Foldable Robotics

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https://faculty/washington.edu/minster/

course website: https://faculty.washington.edu/minster/foldable_robotics_2018/

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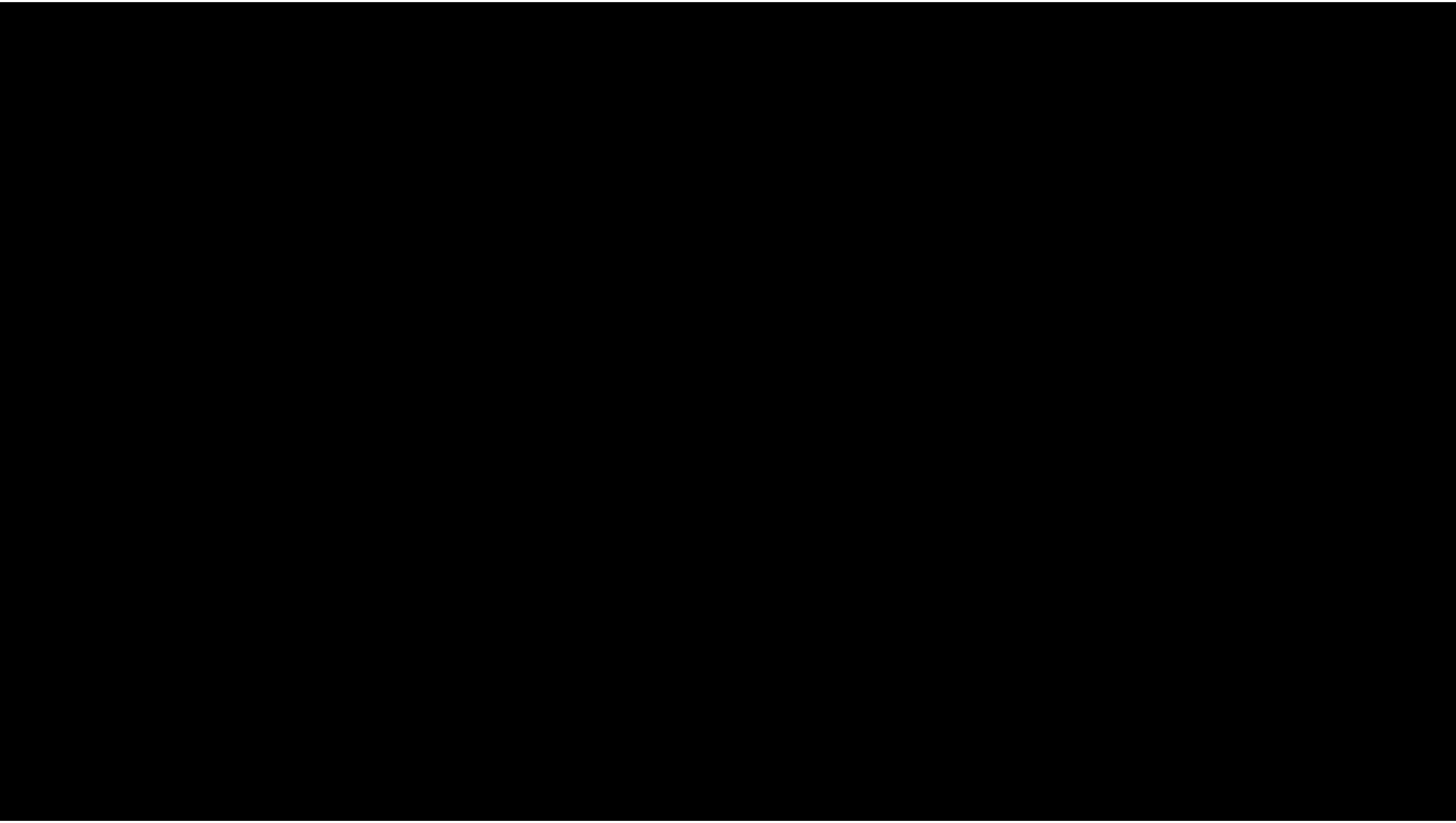


link: https://www.youtube.com/watch?v=ionC1toDJZI

what you will learn

- how to design and build your own laser-cut foldable mechanisms
- where to get parts and materials
- how to program your robot to move using a raspberry pi and off-the-shelf servos

what is not covered

- how to use our specific laser cutter (we will operate it for you)
- kinematics, dynamics, and control of foldable structures

why foldable robotics

- fast! cutting time is just a few minutes (vs. hours for a 3D printer)

- strong

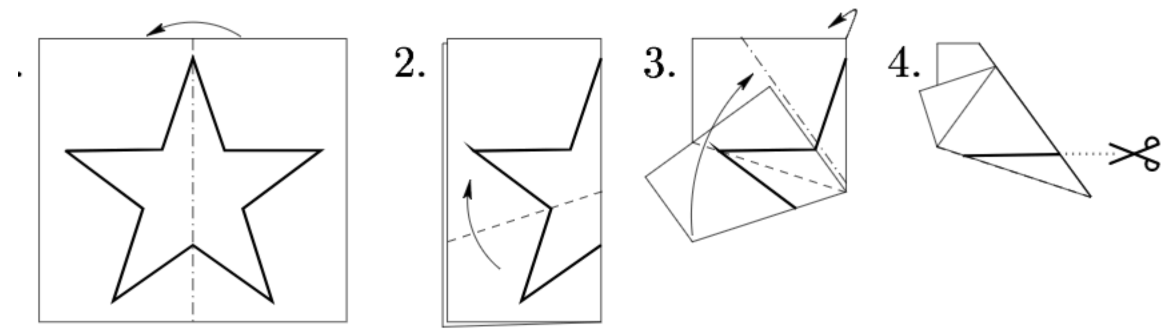
	Cardboard	ABS plastic	Steel	Carbon Fiber
Tensile Strength (kPa)	50,000	40,000	600,000	1,240,000
Density (kg/m³)	750	1200	8000	1580
Strength-to-weight	**67**	**33**	**75**	**785**

- cheap! laser cutter is ~~$4k~~ $2.5k (as of last week!), cardboard sheets ($2), sheet tape ($2)

- no continuous revolution

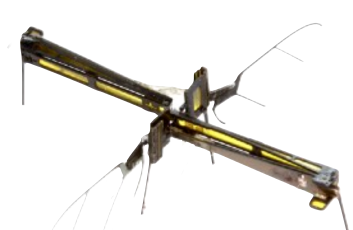
why foldable robotics

- recent advances in origami geometry
  e.g. Demaine et al, 1998:
  proved you can cut any shape
  with the correct fold & single cut

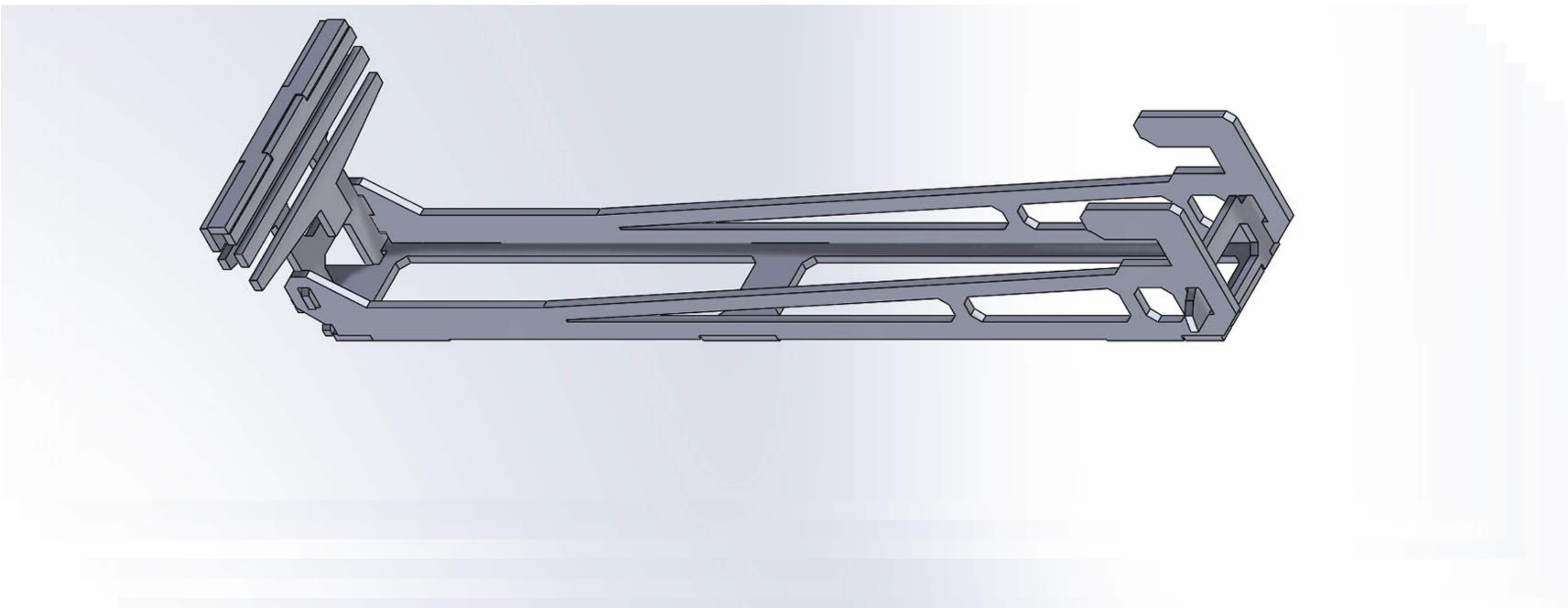


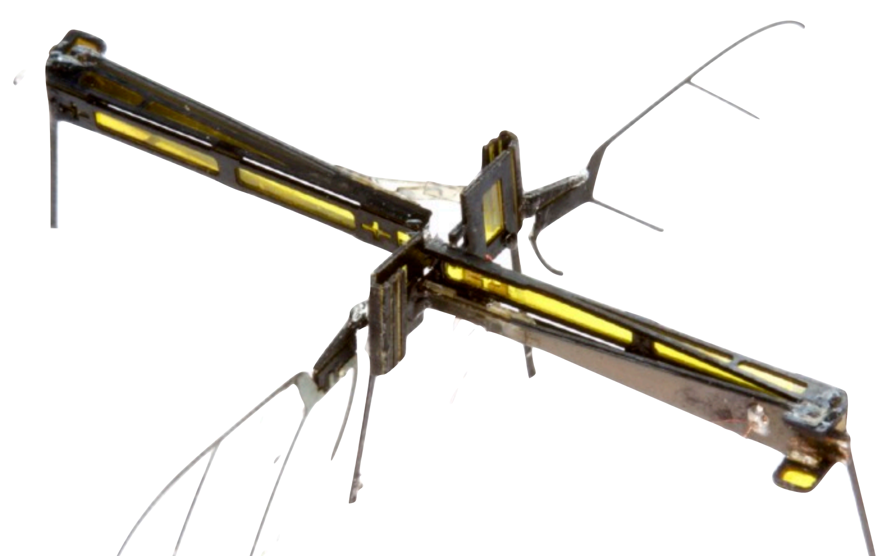
- nature is made of foldable things!
  ladybug wing folding:

- classic revolving pin joints inefficient
  for small <1cm mechanisms



examples





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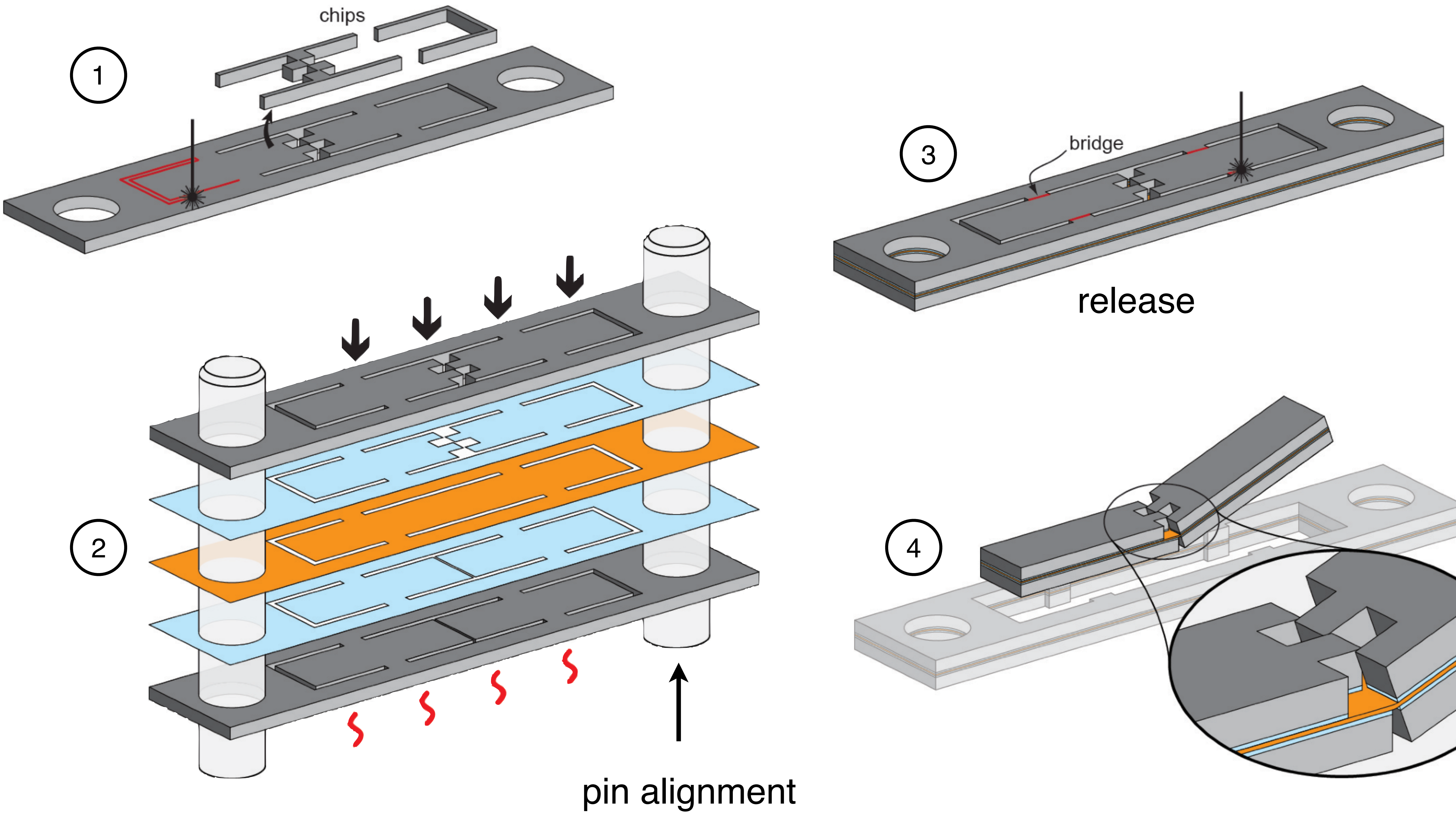
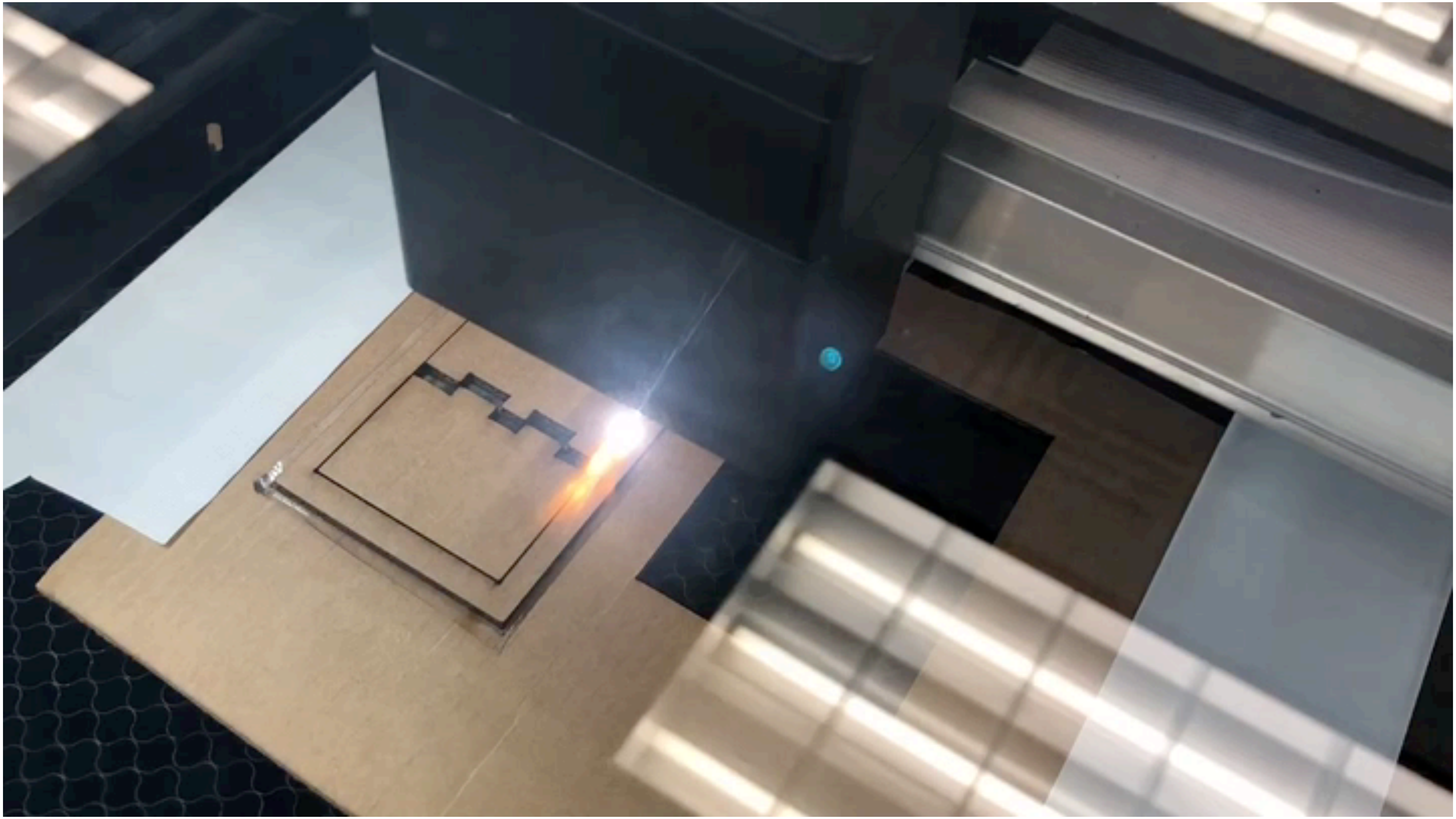
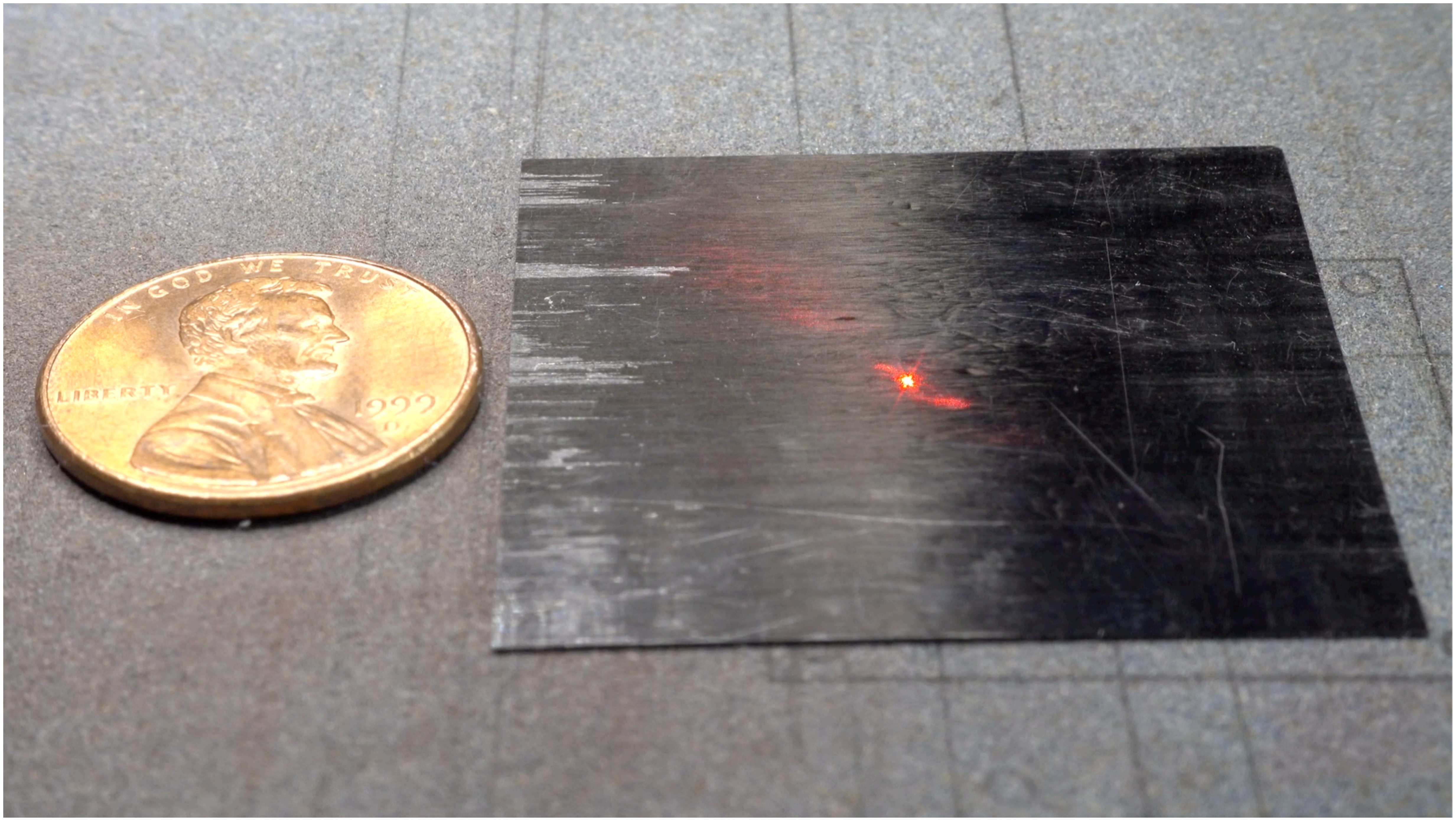
fabricating the basic element: a fold



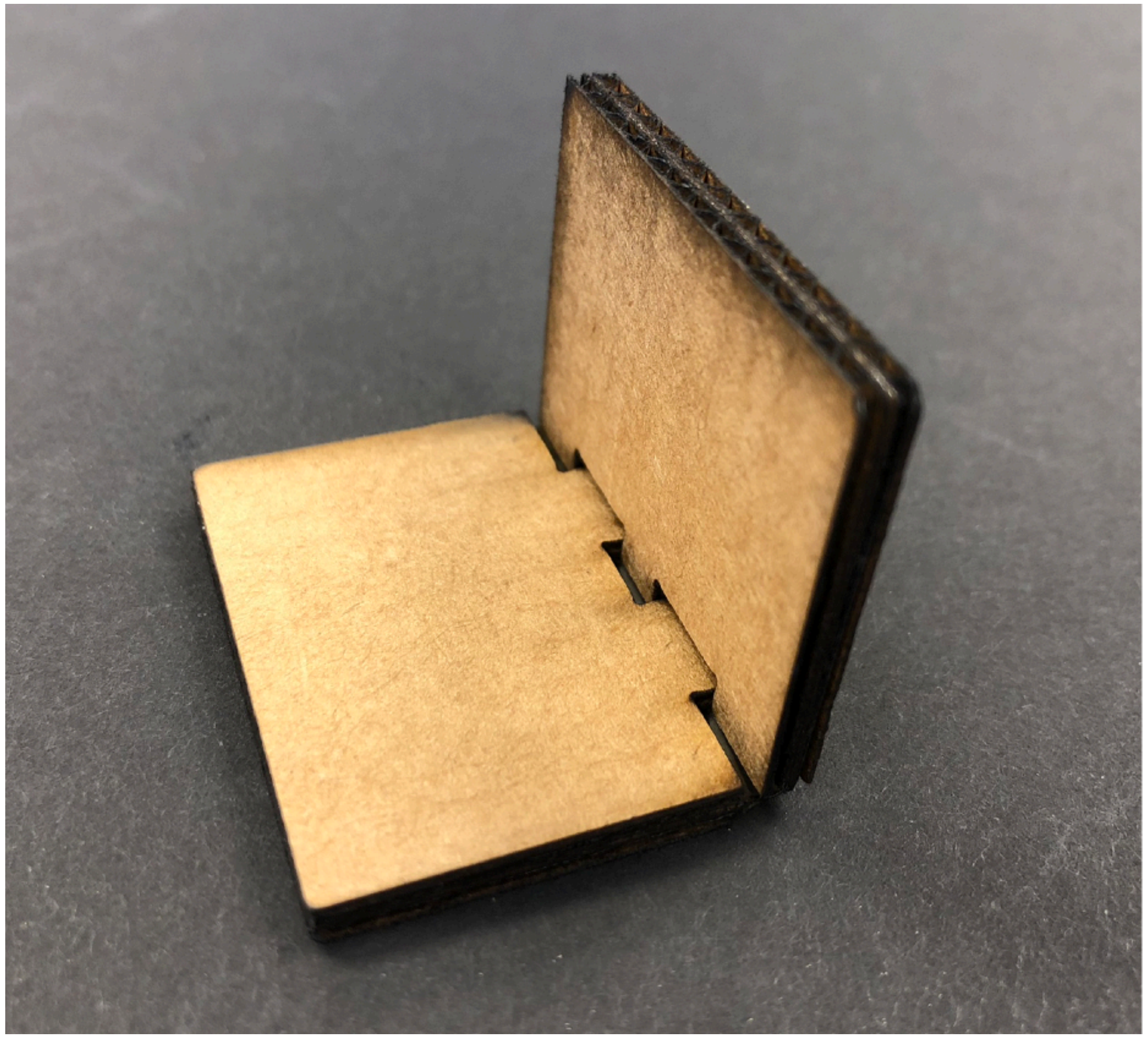
laser cutting



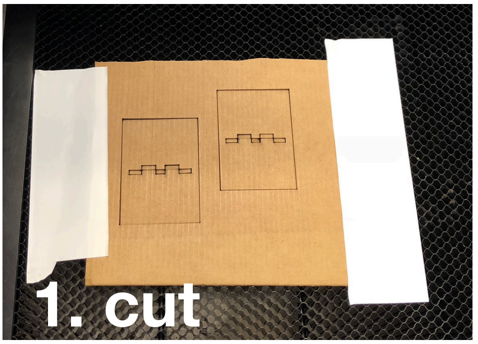
uv laser cutting

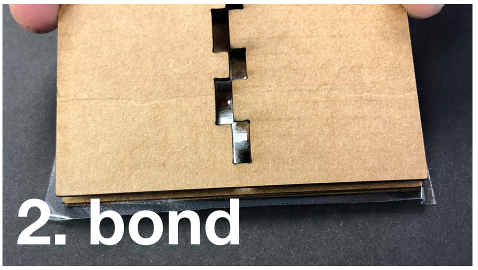


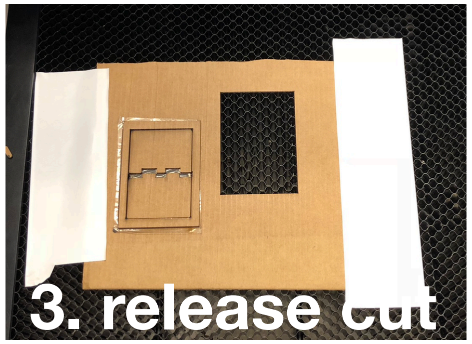
example part

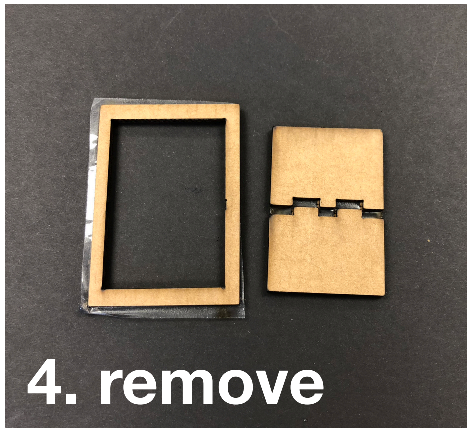


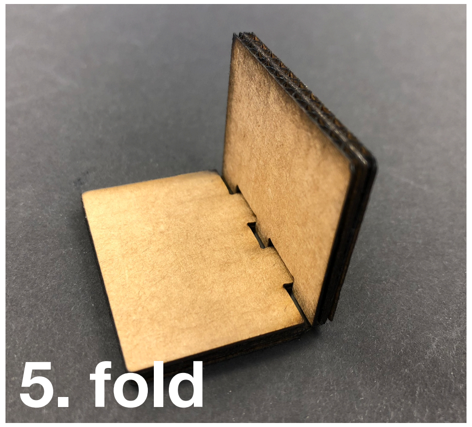
fab process

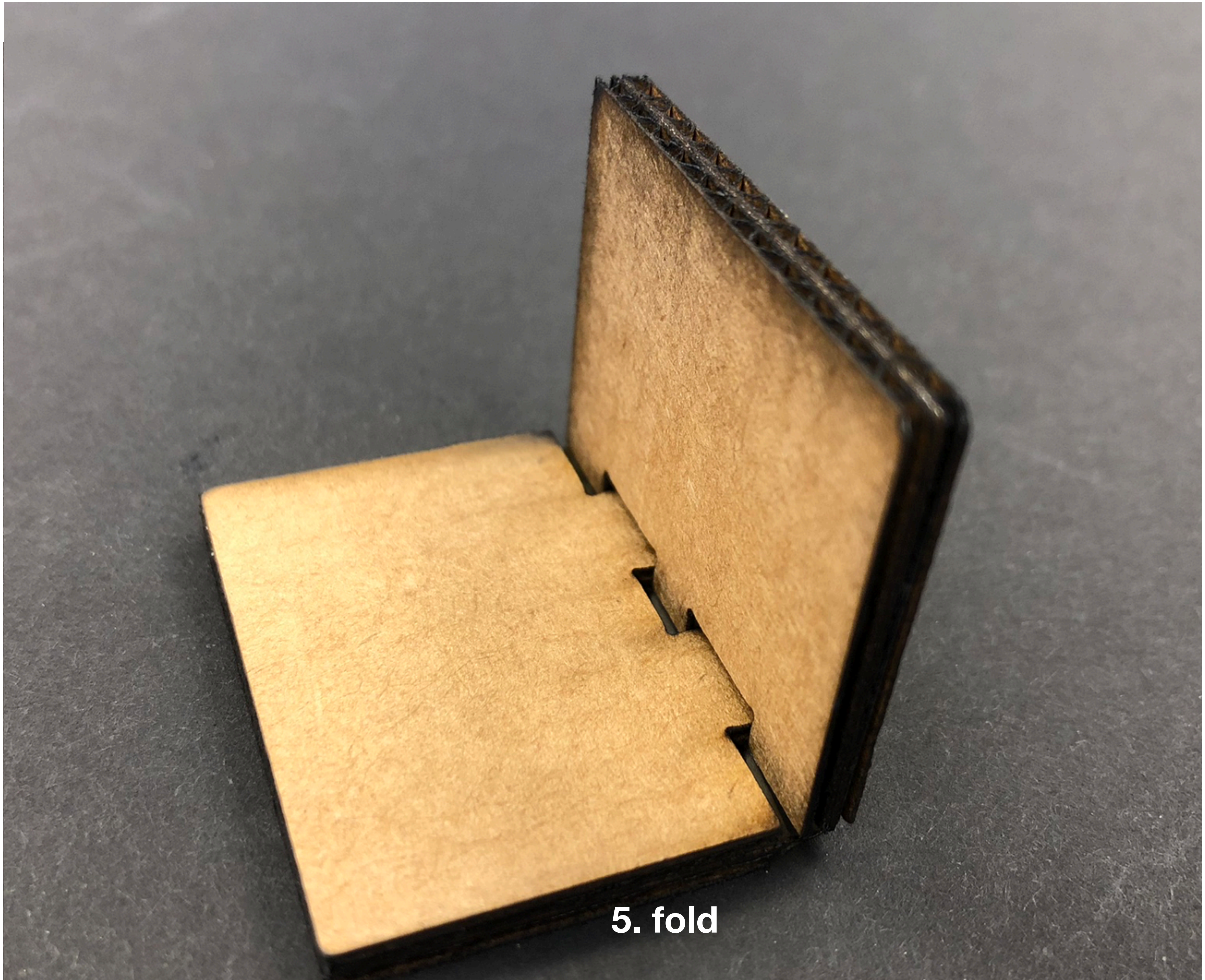




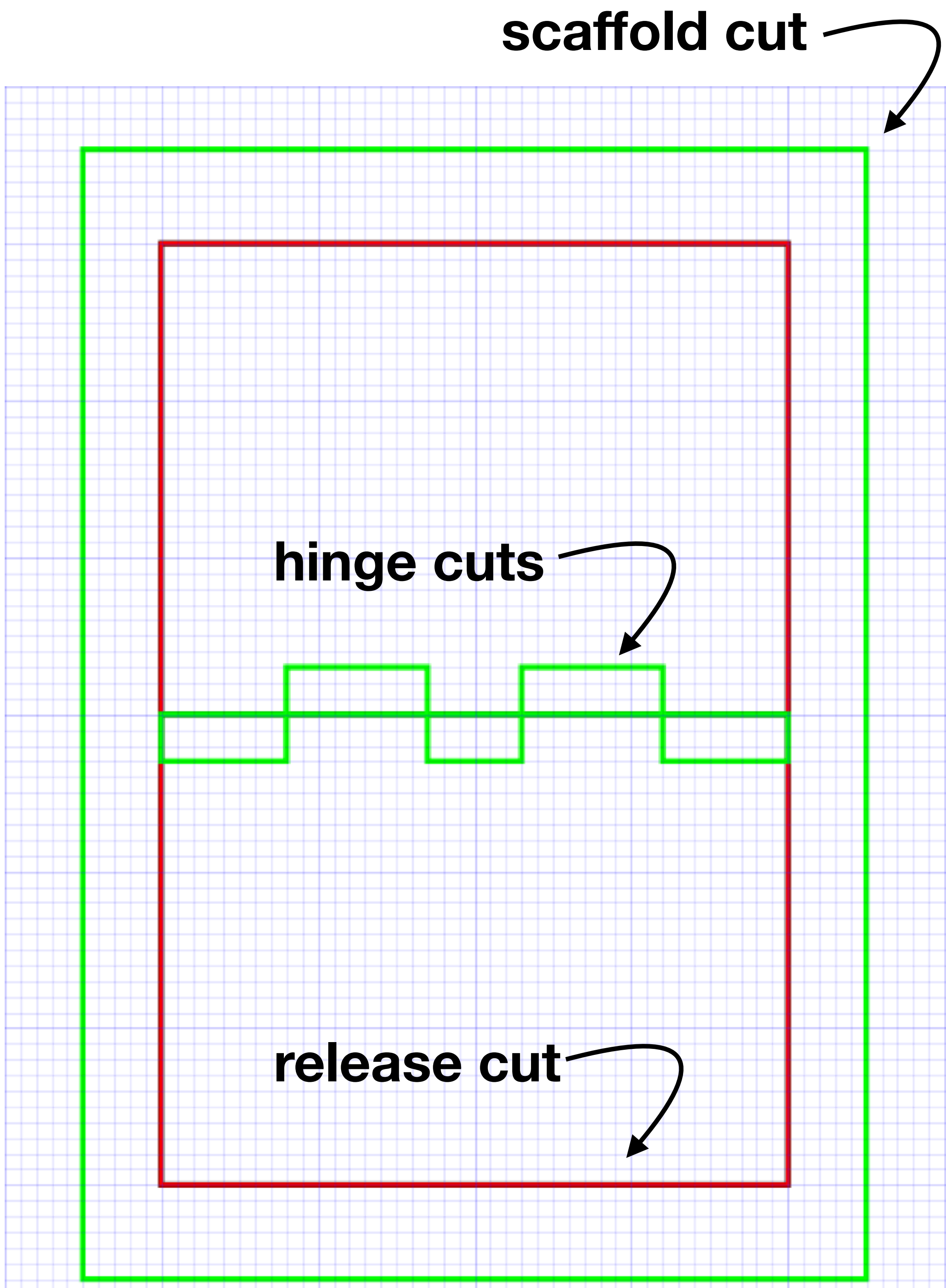




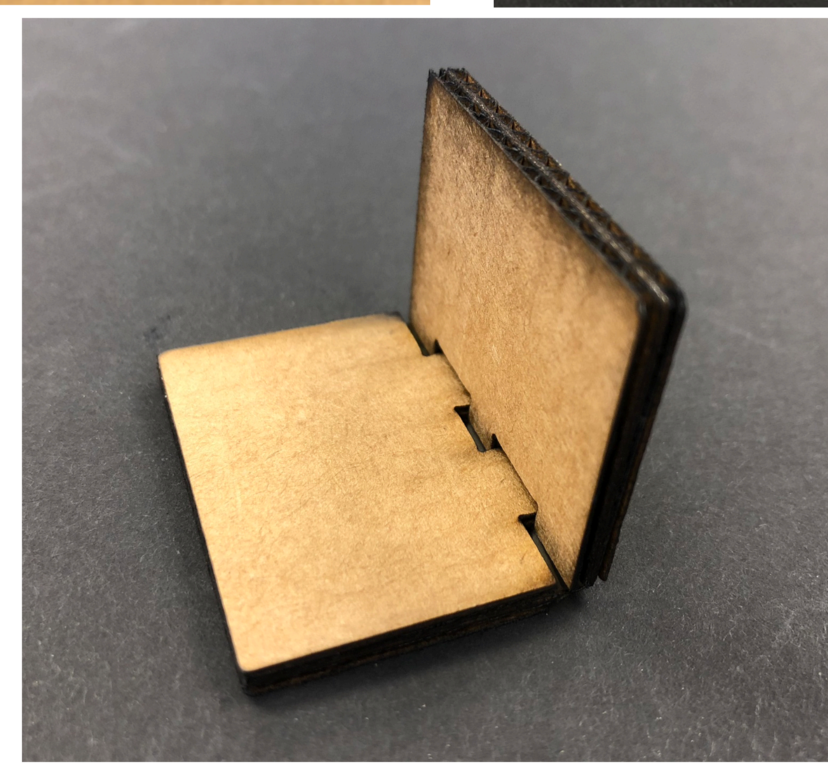




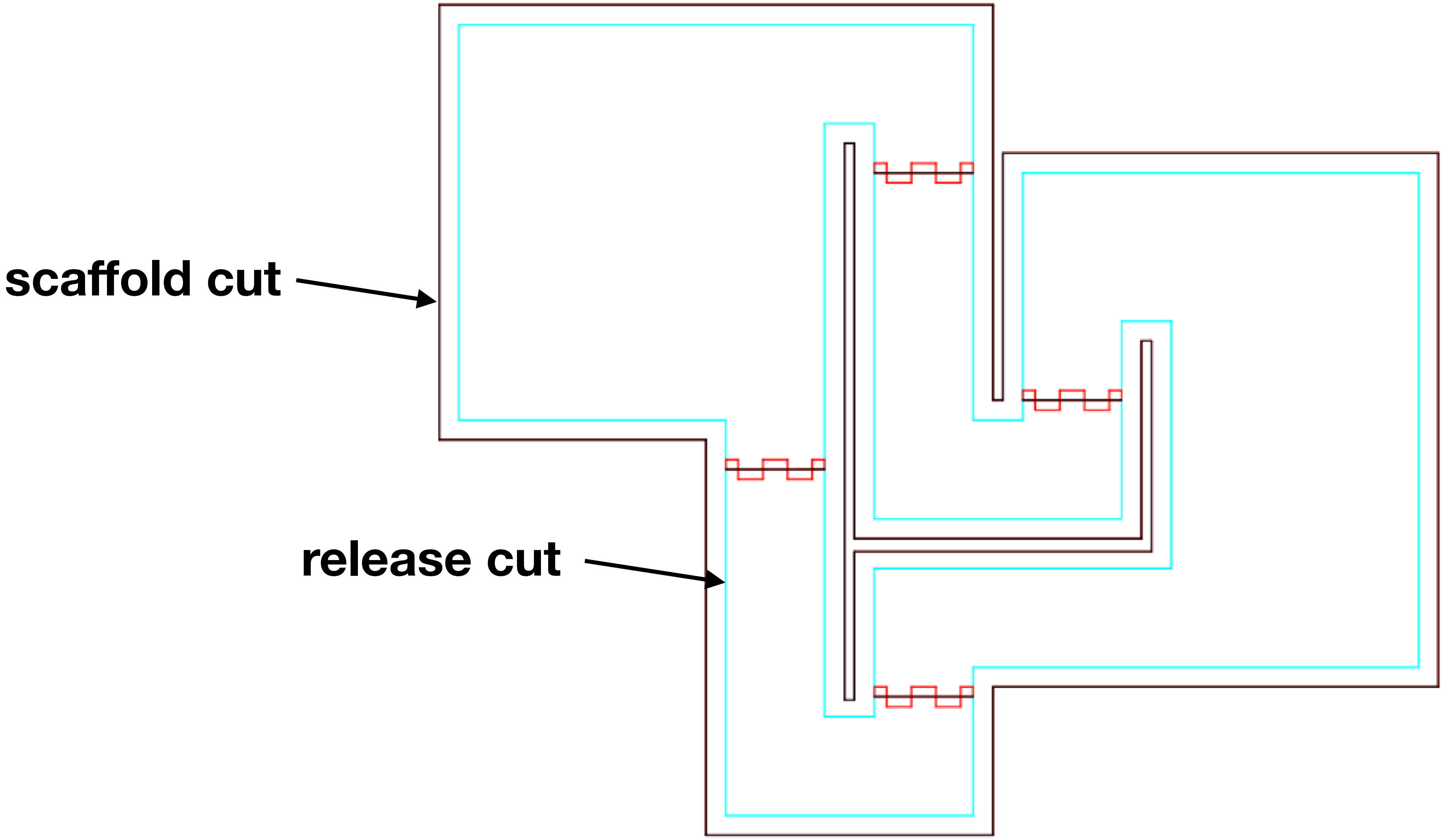
example part drawings



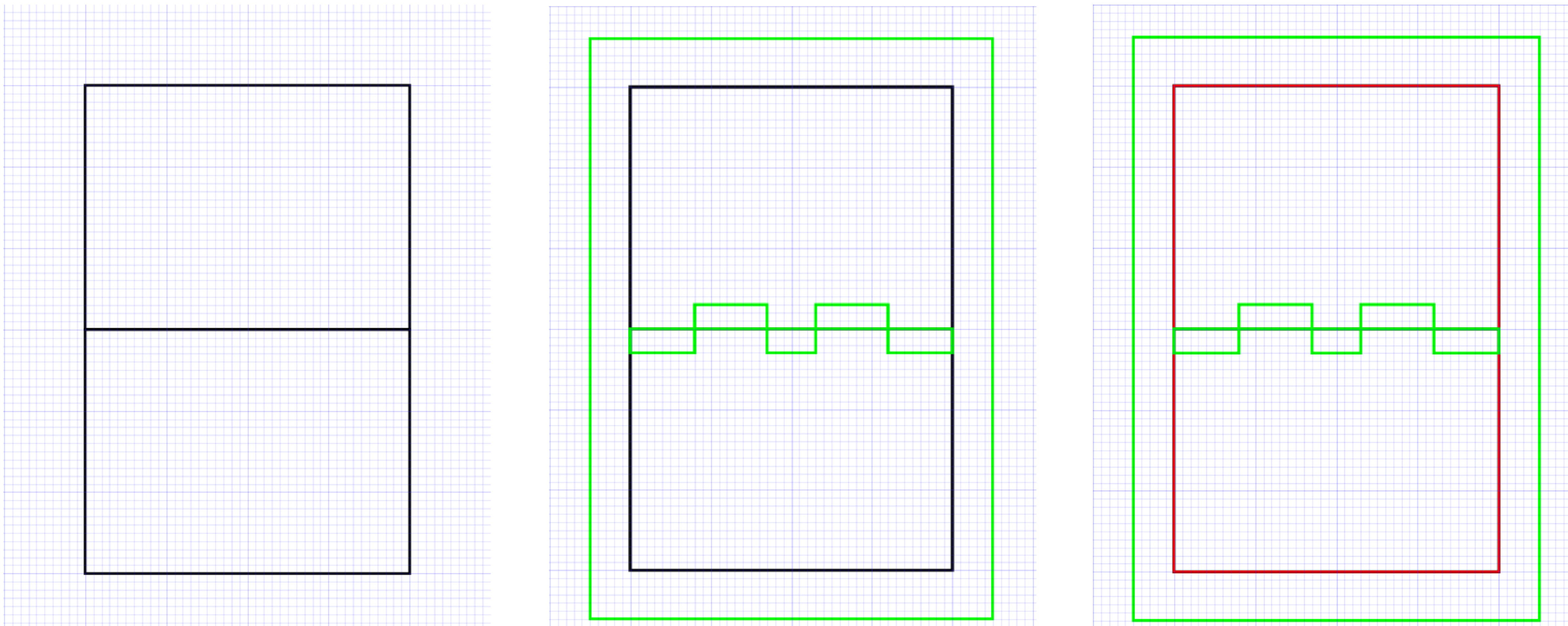
drawing in Inkscape



another drawing example



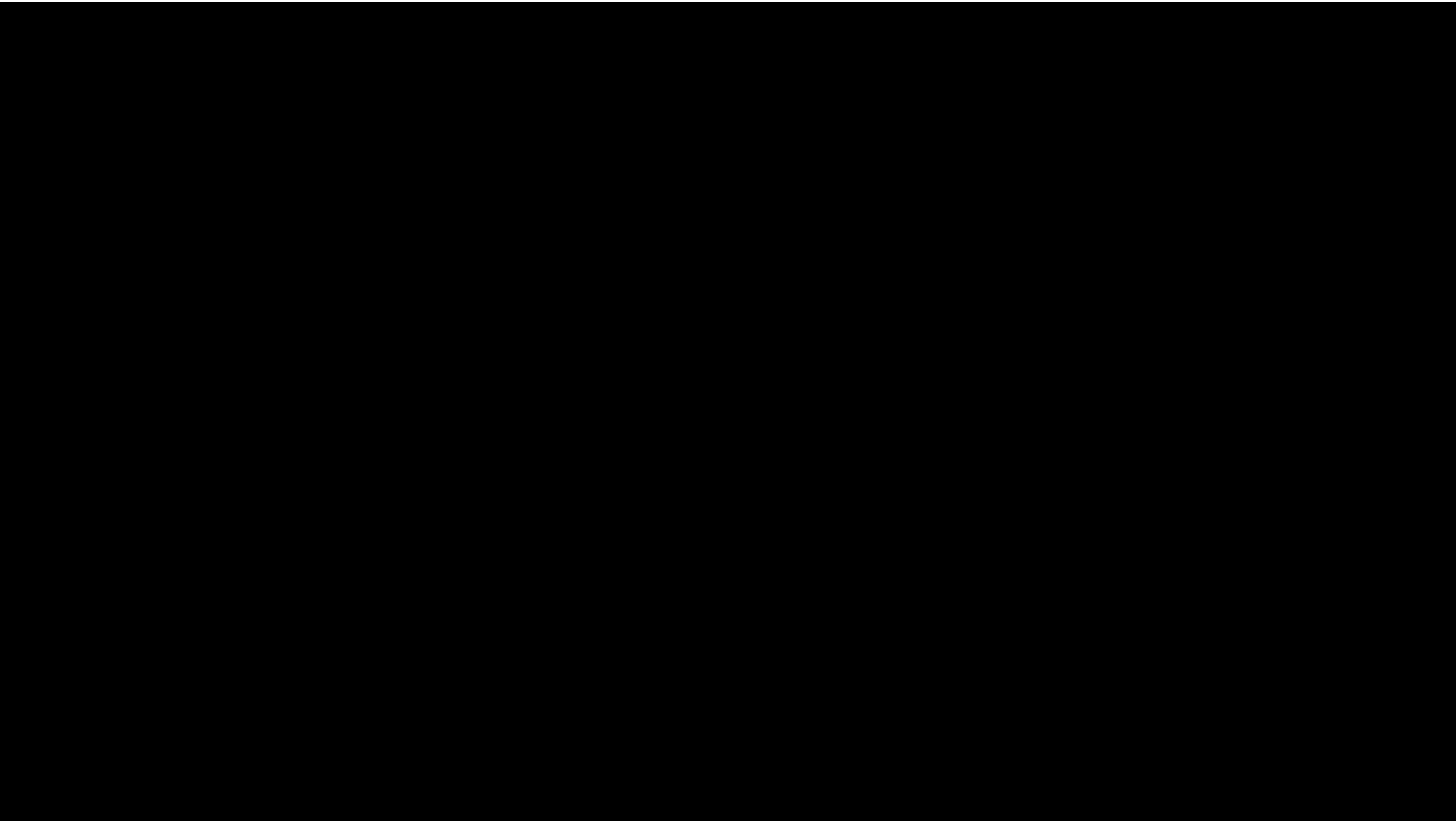
drawing in inkscape



1. draw outline of shapes **2. draw folds & align cut** **3. draw release cut**

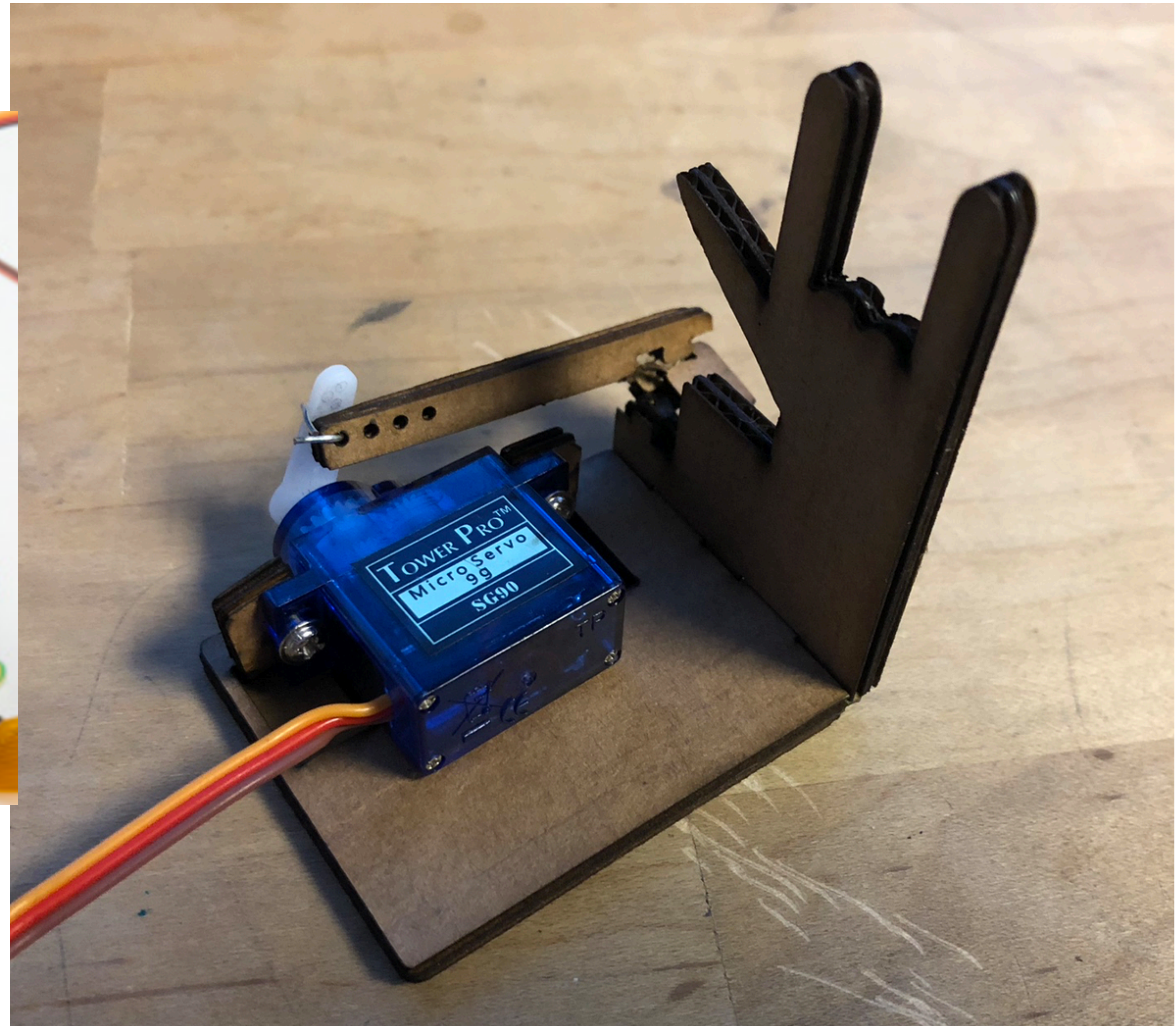
- suggestion: start with blank_drawing.svg on course website, it has useful settings for object snap and units.

designing mechanisms: ideas



link: https://www.youtube.com/watch?v=R5hGiN0Q5Qs

actuating your device with a servo and a raspberry pi



python: the all-purpose language

- run a python program `python servo_wiggle.py`
  - ctrl-c to quit
- edit a program `nano myprogram.py`
  - ctrl-o to save
  - ctrl-x to exit
- example program

```
import time             # timing
from servo import *     # servo driver

servo0(45)              # servo angle 45 deg
                        # range is +/-90
time.sleep(1)           # wait 1 second
servo0(0)
```

- program flow

```
def mult(arg1, arg2):
    return arg1*arg2

if test==1:
    print('hello')
```

```
for deg in range(start, stop):
    servo0(deg)

# note: python blocks are space-
# delimited! use four spaces to
# indent a sub-block
```

more python/linux

- run python one line at a time (ctrl-d to exit)

```
pi@raspberrypi:~$ python
Python 2.7.13 (default, Jan 19 2017, 14:48:08)
[GCC 6.3.0 20170124] on linux2
Type "help", "copyright", "credits" or "license" for more inform
>>> from servo import *
>>> servo1(90)
>>>
```

- list files

```
pi@raspberrypi:~$ ls
Desktop    Music     python_games  slow_move.py  wiggle_servo.py
Documents  Pictures  servo.py      Templates
Downloads  Public    servo.pyc     Videos
```

reference

materials

- cardboard - “illustration board” or “mount board”, 0.04 inches thick
    - 10x15” $2 each https://www.amazon.com/Crescent-99-Illustration-Board-ply/dp/B0044SCQWO
    - 32x40” $7 each https://www.amazon.com/Crescent-Colored-Mat-Board-ply/dp/B0062TLDT0
- sheet adhesive
    - 8x11” $3 each https://www.amazon.com/dp/B00JN9FDN8
    - 6” tape roll (stronger) $40 https://www.amazon.com/dp/B00FARV8NG

laser cutter & raspberry pi

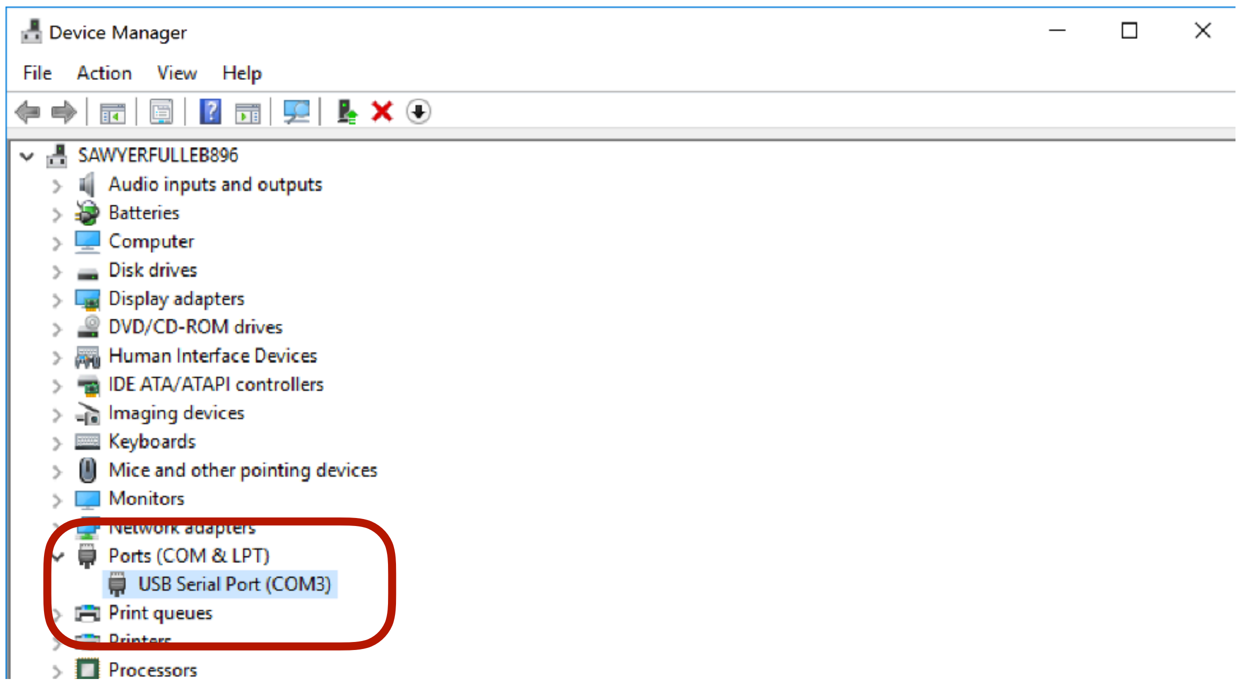
- laser cutter: glowforge basic $2.5k https://glowforge.com/tech-specs
- we will use a raspberry pi zero, total $48
    - raspberry pi zero, $10.00 https://www.sparkfun.com/products/14277
    - servo hat $9.95 https://www.sparkfun.com/products/14328
    - tall header $1.95 https://www.sparkfun.com/products/14017
    - header $0.95 https://www.sparkfun.com/products/14275
    - micro-usb cable 6 foot $4.95 https://www.sparkfun.com/products/10215
    - micro-SD card $19.95 https://www.sparkfun.com/products/13833 (and only $8 here https://www.amazon.com/dp/B00200K1TS)
    - optional power supply $10 https://www.amazon.com/dp/B00MARDJZ4
- cheaper but more limited alternatives: maestro USB $20 https://www.sparkfun.com/products/9664, or arduino $20 https://www.sparkfun.com/products/13975 with servo shield $25 https://www.sparkfun.com/products/14285 (cables extra)
- 5x micro servos at $2 each https://www.amazon.com/dp/B015H5AVZG

configuring raspberry pi

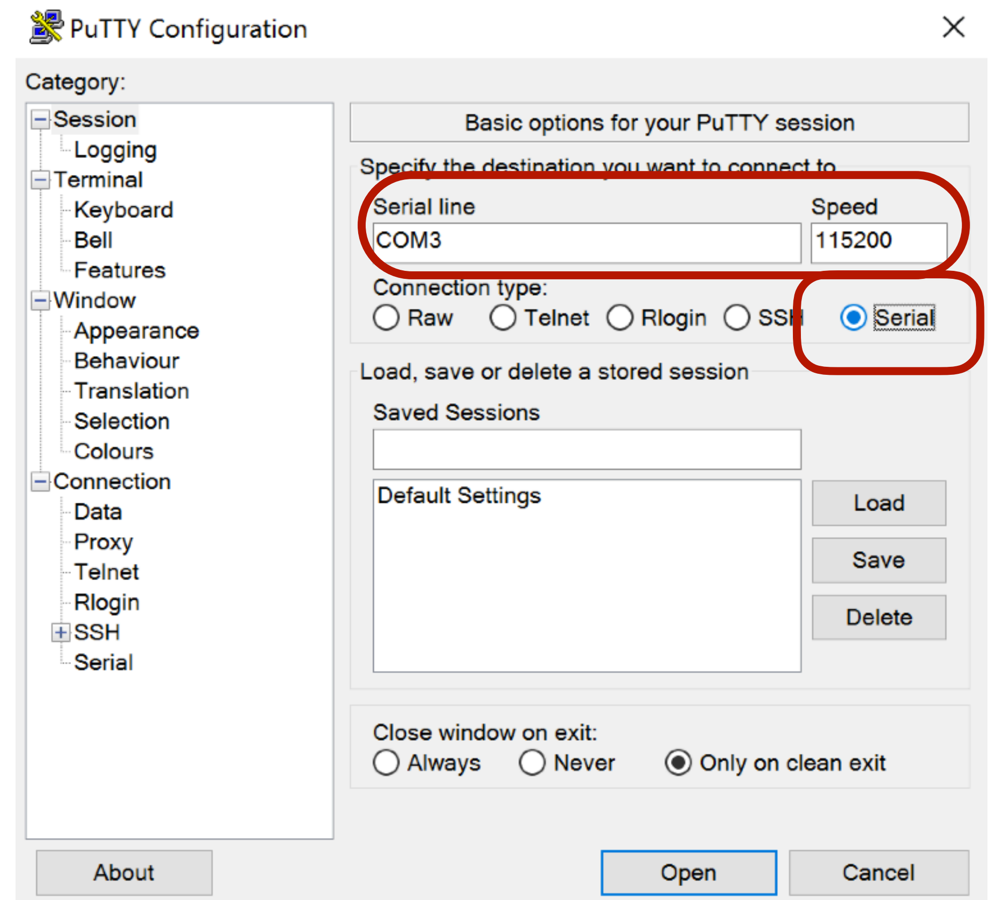
- (these have already been carried out for you)
- based on spark fun's servo hat tutorial https://learn.sparkfun.com/tutorials/setting-up-the-pi-zero-wireless-pan-tilt-camera

1. solder headers onto pi and servo hat to connect them
2. with raspberry pi booted and plugged into an HDMI-capable monitor:
    1. connect to U. Washington WIFI
    2. update linux: run "sudo apt-get update"
    3. enable I2C: run "sudo raspi-config" from a terminal and scroll to "interfacing options" … "I2C", select and say "yes."
    4. run "sudo nano /boot/config.txt", scroll to the end of the file, add "enable_uart=1", ctrl-x to save and exit.

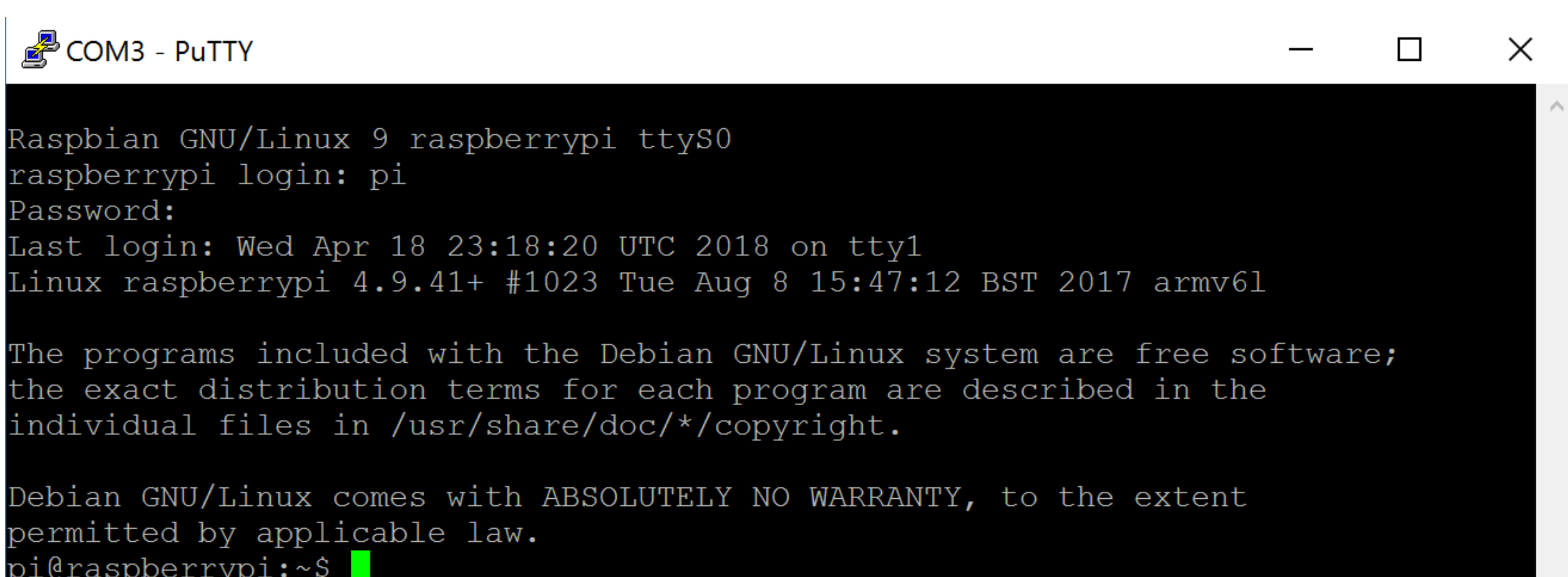
connecting to pi (windows 10)



1. plug in USB cable and open "device manager" to find which com port



2. download and run putty.exe, choose "serial" as connection type, enter in COM# and 115200



3. making sure pi has booted (~2 minutes):

login: "pi"
password" "raspberry"

foldable robotics lab session assignment

course website (with slides and files): https://faculty.washington.edu/minster/foldable_robotics_2018/

1. cut and assemble a basic hinge from a provided drawing

2. perform a basic servo motion
   - to download a servo program from course website to your raspberry pi, use

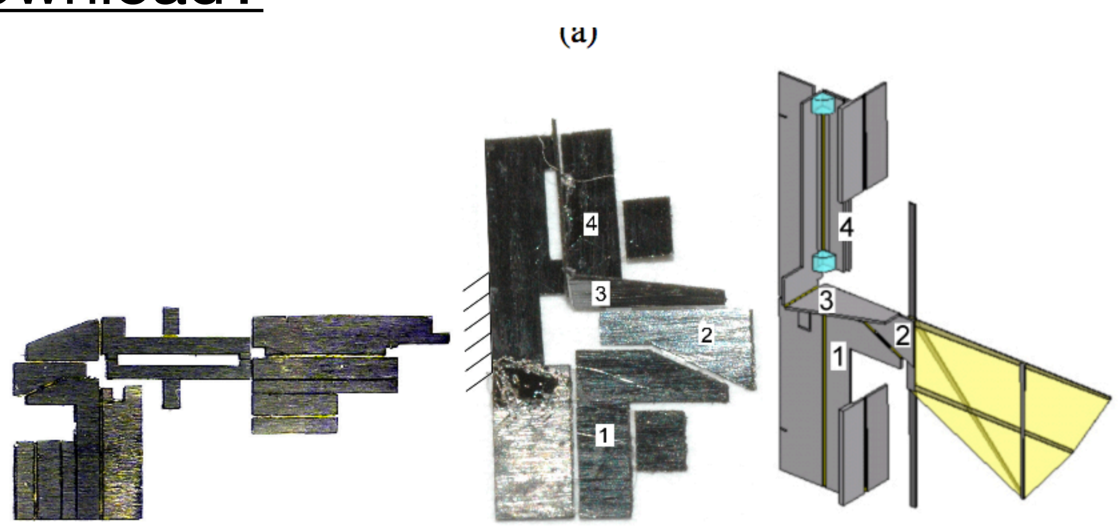
```
wget http://faculty.washington.edu/minster/foldable_robotics_2018/files/servo.py
```

3. cut and fab a more advanced design (open-ended)
   - add servo control
   - make your own design

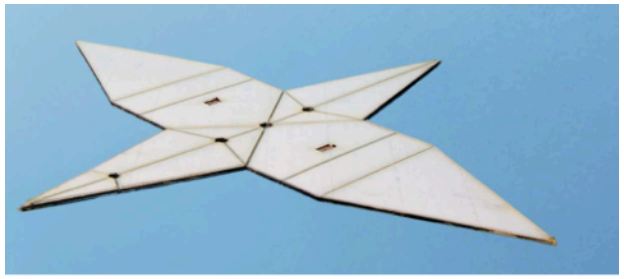
You can take home what you make! (servos excepted)

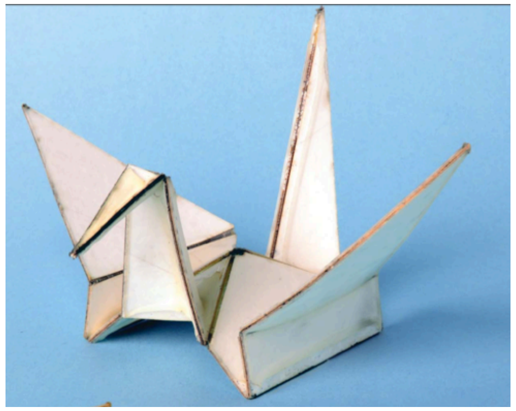
ideas

- sarrrus linkage
- wing motion using spherical 5-bar - wood2004 http://citeseerx.ist.psu.edu/viewdoc/download?dc



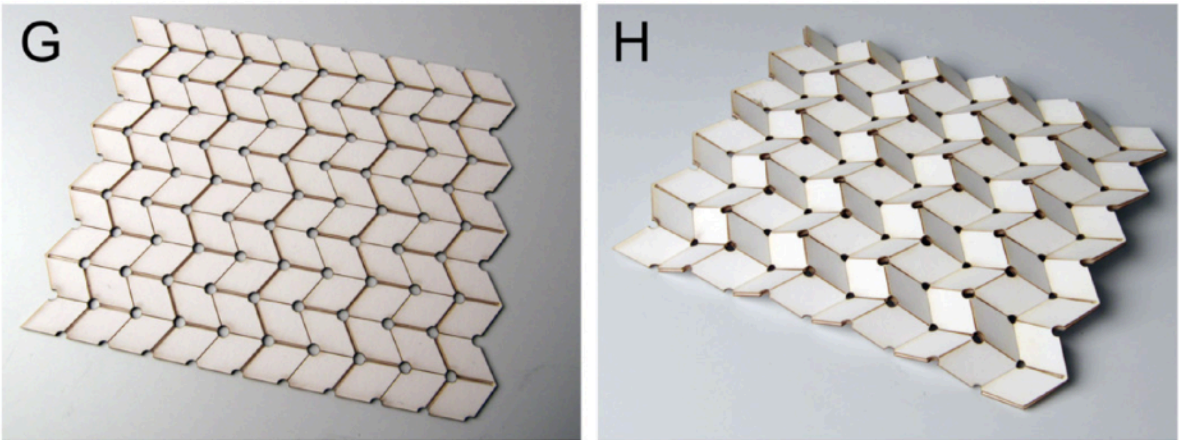
- crane



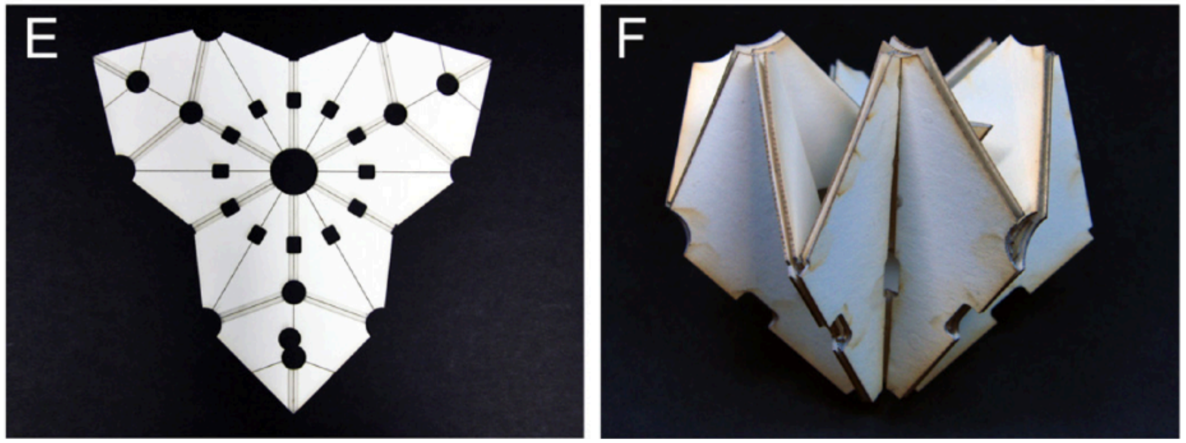


- robotic gripper

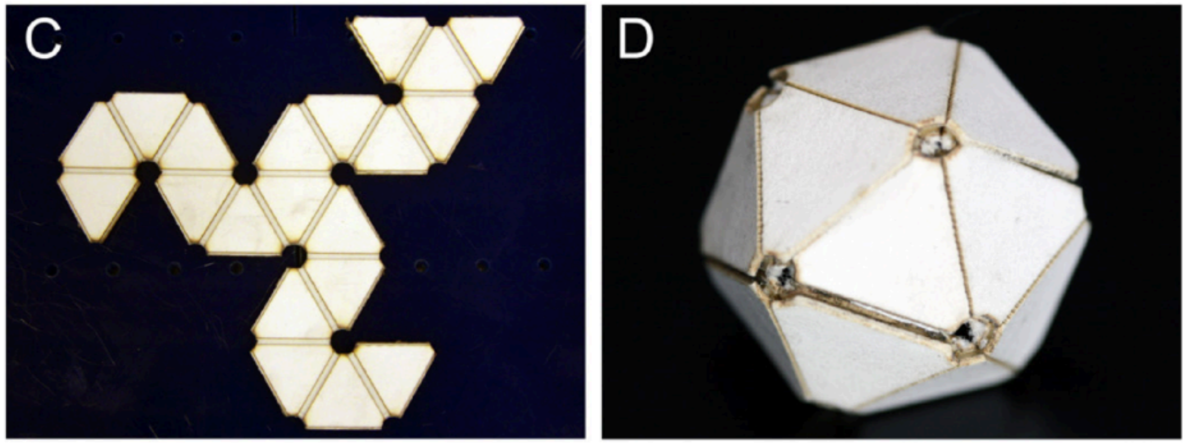
- muira pattern



- flower pattern



- icosahedron



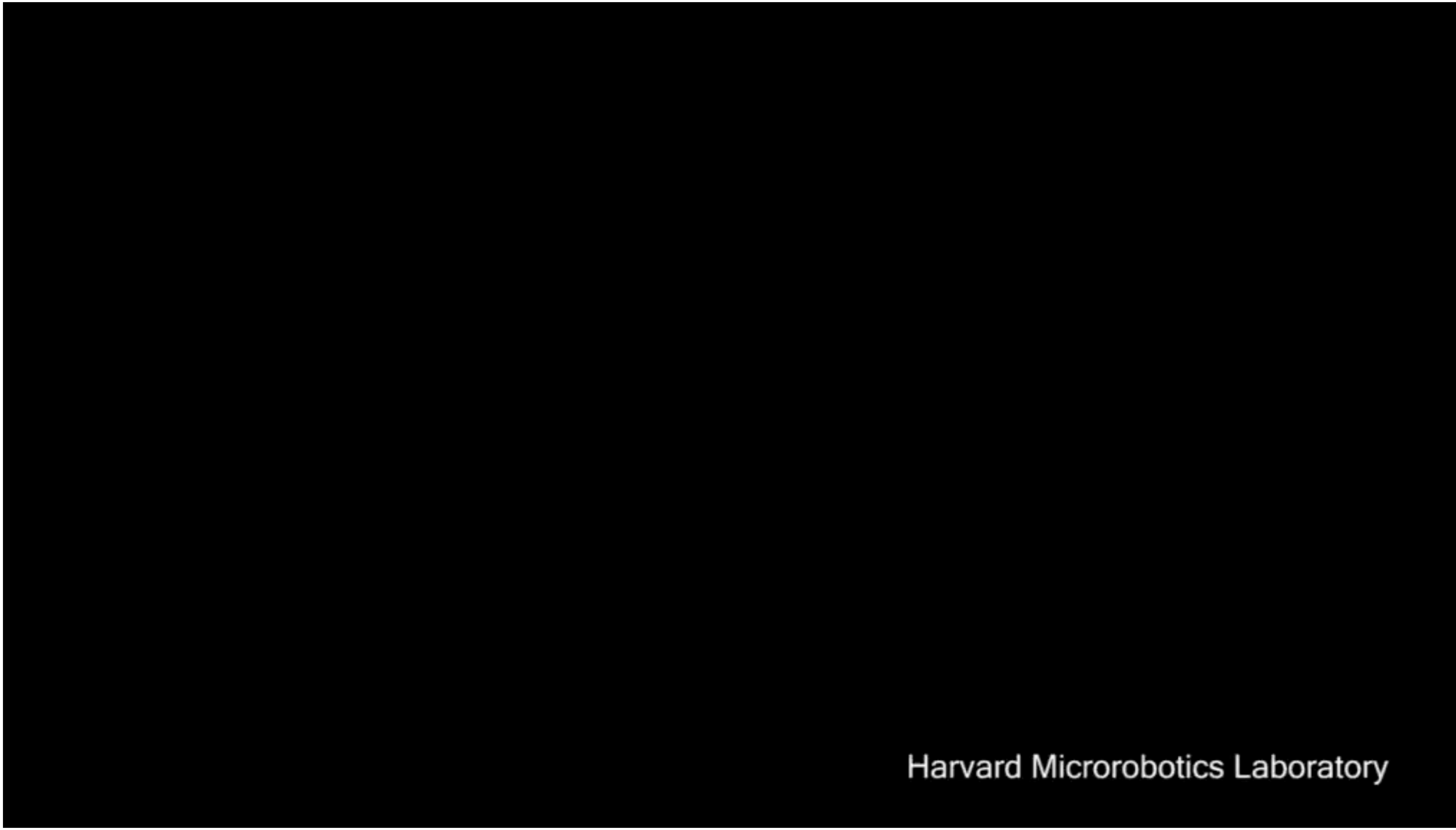
Ice-breaker activity: meet your group

- be prepared to answer either (1-2 minutes per person):
  - if you could be any animal, what would you be and why?
  - or, if you could have an endless supply of any food, what would you

Next

walk over to Fuller Lab,
Mechanical Engineering Building Room 113

examples



https://www.youtube.com/watch?v=VxSs1kGZQqc