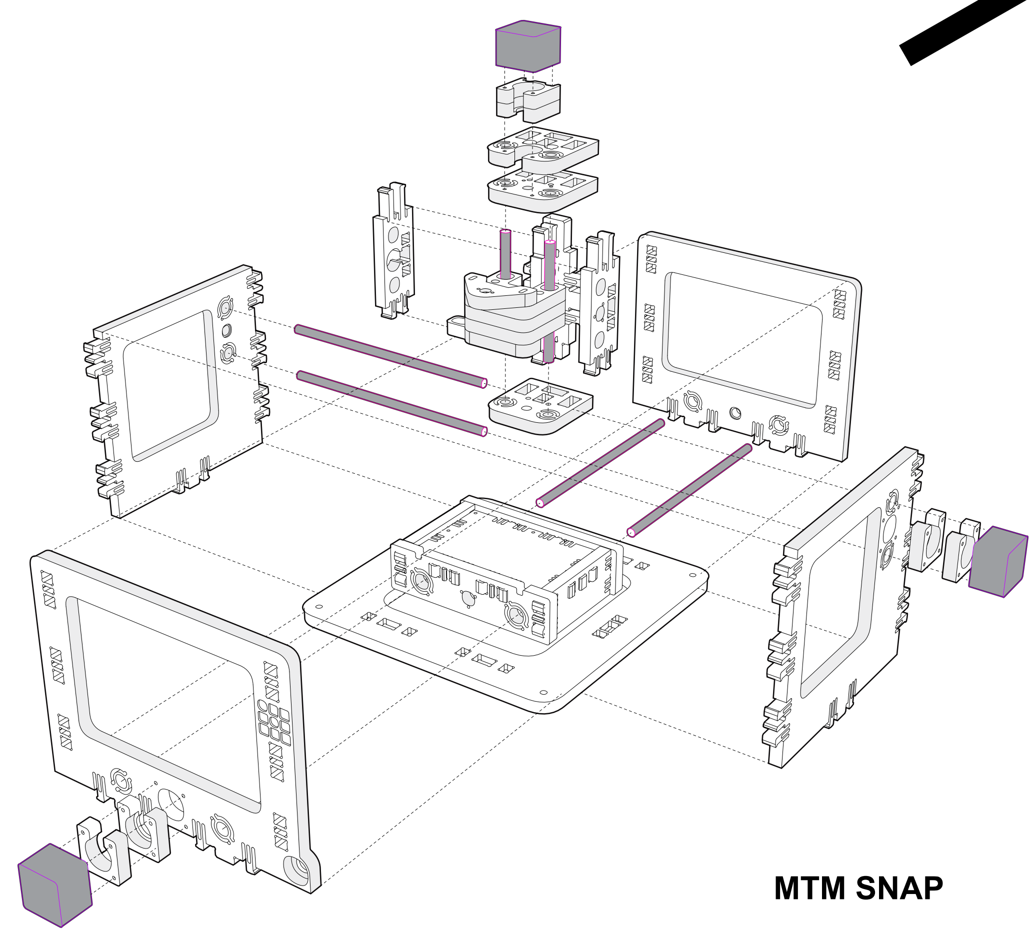
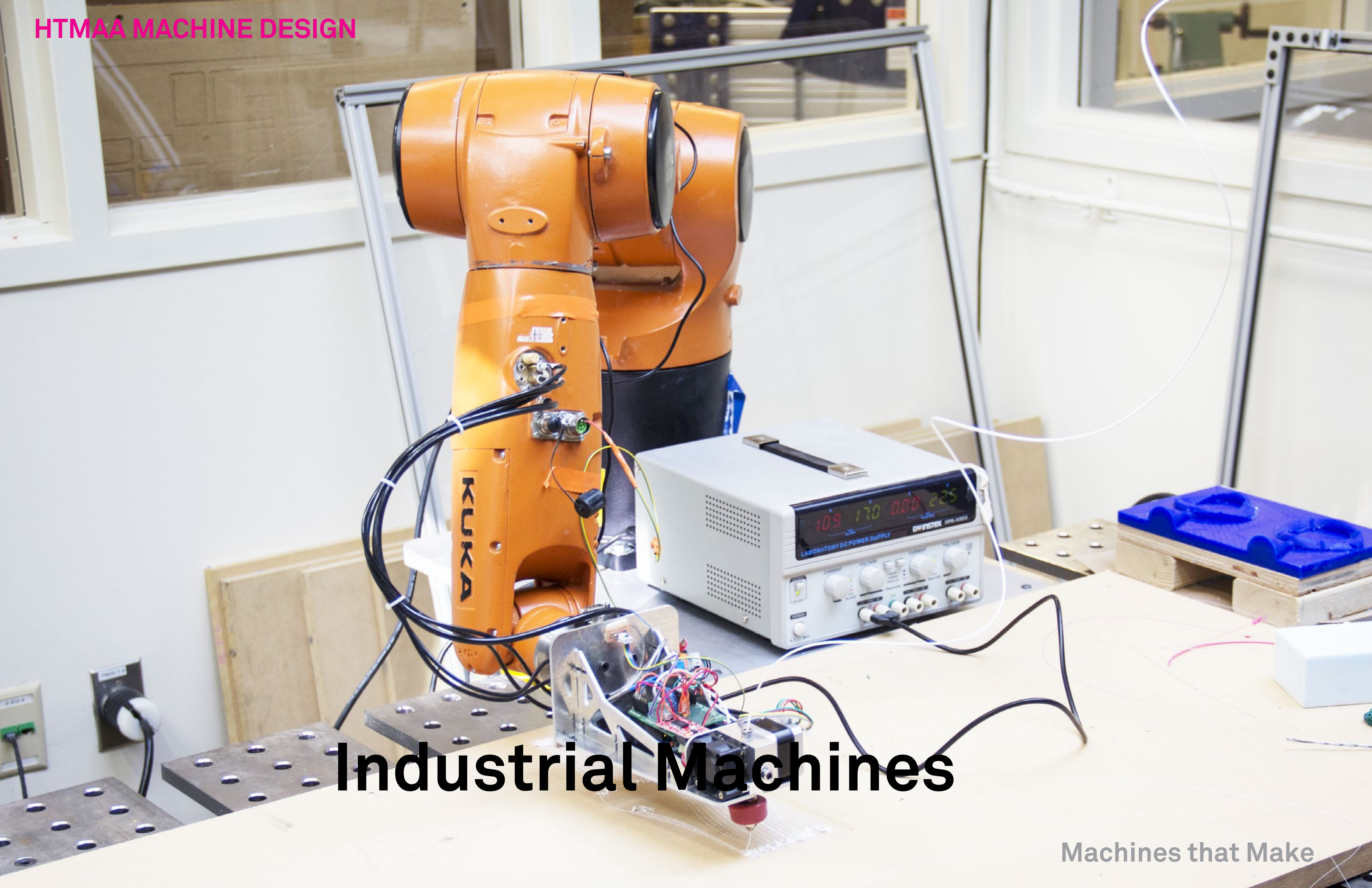
How to Make Almost ~~Anything~~ Machine!



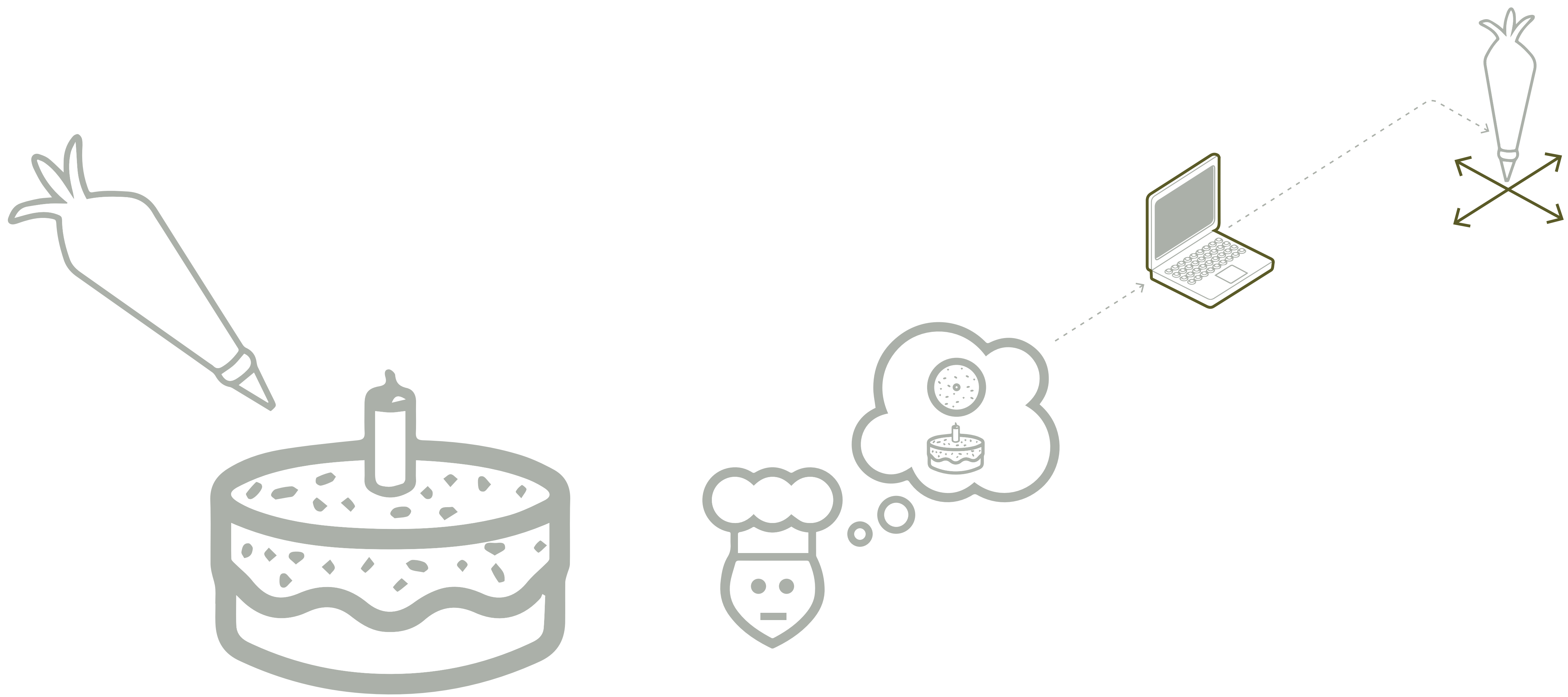
MTM SNAP

Industrial Machines


Industrial Machines


HTMAA MACHINE DESIGN
Industrial Machines
Machines that Make
KUKA
LABORATORY DC POWER SUPPLY

Consumer machines



Personal Fabrication

Machines that Make

The Machine that make project at the MIT Center for Bits and Atoms seeks to develop low-cost machines that can be made using CNC equipment, like available in fab labs.

[m]MTM: modular machines that make

More modular machines out of prototyping materials for prototyping

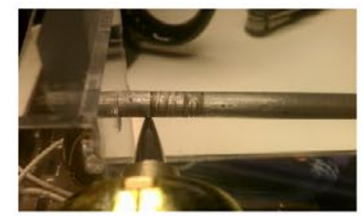
Reconfigurable Stages

Reconfigurable one-axis stages for multi-purpose motion.

foldafab

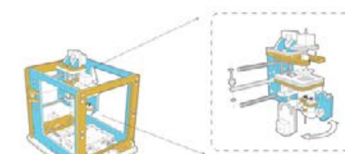
A deployable medium-format CNC router.

DIY EDM



An entry level (under $500) EDM machine for making carbide/HSS tooling and/or lead screws

5 Axis Timing Belt MTM

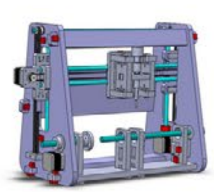


Low cost 5 axis machining.

POP Fab

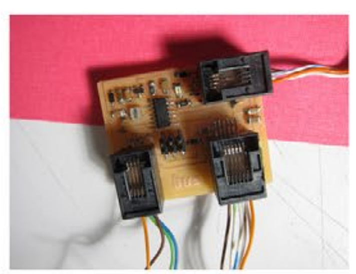
A suitcase milling machine, 3d printer, and vinyl cutter.

Multi-processes lathe



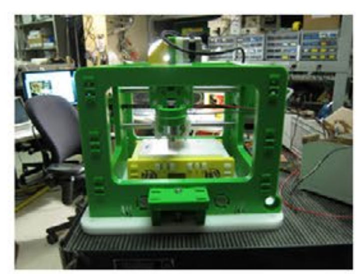
The additive lathe is a 3D printer that prints on rotation objects.

Virtual Machine Network



Modular control for the MTM project.

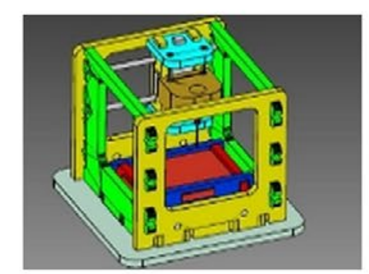
Timing Belt MTM



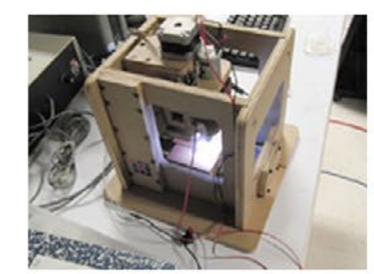
A design without lead screws, reducing cost.

Fab-In-A-Box

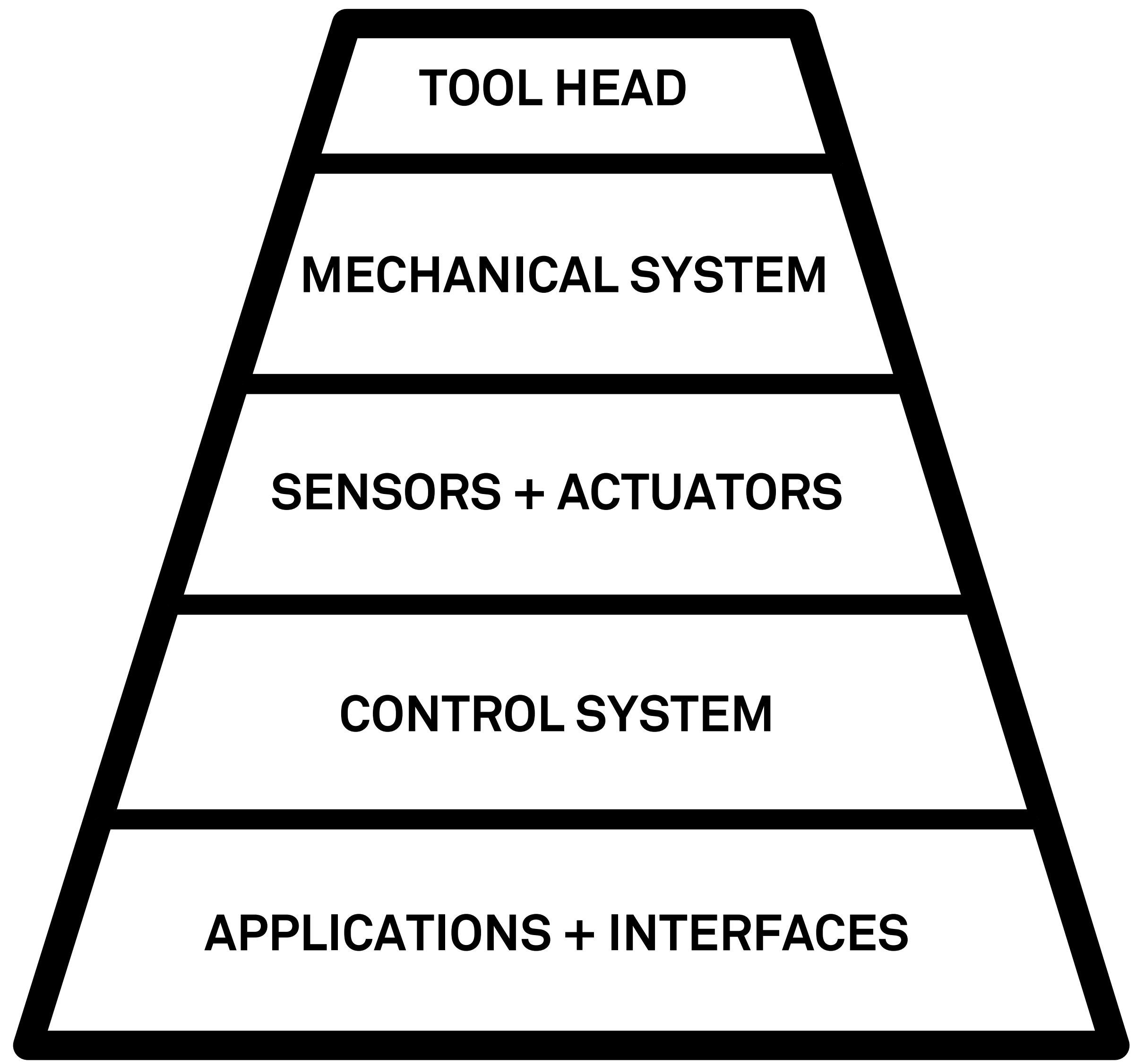
MtM Snap-Lock

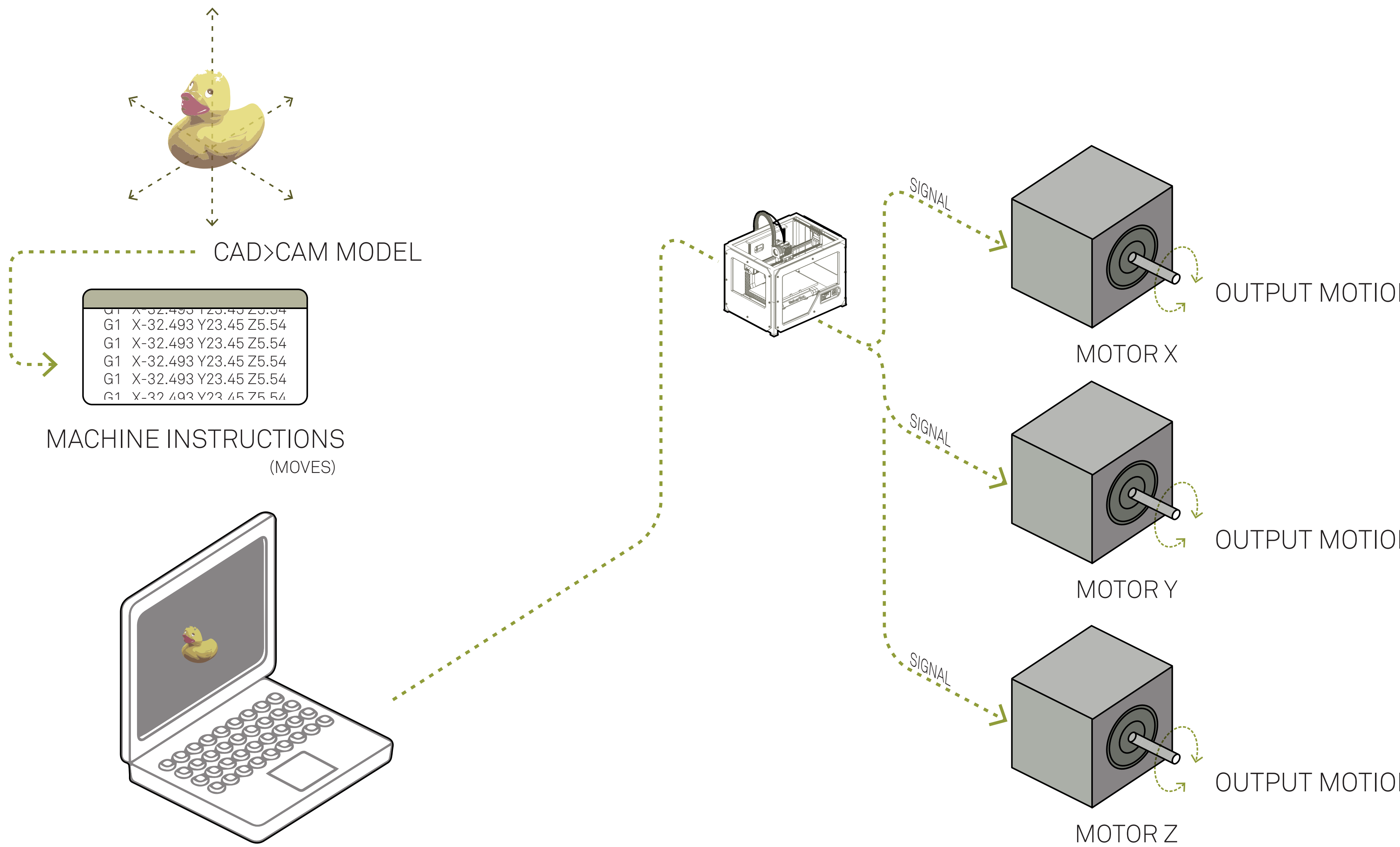


MtM A-Z



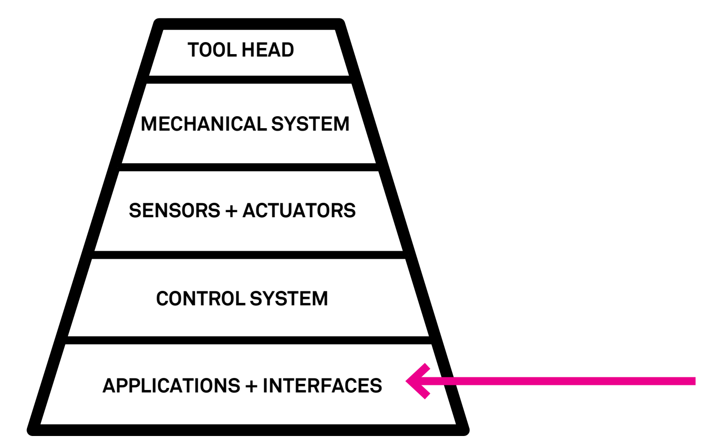
MAKING
MACHINES THAT MAKE



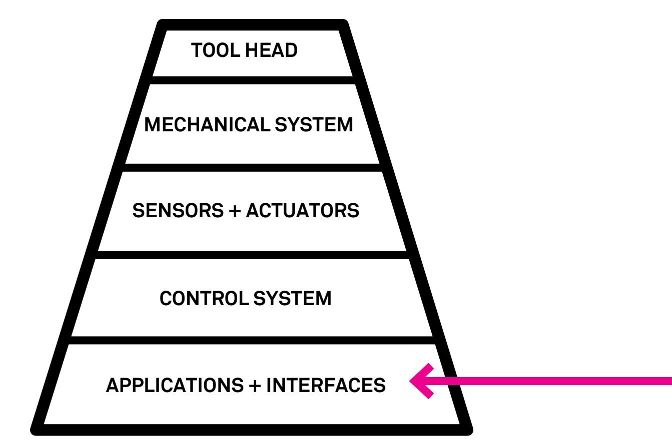


Machine programming and control

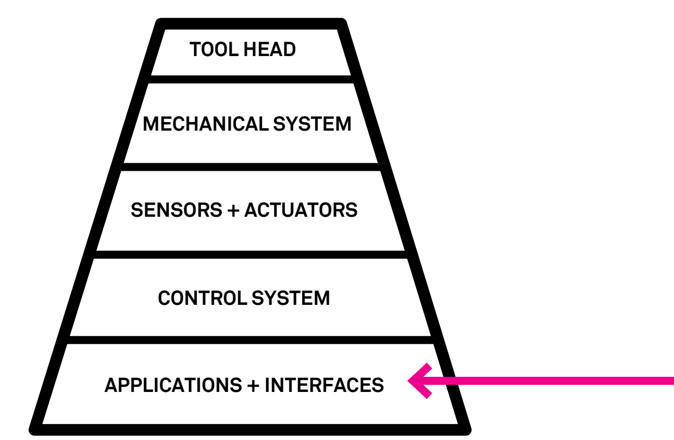

EPILOG
www.epiloglaser.com

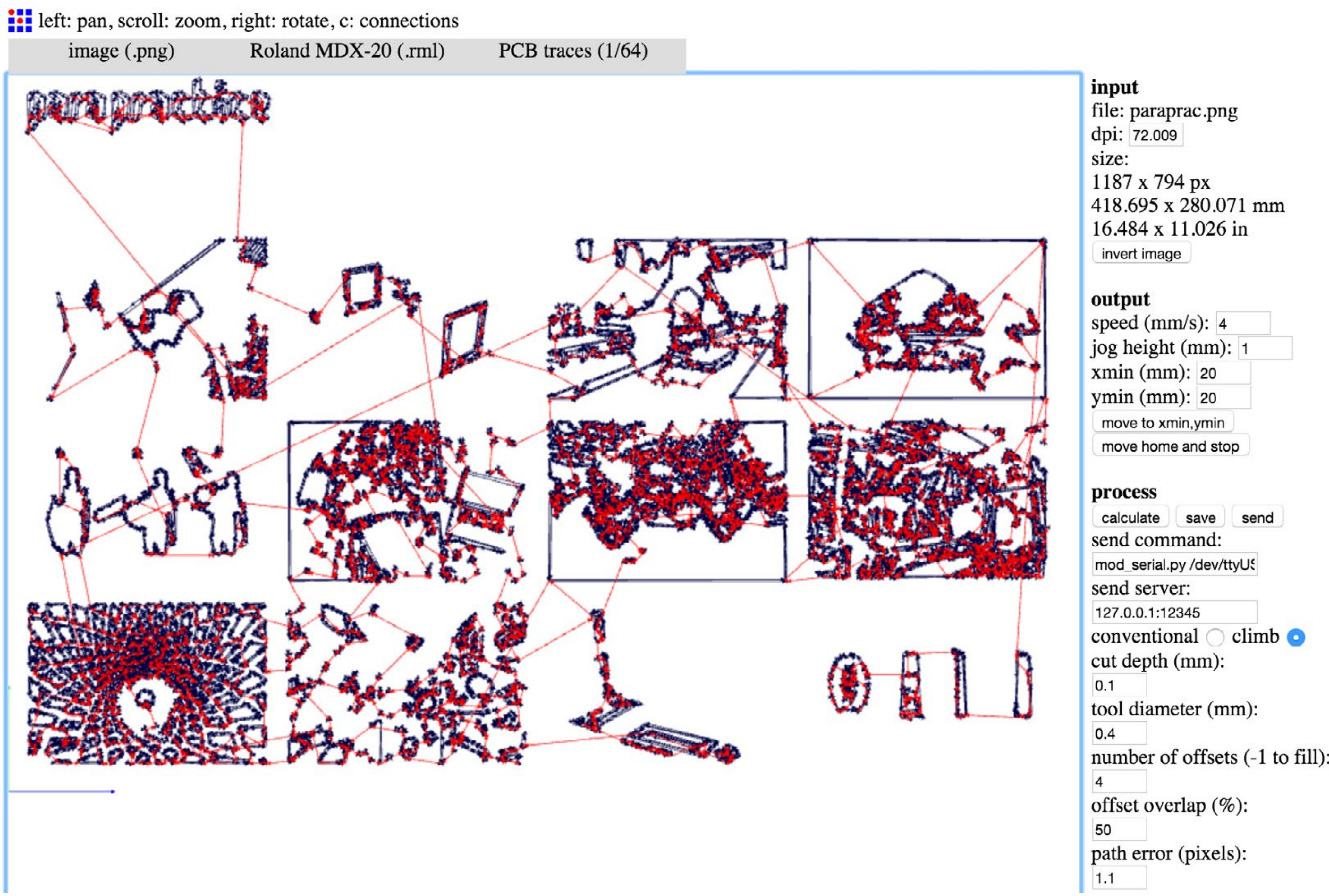

TOOL HEAD
MECHANICAL SYSTEM
SENSORS + ACTUATORS
CONTROL SYSTEM
APPLICATIONS + INTERFACES


OMAX
OMAX
OMAX
2652 JetMachining® Center

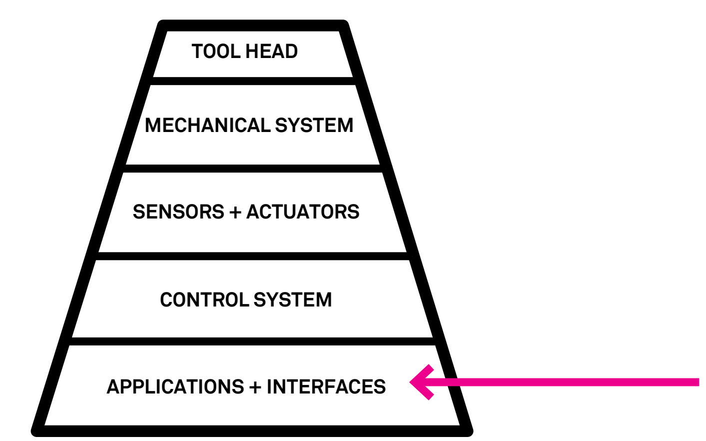

TOOL HEAD
MECHANICAL SYSTEM
SENSORS + ACTUATORS
CONTROL SYSTEM
APPLICATIONS + INTERFACES

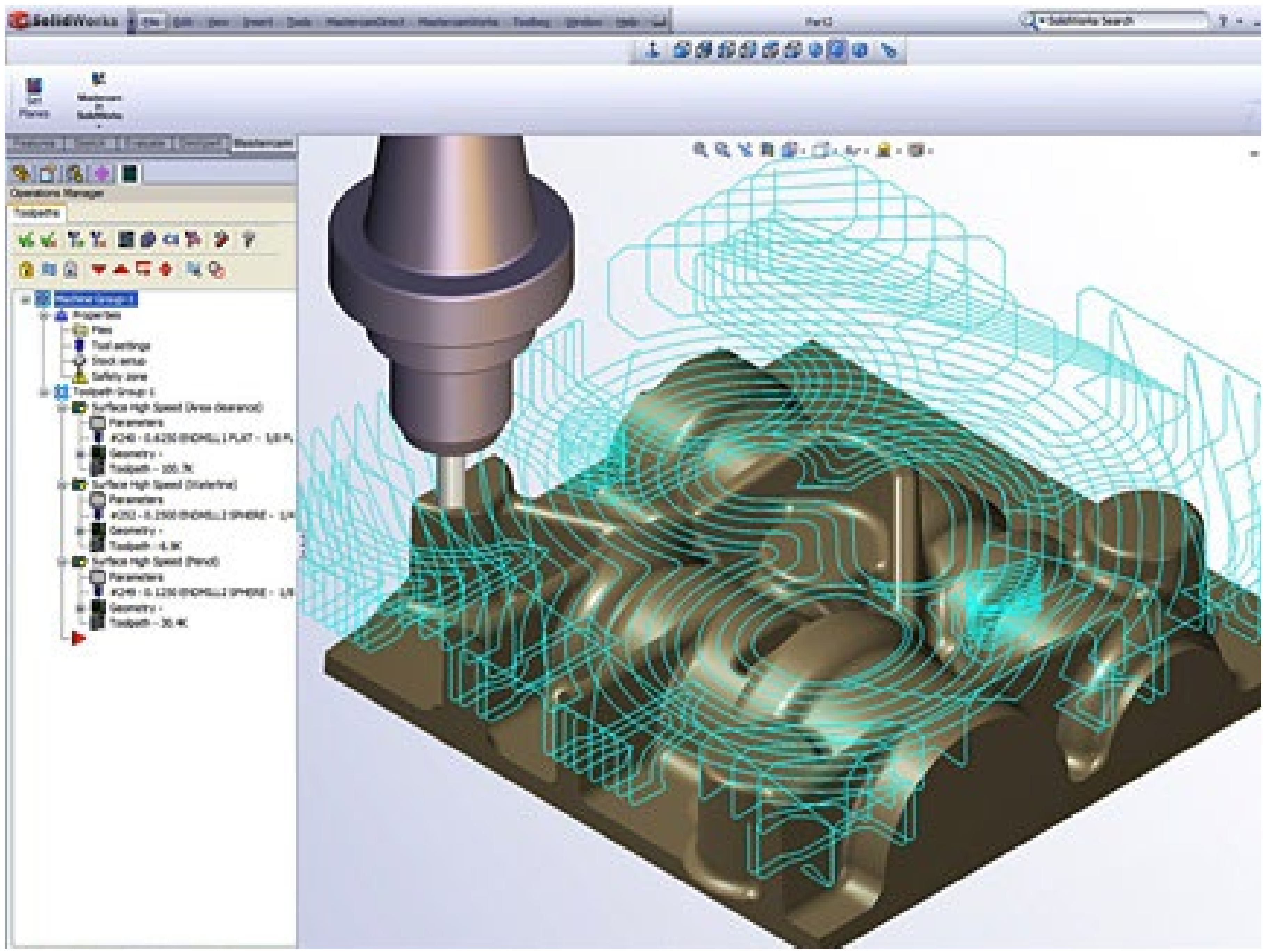

HAAS
POWER ON
POWER OFF
EMERGENCY STOP
SETUP: JOG
O00001
N00000100
O00001 (LSR HEAD INTAKE2A) ;
(SAM RACING) ;
(POSTED FOR HAAS ES-5-4T) ;
(DATE - 02-07-10 TIME - 09:51) ;
(T1 | SFS 3/8) ;
G20 ;
G00 G17 G40 G80 G90 G94 G98 ;
G00 G91 G28 Z0. ;
G00 G91 G28 X0. Y0. A0. ;
(SFS 3/8) ;
N100 T1 M06 ;
G00 G90 G94 G54 X-4.1972 Y1.8518 B21.392
A17.186 S3500 M03 ;
M11 ;
M13 ;
G187 P2 E0.025 ;
G43 H01 24.4025 ;
Z0.5025 ;
G01 Z0.4025 F21. ;
G93 X-4.2251 Y1.7947 Z0.4262 B20.704 A17.52
F840.2 ;
X-4.2509 Y1.7357 Z0.4527 B19.996 A17.82
F839.32 ;
X-4.276 Y1.6751 Z0.4793 B19.273 A18.109
F840.78 ;
X-4.3014 Y1.613 Z0.5045 B18.535 A18.402
F840.33 ;
X-4.326 Y1.5493 Z0.5298 B17.78 A18.684
F840.83 ;
X-4.3495 Y1.4837 Z0.5558 B17.007 A18.949
F839.28 ;
<< TOOL INFO
TOOL OFFSET
TOOL
COOLANT POSITION
H(LENGTH)
GEOMETRY
1 SPINDLE
WORK ZERO OFFSE
G CODE
X AXIS
Y AXIS
G54 -19.8890 -16.2096
G55 -29.3963 -13.0365
G56
G57
G58
G59
G154 P1
G154 P2
G154 P3
MAIN SPINDLE
STOP
Commanded RPM: 3500
Actual RPM: 0
Load: 0
SPINDLE: 100%
FEED:
RAPID:
POSITION: (IN) JOG RATE 0.0010
OPERATOR
WORK G 54
MACHINE
DIST
X -24.2045 -4.3155 -24.2045
Y -14.4668 1.7428 -14.4668
Z -14.4077 -14.4077 -14.4077
A 30.958 30.958 30.958
B 49.450 20.069 49.450


TOOL HEAD
MECHANICAL SYSTEM
SENSORS + ACTUATORS
CONTROL SYSTEM
APPLICATIONS + INTERFACES

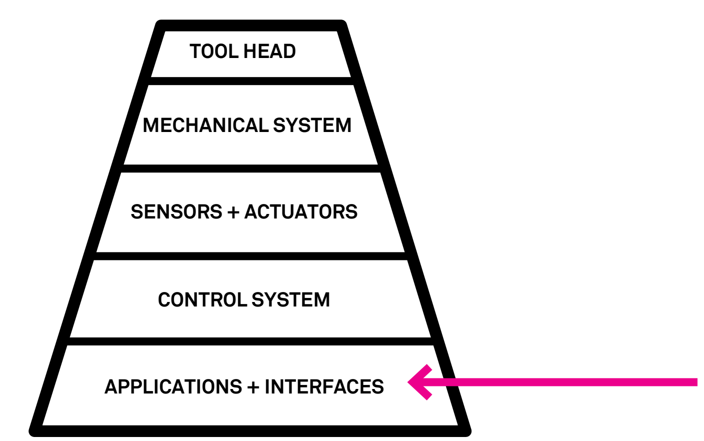


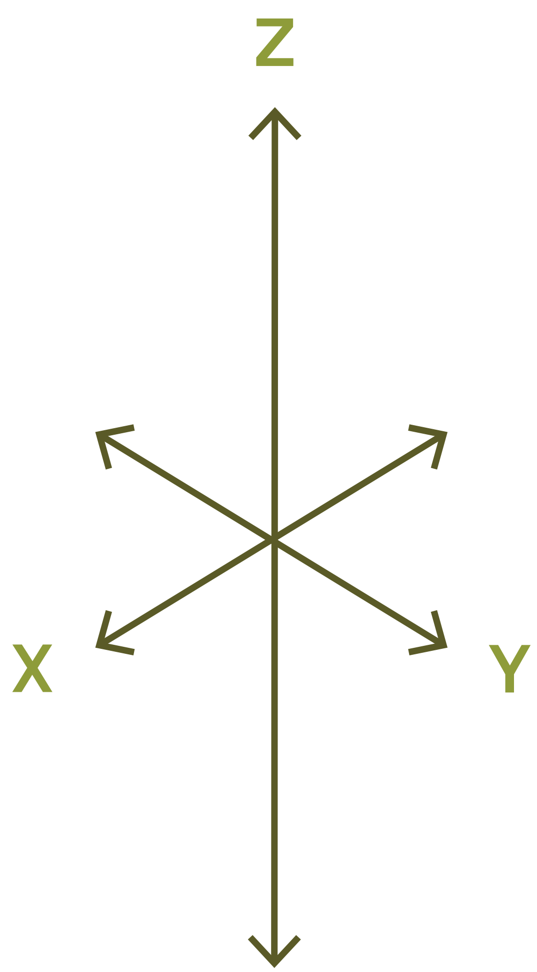
Toolpathing

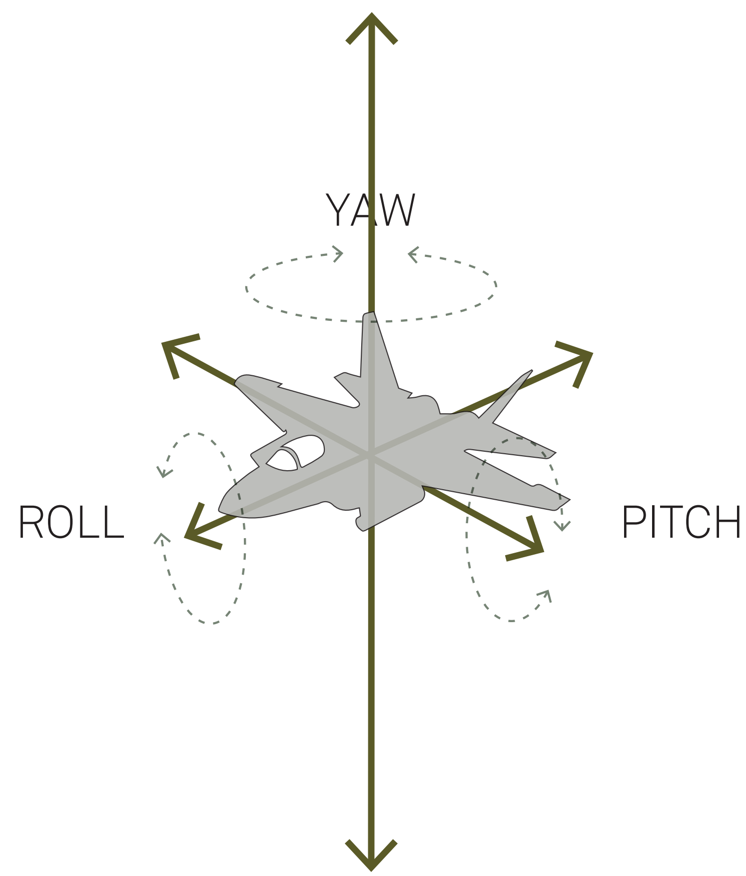


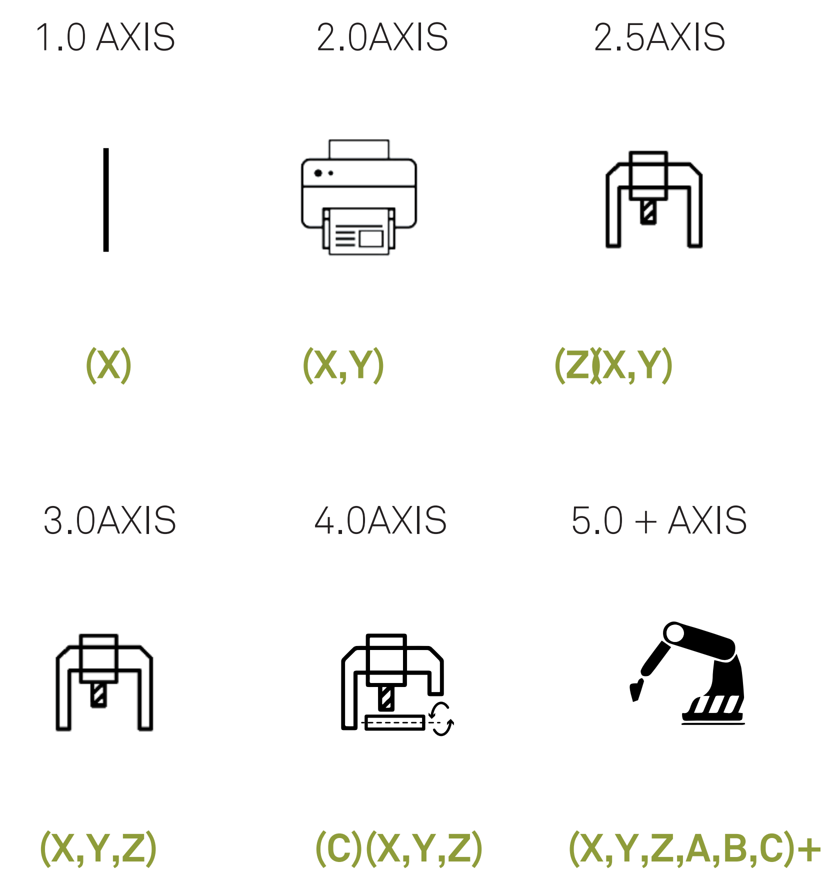


Toolpathing









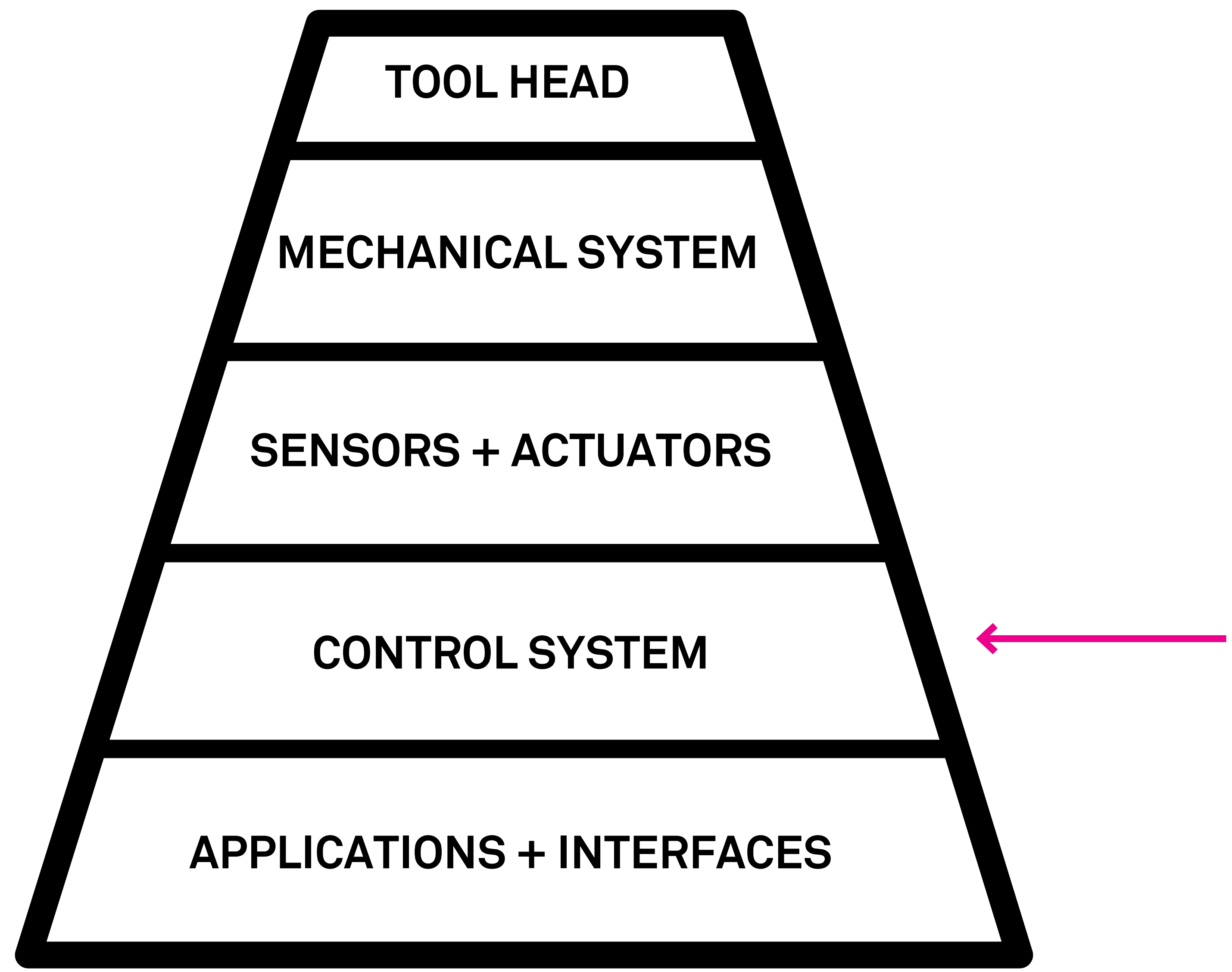
Machine instructions/ post processors

G-code	Functions
G0	Rapid positioning
G1	Linear interpolation
G2	Clockwise circular / helical interpolation
G3	Counterclockwise circular / helical interpolation
G4	Dwell
G10	Coordinate system origin setting
G12	Clockwise circular pocket
G13	Counterclockwise circular pocket
G15	Polar Coordinate moves in G0 and G1
G16	Cancel polar Coordinate moves in G0 and G1
G17	XY plane select
G18	XZ plane select
G19	YZ plane select
G20	Inch unit
G21	Millimeter unit
G28	Return machine home (parameters 5161 to 5166)
G30	Return machine home (parameters 5181 to 5186)
G28.1	Reference axis
G31	Straight Probe
G40	Cancel cutter radius compensation
G41	Start cutter radius compensation left
G42	Start cutter radius compensation right
G43	Apply tool lenght offset (plus)
G49	Cancel tool lenght offset
G50	Reset all scale factors to 1.0
G51	Set axis data input scale factors

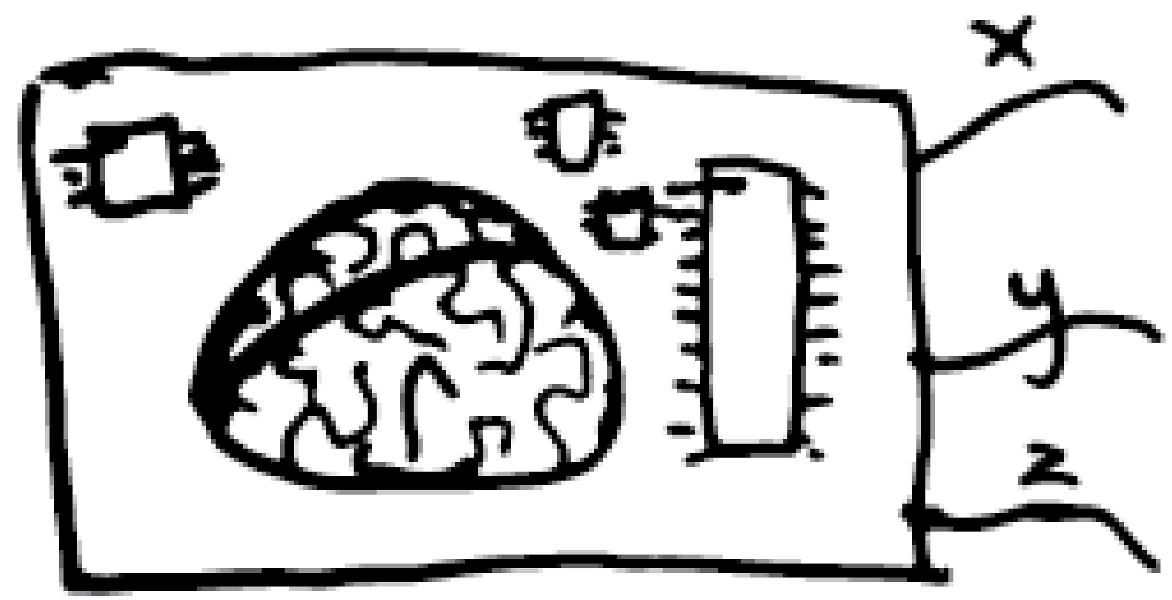
G-code	Functions
G53	Move in absolute machine coordinate system
G54 à G59	Use fixture offset 1 to 6, G59 to select a general fixture number
G61	Exact Stop mode
G64	Constant Velocity mode
G73	Canned cycle - drilling - fast pullback
G80	Cancel canned cycle mode
G81	Canned cycle - drilling
G82	Canned cycle - drilling with dwell
G83	Canned cycle - peck drilling
G84	Canned cycle - right hand rigid taping (not yet implemented)
G85	Canned cycle - boring, no dwell, feed out
G86	Canned cycle - boring, spindle stop, rapid out
G87	Canned cycle - back boring (not yet implemented)
G88	Canned cycle - boring, spindle stop, manual out
G89	Canned cycle - boring, dwell, feed out
G90	Absolute distance mode
G91	Incremental distance mode
G92	Offset coordinates and set parameters
G92.1	Reset G92 offset and parameter
G92.2	Reset G92 offset but leave parameters untouched
G92.3	Recall G92 from parameters
G93	Inverse time feed mode
G94	Feed per minute mode
G95	Feed per revolution mode
G98	Initial level return after canned cycles
G99	R-point level return after canned cycles

G-code (and M-code)

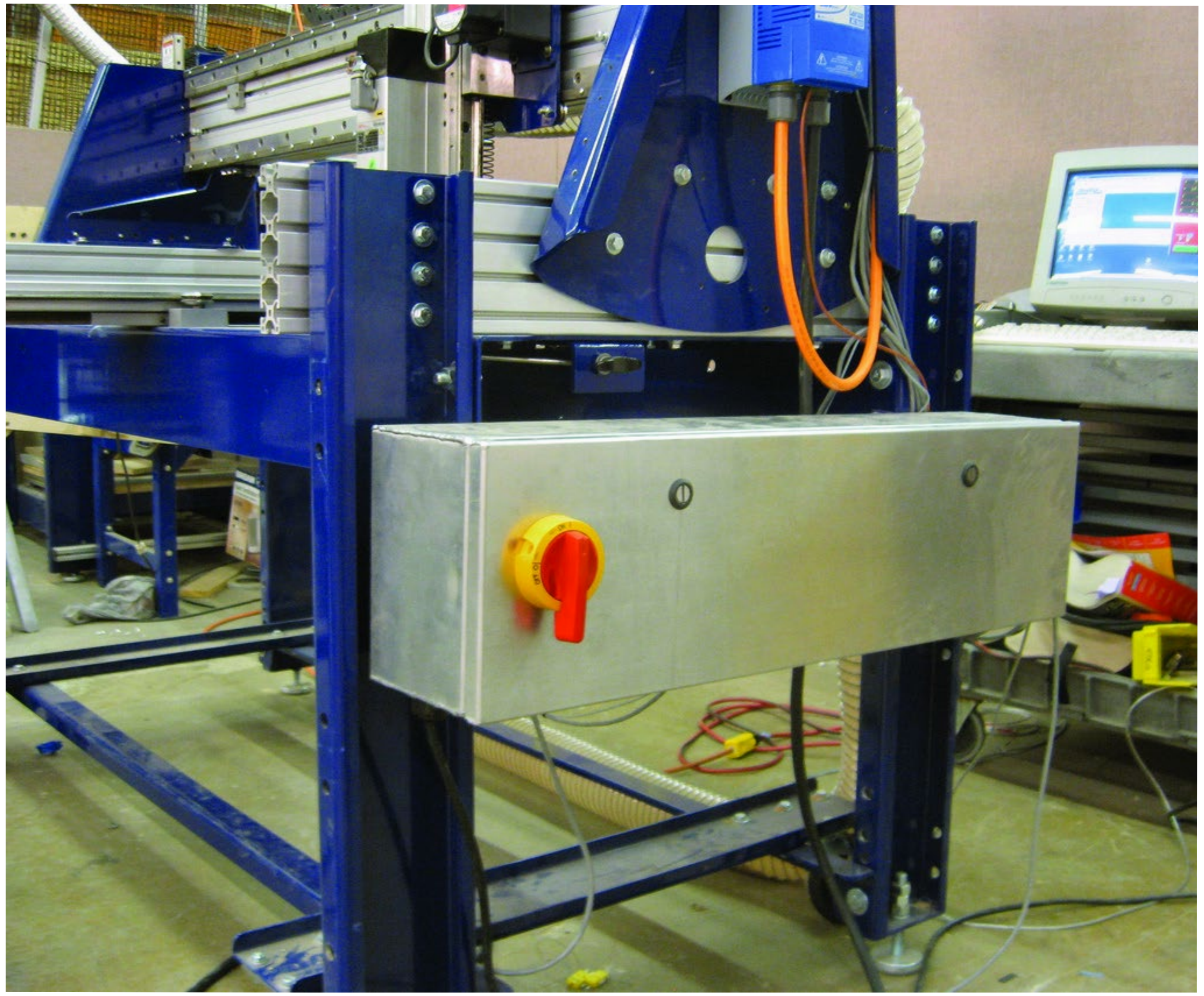
MAKING
MACHINES THAT MAKE

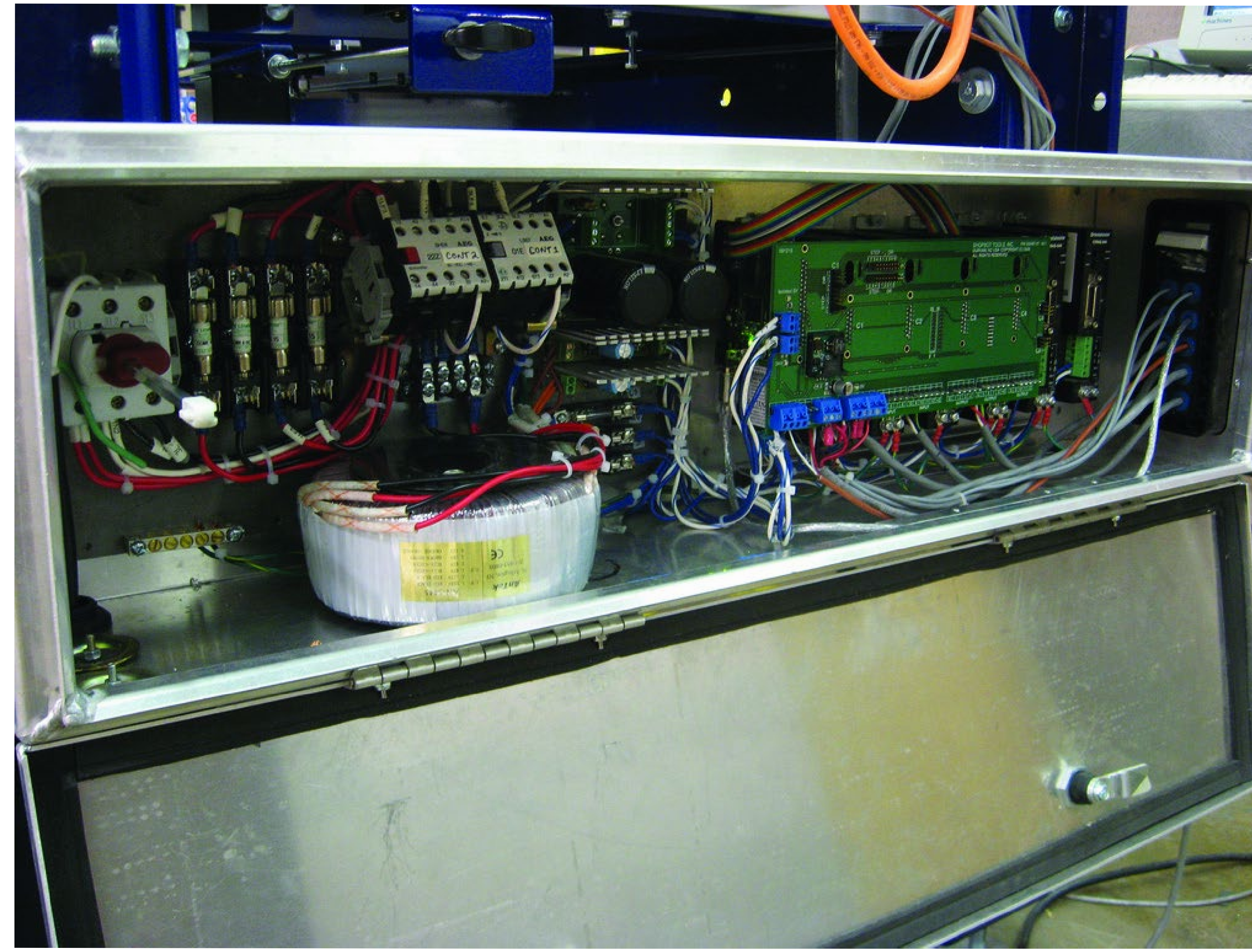


Maybe your control system is one electronic brain that interprets machine coordinates, (e.g. G-code).

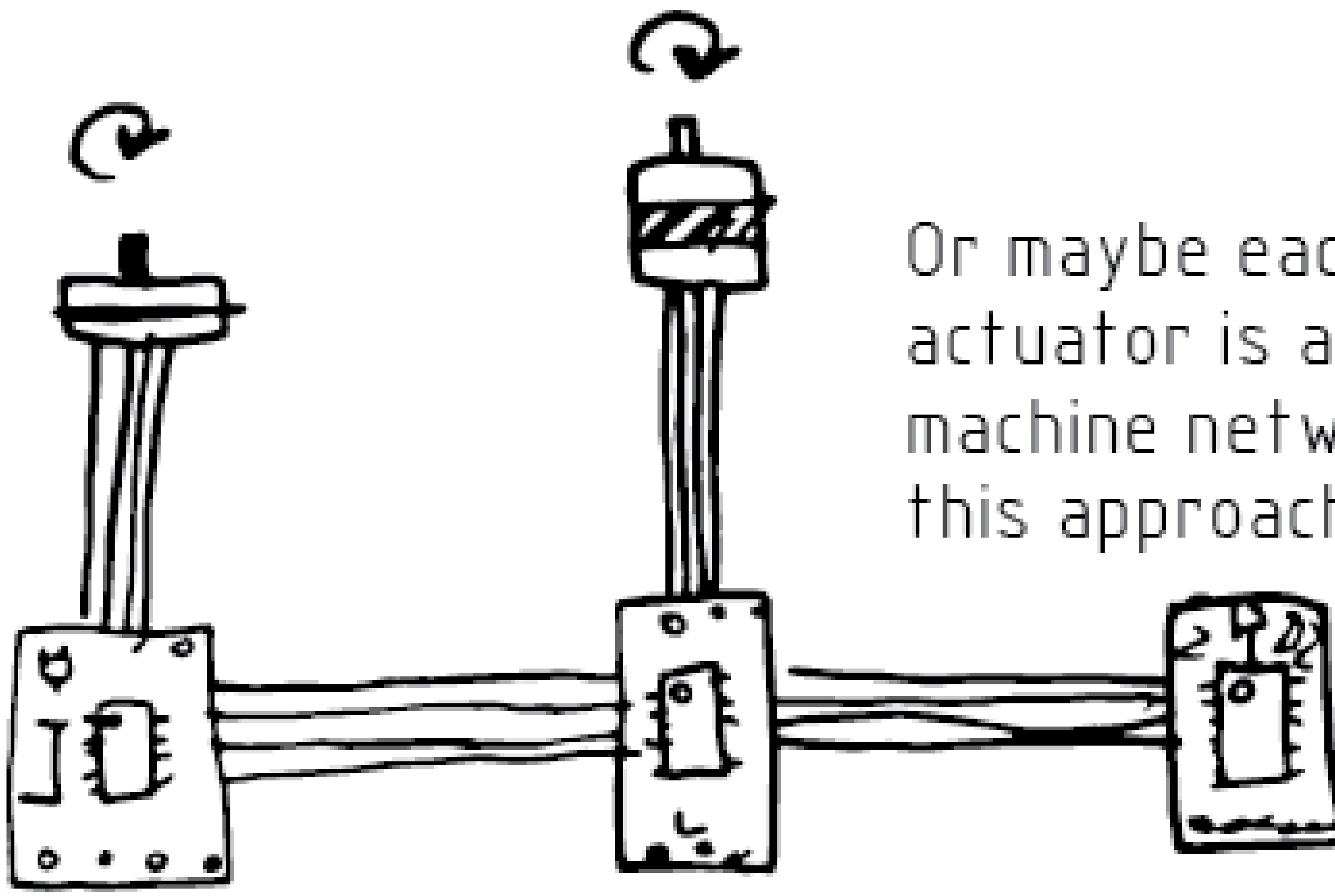


Machine control box





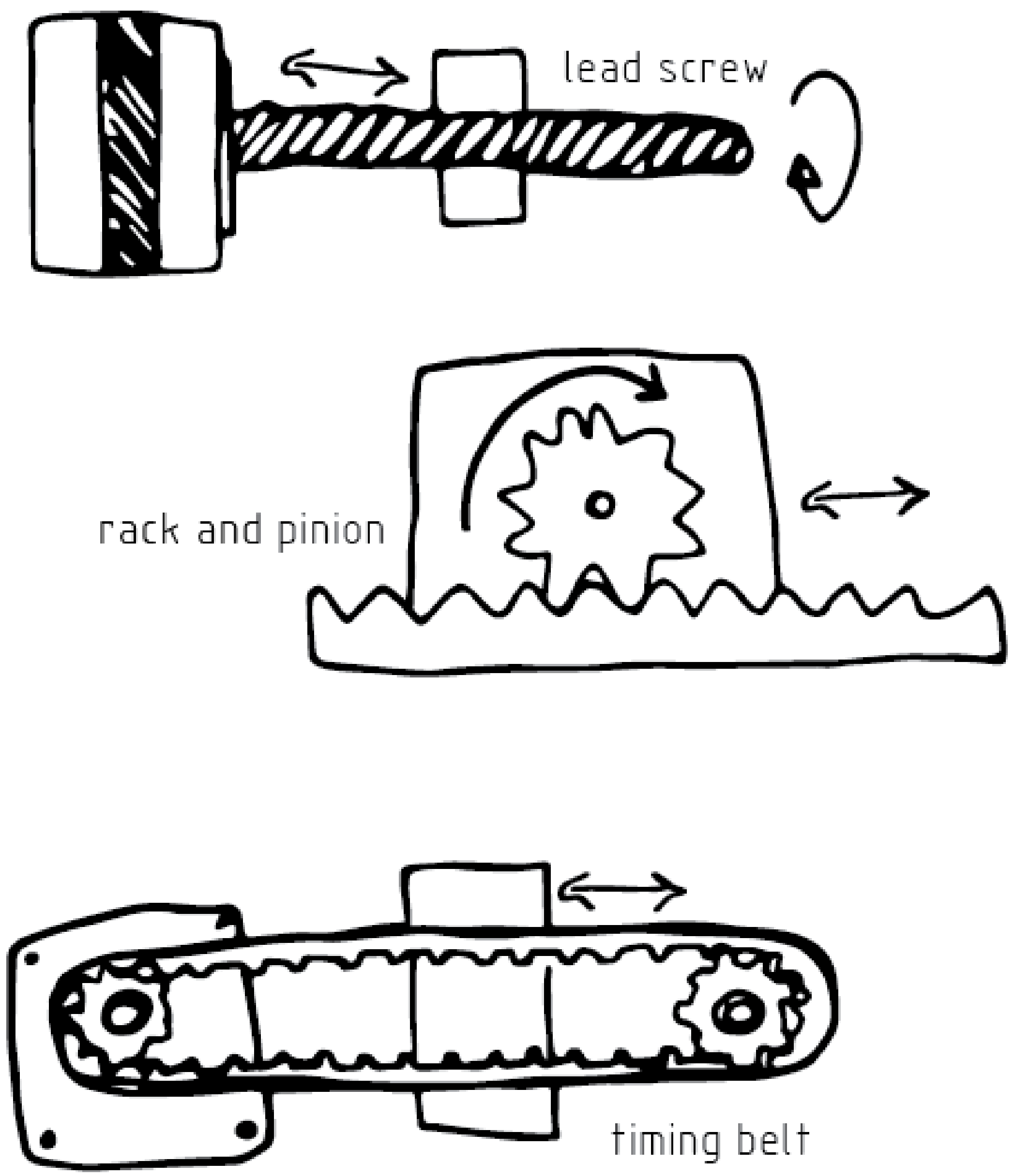
Machine control box



Or maybe each sensor and actuator is a node on a machine network! We like this approach.

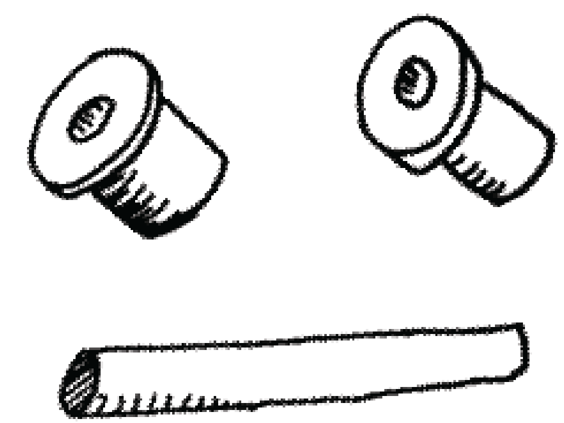
Machine control network

Moving things

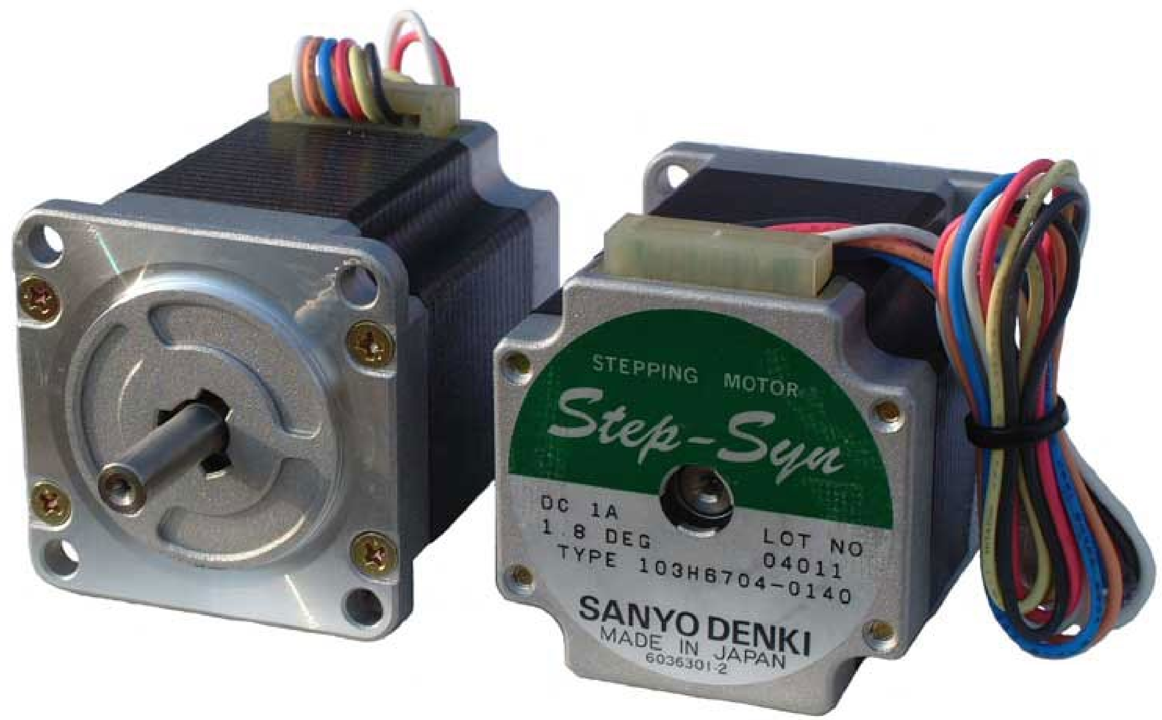


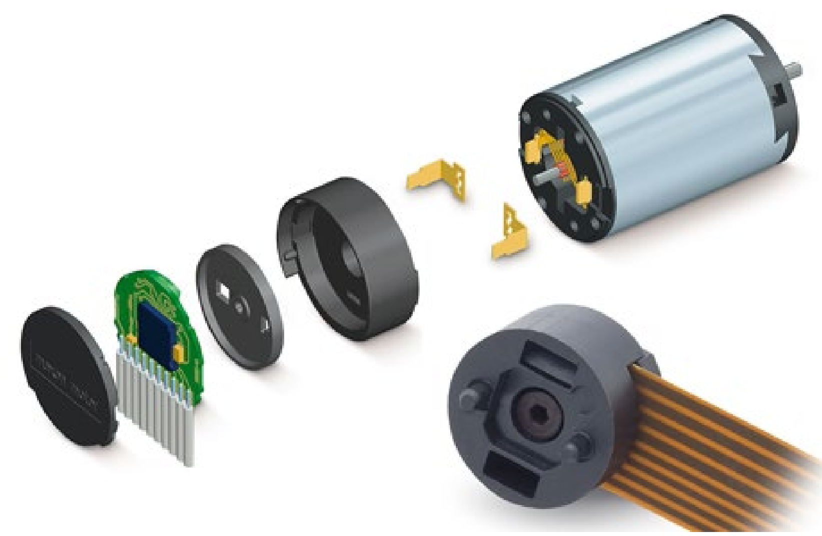
Different drive trains are better at different things, like timing belts are fast, racks and pinions are stiff, lead screws are strong. Some systems are cheaper, some are easier to assemble. These are all things to take into consideration for your machine!

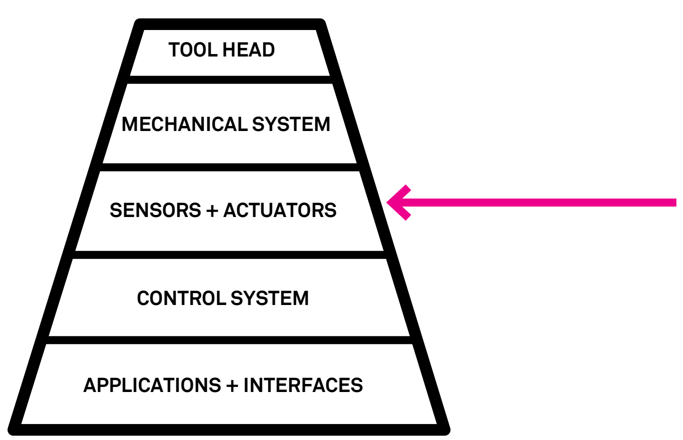
What kind of machines do you know that use these different kinds of drive trains?



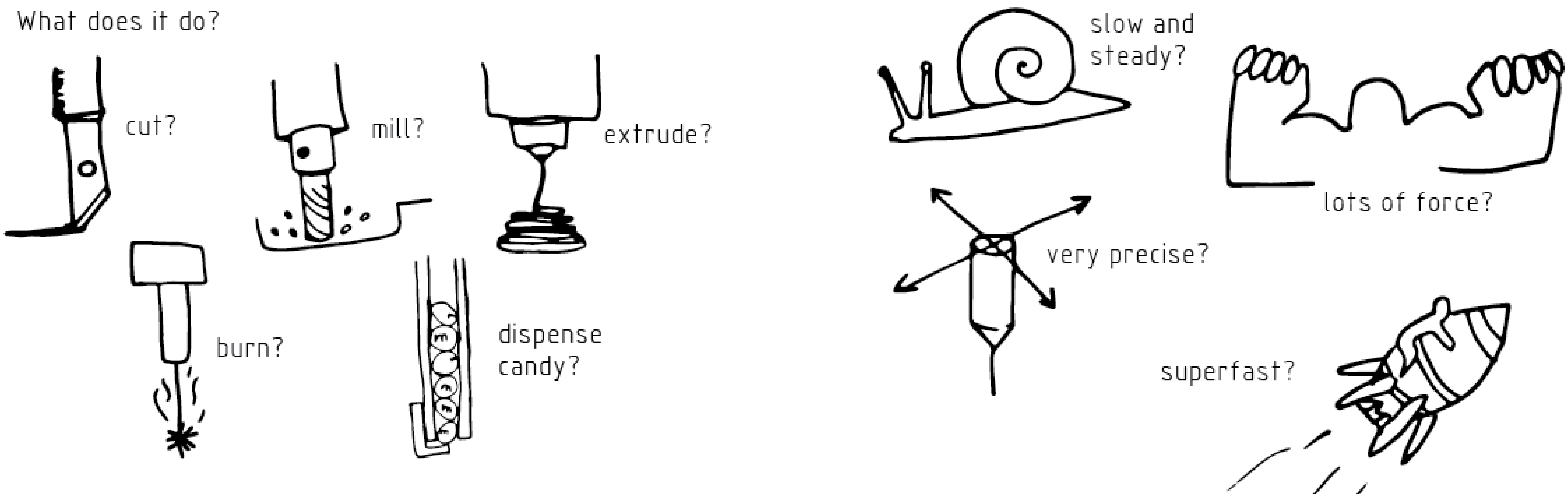
The drive trains motion needs to be restricted in the axes you want to move in. You can do this with guide shafts, tracks, cable guides, linkages, and many other ways.



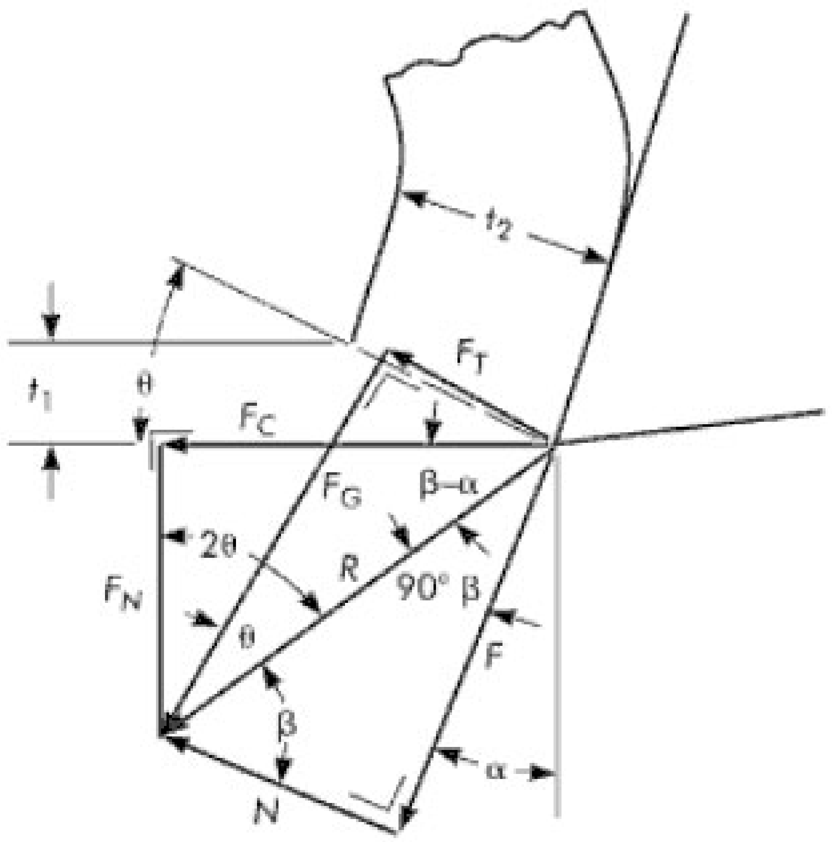




Moving things

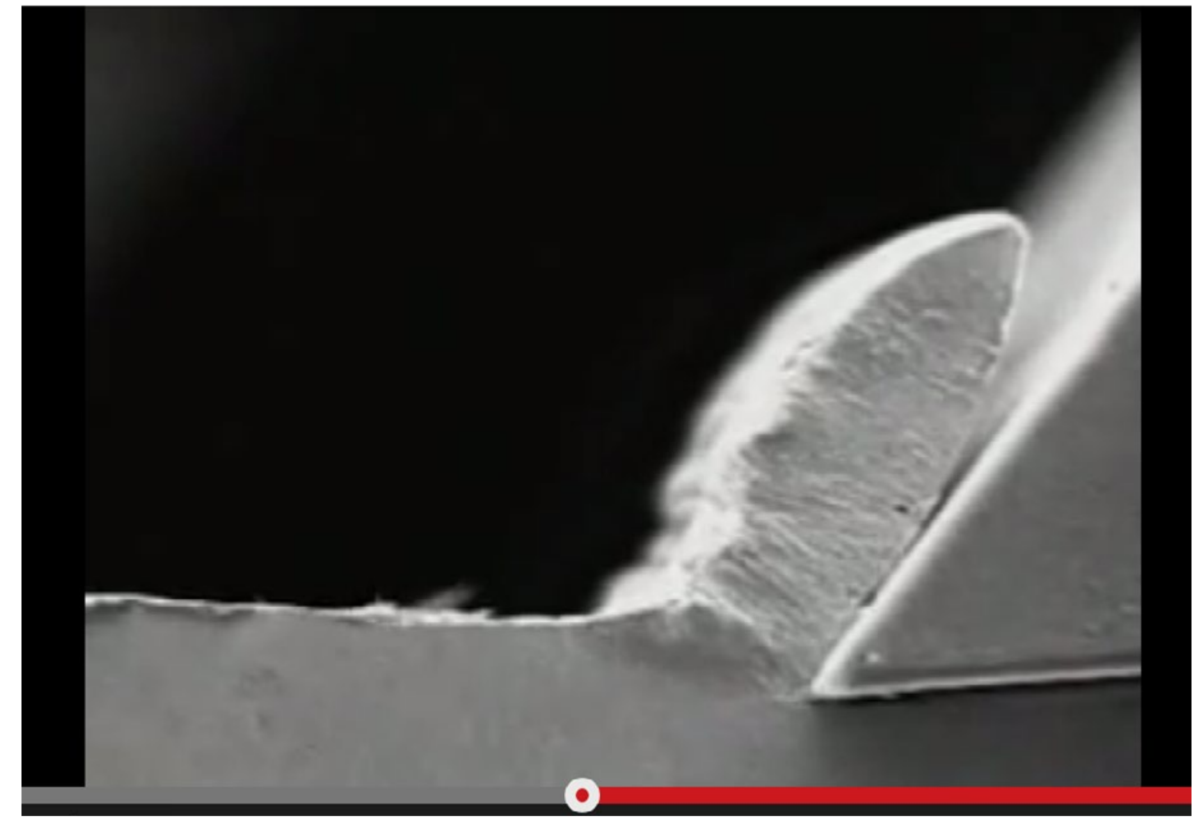


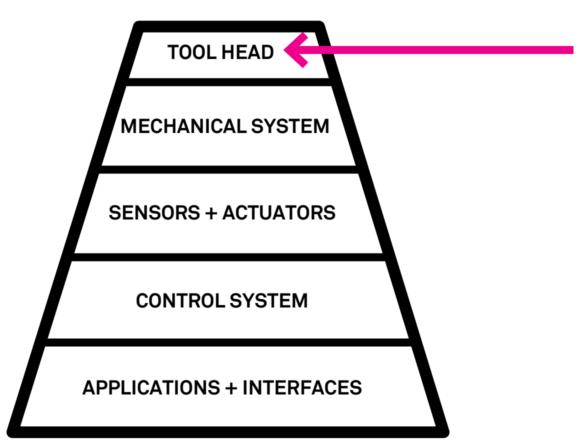
Tool force, precision, speed



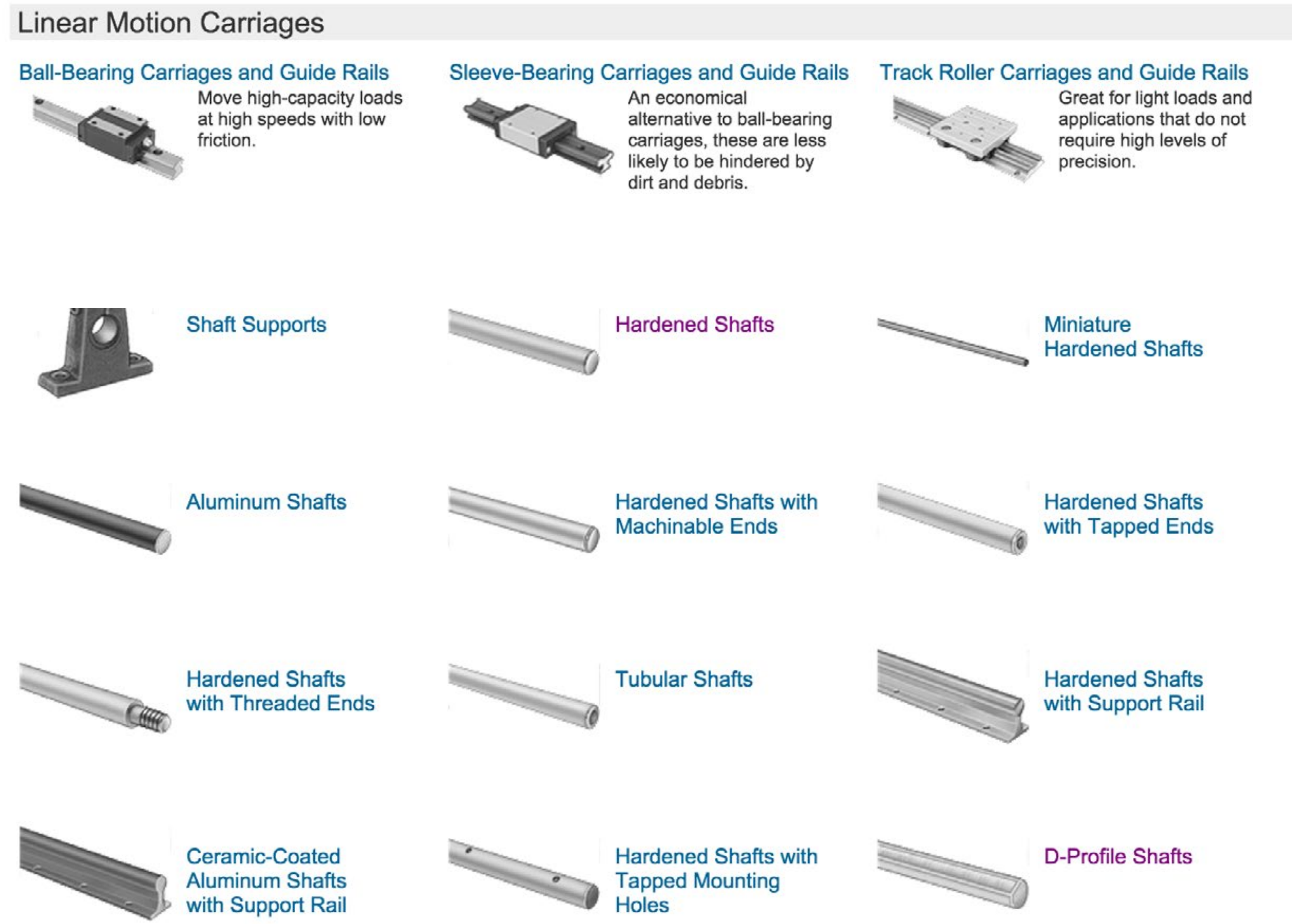
R = resultant cutting force, lbf (kN)
F_T = shear force, lbf (kN)
F_G = normal to shear force, lbf (kN)
F_C = cutting force, lbf (kN)
F_N = normal to cutting force, lbf (kN)
F = friction force, lbf (kN)
N = normal to friction force, lbf (kN)
t_1 = depth of cut or feed, in. (mm)
t_2 = chip thickness, in. (mm)
θ = shear angle, °
β = friction angle, °
α = rake angle, °

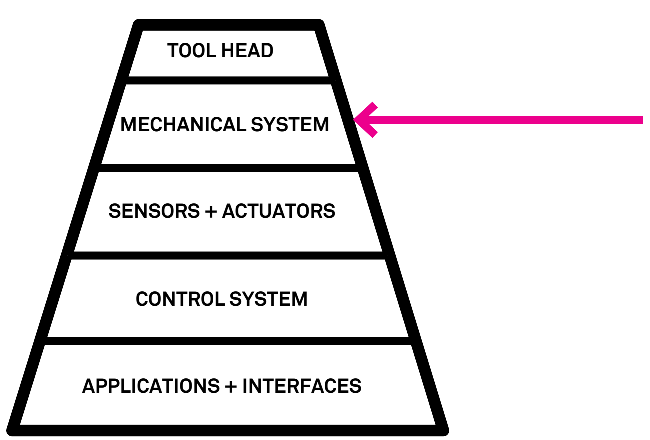
lots of force?





Machining parameters





Linear Motion guides

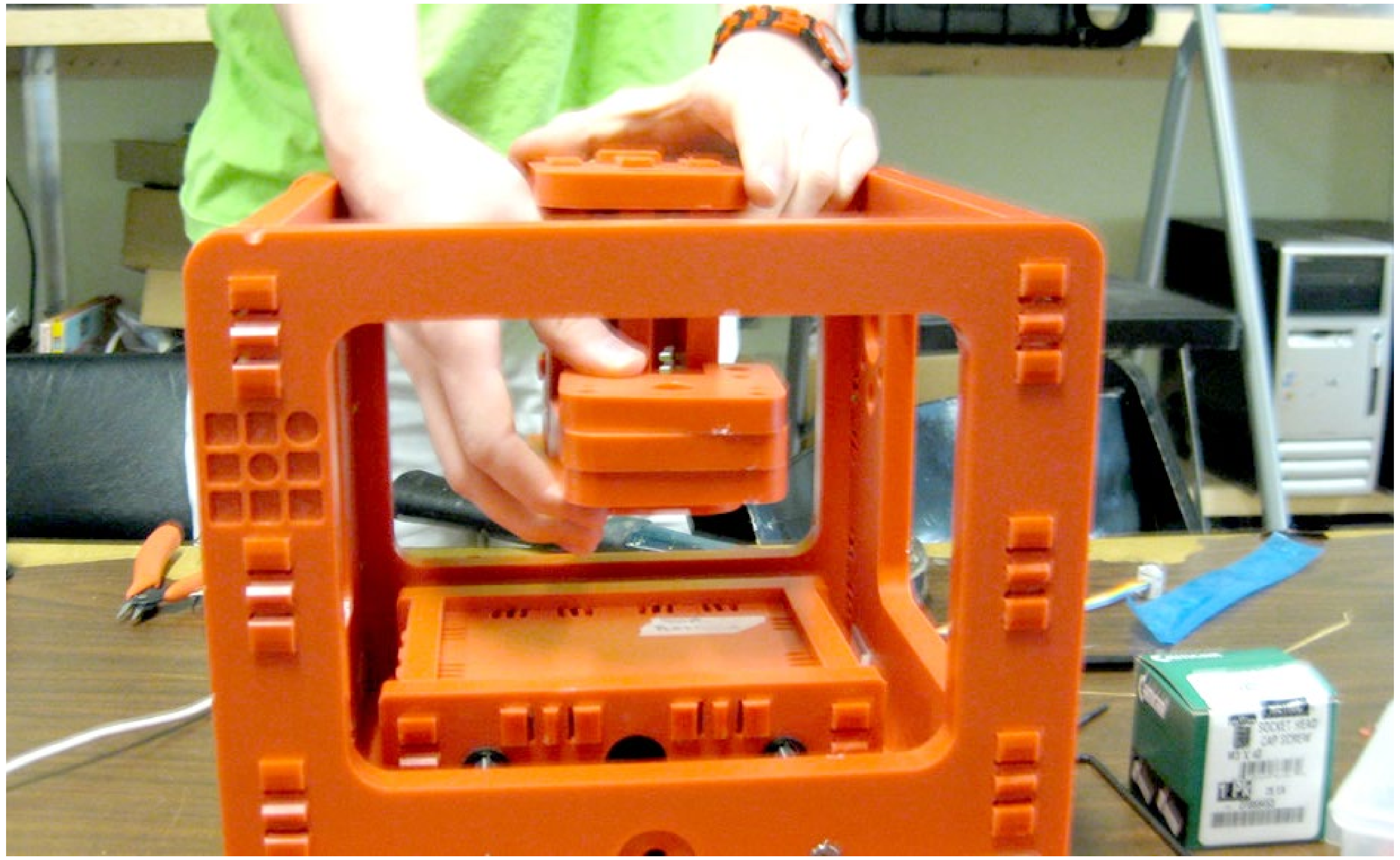
Bushings

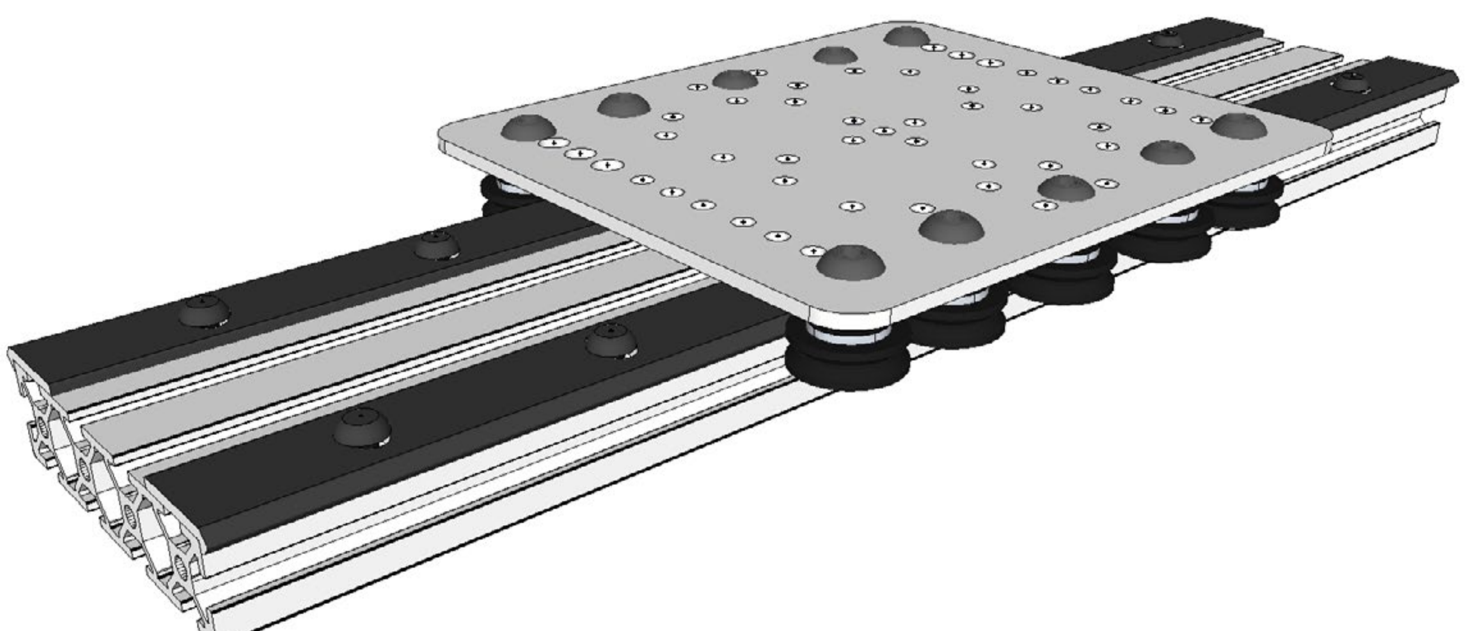
Thrust

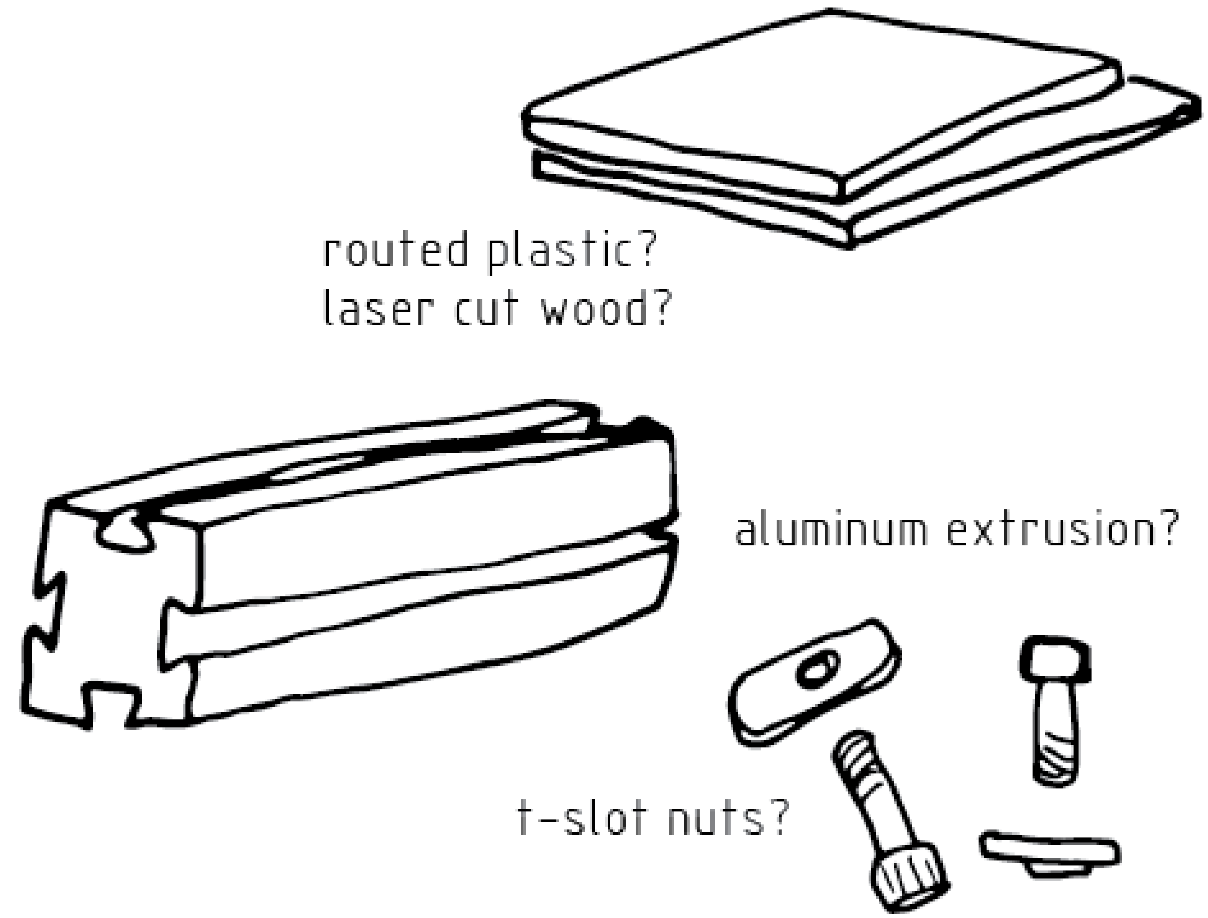
Taper

Roller/Radial

Bearings

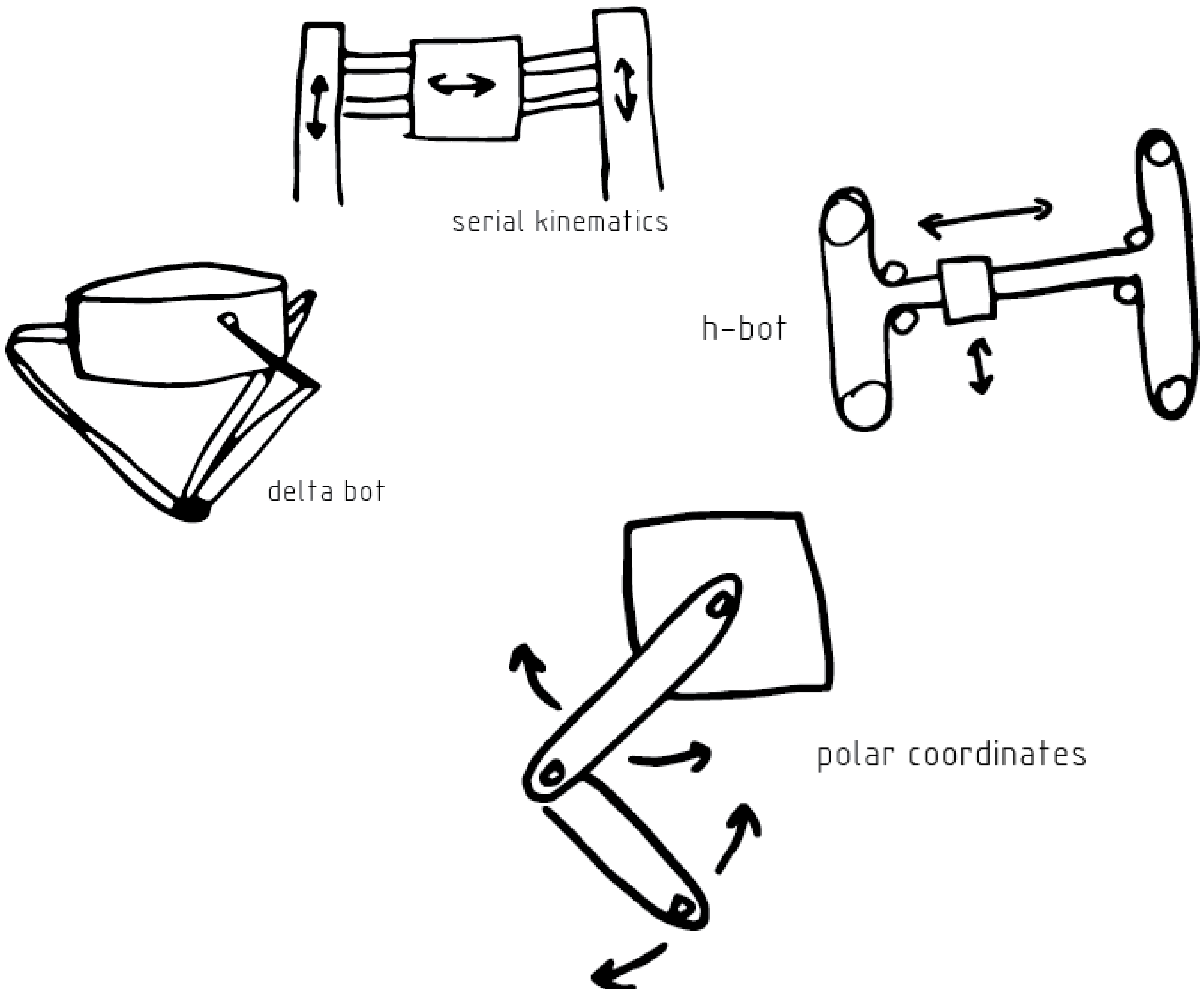


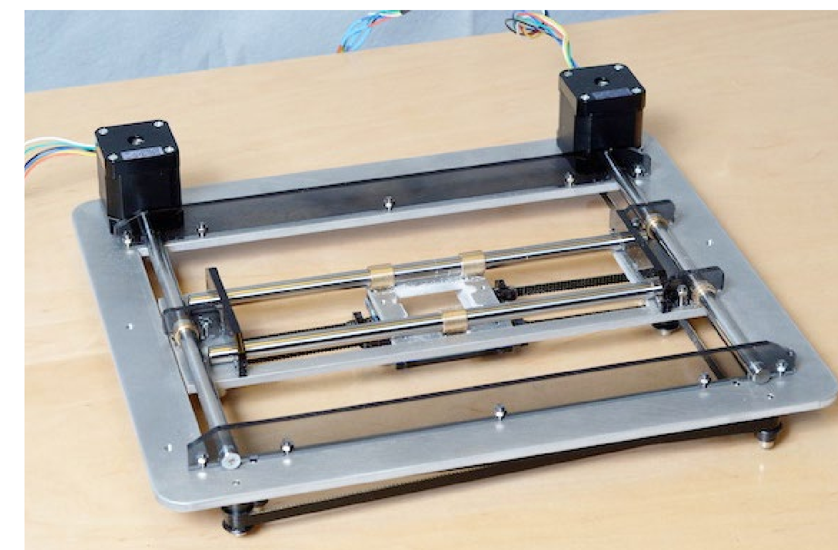




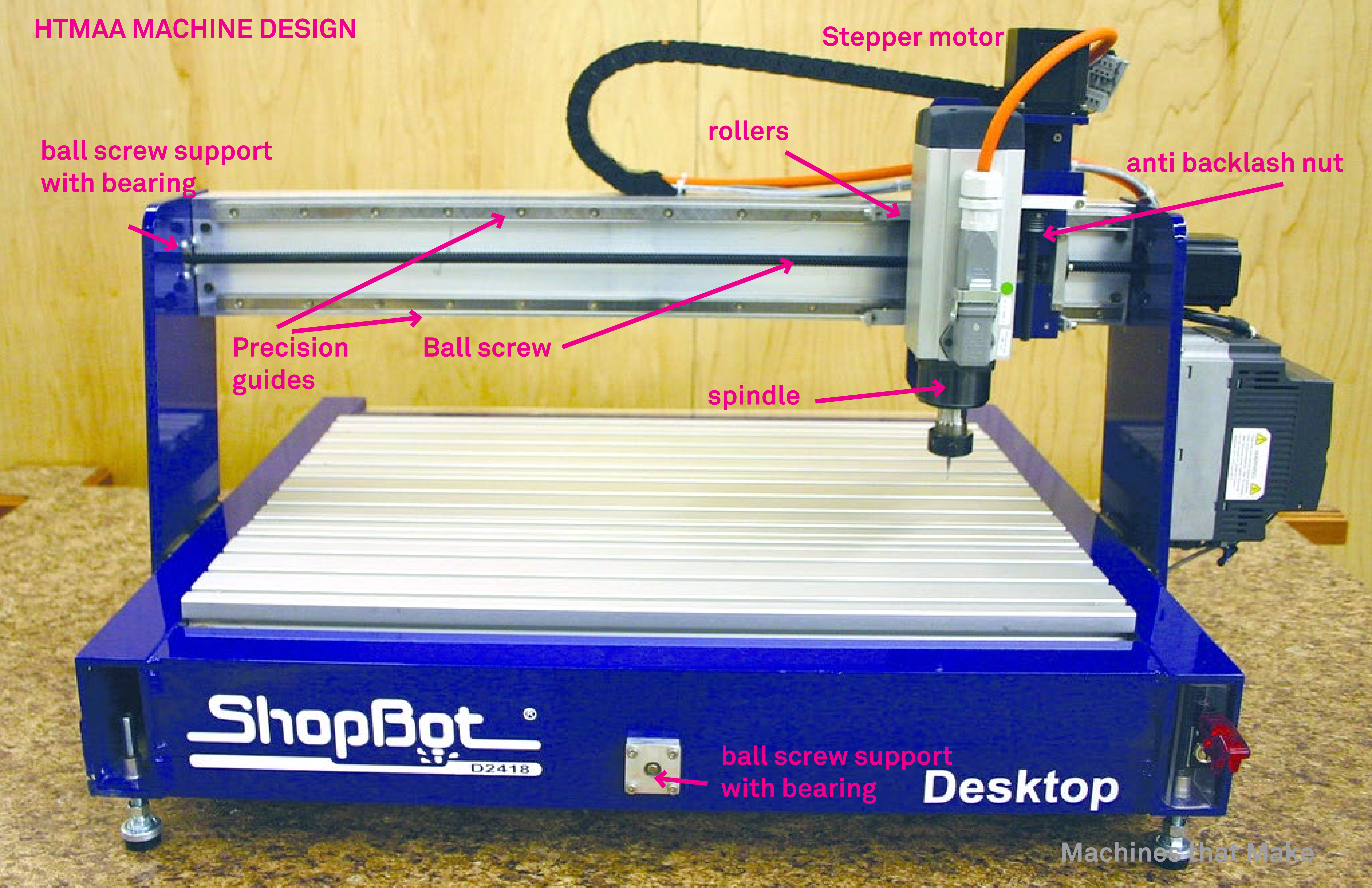
Laser cutting is fast, but not super precise. Aluminum extrusion is expensive, and you have to assemble each piece separately. How do you hold the frame together? Glue? Machine screws? T-slot nuts? All things to consider!

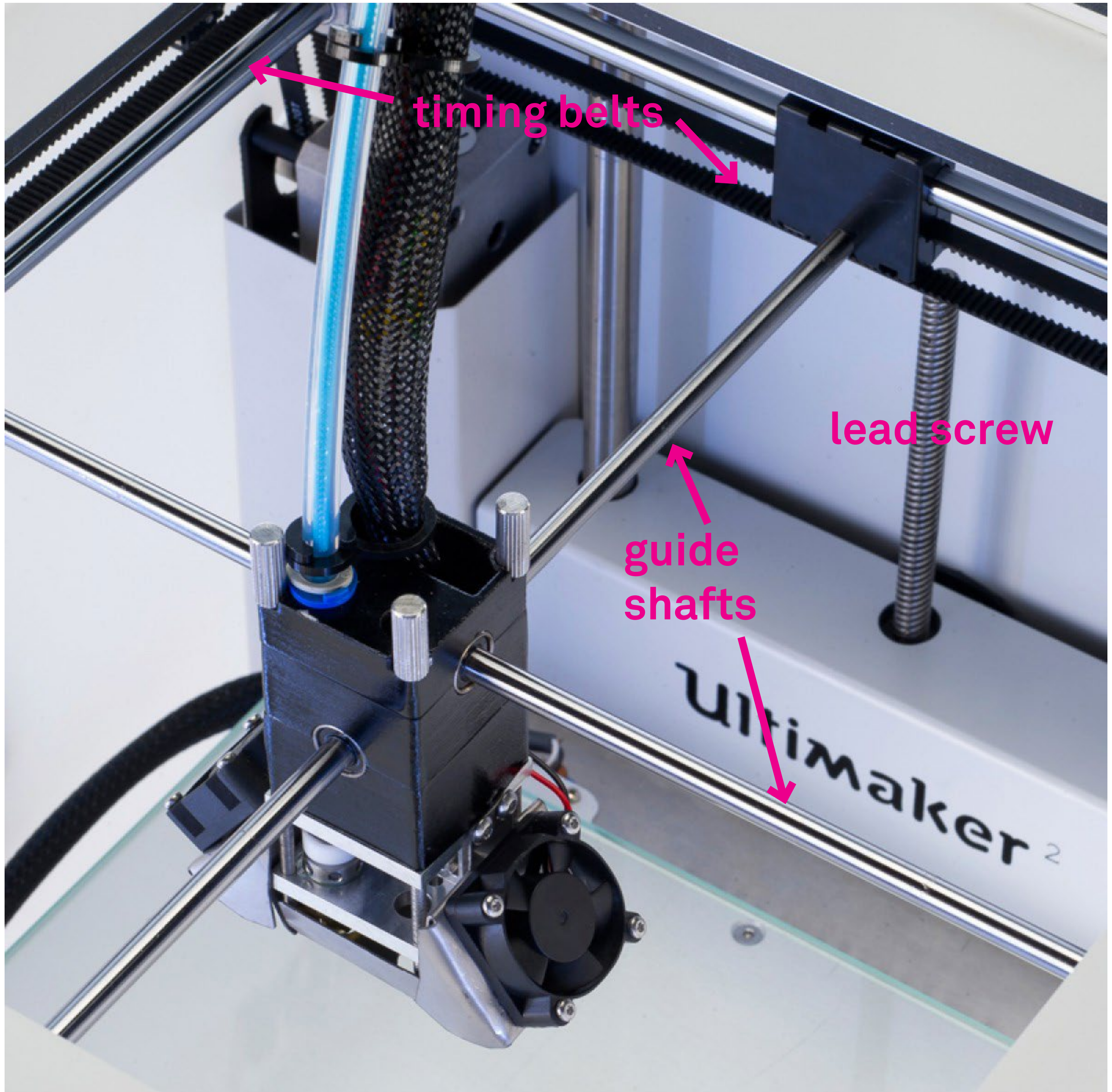
Frames

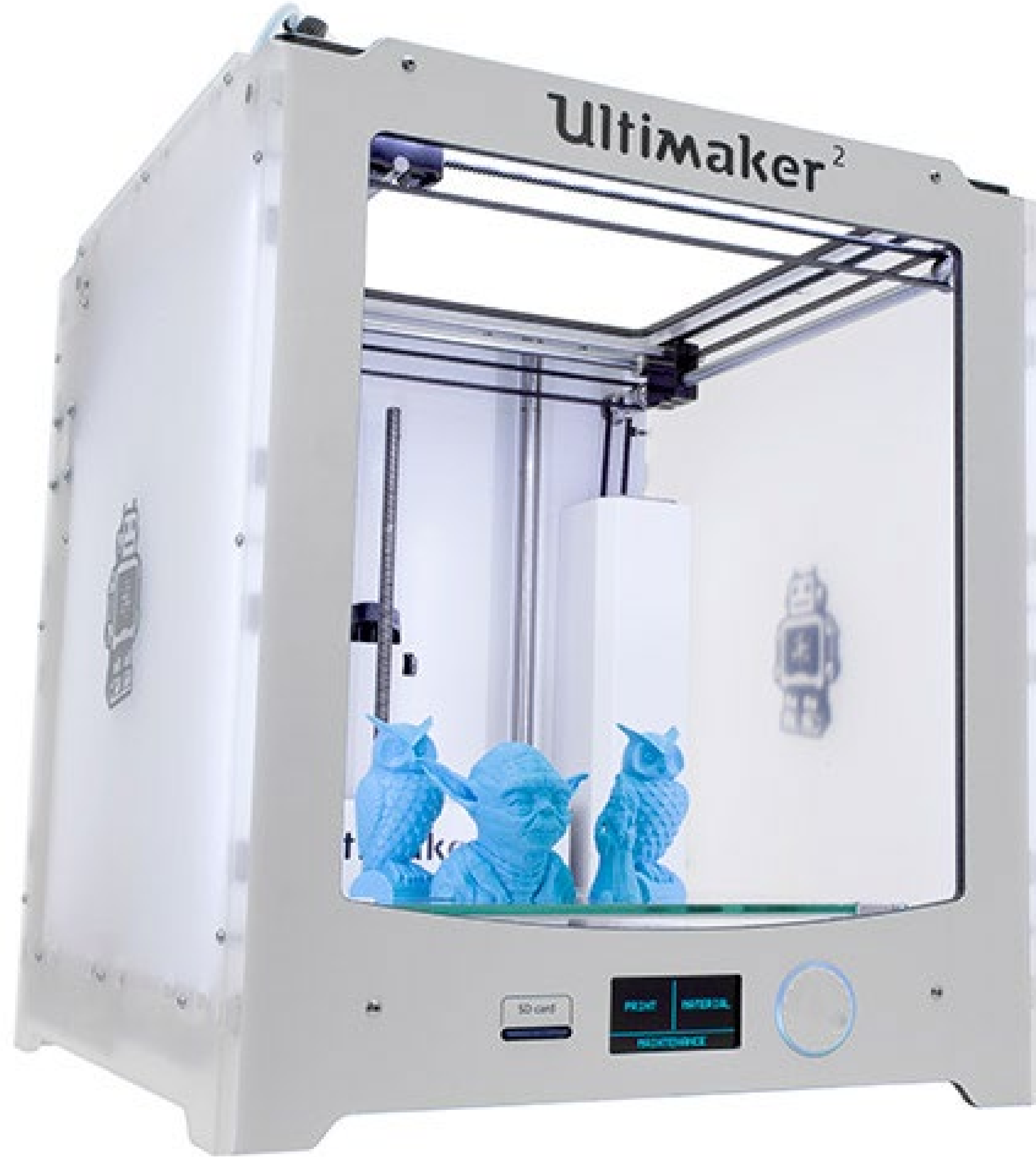




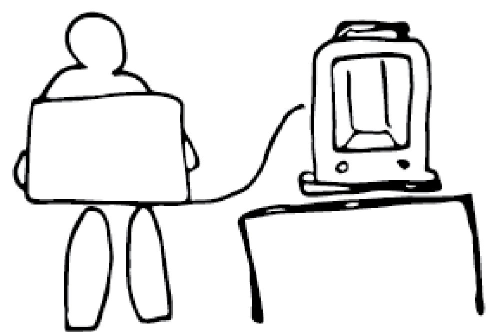
Kinematics

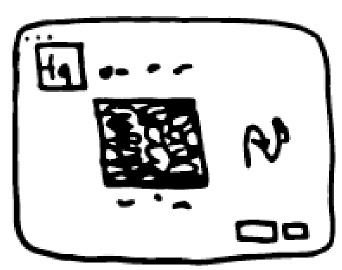

HTMAA MACHINE DESIGN
Stepper motor
rollers
ball screw support
with bearing
anti backlash nut
Precision
guides
Ball screw
spindle
ShopBot
D2418
ball screw support
with bearing
Desktop
Machines that Make


timing belts
lead screw
guide
shafts
Ultimaker 2


Ultimaker 2

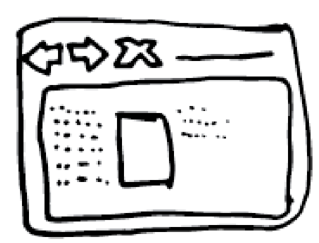
Finally, how are you going to control the machine? There are different kinds of software to stream machine code to machines with, how do you want yours to work?





Maybe a drawing program interfaces directly to the machine

Maybe the machine is controlled from a browser...

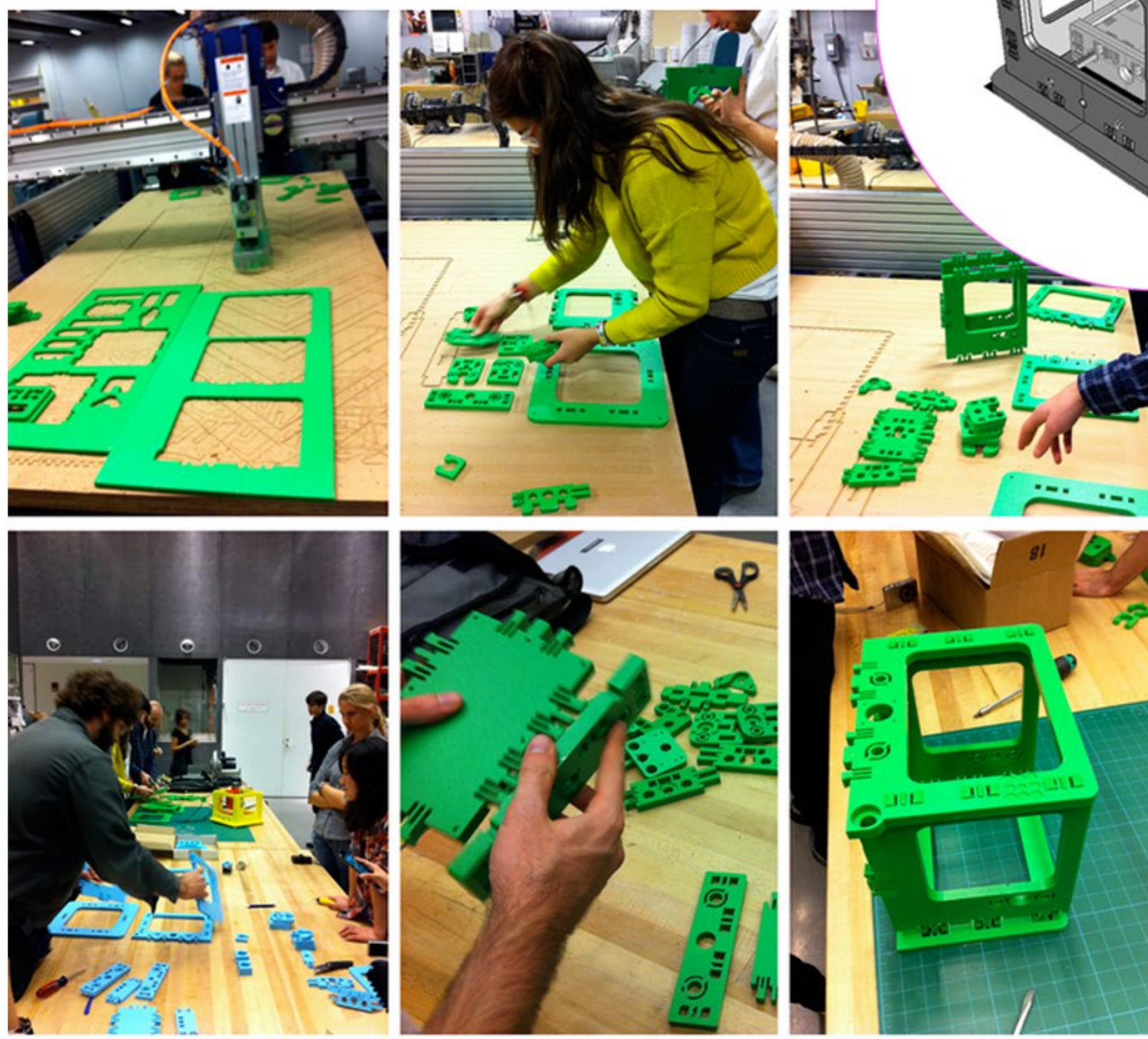


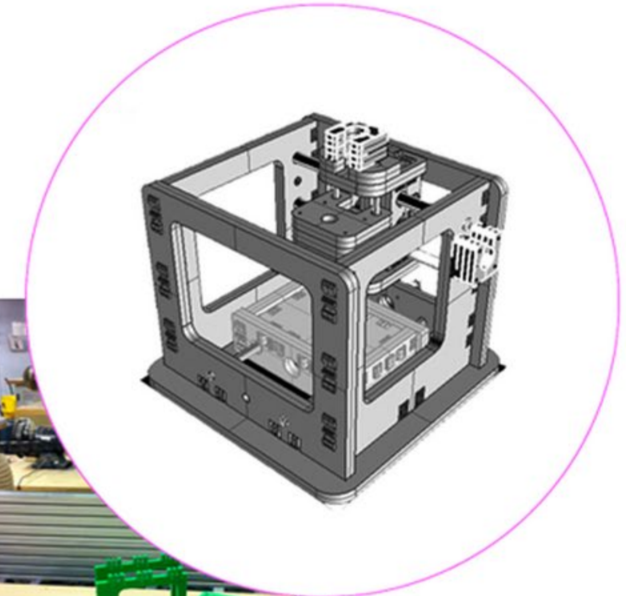
Those were some tips for making your own machines, we hope they were helpful. Now go on, cook up some machines, and have fun!

I made my machine,
it is just right for me

Each section must MAKE A MACHINE!!!

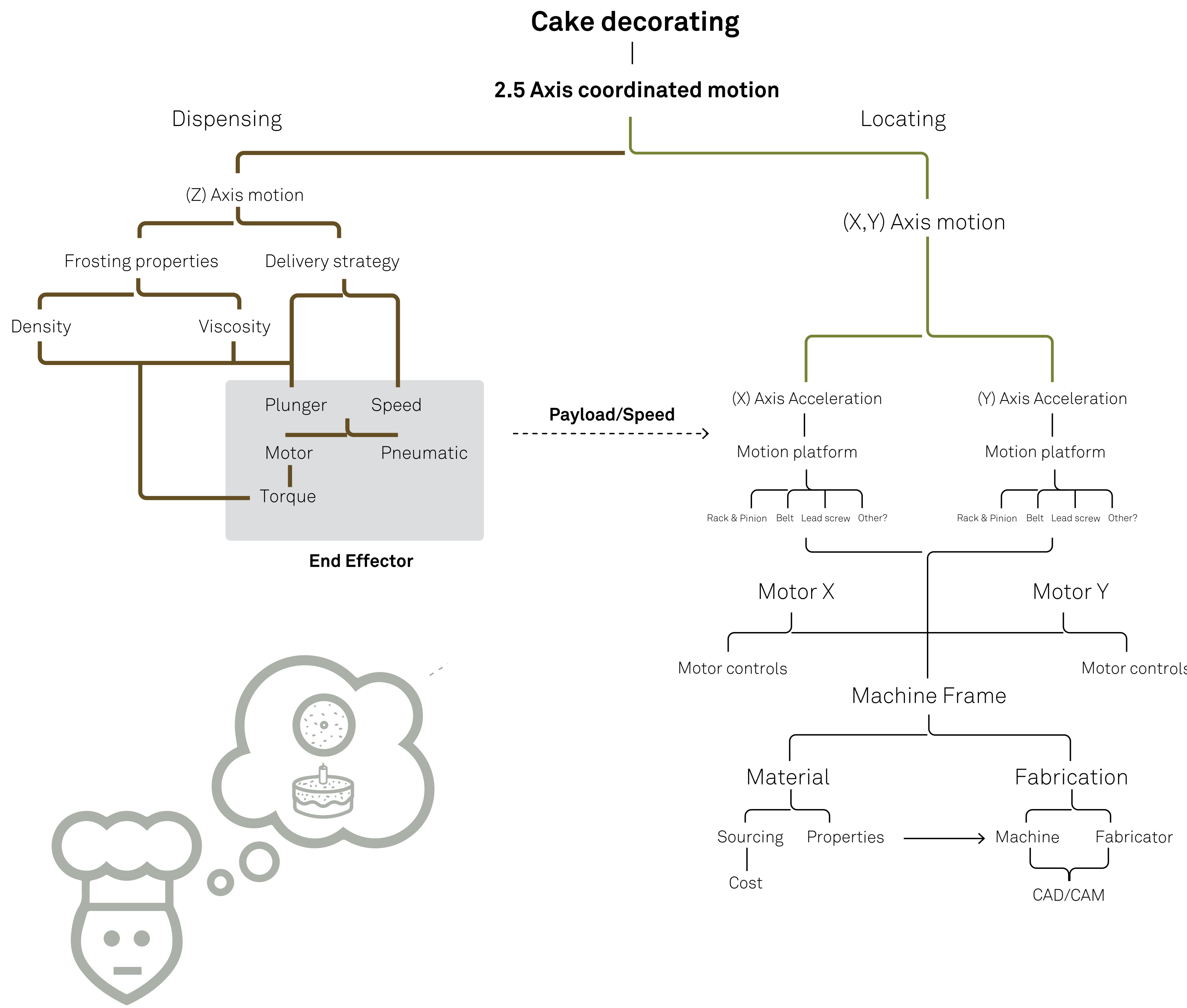
The Assignment



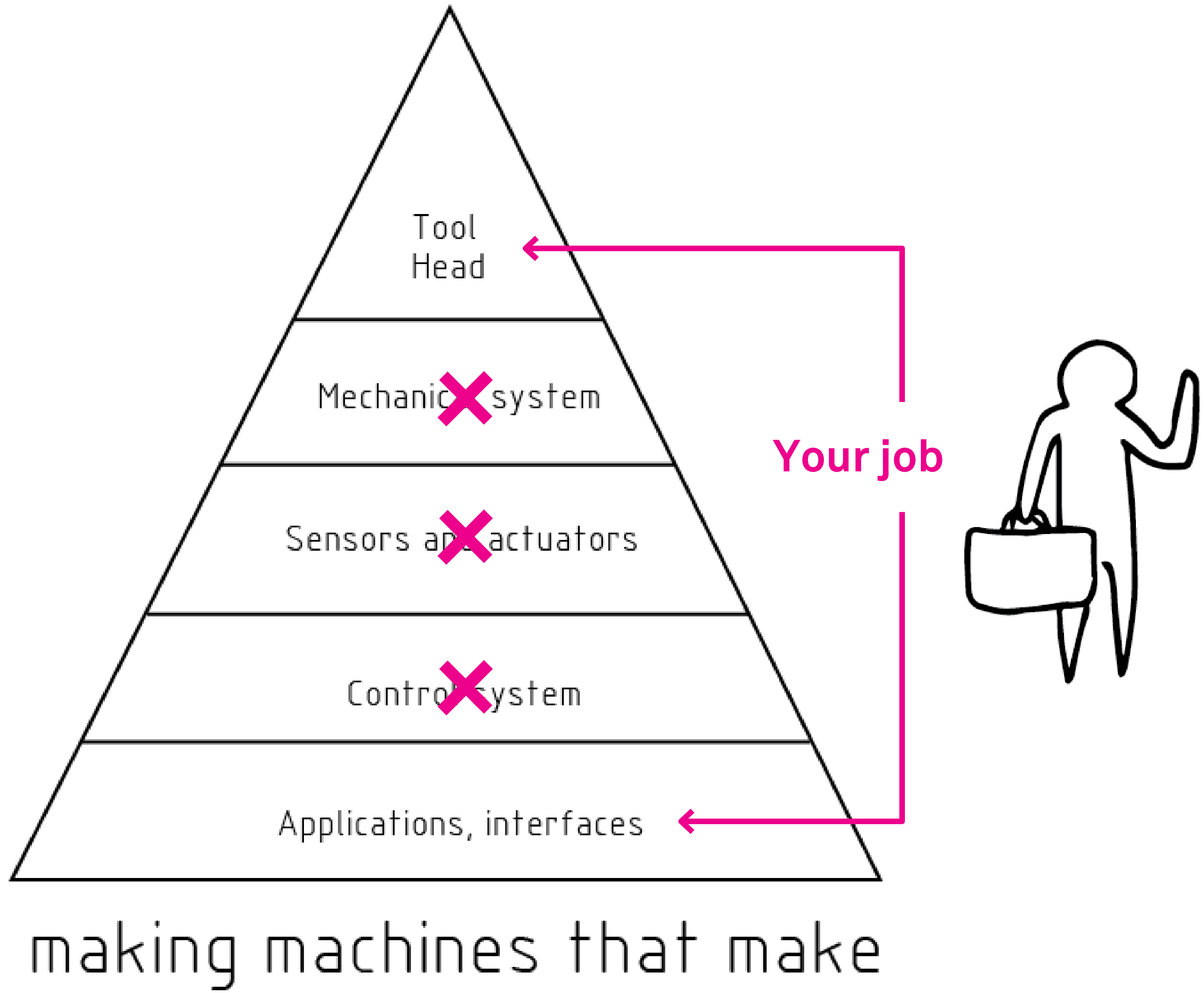


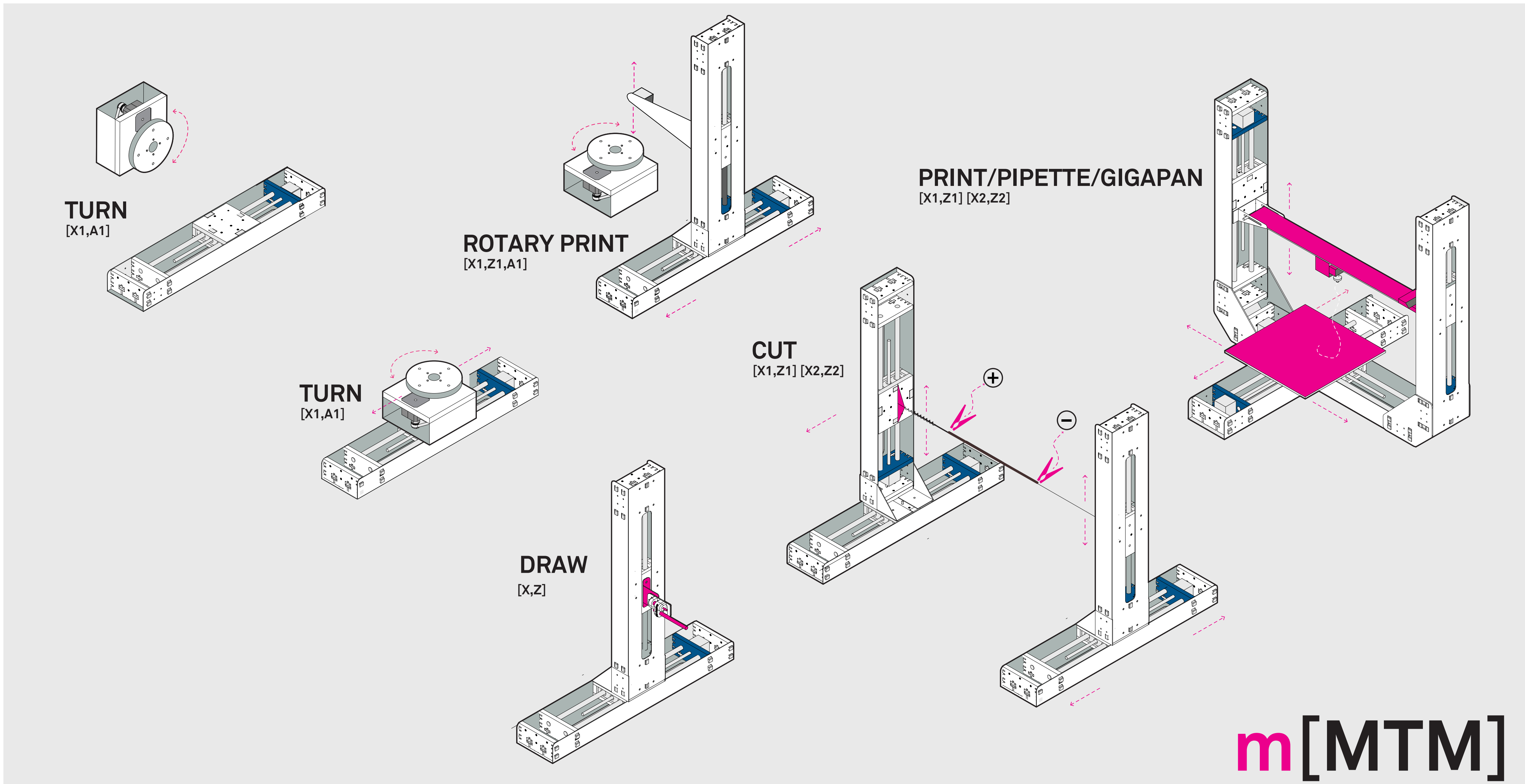
I spent most of my time preparing for the final project. **Click on the icon below to view my action plan.**

The trouble

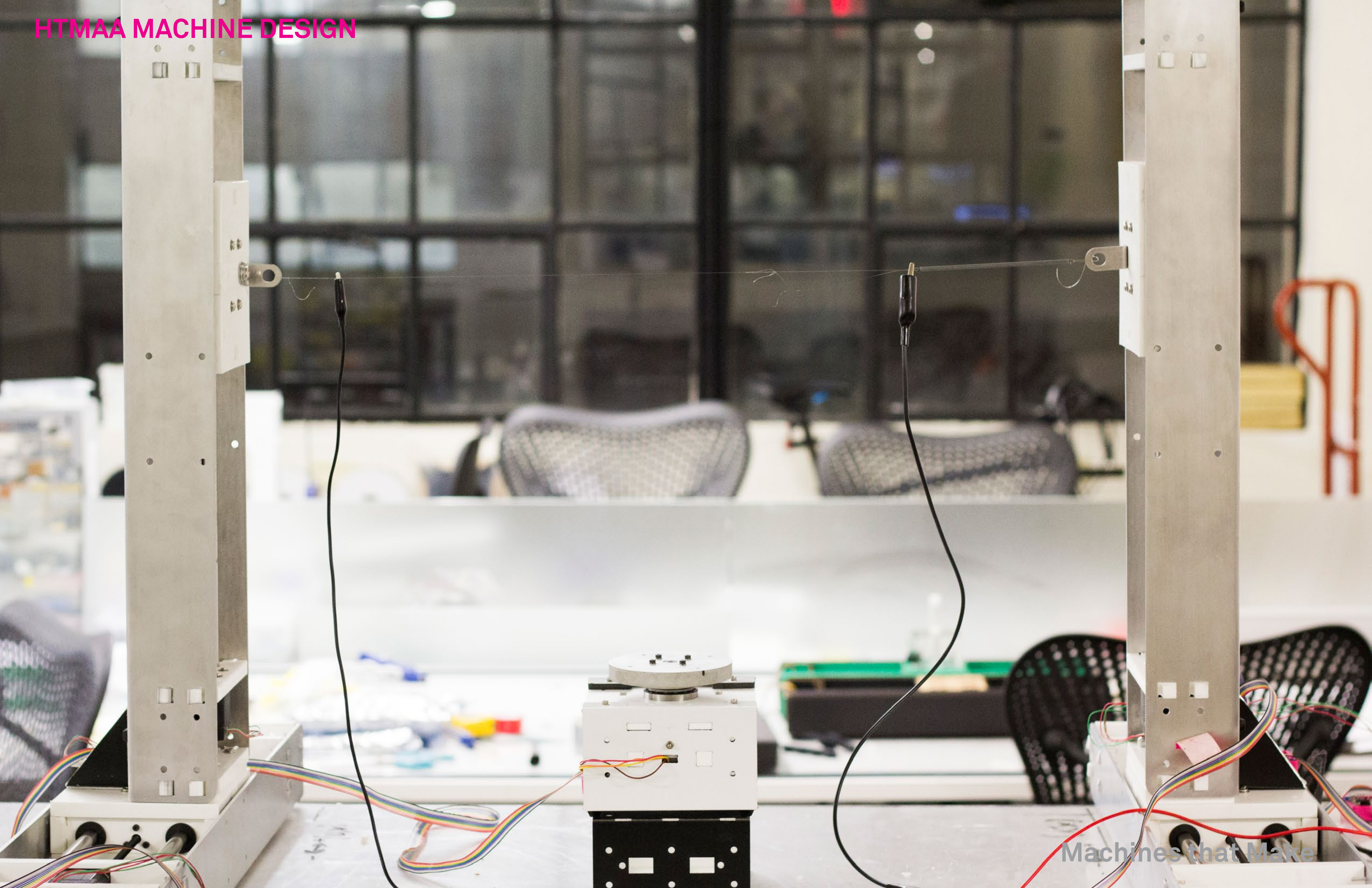


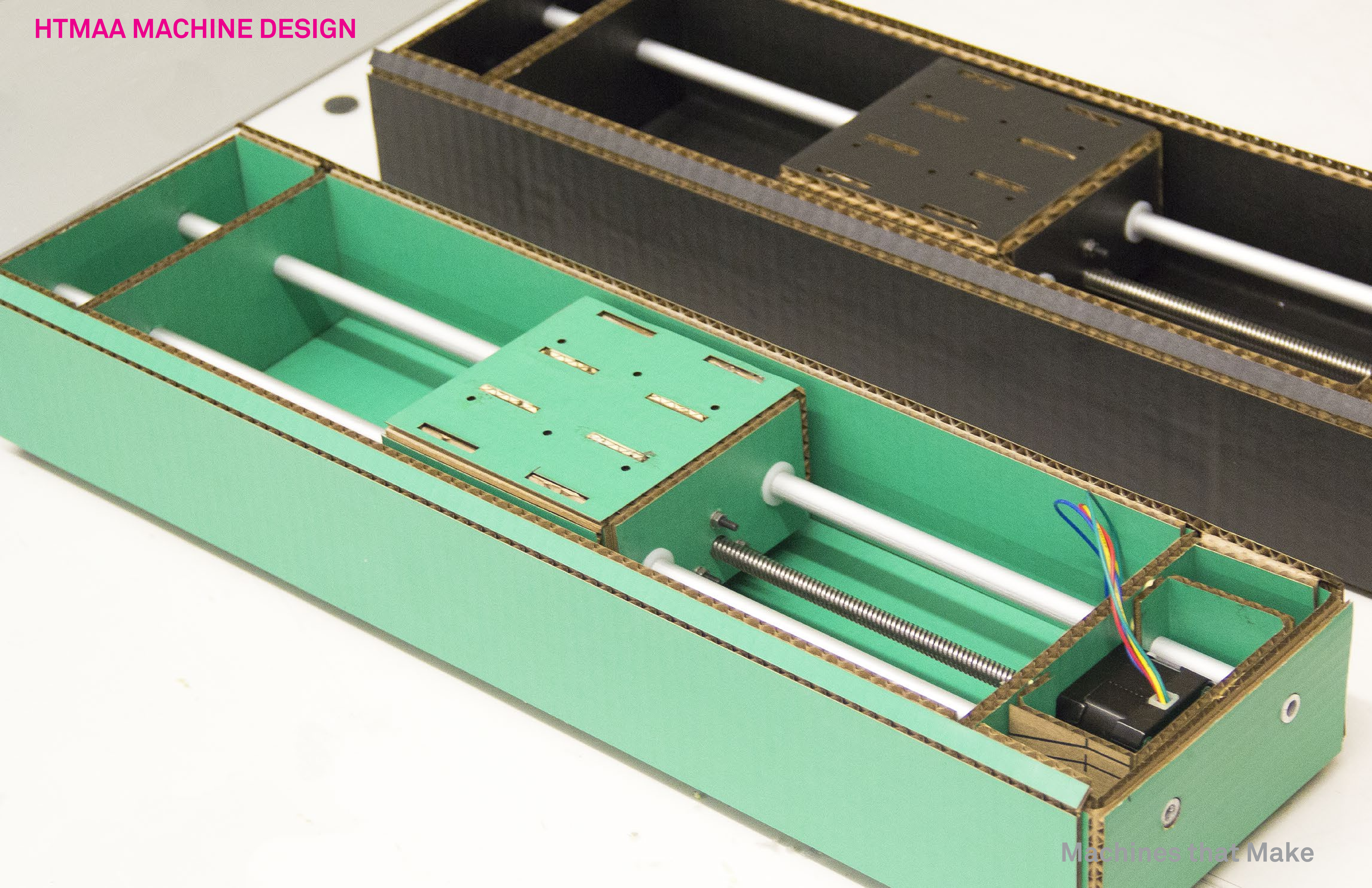
The strategy

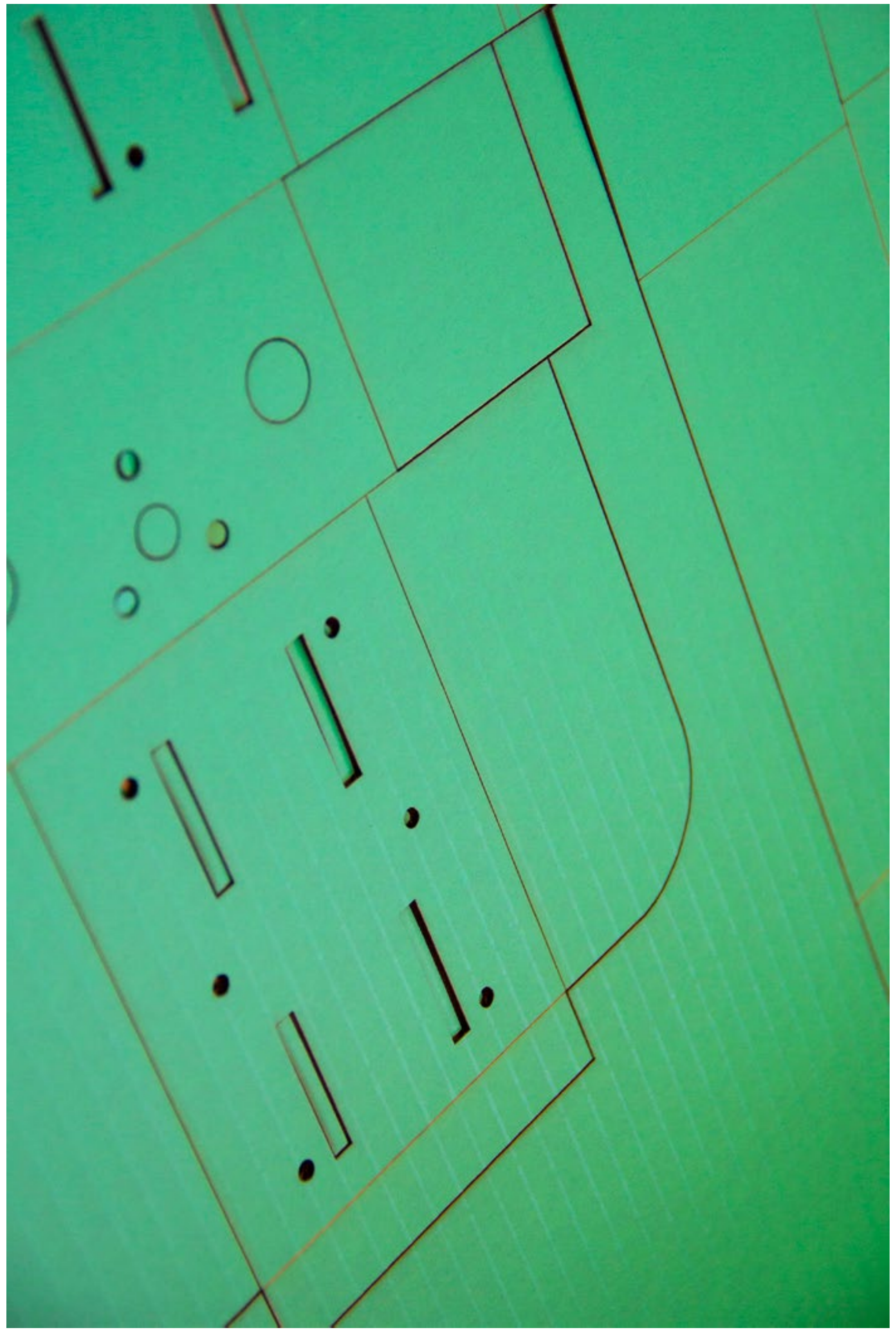

Tool
Head
Mechanic system
Sensors an actuators
Control system
Applications, interfaces
Your job
making machines that make

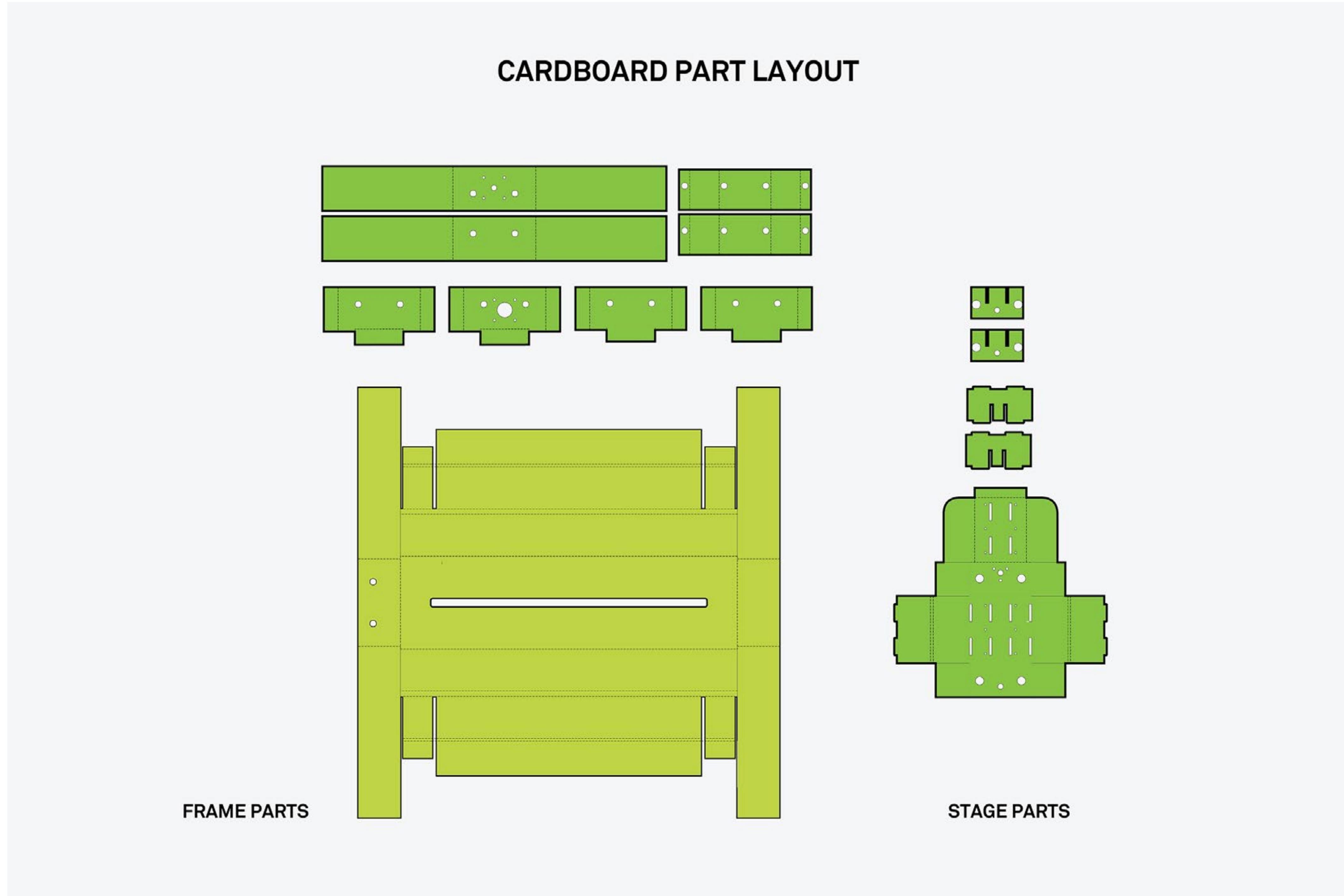


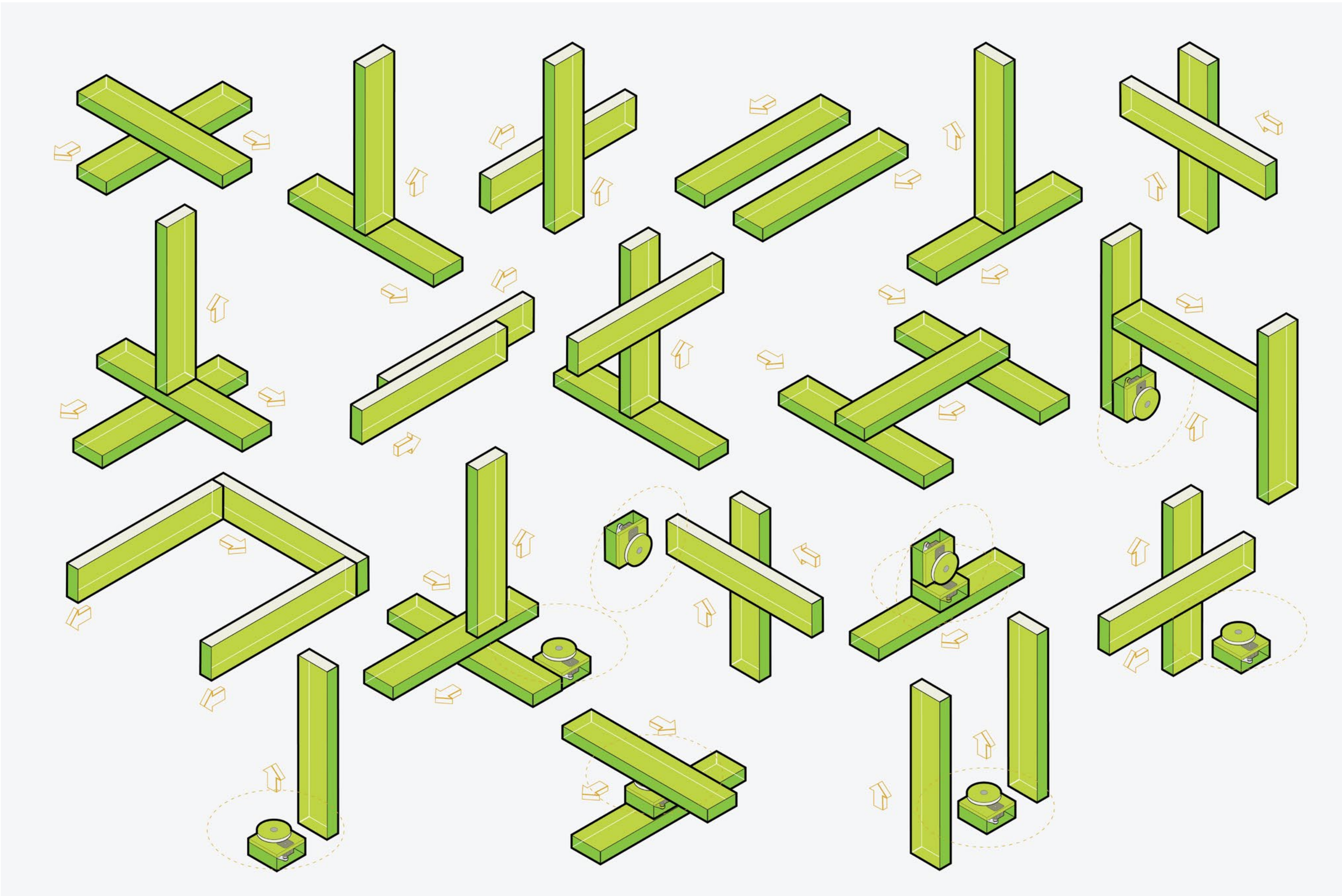
[modular] Machines that Make

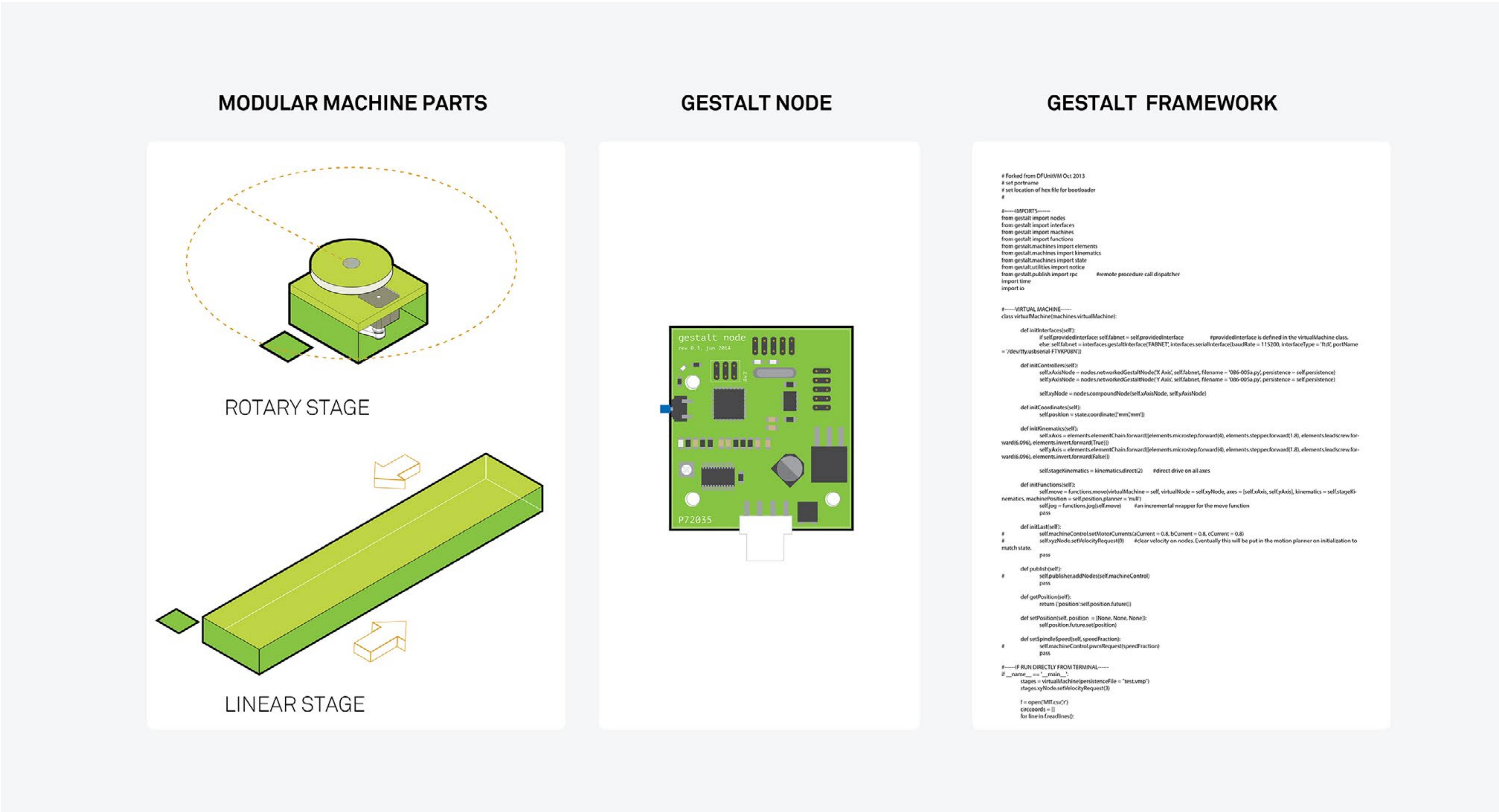




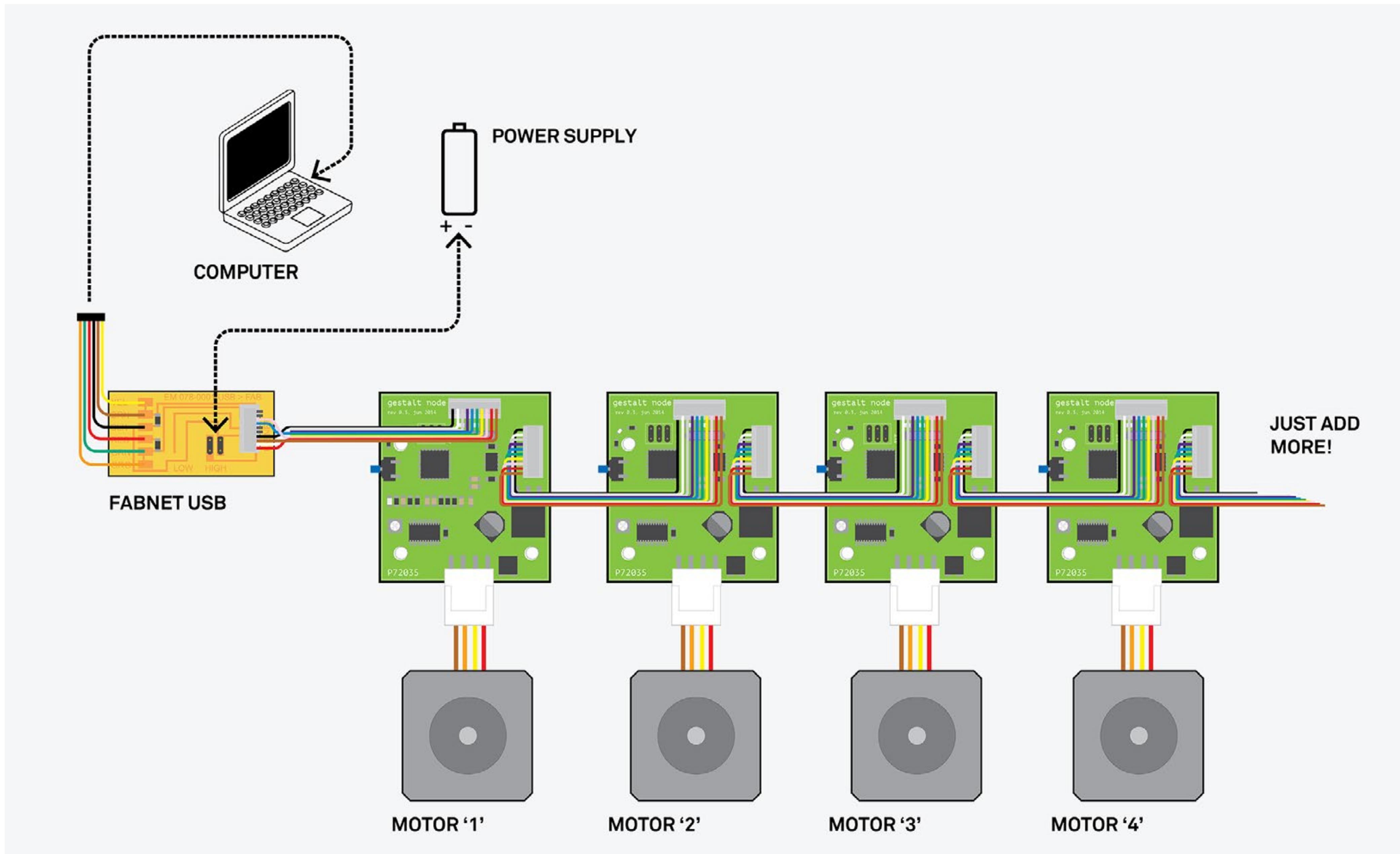



CARDBOARD PART LAYOUT
FRAME PARTS
STAGE PARTS





Gestalt Framework



Networked nodes

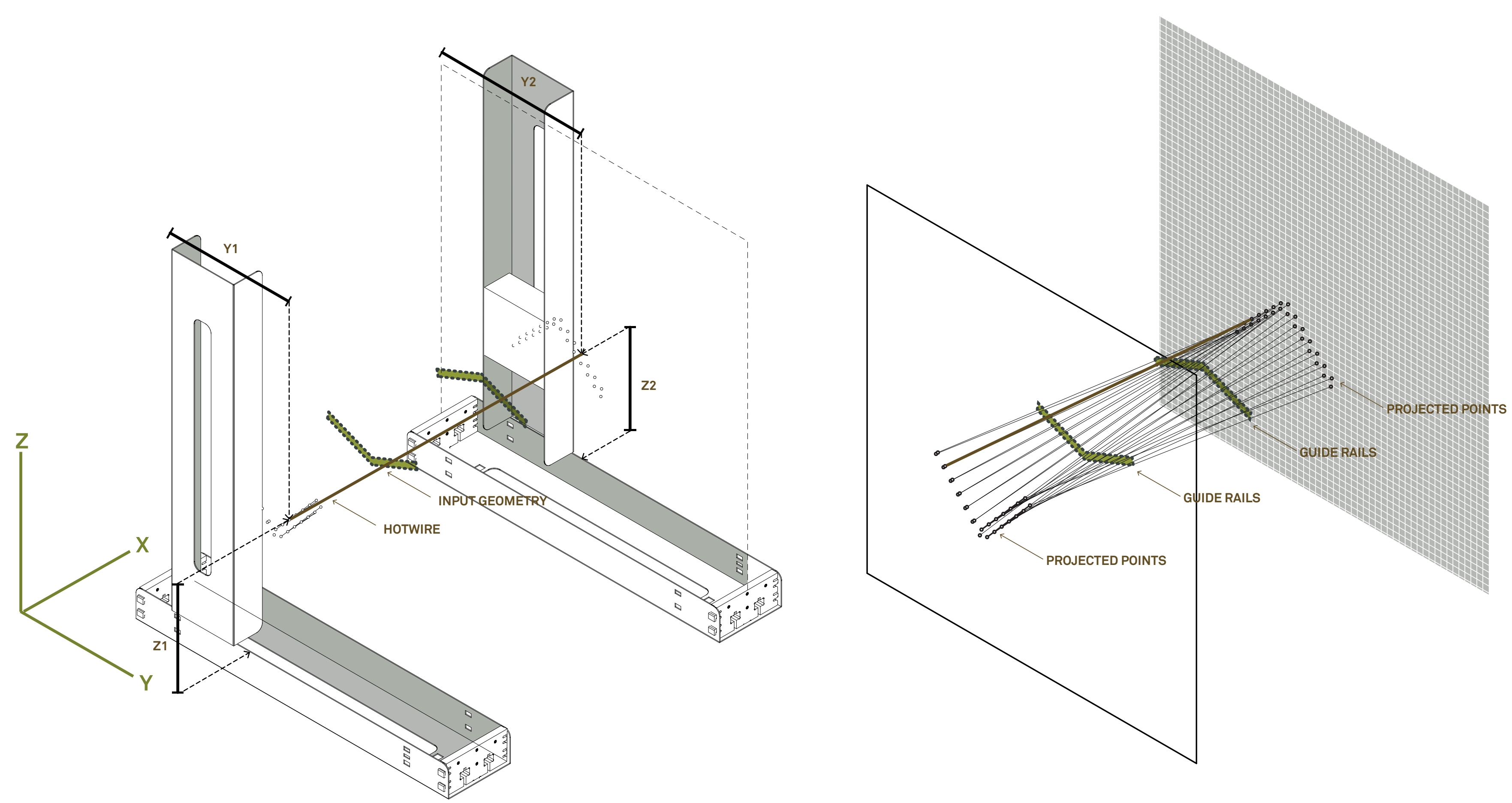
Per machine:

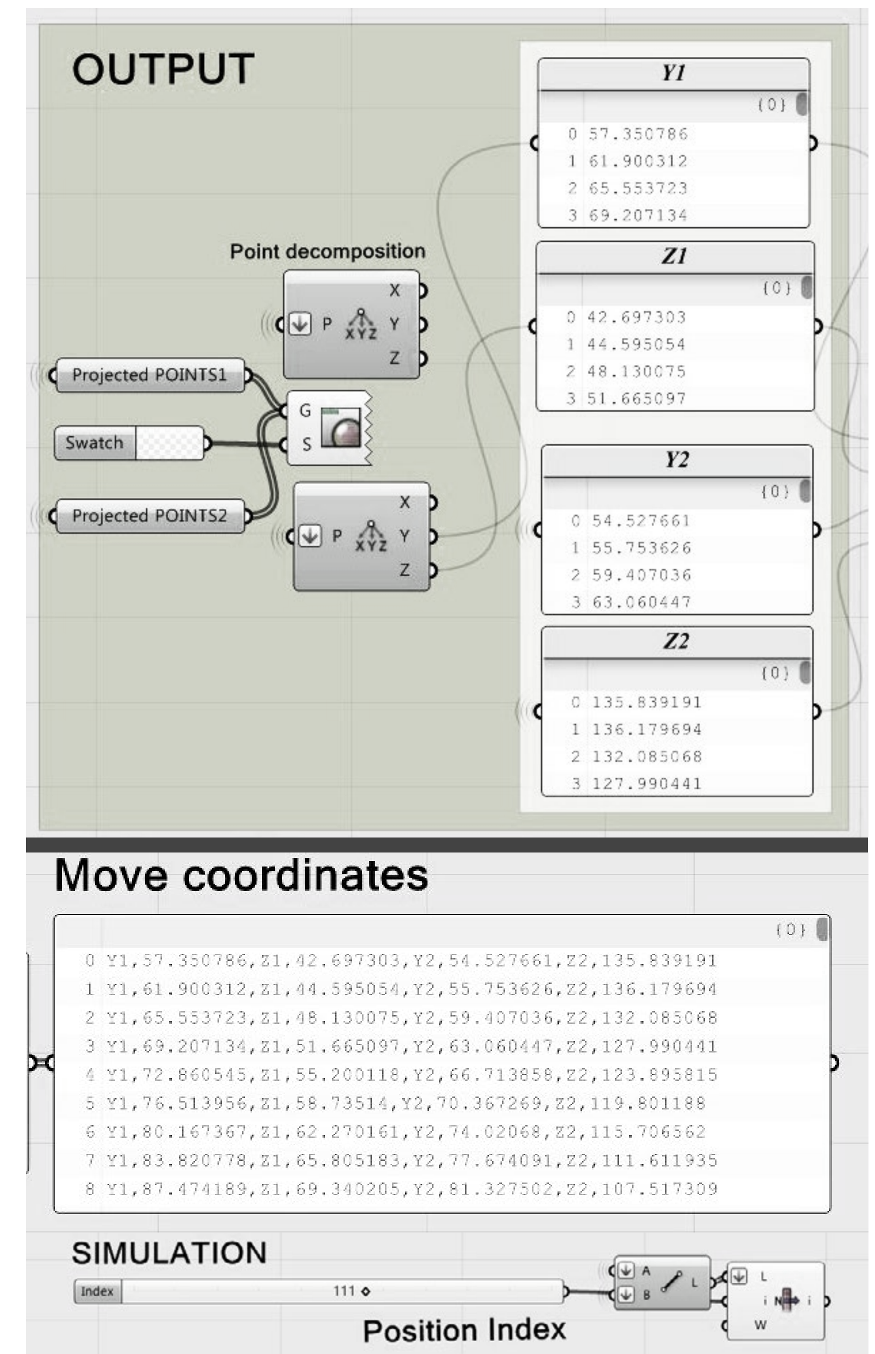
1: stages + gestalt nodes
2: power supply + power supply/usb board
3: Virtual machine file

NO hot plugging

NO backdriving

NO drama!





Toolpathing

END EFFECTOR POSITION $= \begin{pmatrix} x_E \\ y_E \\ z_E \end{pmatrix}$

FORWARD KINEMATICS

$$x_E = (l_2 * \cos\theta_2)\cos\theta_1 + dx$$

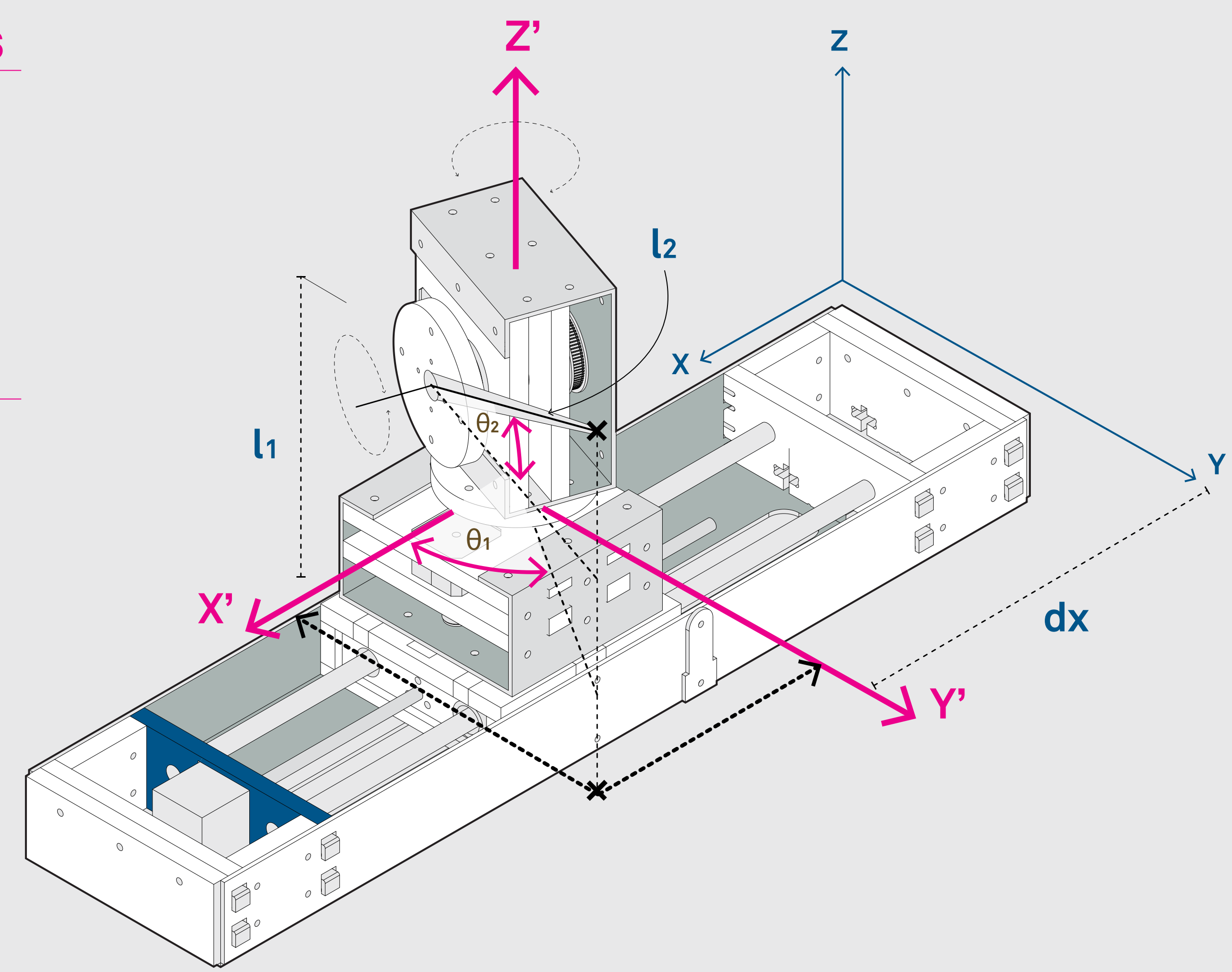
$$y_E = (l_2 * \cos\theta_2)\sin\theta_1$$

$$z_E = (l_2 * \sin\theta_2) + l_1$$

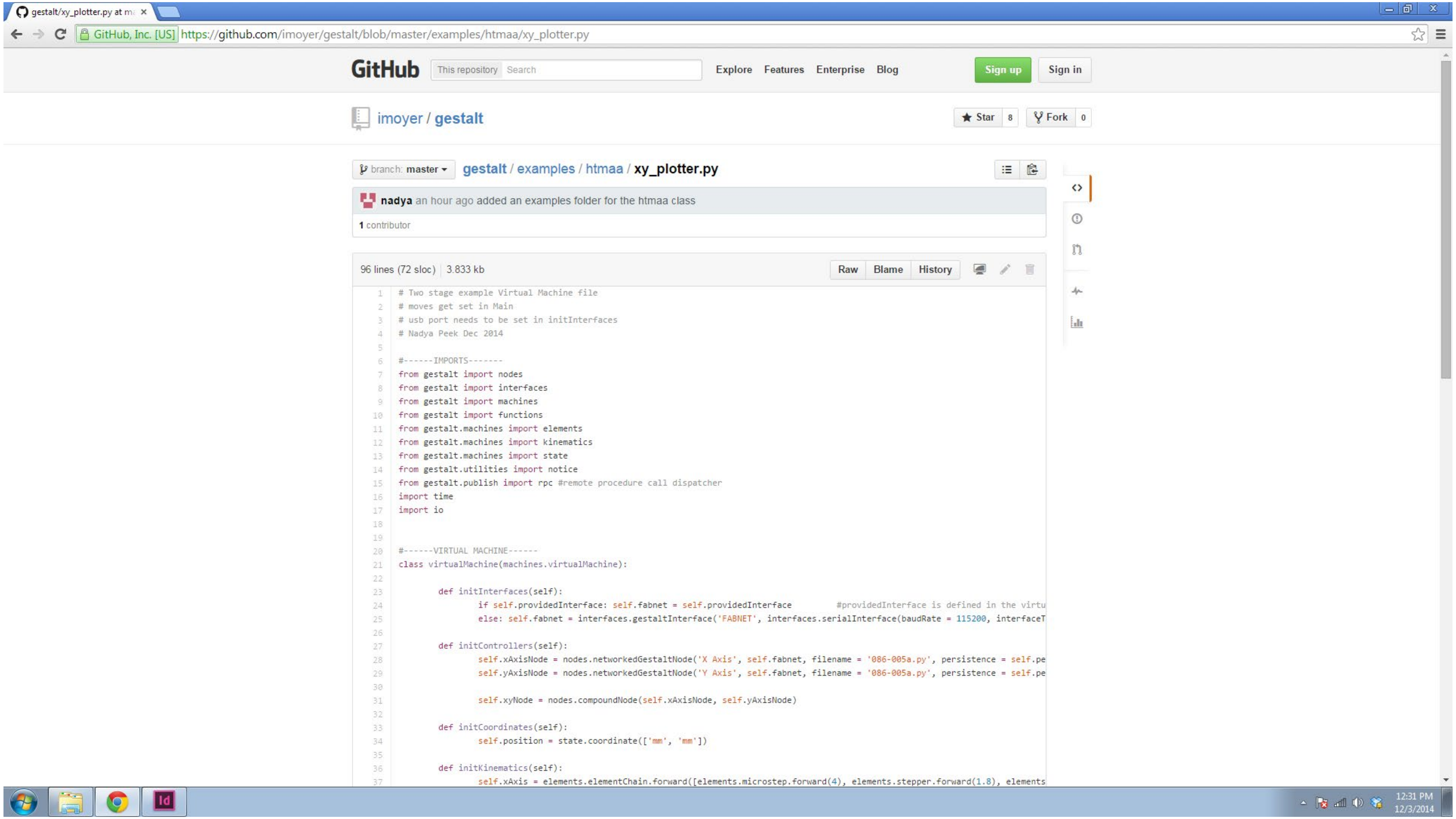
INVERSE KINEMATICS

$$\theta_1 = \tan^{-1}\left(\frac{y_E}{x_E + dx}\right)$$

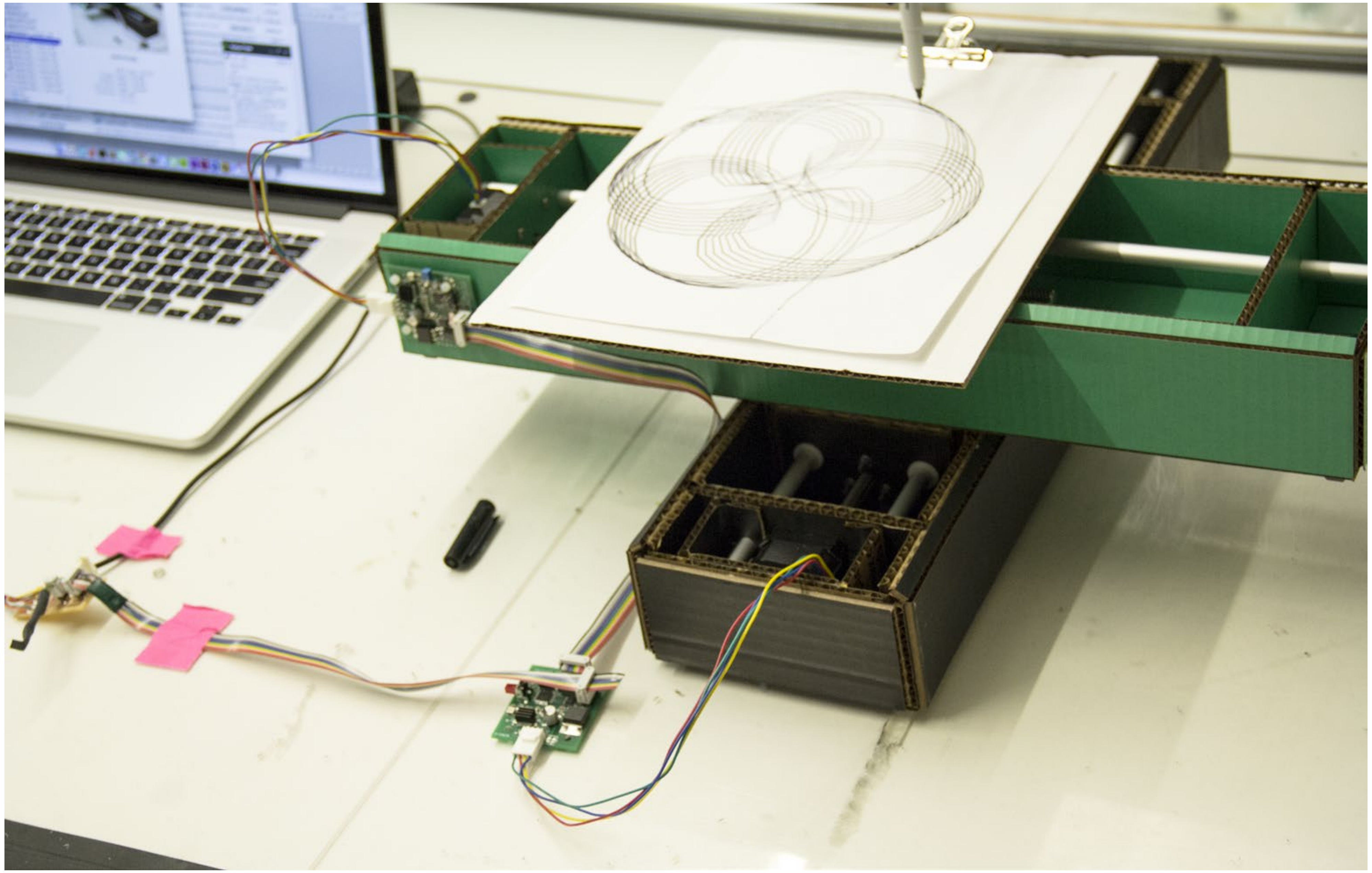
$$\theta_2 = \tan^{-1}\left(\frac{(z_E - l_1)^2}{\sqrt{(l_2)^2 - (z_E - l_1)^2}}\right)$$



Kinematics



Virtual machine



Assignment: make your own machine w/ end effector

HTMAA MACHINE DESIGN