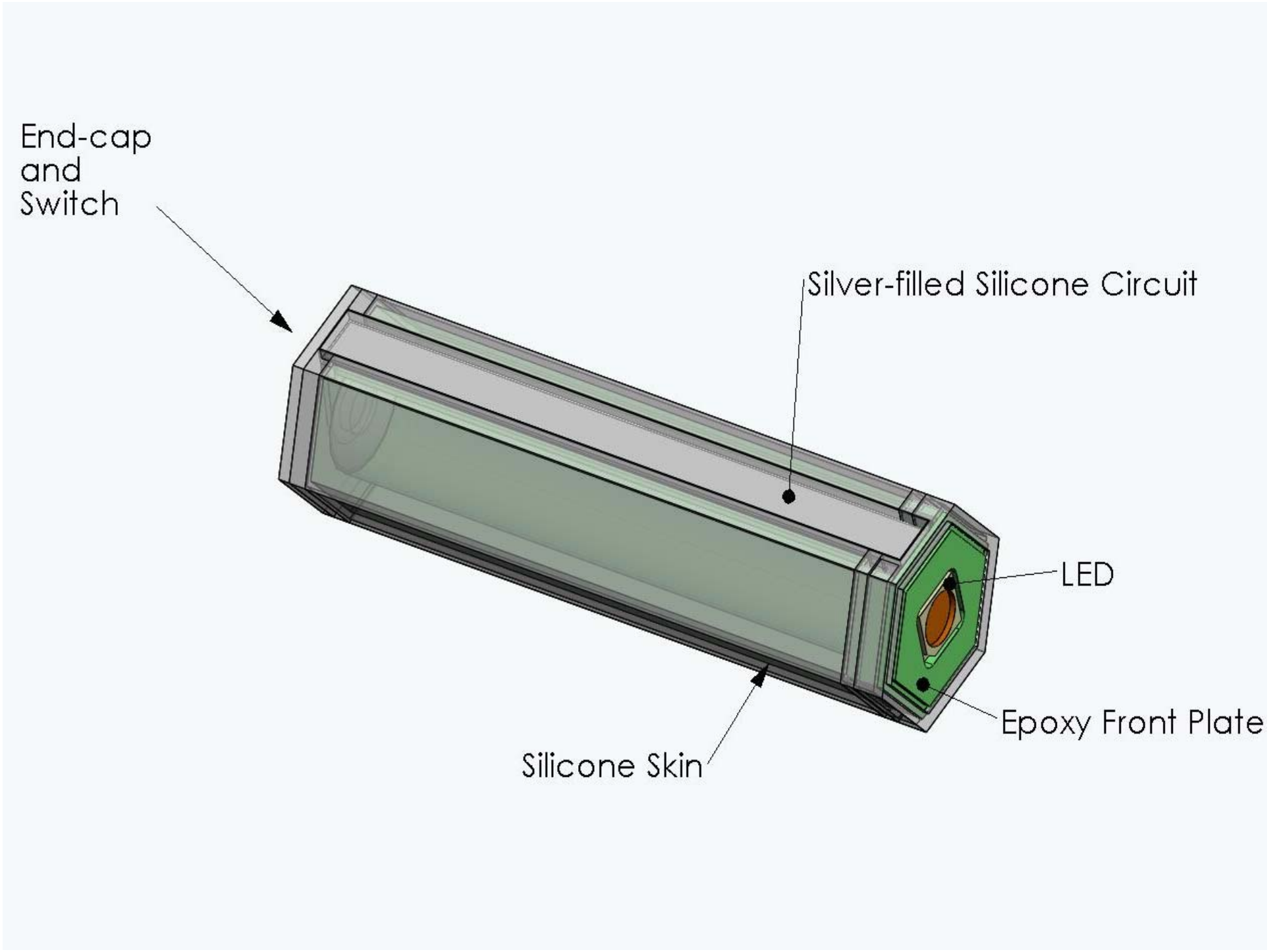
- LED Flashlight
- Epoxy Propeller
- Watchband with embedded watch
- Silicone bottle
- Lego truck sporting replica Lego tire

Food Products

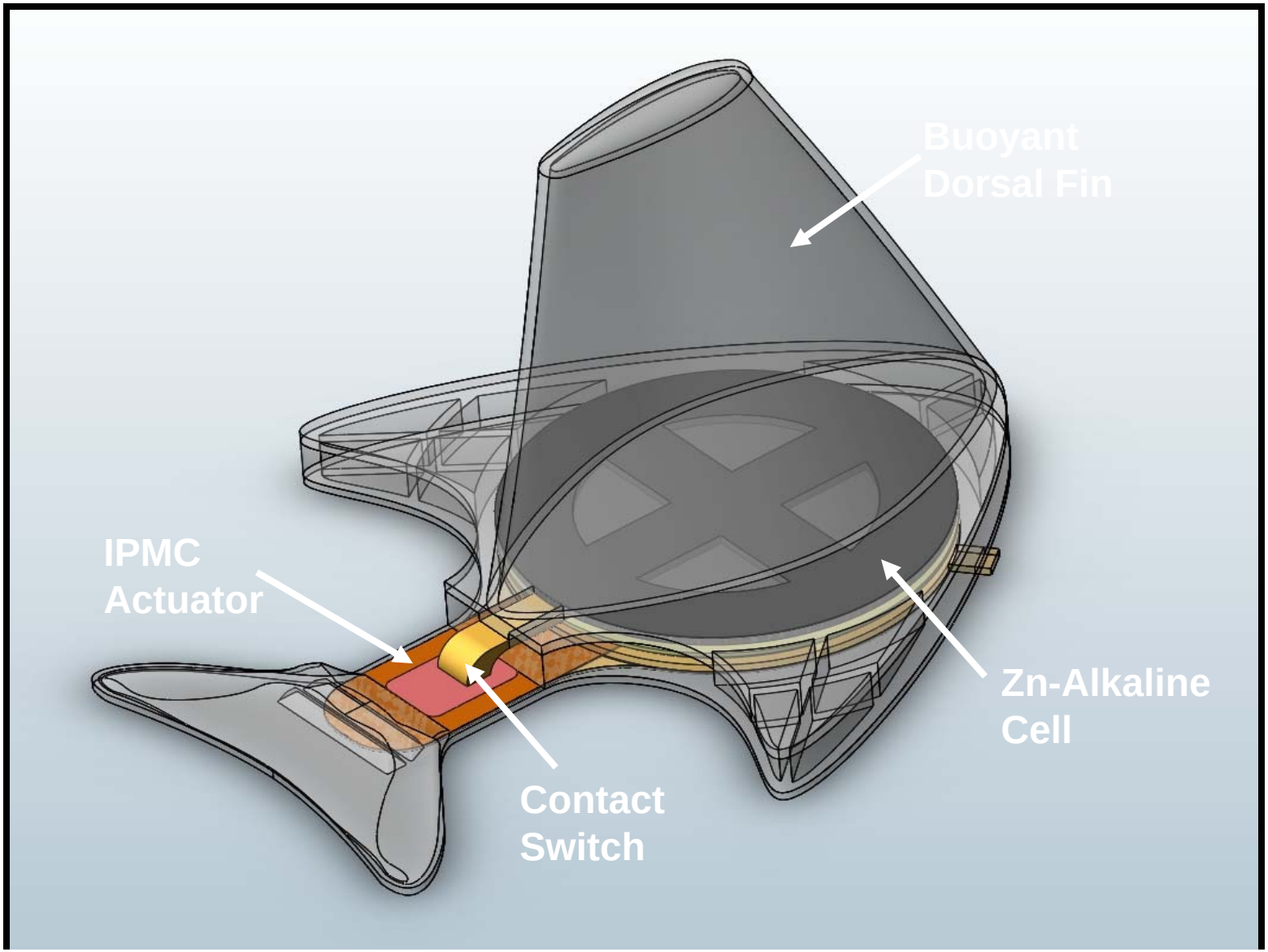


Frosting Cake Decoration, D. Periard, Cornell Univ., NY, USA

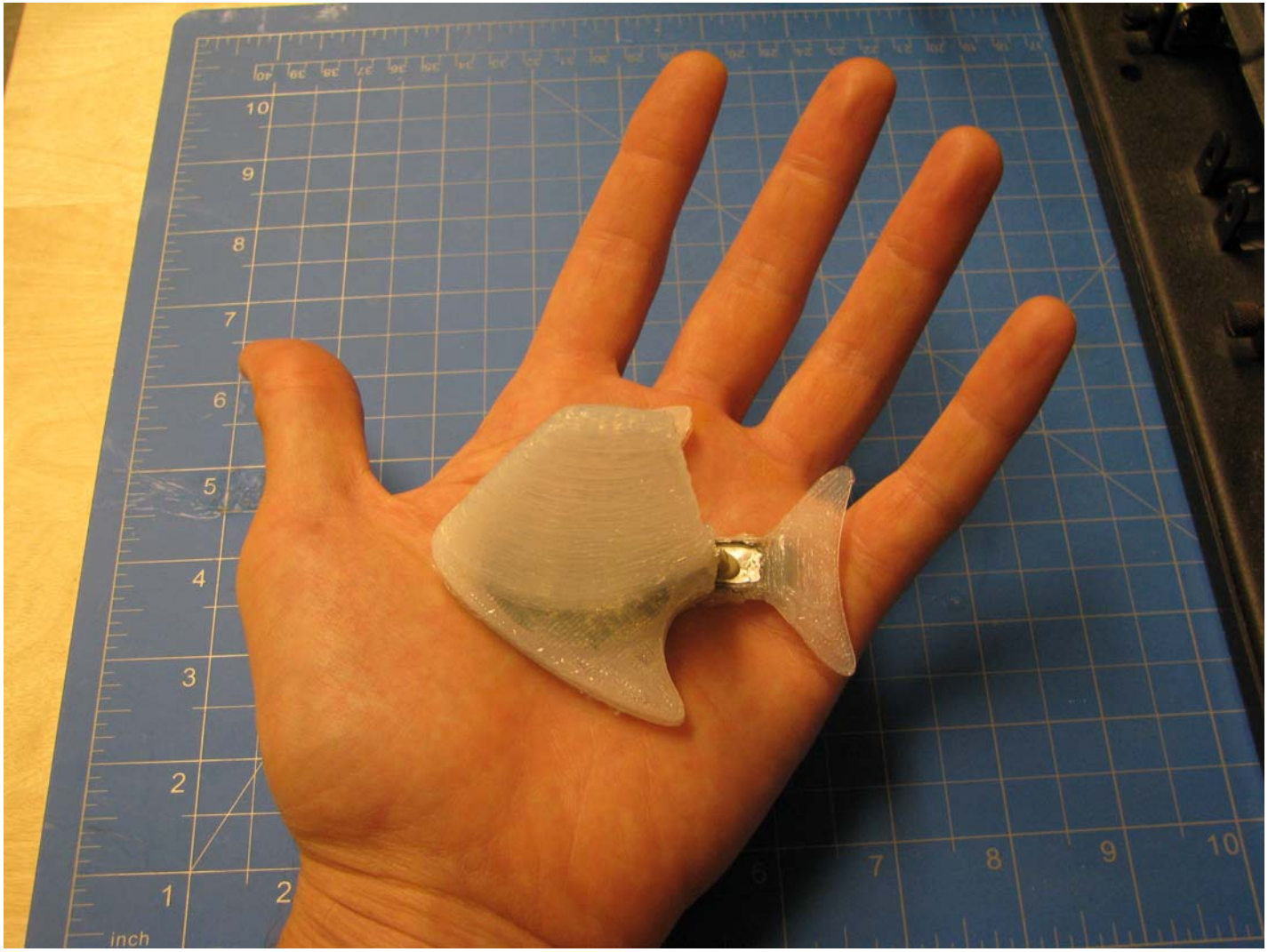
Printed Chocolate, N. Schaal, Manual H.S., KY, USA


End-cap
and
Switch
Silver-filled Silicone Circuit
LED
Epoxy Front Plate
Silicone Skin

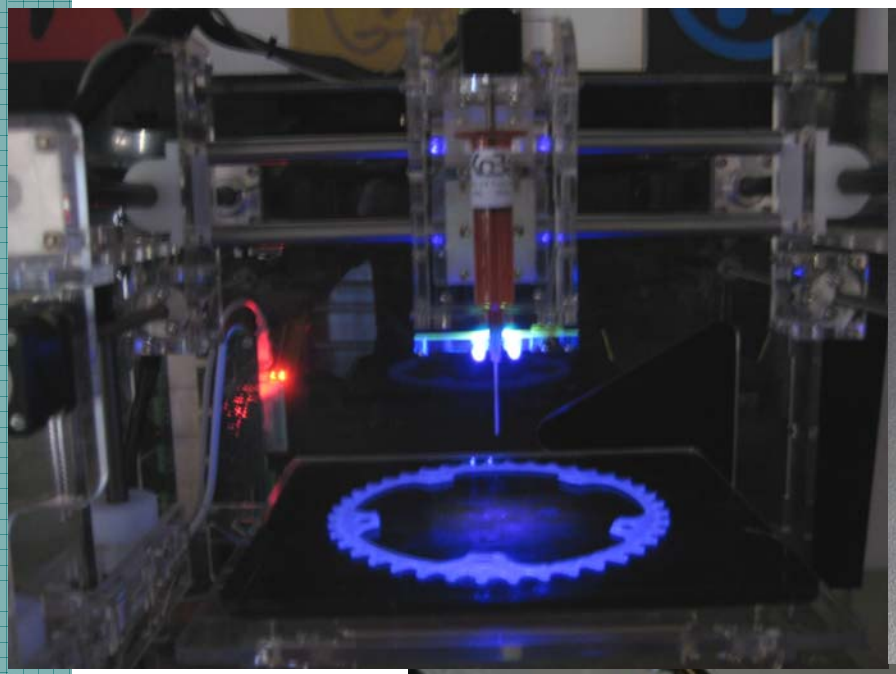
Printed “Fish Robot” Concept



Printed “Fish Robot” Prototype

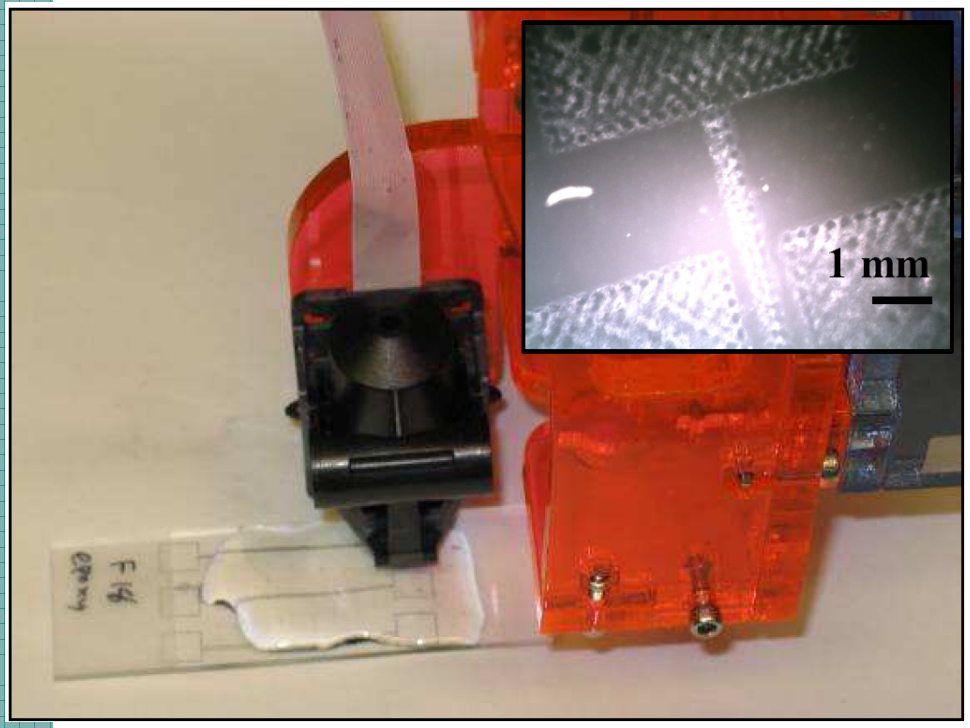


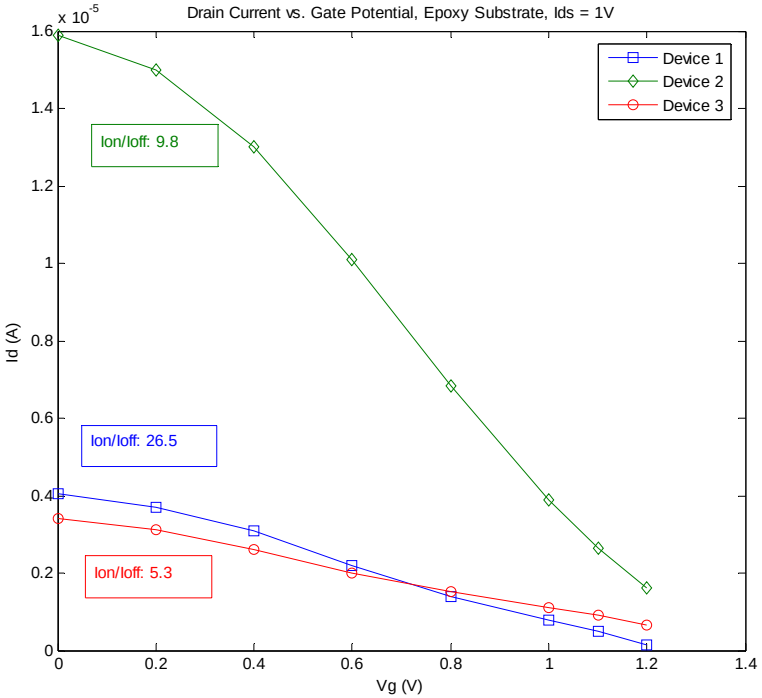
New Process: UV-cure Epoxy



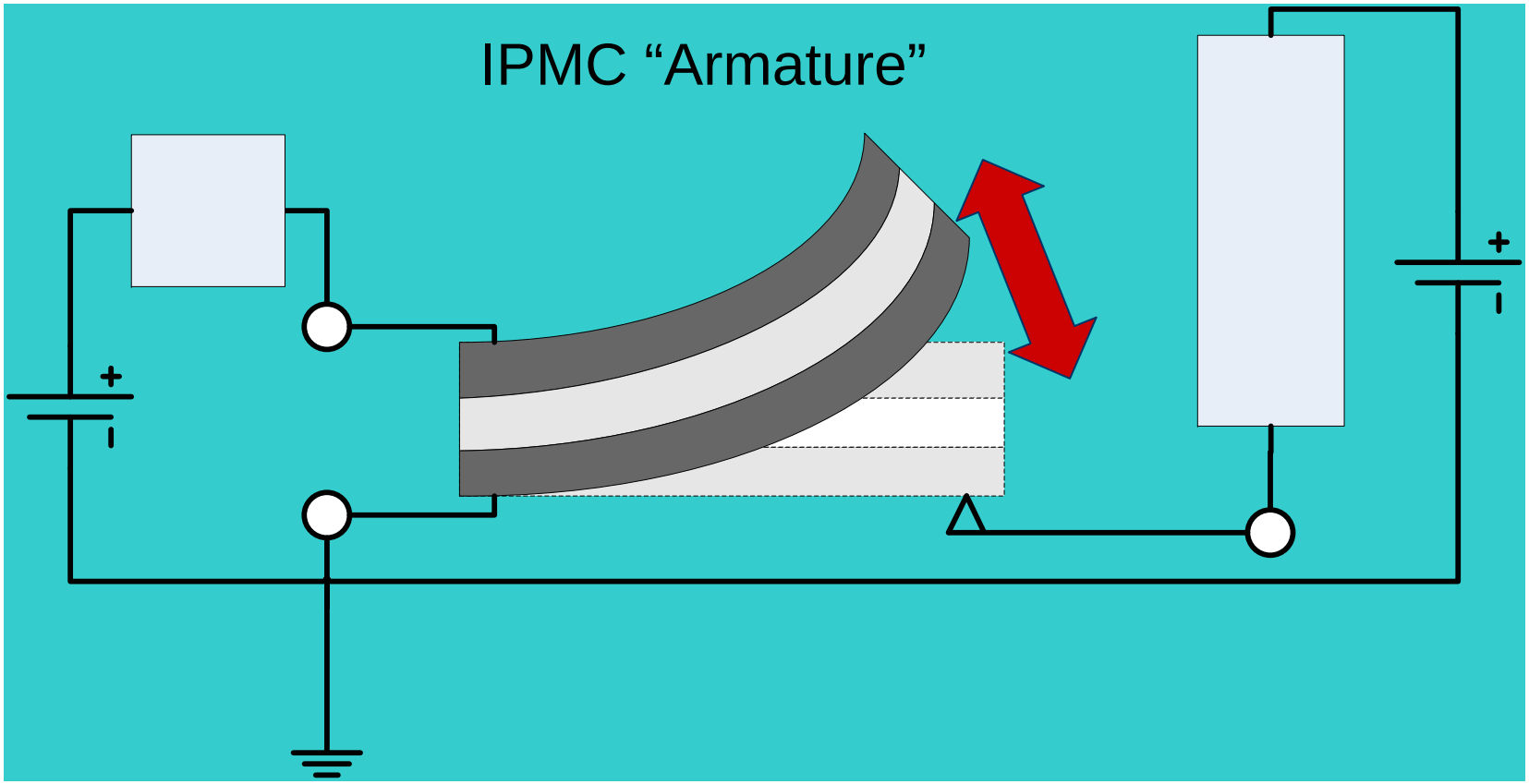
Work by Koba Industries, Albuquerque NM USA

Organic Transistors

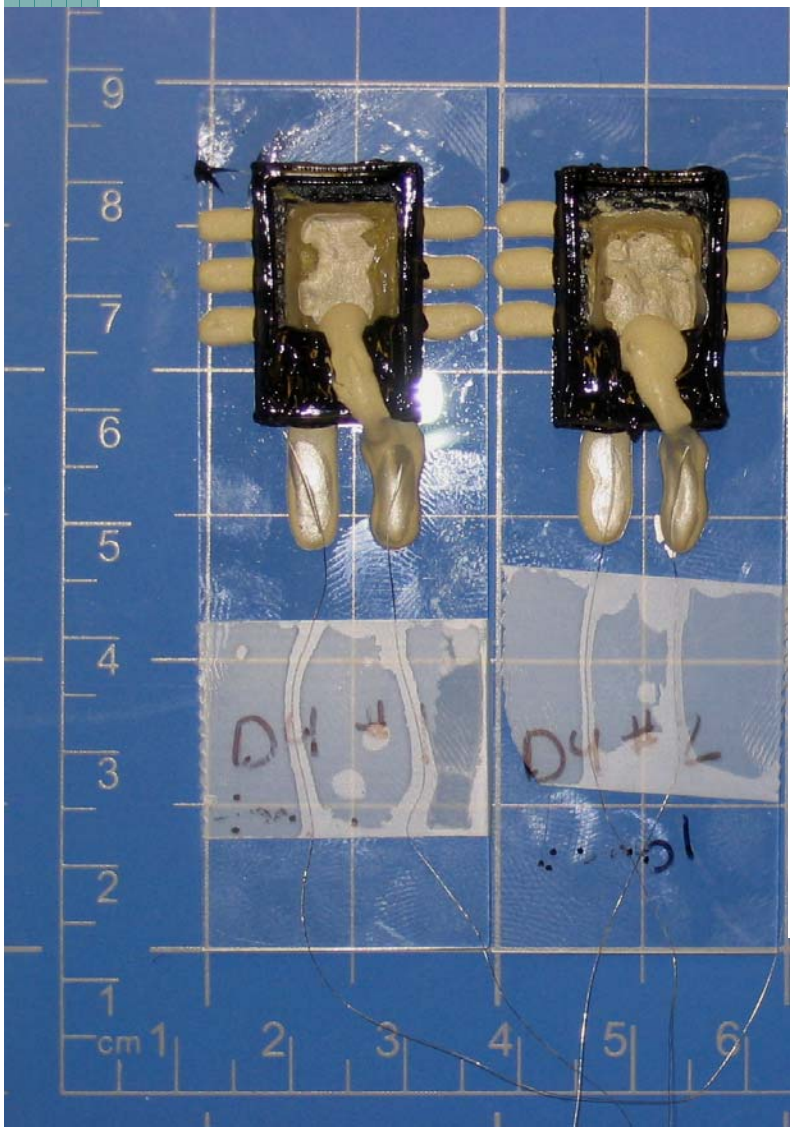


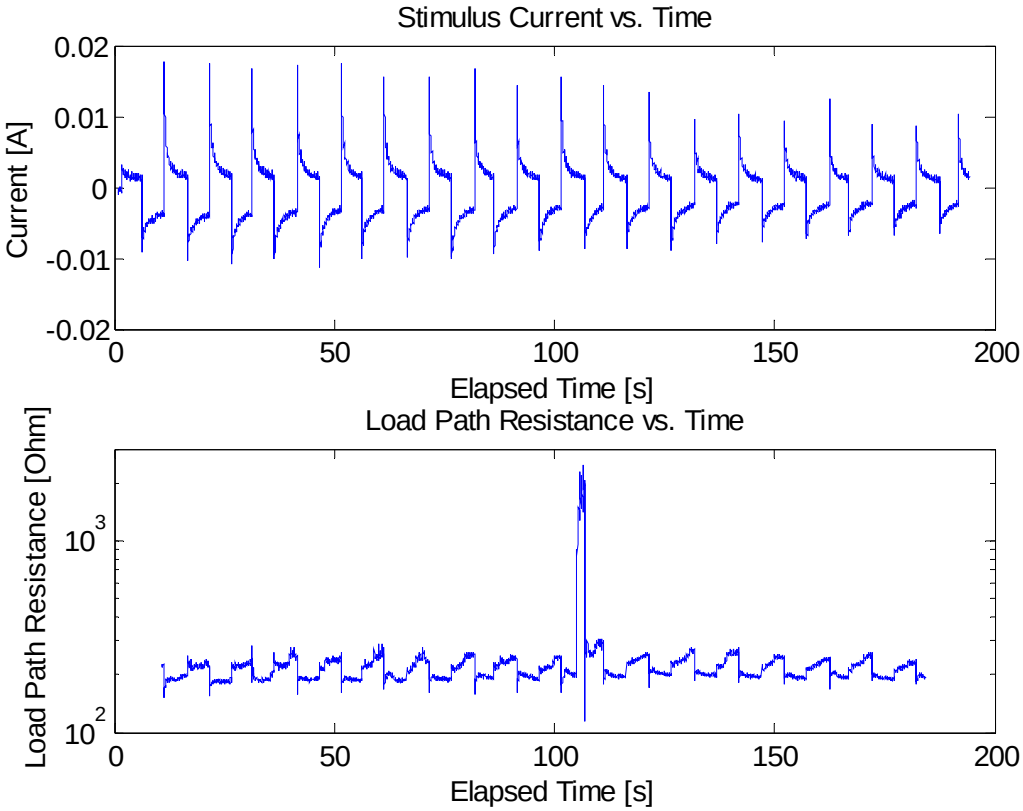


IPMC Relay

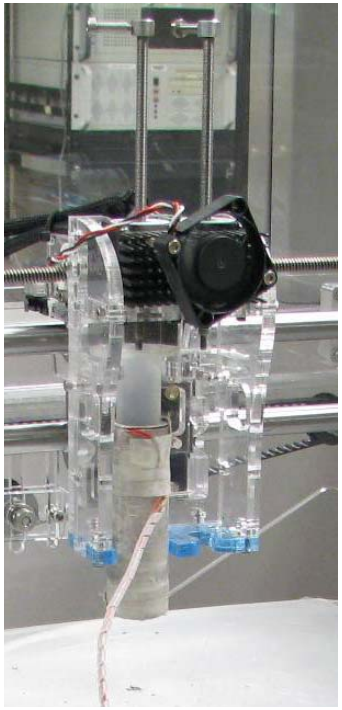


IPMC Relay Prototypes





New Process: Sintered Stainless



- 17-4 PH Stainless Steel powder, 12µm
- Polysaccharide binder; aqueous
- Deposited at 85° C via heated syringe
- Sintered 8h @ 1350°C in 6% H - 94% Ar
- 35% UTS of bulk 17-4 PH
- 17% linear shrinkage

Work by Maxim Lobovsky, Cornell University

Future?

- Model 2
- Modular Personal Fabrication Architecture & Standards