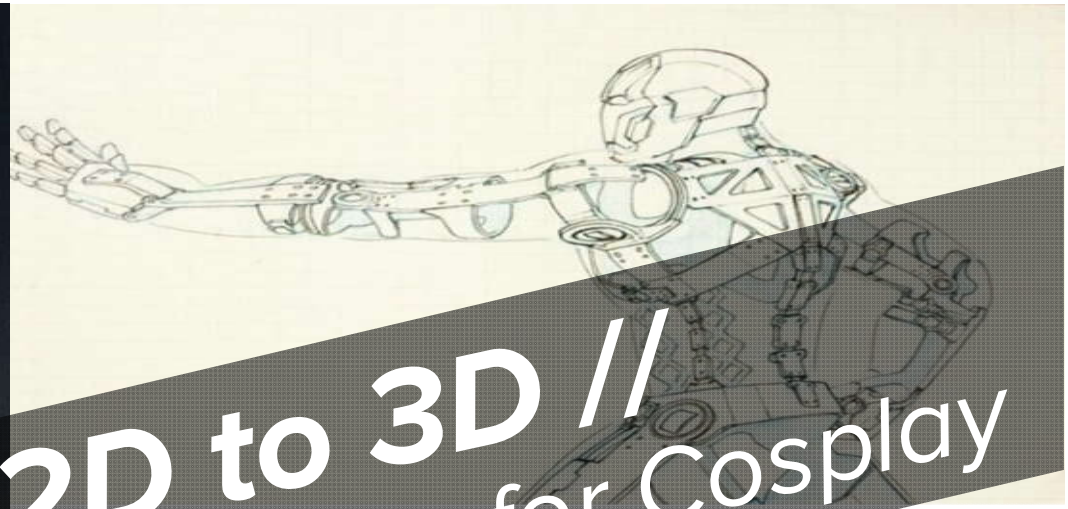
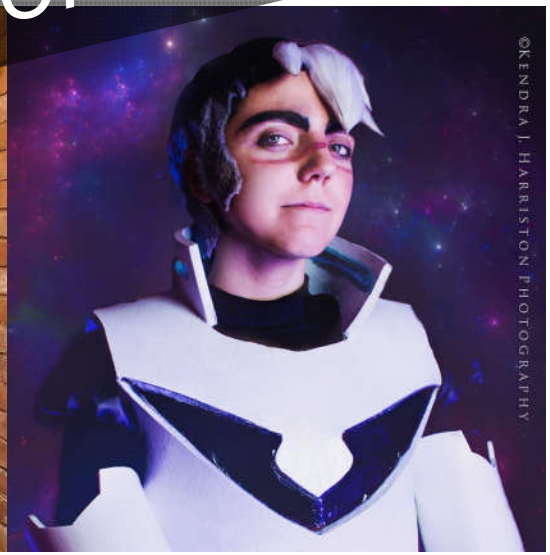
// From 2D to 3D //
Manufacturing Techniques for Cosplay





CASS L

Hi, I'm **Cass.**

I like making **simple things fancy!**

10+ years of cosplay
(goshdang it's been a long time)

I do everything from **sewing** to **armor** to **props** to **wigs** and all *the stuff in between*!

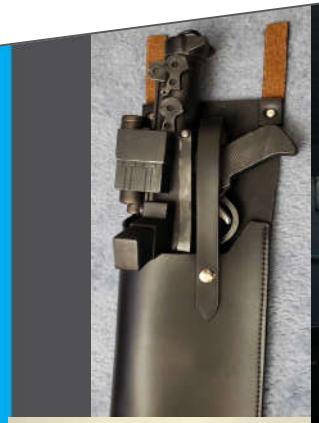
@STARSOFCASSIOPEIA

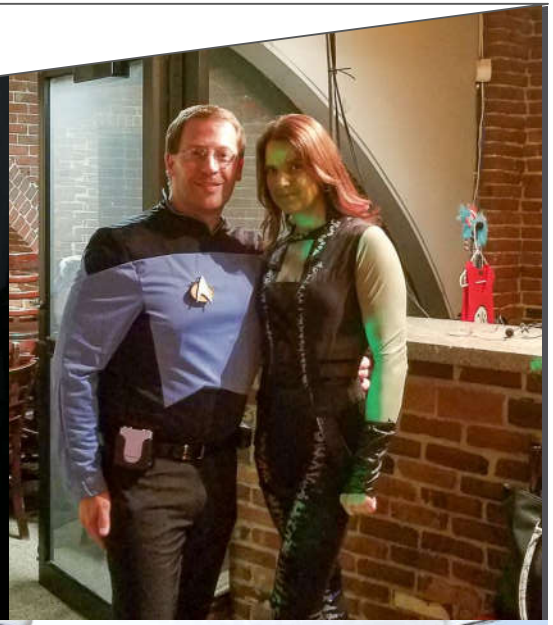
ZAC Z

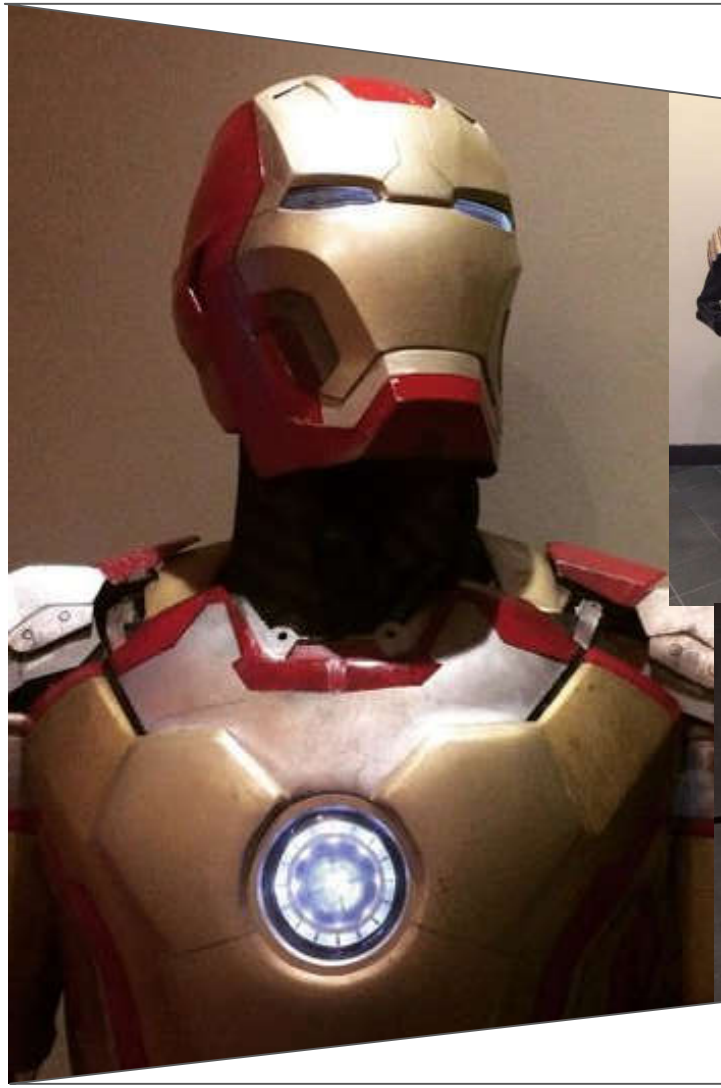
Halloween

Star Trek
Star Wars
CASS

projectsbyzac.com







BRIAN CHAN

Iron Man

some other stuff

- Traditional (looking) props
- Articulation
- Folding structures

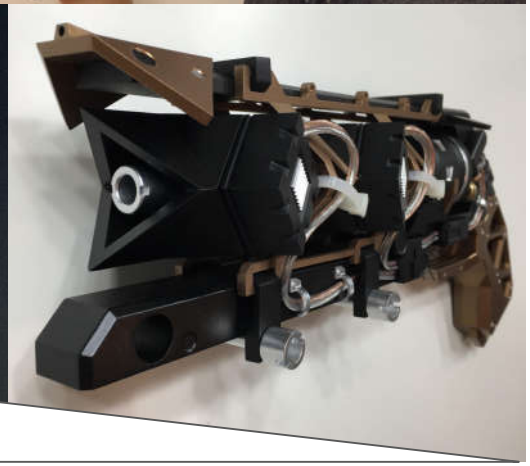
@CHOSETEC

ADRIAN TANNER

Movie + video game replicas

Lasers pew pew

IDK lots of guns sry



@ADRIANTANNER


Outside of cosplay...
We're all engineers.

OUTLINE

Intro // Breakdown // DFM & DFA // CAD Basics //

[That's this, right now]

[Simplifying shapes, proportional scaling]

[Making stuff that moves & breaks down]

[Digital sculpting & patterning]

3D Printing // Other Tech Tools // Access // Conclusion

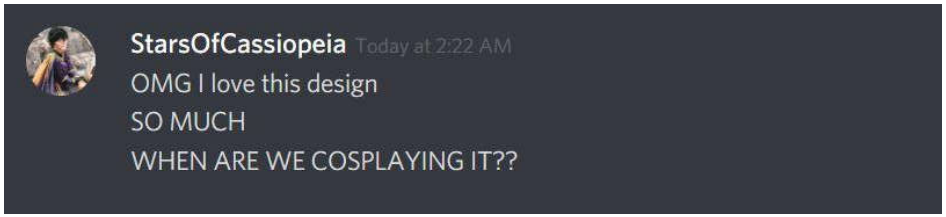
[Rapid Prototyping]

[Lasers & heat shaping & vacuums, oh my]

[Buy it, use it, borrow it-- easier than you think]

// BREAKDOWN //
Planning Your Design

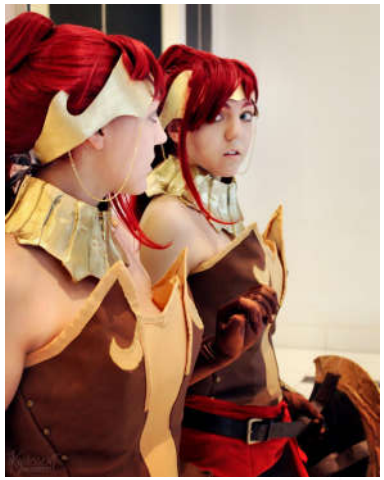
So, you've got a character / concept you love...



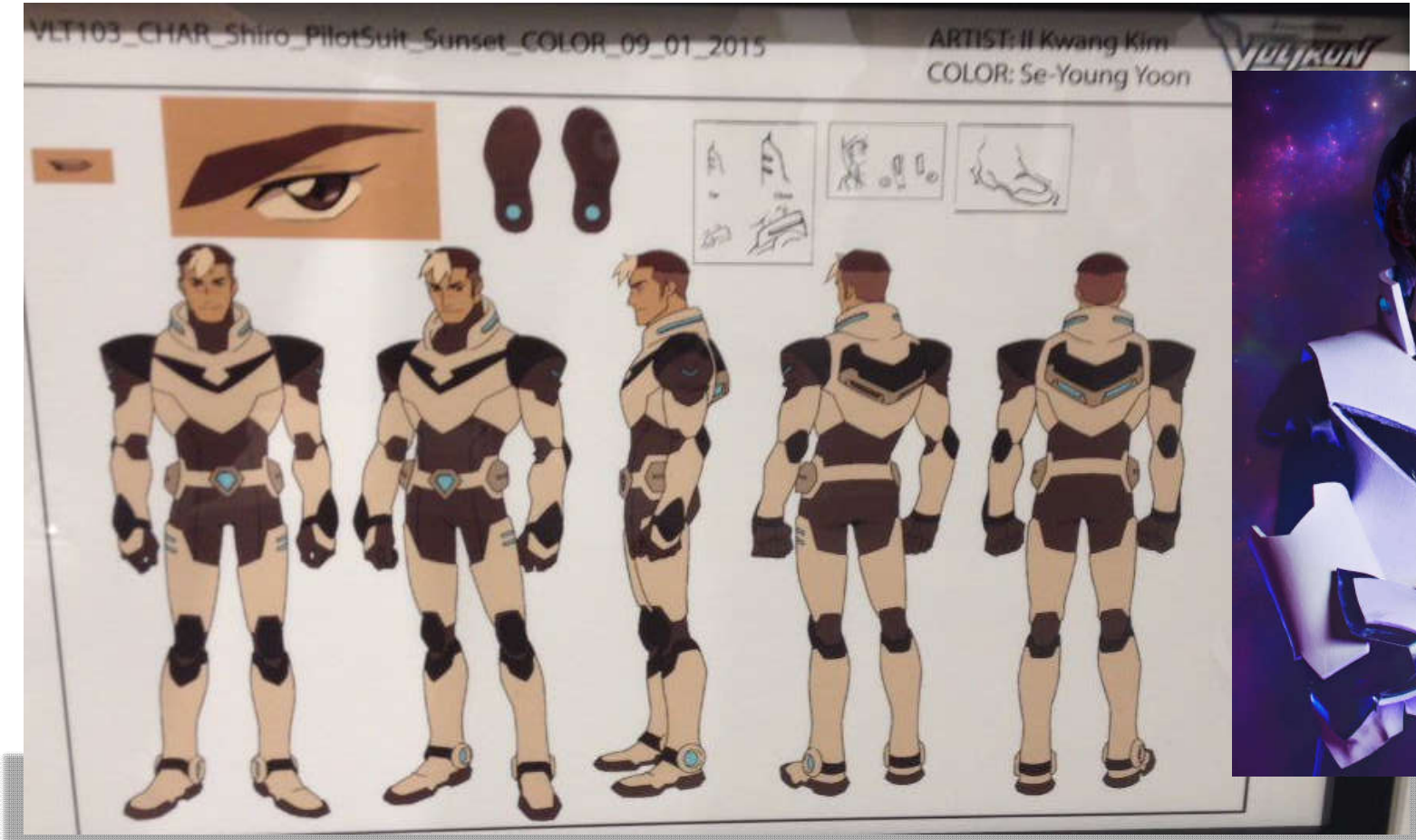
... it's time to do some work.

REFERENCES

- Front views
- Back views
- Side views
- 3D models, if applicable
- Concept Art
- Detail crops
- GIFs
    - Motion!

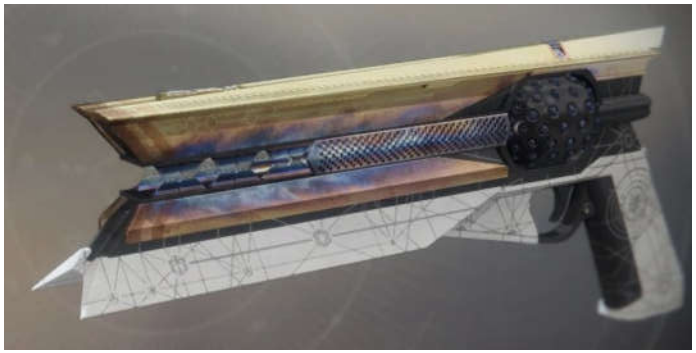


REFERENCES: CONCEPT ART



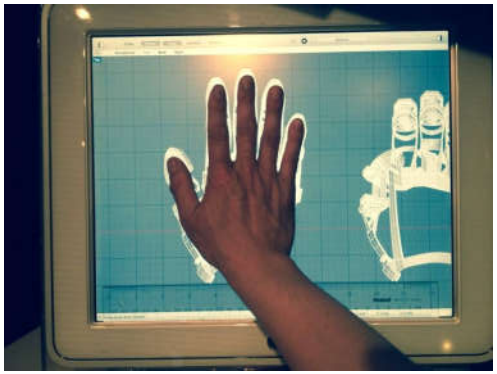
MORE REFERENCES

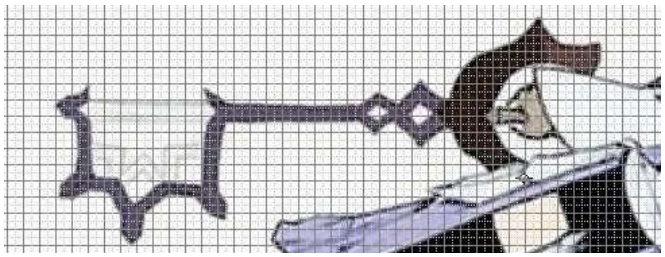
- Lighting, angles
- Characters or objects **for scale**

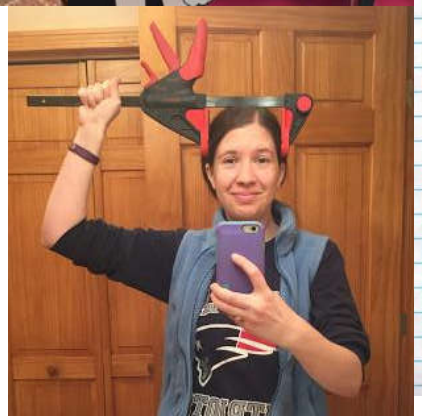


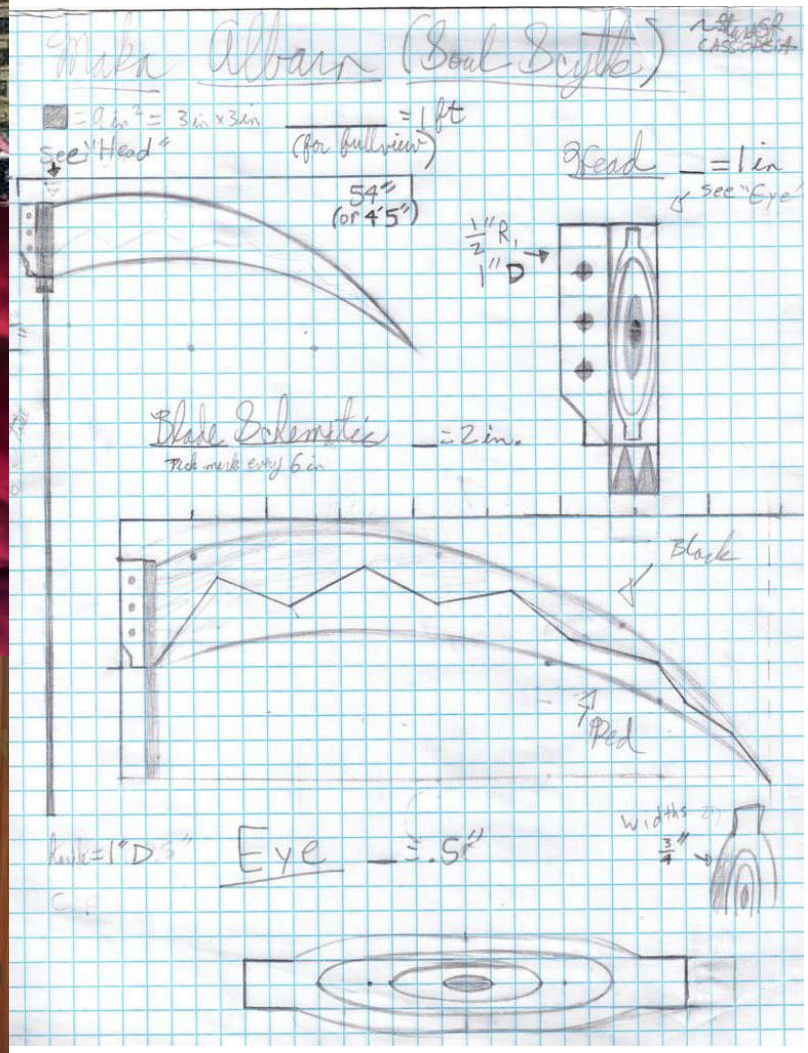
SCALING

- Measure yourself
- Superimpose measurement on reference
- Grid that bad boy out
- Scale drawings!!



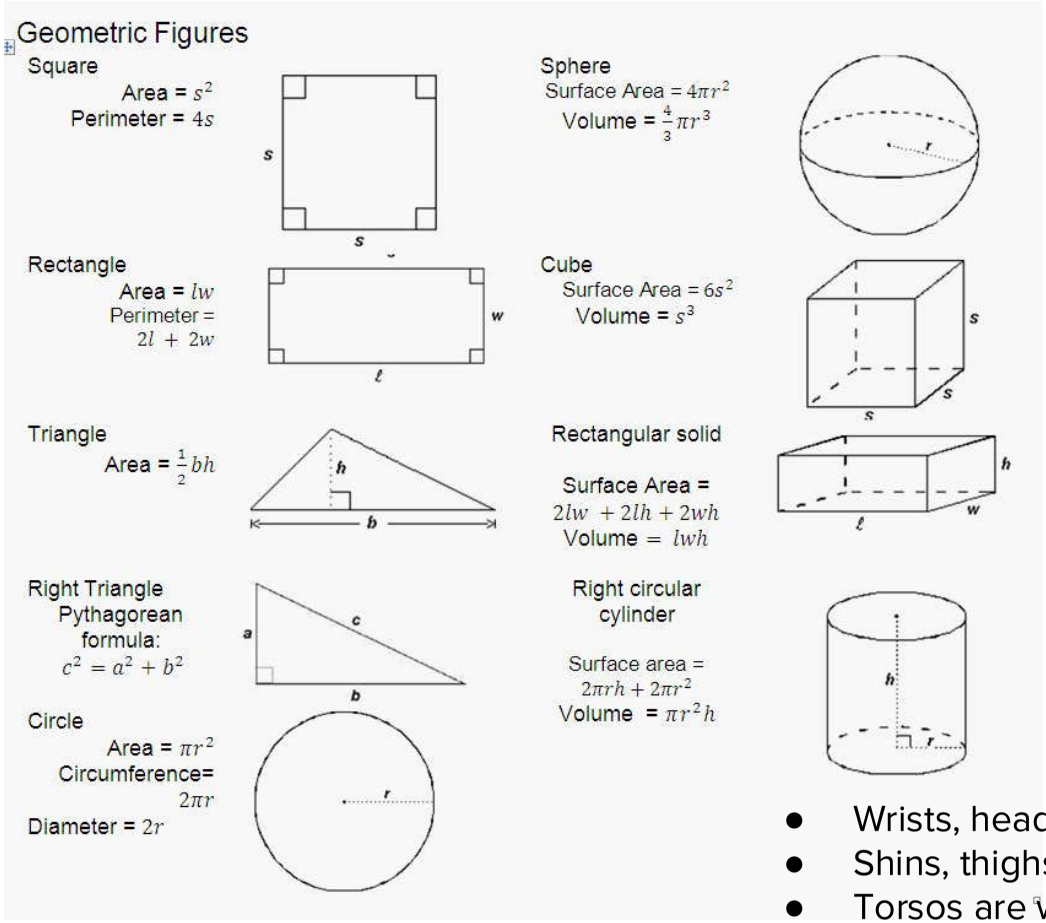


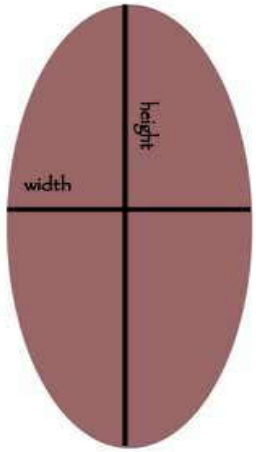


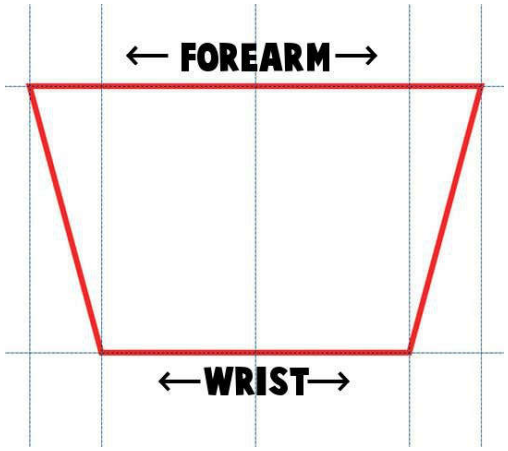


DESIGNING FOR HUMANS

Break your costume designs into simple geometric shapes!







- Wrists, head, torso, etc are mostly **ovals**
- Shins, thighs, forearms, upper arms = **trapezoids**
- Torsos are weird, break them down into smaller sections

BREAK INTO SIMPLE SHAPES

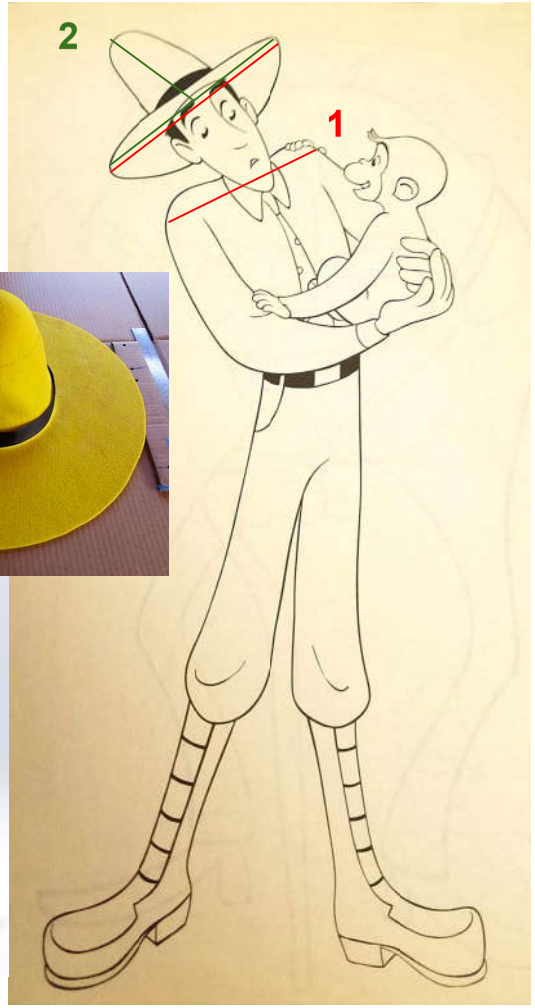
(But maintain proportion!)

Ratios of key points matter in scaling from a reference

1. Hat brim size to shoulder
2. Brim to height

Key scaling feature: *The circumference of your head at brim*

This sets the size of your pattern



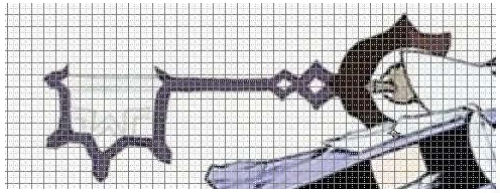
<u>Break your designs down into simpler shapes</u>:

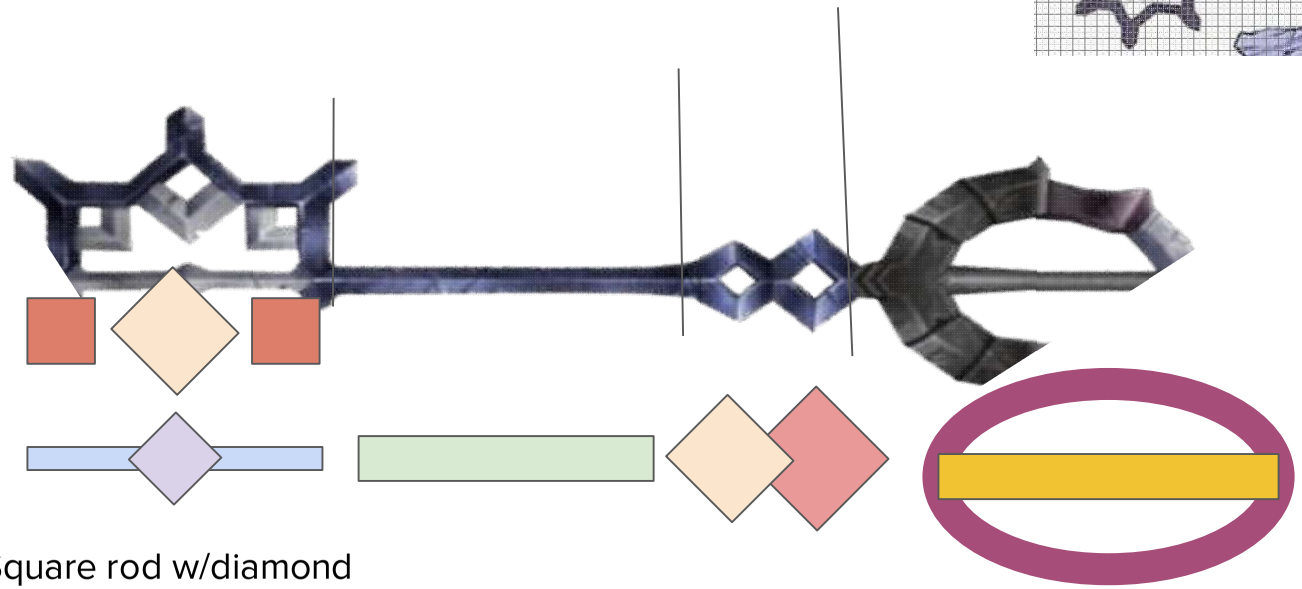
A hemisphere, on top of a frustum, on top of an annulus

(AKA half sphere, cut off cone, disc with a hole)

A MORE COMPLEX EXAMPLE...

Aqua's Keyblade (KH)





Square rod w/diamond Squares w/beveled cutouts
Square rods around outside

Square rod

Overlapping square pyramids with a diamond cutout

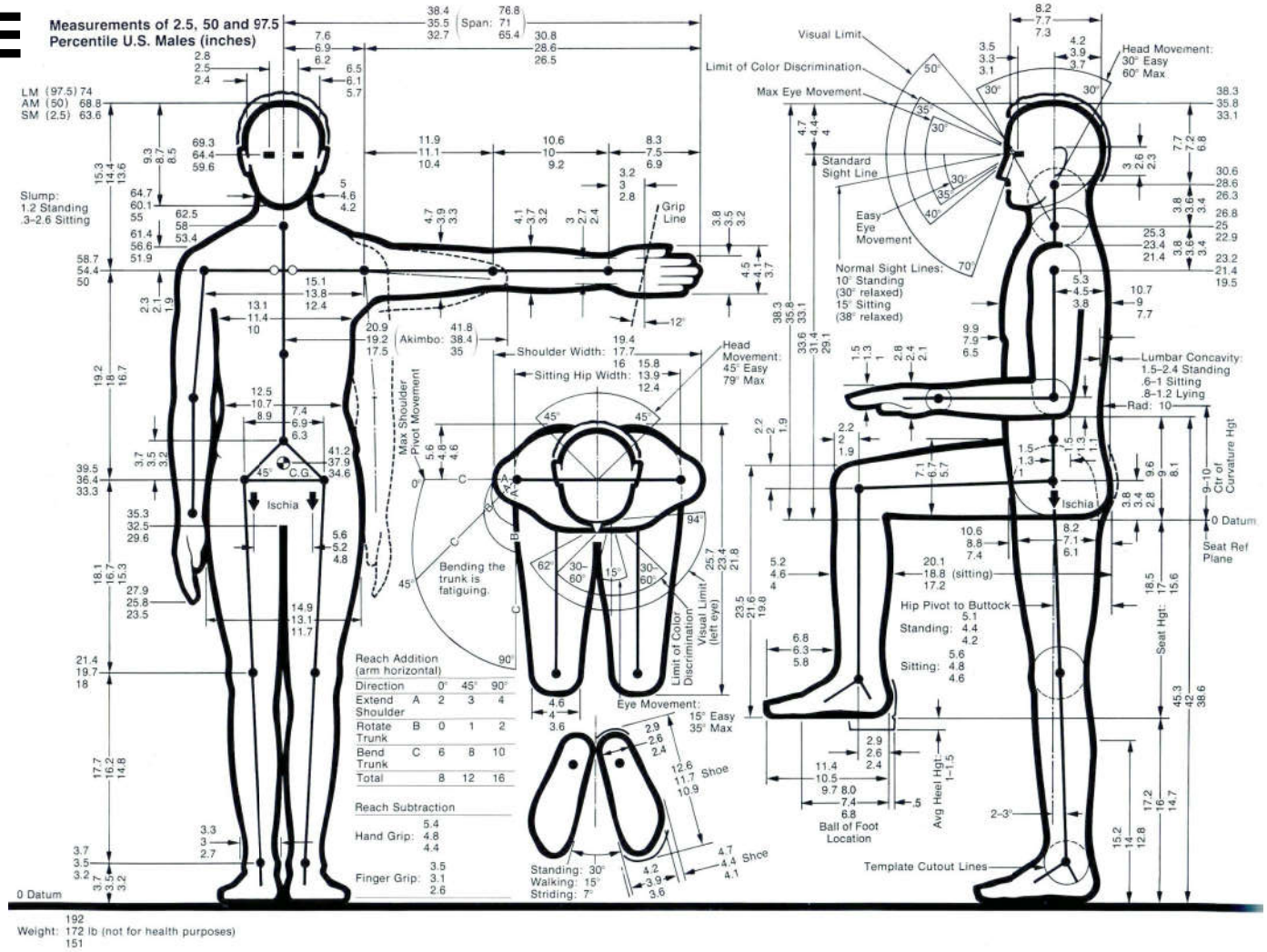
Oval with bevel; Cone & straight rod for handle

HUMANSCALE

A super useful reference based on the averaged measurements of many people

⚠ CAUTION

These are AVERAGES & must be adjusted for each individual!



Don’t understand what shapes you need? --> TAPE METHOD

Plastic wrap yourself. Tape over. Draw segments. Cut off!

// DFM & DFA //
Design For Manufacturing
Design For Assembly

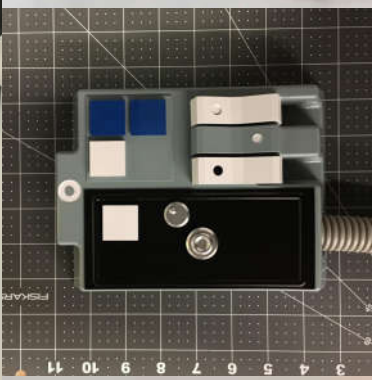
Designing from a Reference:

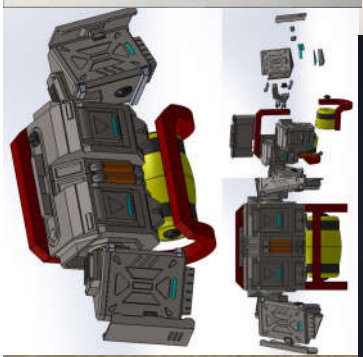
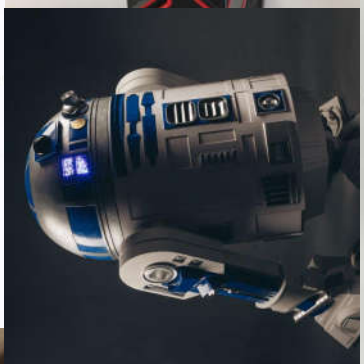
Going from 2D to 3D

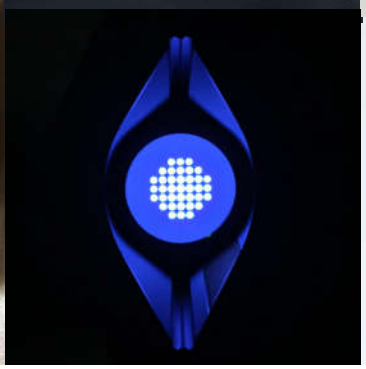






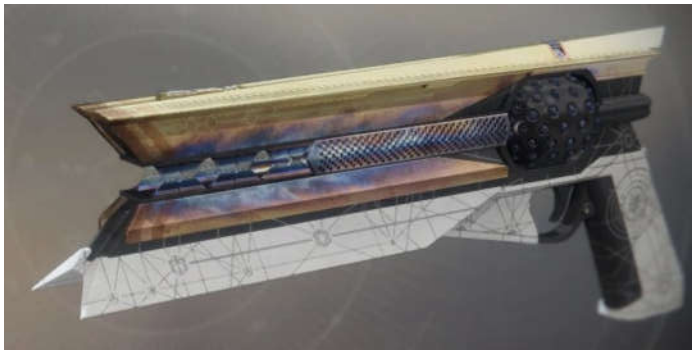


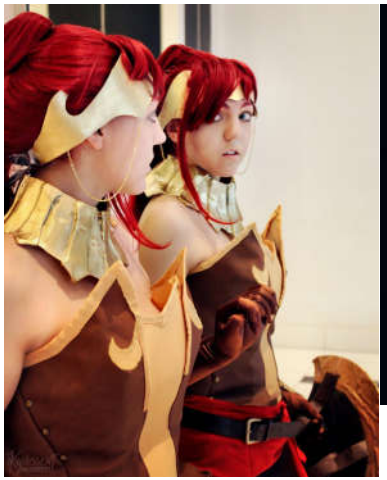

References

- Lighting, angles
- Characters or objects for scale
- What makes sense for YOU*?



References

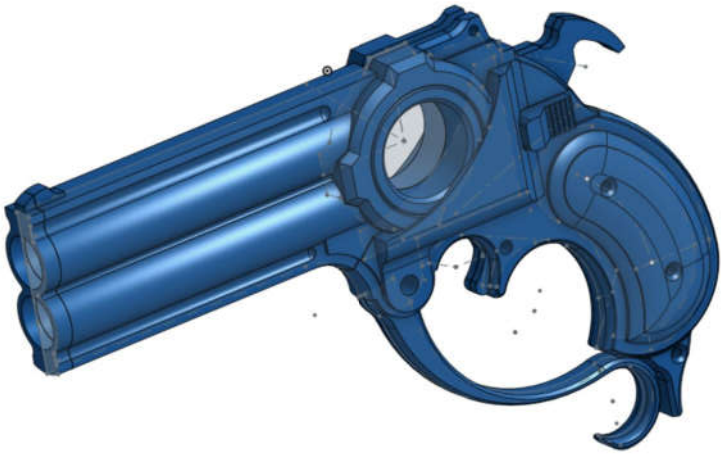
- Front views
- Back views
- Side views
- 3D models, if applicable
- Detail crops
- GIFs
  - Motion!



// CAD BASICS //
Computer Aided Design

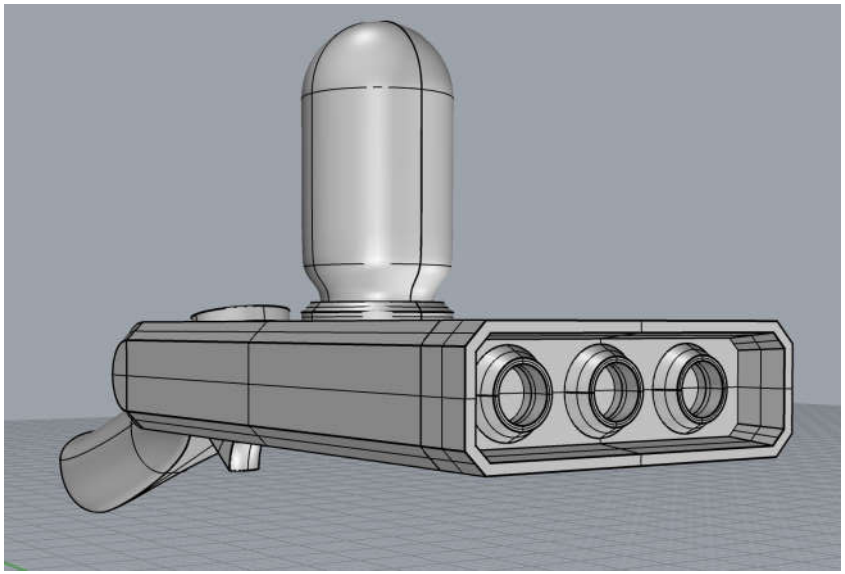
CAD software types:

- **Solid + Surface Modeling**
- **Mesh Modeling**
- **Virtual Clay**



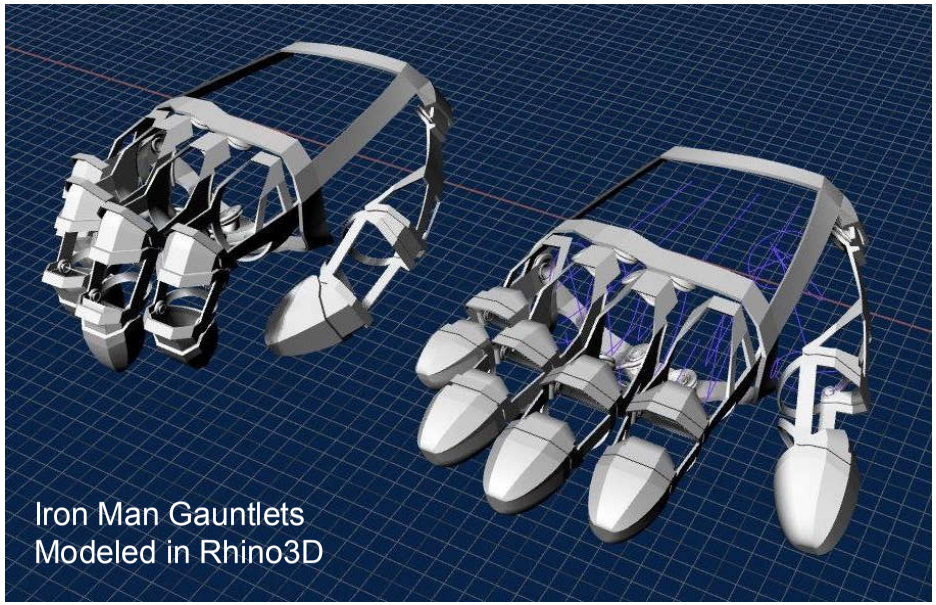
Solid Modeling

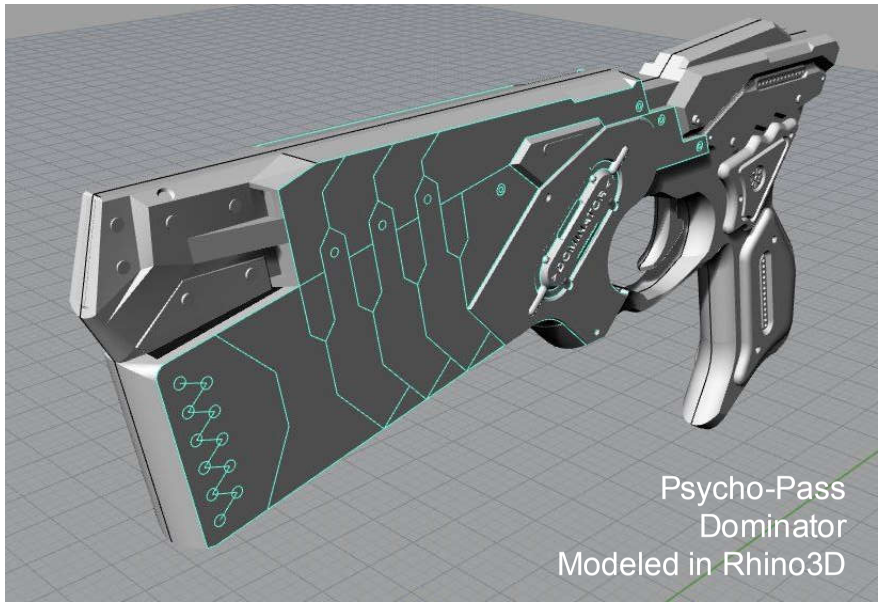
- Solidworks, Onshape, Rhino3D
- Allows you to design precise shapes.
- Good for mechanical models and “machine-like” props



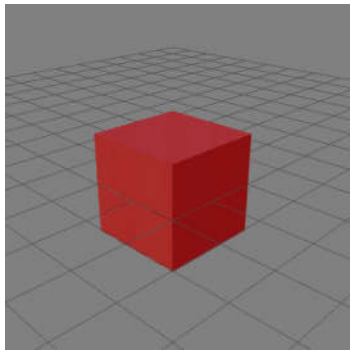
Surface Modeling

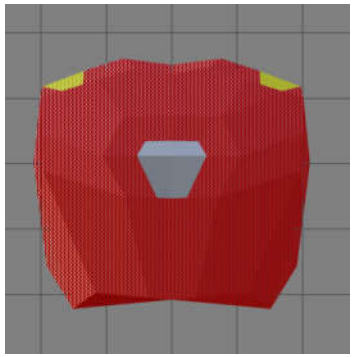
- Related to Solid Modeling: In computer, joined surfaces are practically the same as a solid

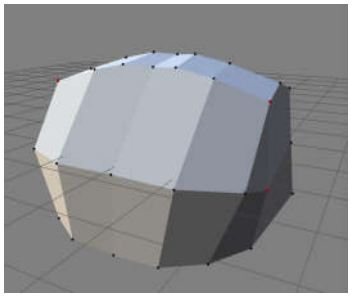

Iron Man Gauntlets
Modeled in Rhino3D


Psycho-Pass
Dominator
Modeled in Rhino3D

Mesh Modeling

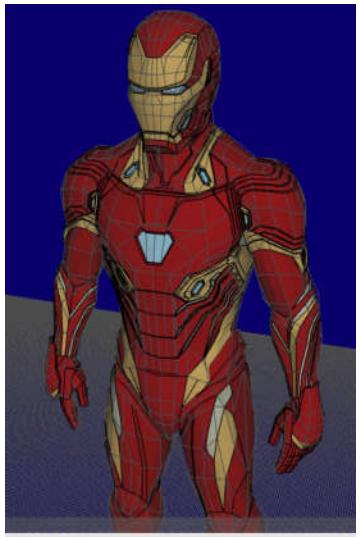




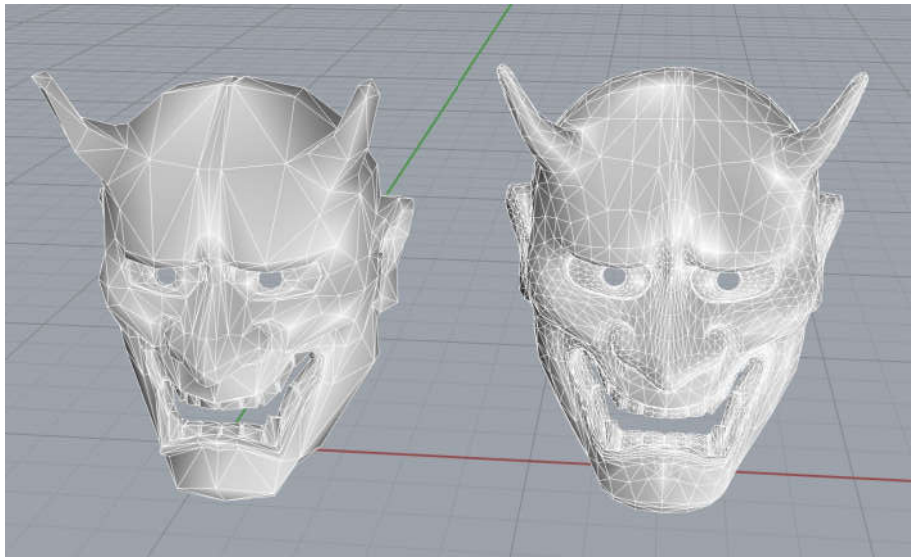


- Less precise
- Almost the fastest

From cube to Iron Man in Wings 3D



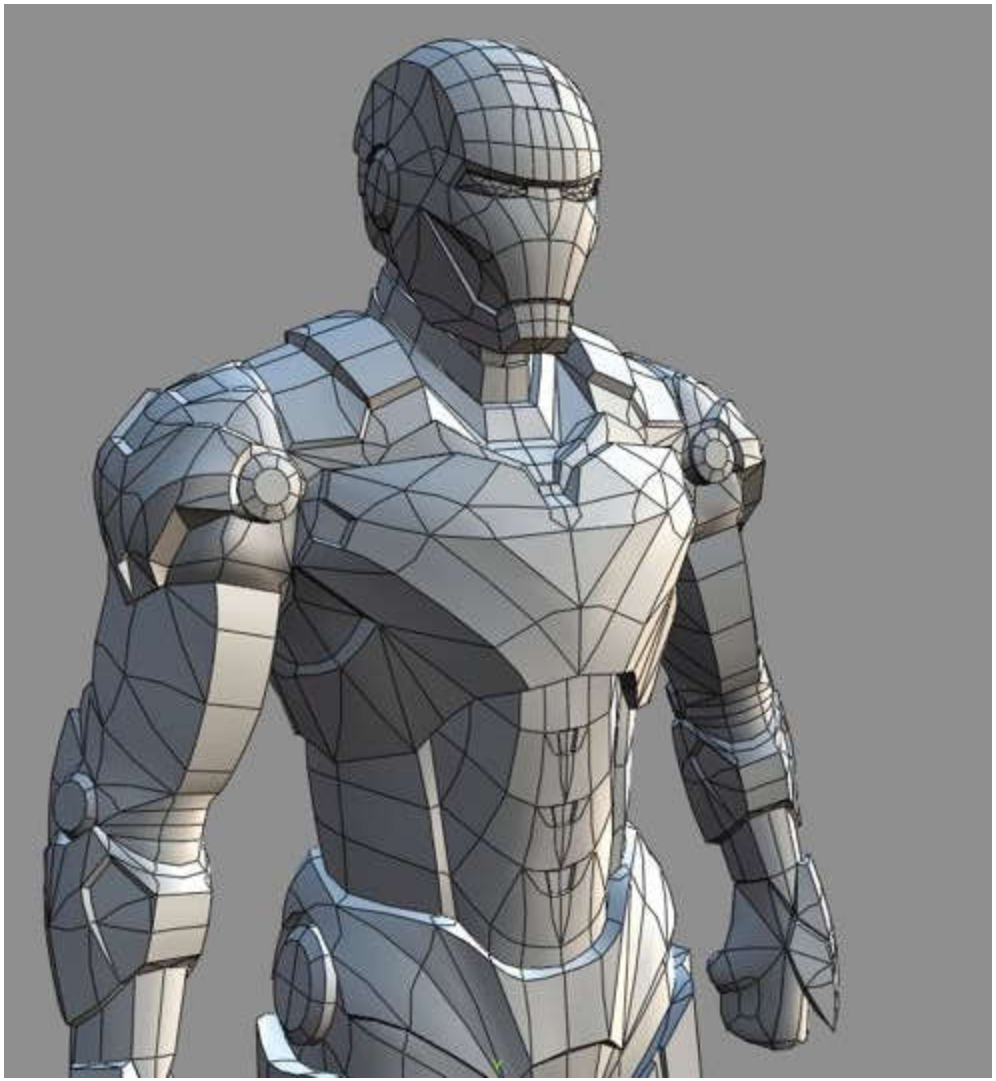
Mesh Modeling



Hannya mask modeled in Wings3D
Low-poly base model vs auto-smooth model

Free - form (manipulate) individual vertices, edges, and faces to make low-poly models

These models can be auto-smoothed into more sculptural looking forms



Iron Man Mk. 6

Low-poly model, Modeled in Wings3D,

smoothed into final form

Virtual Clay

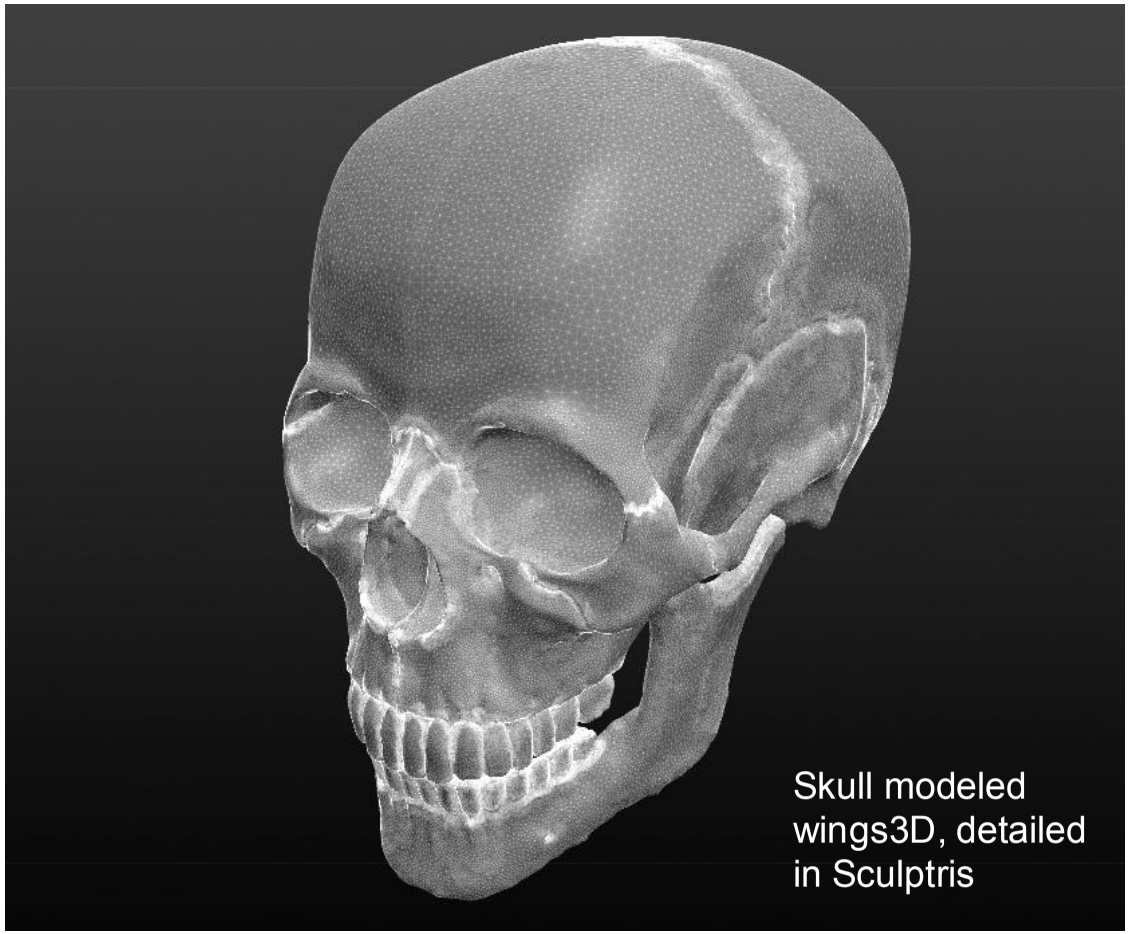
Sculptris (free), Zbrush (not so free)

- least precise

- fastest

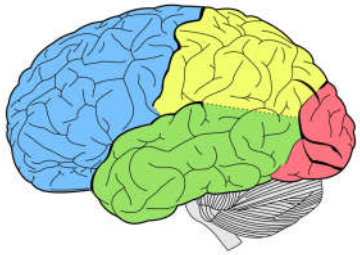
- most organic shapes

- like “3D photoshop”

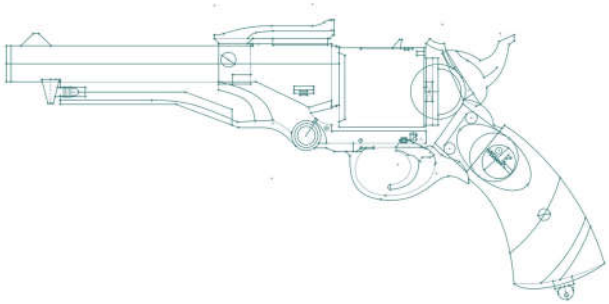


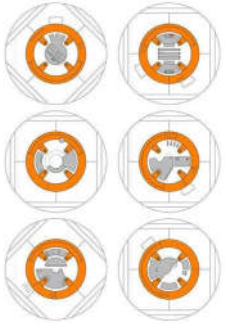
Planning Your Build

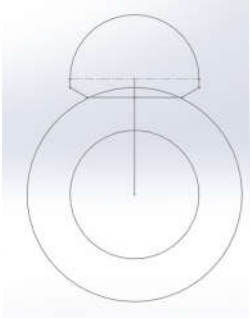
This means you need to stop and think →

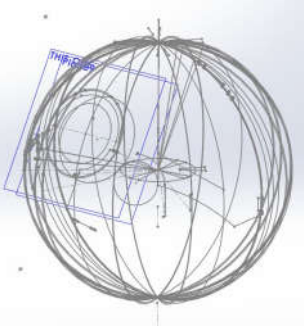


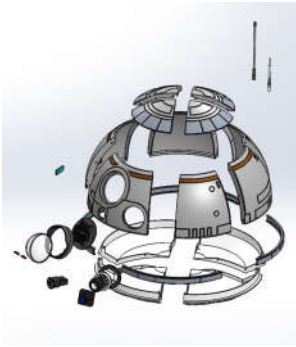
- Master modeling
  - Sketching out every feature before you start designing





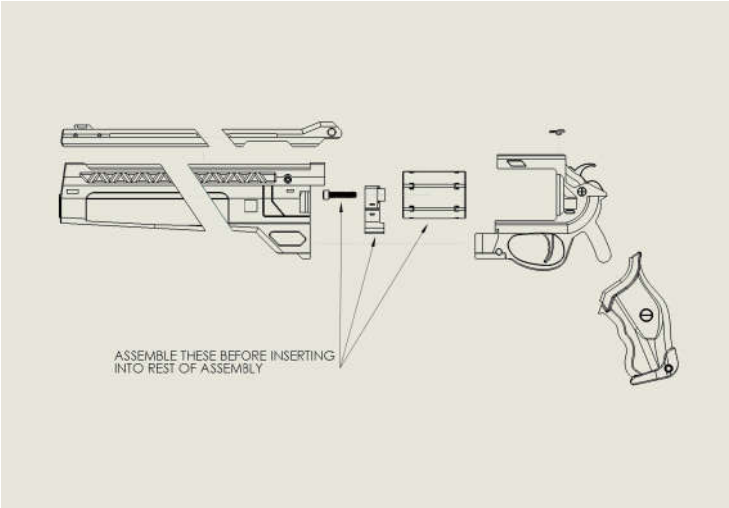






Planning Your Build

- Scale vs. experience
- Resources
- ‘How bad do you want it’



10 Parts

42 Parts + Electronics

Planning Your Build

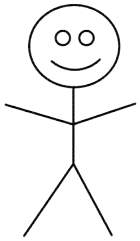
- Scale vs. increasing experience

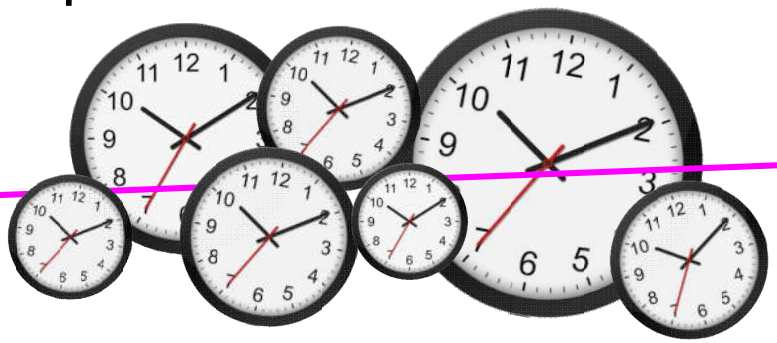
2017: 10 Parts

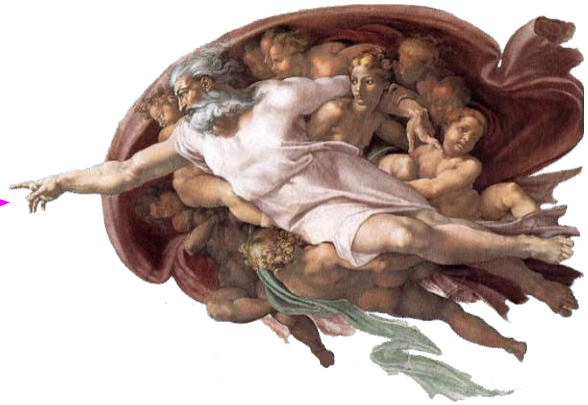
2019: 12 parts

CAD Your Build

- Paid/**Free**
  - Blender
  - Sculptris
  - Wings3D
  - OnShape





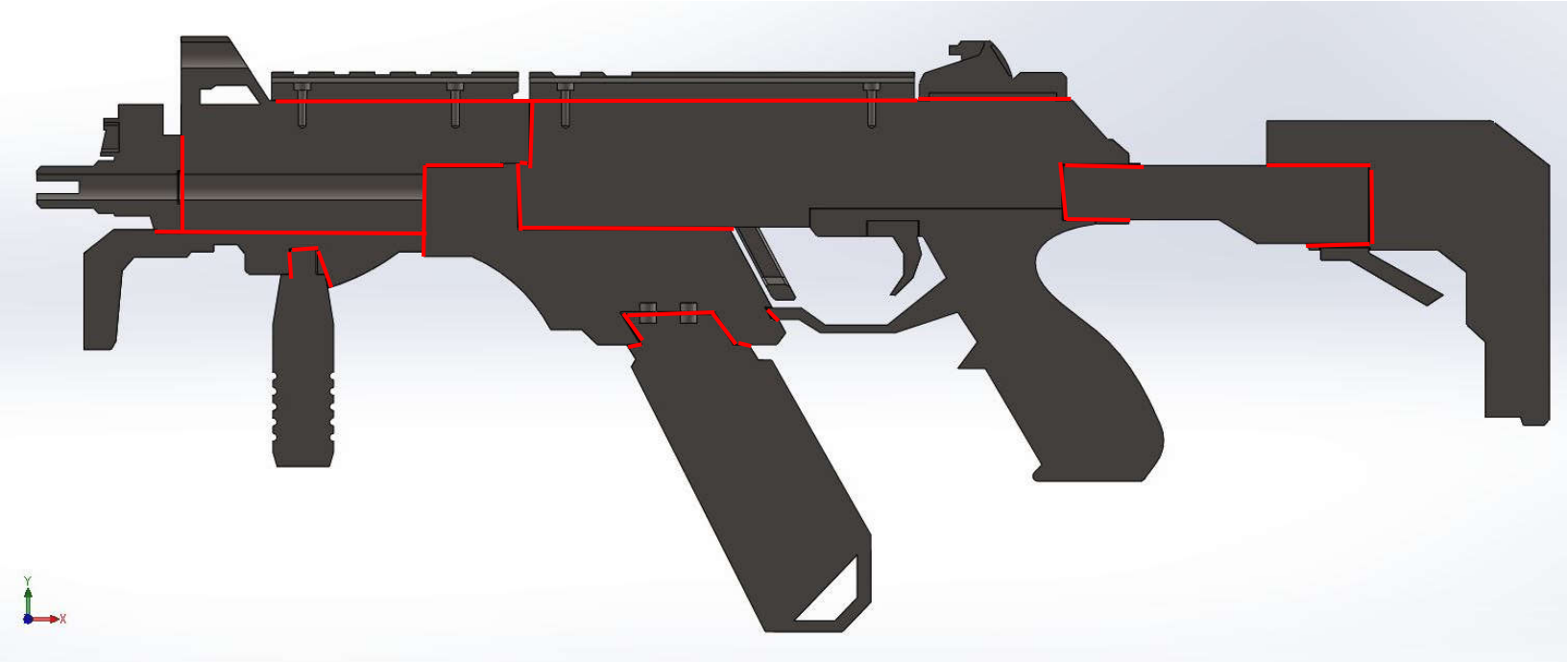


CAD Your Build

- Clearances
- Fabrication methods
- Material considerations

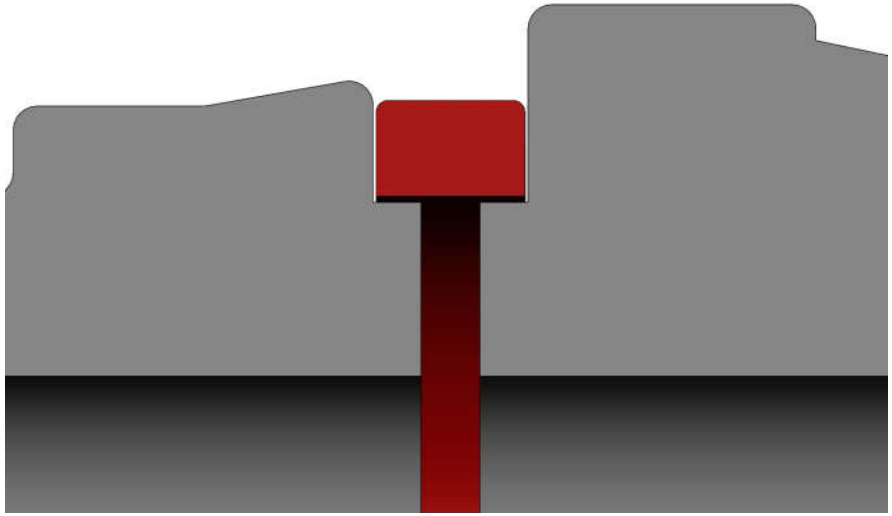
CAD Your Build

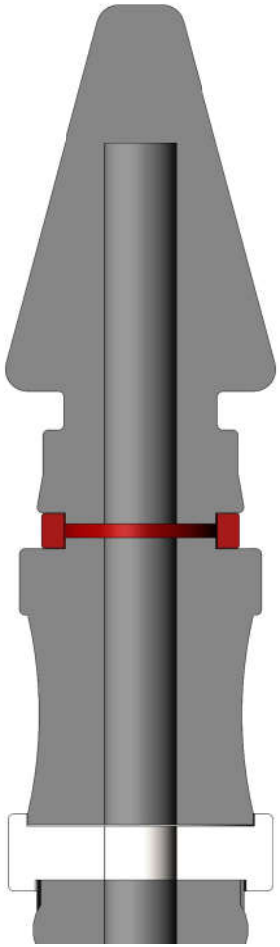
- Clearances aka **leave some room for error**



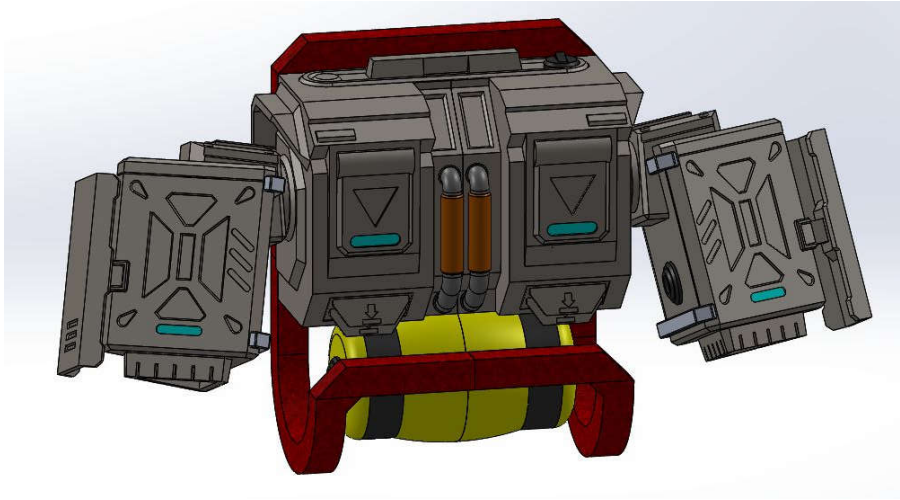
CAD Your Build

- 3D printing clearances
  - Vary printer <> printer
    - SLA: 0.125 - 0.375mm *on all sides*
    - FDM: 0.25mm - 0.5mm *on all sides*

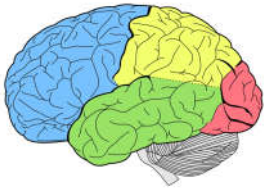


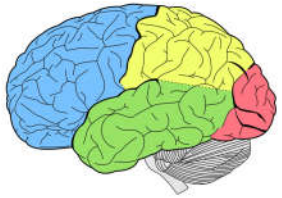


CAD Your Build

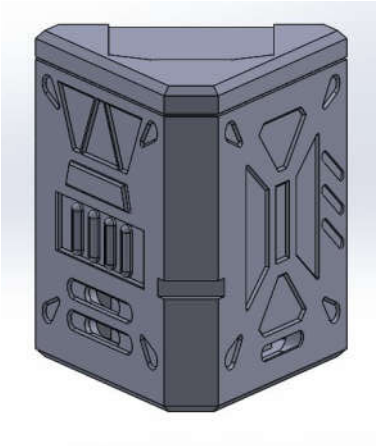


- Fabrication methods

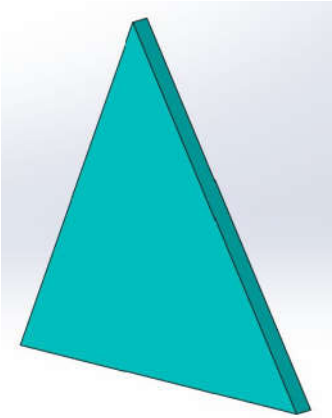


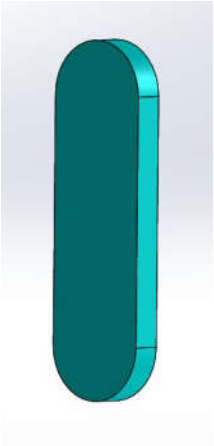


PRINT

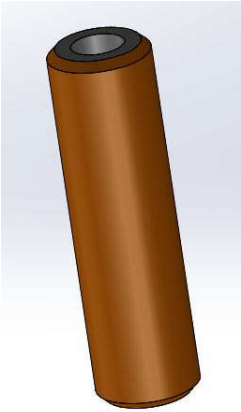


2D CUT

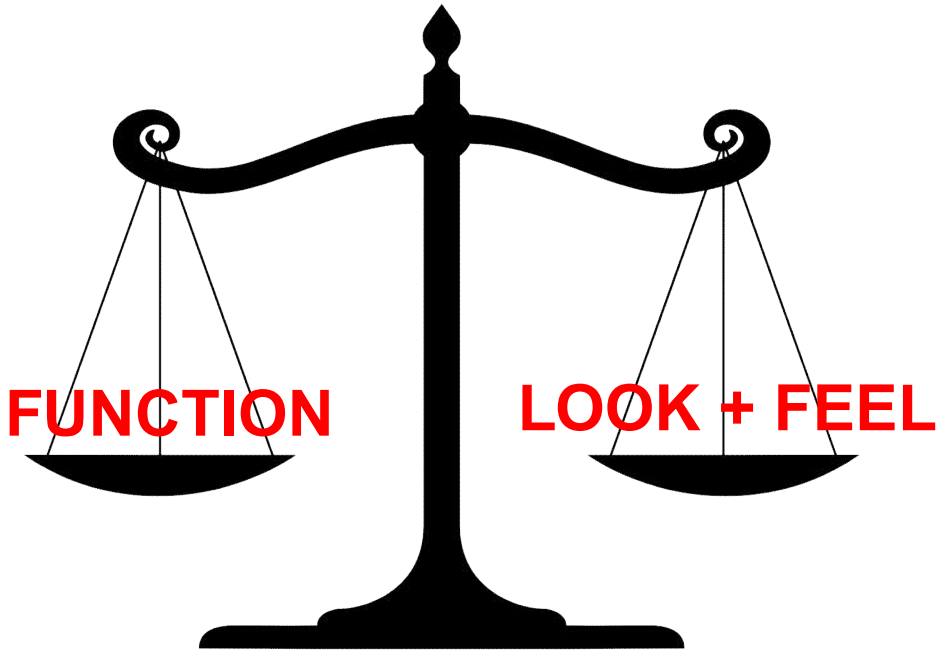




OTS PART



CAD → DFM/DFA



Structural <> Both <> Cosmetic

Material Considerations

ABS (LEGO) $
- **Common FDM 3D printing material**
- Tough/impact resistant
- Easy to sand and paint

Acrylics (plexiglas) $
- Laser cuttable, thermoformable
- Many thicknesses, can be optically clear
- Strong but brittle - will crack if dropped!

X-Acrylates $$$
- **Common SLA 3D printing material**
- Can be sanded and painted to a *perfect* finish (with patience and practice)
- Strong but brittle! Will crack if dropped!

Metals $$
- Aluminum (macbook shells)
  - Lighter, expensive, more easily formed
- Steel (most commercial hardware)
  - Heavier, cheaper, more difficult to form

Rubber/foams $ (Yoga mats, tool grips)
- Grippy, comes in sheets, easily cut/molded
- Many textures/thicknesses/stiffnesses

Mo’ Materials

Mo’ metals
- Copper
  - Comes in pipes, sheets of standard sizes
  - Great for adding texture and color variety
  - Nonmagnetic

Mo’ plastics
- PLA
  - **Common FDM 3d printing material**
  - Not *actually* biodegradable in the conventional sense
  - Cheap, generally easy to print
  - Strong but reasonably brittle, low melting temperature (don’t leave me in a hot car)
- PP/PE
  - Slippery, easy to cut and form into moving parts. Rivets are great for these.
  - Not easily paintable or gluable, but comes in colored sheets
- PVC
  - Standard pipe sizes, cheap, paints easily
  - Impact resistant

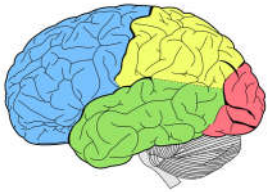
Mo’ 3D printing materials

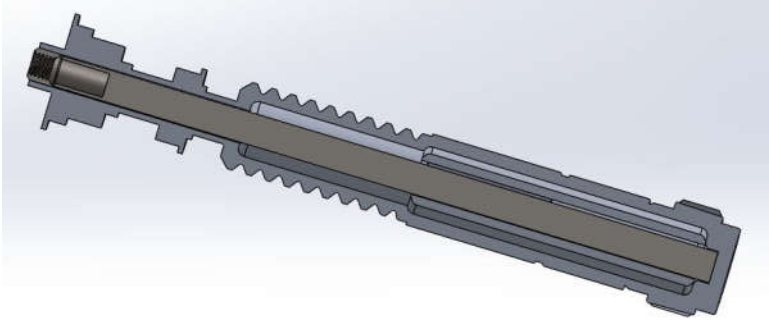
- NinjaFlex and TPU
  - Medium levels of detail, good for flexible armor pieces
- Formlabs Durable Resin
  - Stiff but flexible plastic, very impact resistant, can be tweaked under hot water
- SLS Nylons
  - Extremely strong, grainy surface finish

Paints
- Use a plastic/metal/whatever primer if you aren’t sure it will stick
  - Some things just won’t accept paint, sorry
- Krylon for regular aerosol paints
- Design Master for Metallics

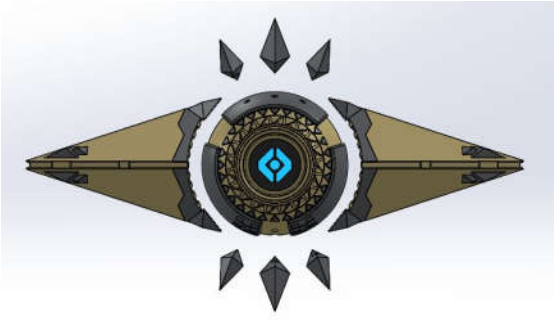
Laser Cutting Materials Safety

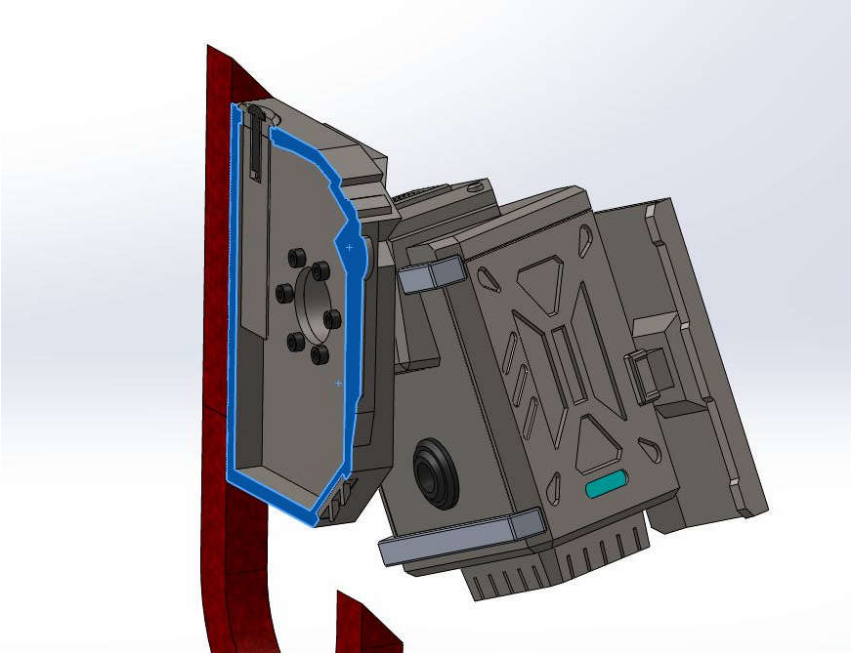
DFM/DFA





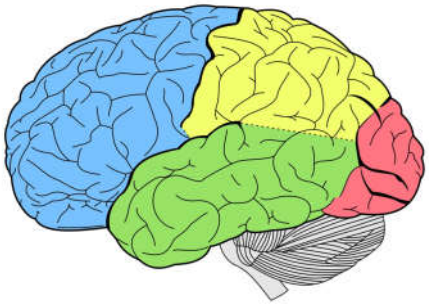
- How will the pieces go together
  - Fastening, strength
- Overlaps to hide seams
- Base first, build out
- **Be Realistic**

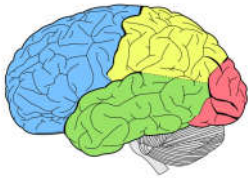


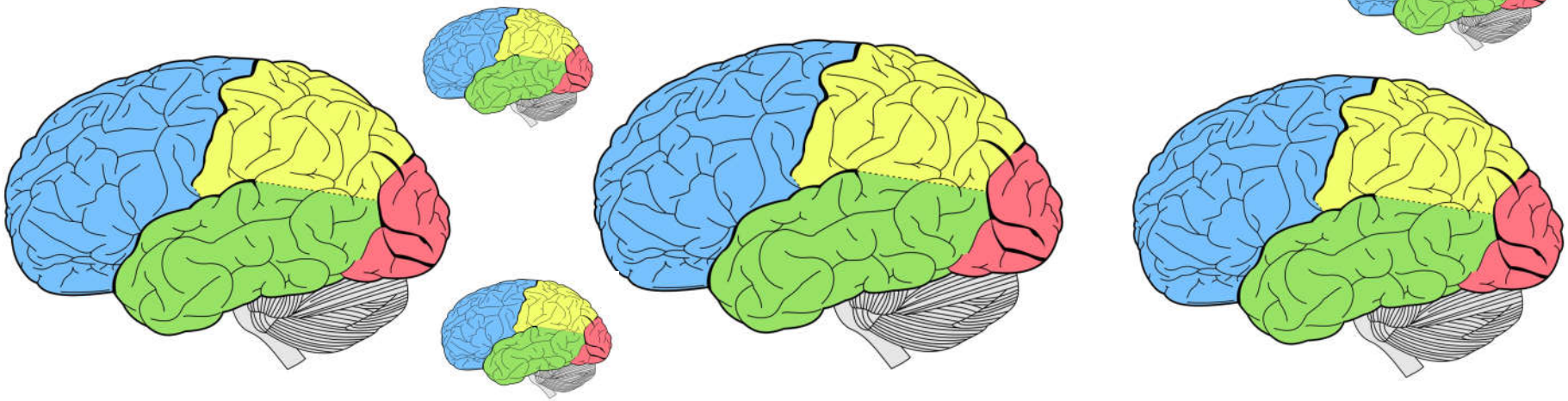


Design For Actually Getting into the Con

- CON REGULATIONS ARE REAL
  - NO PROJECTILES (NERF)
  - NO METAL BLADES
  - LOOK UP THE RULES FOR **YOUR** CON



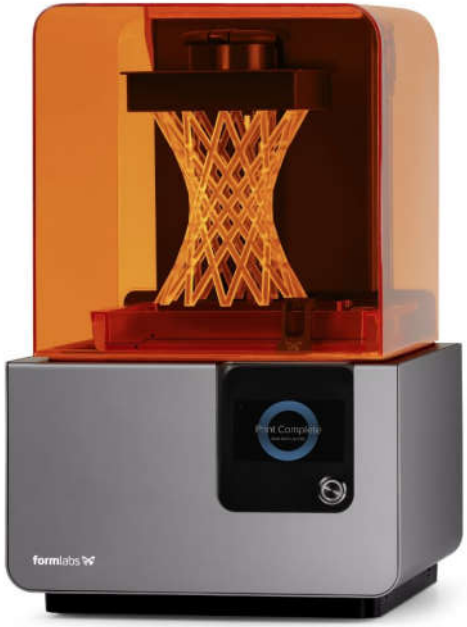




Fab Your Build

vs

- Print it (cut it, sand it, glue it, paint it)
- ‘Low-Tech’ == cheaper (usually)
  - Post-processing
- **BE SAFE. HELP IS OKAY**



GO MAKE SOME DOPE STUFF

@adriantanner

ARTICULATION
Designing For Movement

Where to use motion

Props that move/transform

Segmented armor

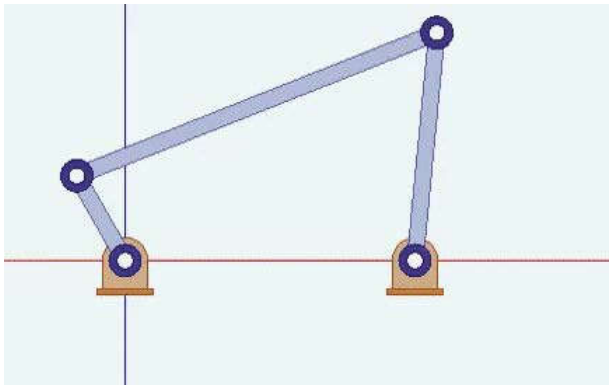
Basic motions

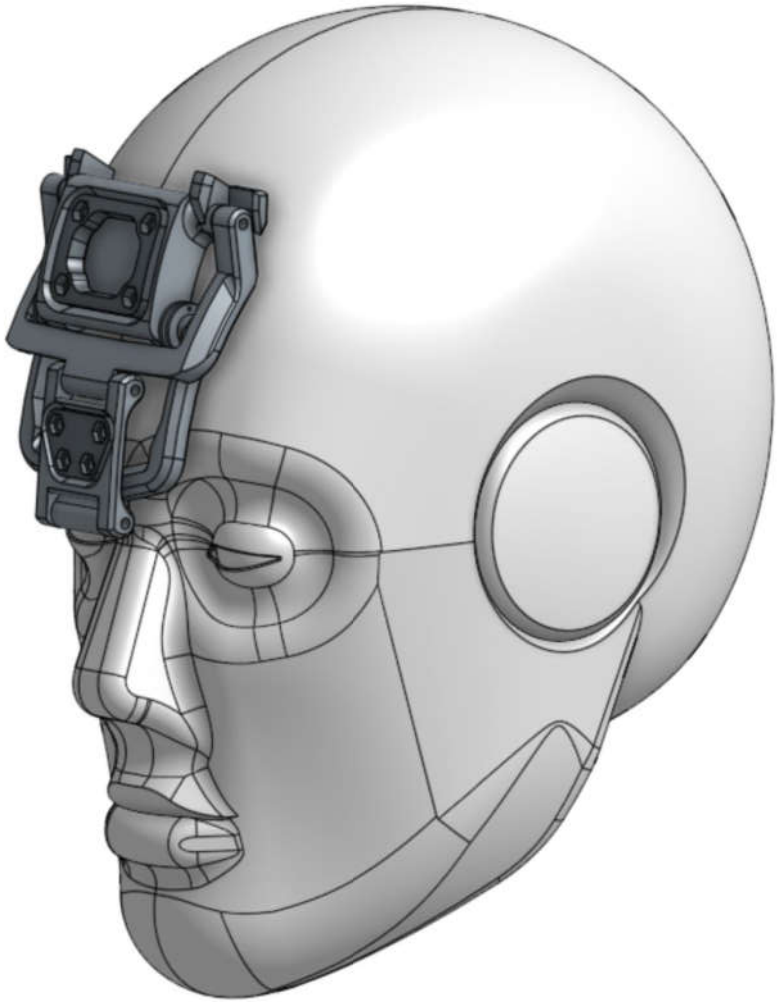
Pivot joints 

Ball joints 

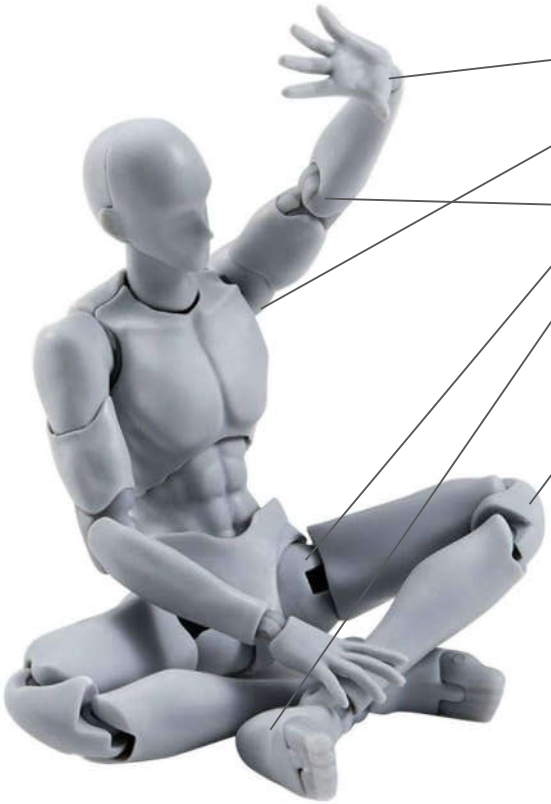
Sliding joints 

Four-bar linkages





Basic hinges of the human body (an approximation)



Ball joints - spine, shoulders, hips, wrist, ankle, finger first segments

Pivot joints - elbows, knees, finger last 2 segments

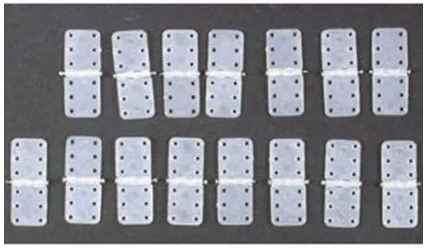
Physical Joints

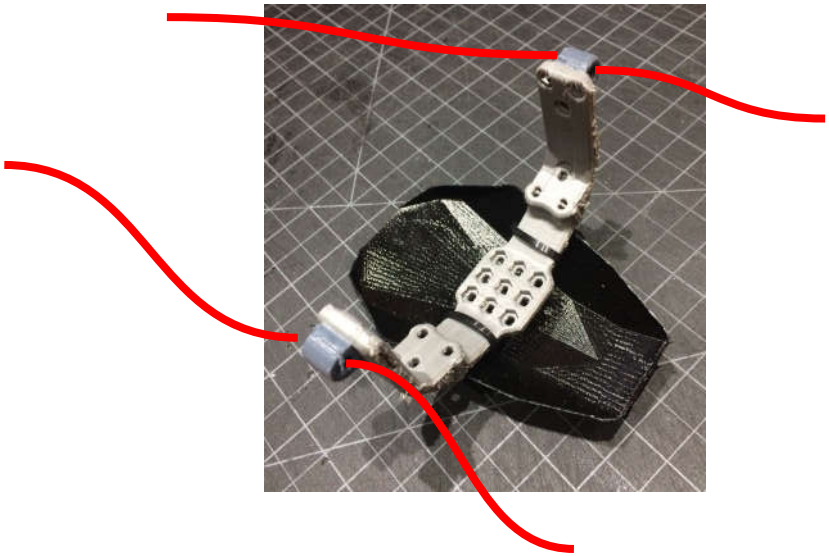
Furniture hinges

RC airplane hinges

3D printed hinges

Bungee cord method

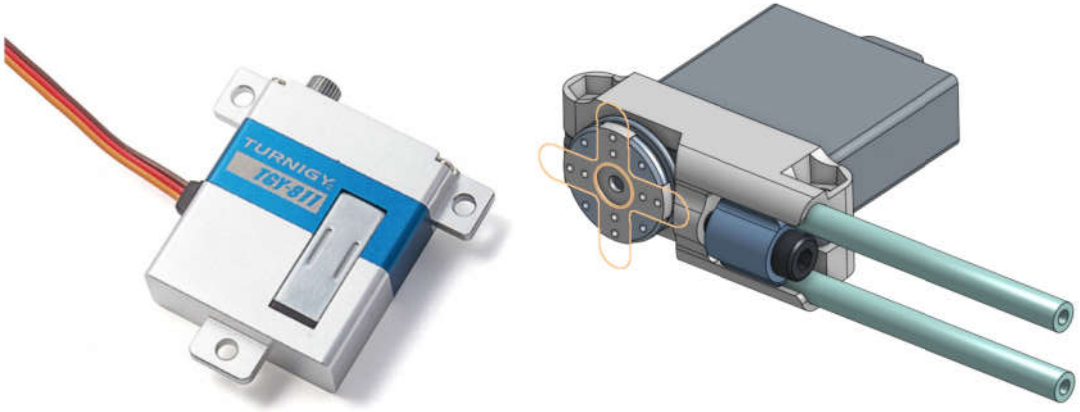


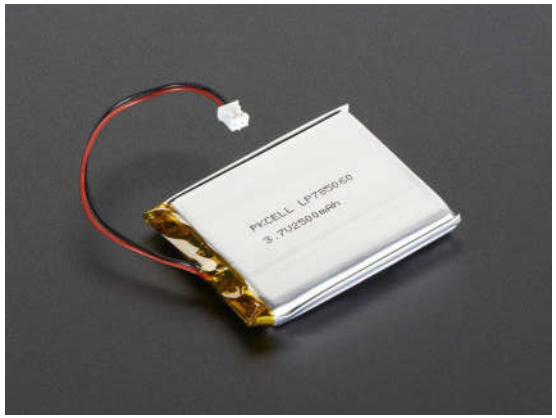


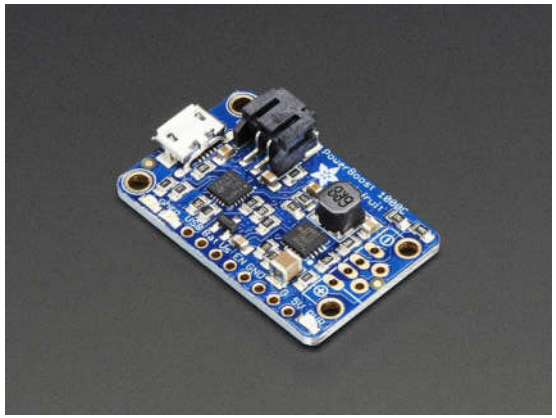
Actuation & Control

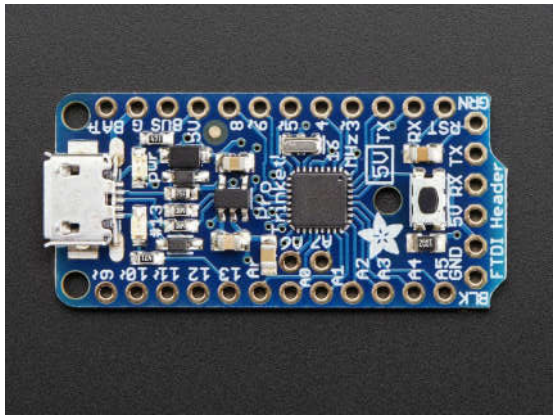
Motors, Servos - the “muscle”

Microcontrollers - the “brains”









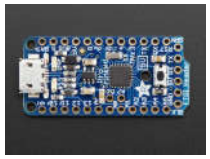
Arduino

One of the most approachable microcontroller platforms for learning

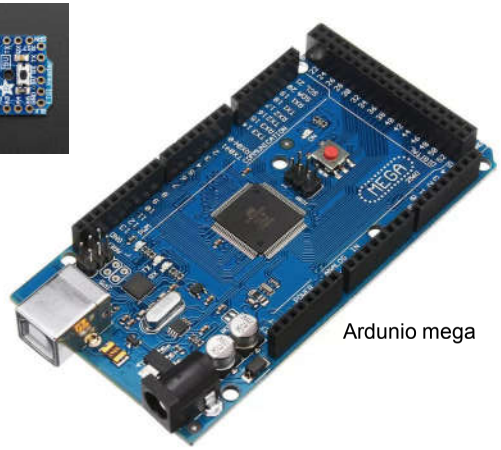
- Open-source
- Well - documented, with lots of example code
- No frills
- Inexpensive (typically $5-$20)

Adafruit.com - supplies and tutorials all in one spot

Ardunio Trinket



Ardunio Uno



Ardunio mega

flipper | Arduino 1.8.5

flipper

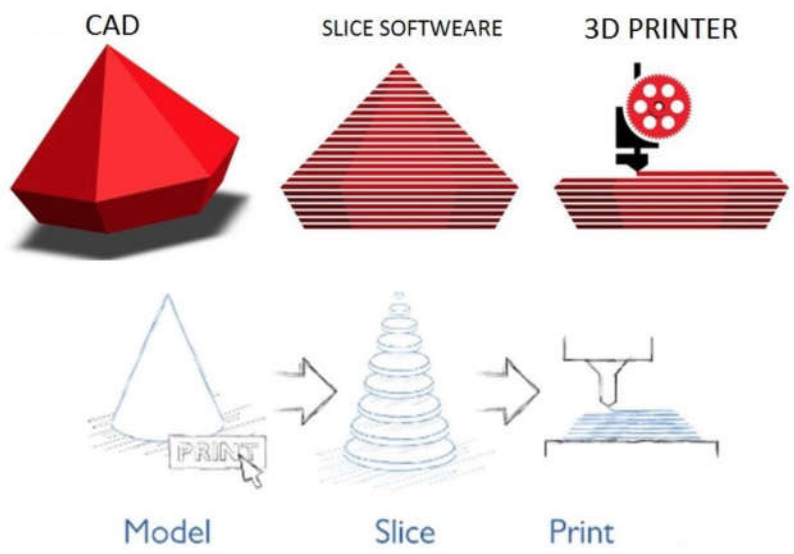
```
#include <Servo.h>

Servo flipservo;  // create servo object to control a servo

const int buttonPin = 10;  // activation button
const int servoPin = 9;    // servo
const int eyePin = 12;     // for lighting the Eyes
const int upangle = 130;   // flip up angle
const int downangle = 5;   // flip down angle

const int ledPin =  13;      // the number of the LED pin


int reading;
int buttonState;
int lastButtonState = LOW;

int pos = 180;                  // variable to store the servo position (degrees)
int flipState = HIGH;           // variable to describe if helmet is flipped open or not (HI

unsigned long lastDebounceTime = 0;   // the last time the flipState was toggled
unsigned long debounceDelay = 1000;   // the debounce time, increase if the output flickers

void setup() {
  pinMode(buttonPin, INPUT);         // set the button pin to be read
  pinMode(eyePin, OUTPUT);           // set the eye button pin to output
  pinMode(ledPin, OUTPUT);           // set the LED pin to output
  flipservo.attach(servoPin);        // attaches the servo on pin 9 to the servo object
  digitalWrite(eyePin, LOW);         // turn off the eye glow
}

void loop() {
  reading = digitalRead(buttonPin); //read the button

  if (reading == HIGH) {
    // turn LED on:
    digitalWrite(ledPin, HIGH);
  } else {
    // turn LED off:
    digitalWrite(ledPin, LOW);
  }
```

// 3D PRINTING //
The Crash Course

3D Printing

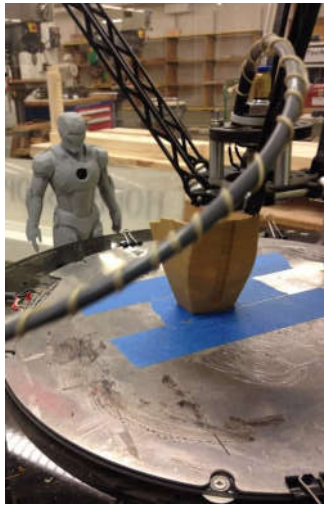
(Additive Manufacturing)

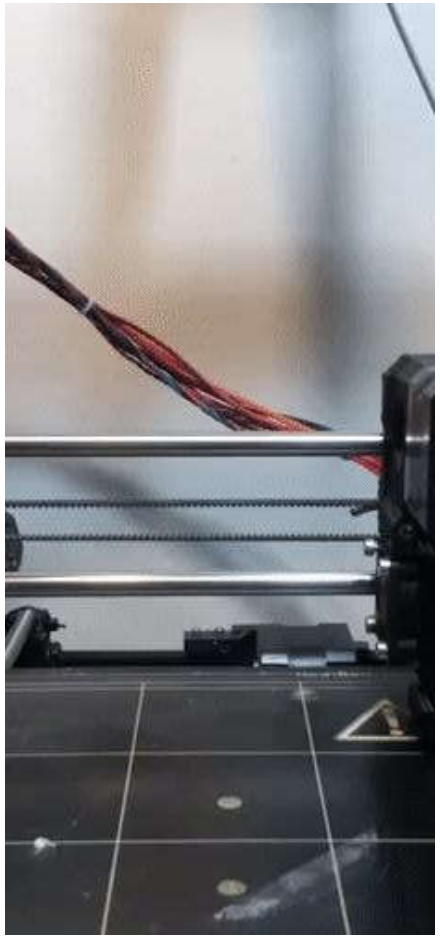
How it Works



Basic Process

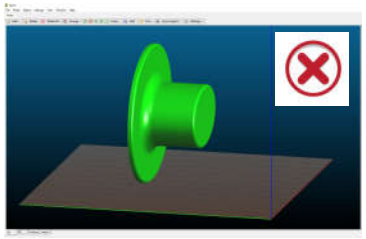
1. Create digital 3D object
2. Convert to .STL
3. Import to printer software
4. Orient, support, duplicate
5. PRINT!
6. Post process



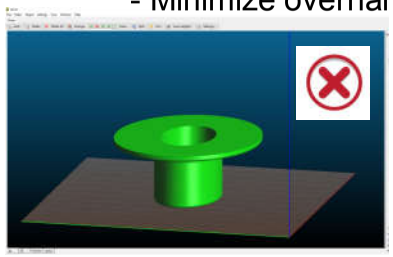


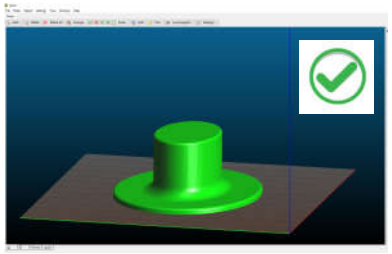
3D Printing Orienting your parts for success

(Additive Manufacturing)

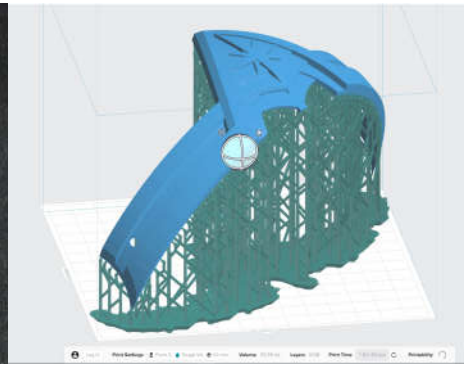


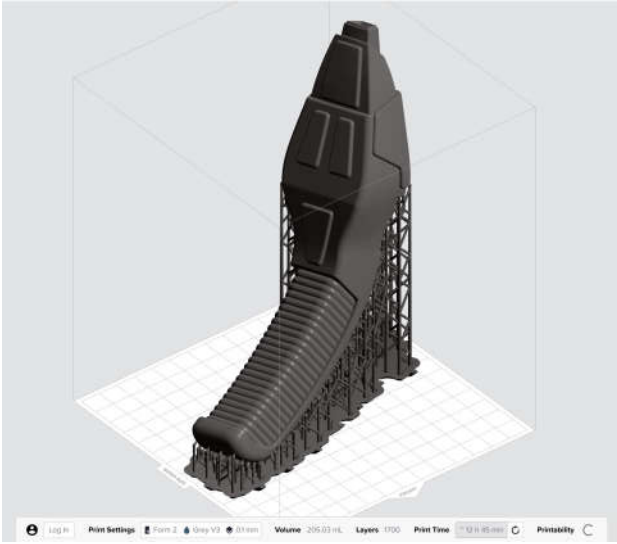
FDM - Maximize build platform contact
- Minimize overhangs





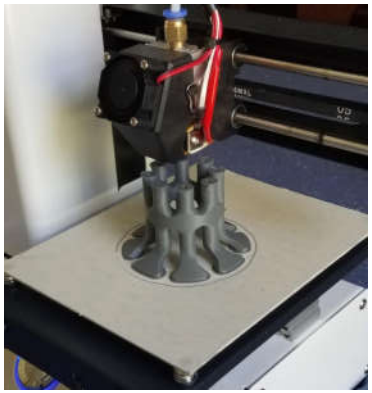
SLA - Start from a single edge
- Minimize supports on visible





3D Printing

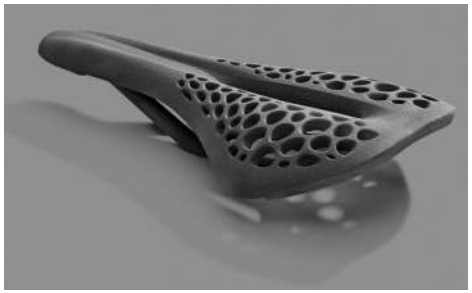
(Additive Manufacturing)



Most Common types of 3D printing

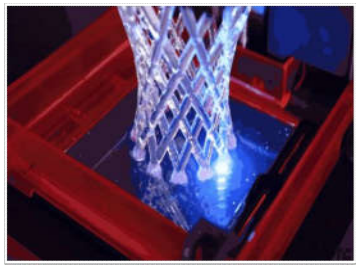
FDM - melted plastic extruded from a tiny extruder

SLA - liquid cured with a laser



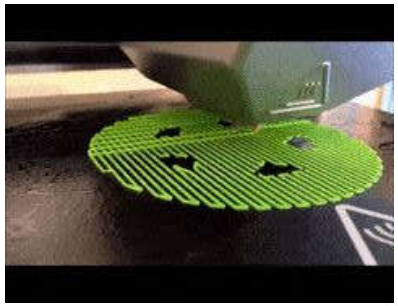
SLS - powder melted together with a laser

Others: DMLS, Poly Jet, Binder Jet, etc



FDM - Fused Deposition Modeling (aka Fused Filament Fabrication)

"Hot glue gun on a robot gantry"



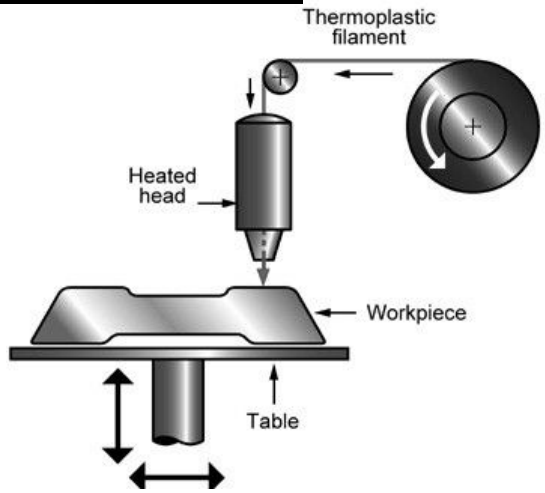
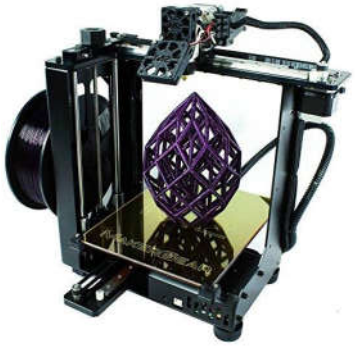


Image Source: https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/

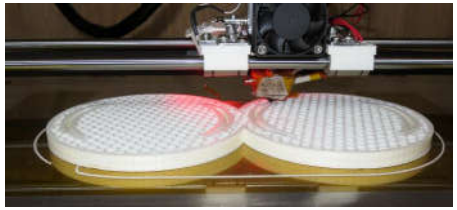
Monoprice
MP Select Mini V2
($220)

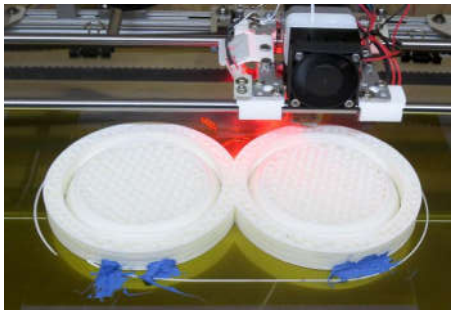


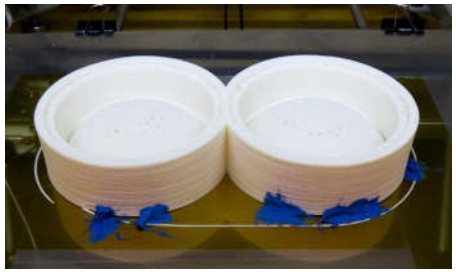
MakerGear M2 Printer
(~$1825)

Lowest cost (starting at ~$200)
Most accessible
Many designs and printers

Prints quickly
Thermoplastic Filament
(ABS, PLA, Nylon, TPU)
Good Mechanical Properties



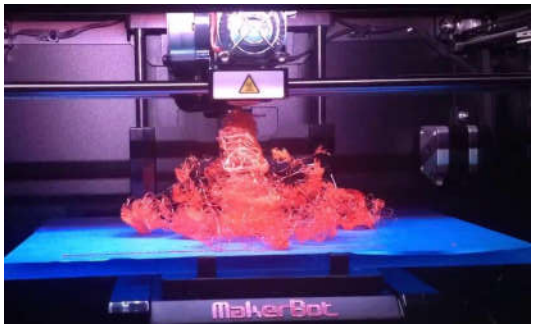




FDM - Fused Deposition Modeling

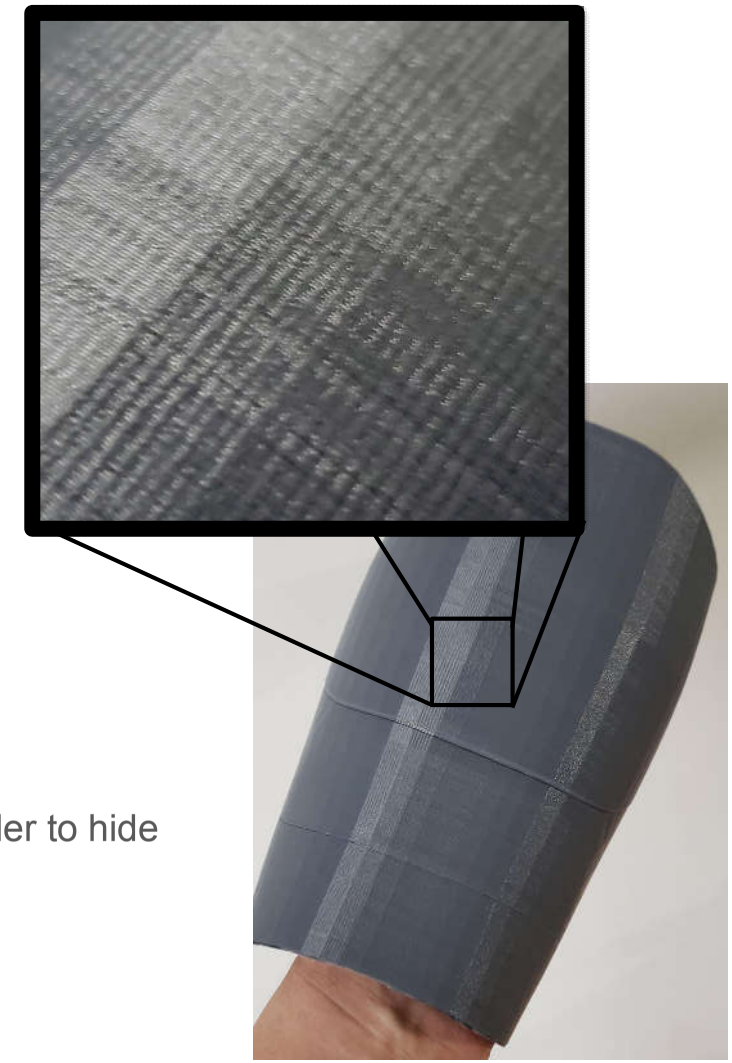
Pros

- medium and low-resolution prints
- low cost, affordable to the hobbyist (~$200 for a basic printer, ~$1000 for a medium-level printer, ~ $3000 for a high-end printer)
- fast "vase mode"
- Multiple materials with good properties



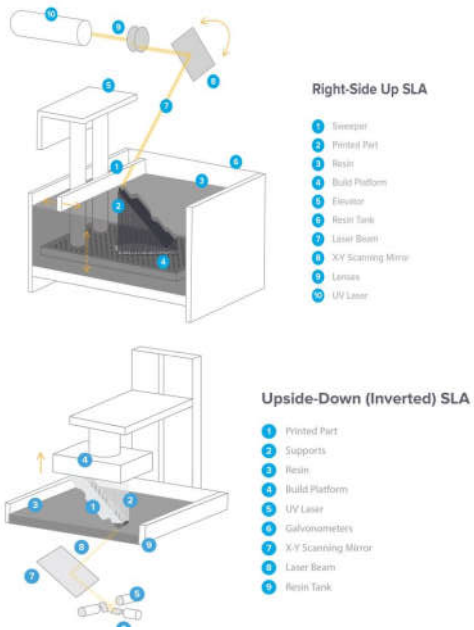
Cons

- Poor surface quality
- Larger layers = more sanding/filler to hide
- Weaker in Z direction



SLA - Stereolithography

Use light convert liquid plastic into solid objects

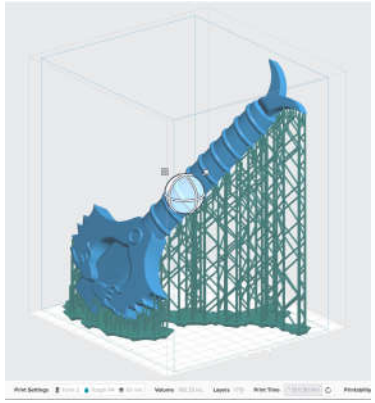


Best at small finely detailed objects

Best surface finish (25um layer heights)

Parts have minimal design constraints

Overhangs require supports



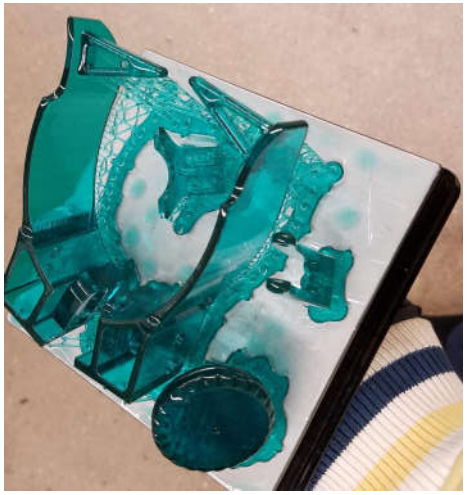
Formlabs Form 2
(~cost $3350)

Image Source: https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/

SLA - Stereolithography

Pros

- High-resolution prints are great for Highly Detailed Objects
- Surface finish second to none (25um needs no sanding)
- Many materials ranging from soft flexible to strong stiff glass reinforced resins



Cons

- More expensive than FDM, especially materials costs
- Lots of post processing:
  - Washing
  - Support Removal
  - Post Curing
- SLA Resin (liquid goo) is STICKY!

SLS - Selective Laser Sintering

Powder is sintered together into solid objects with laser energy

Formlabs Fuse1
(~cost $9999)

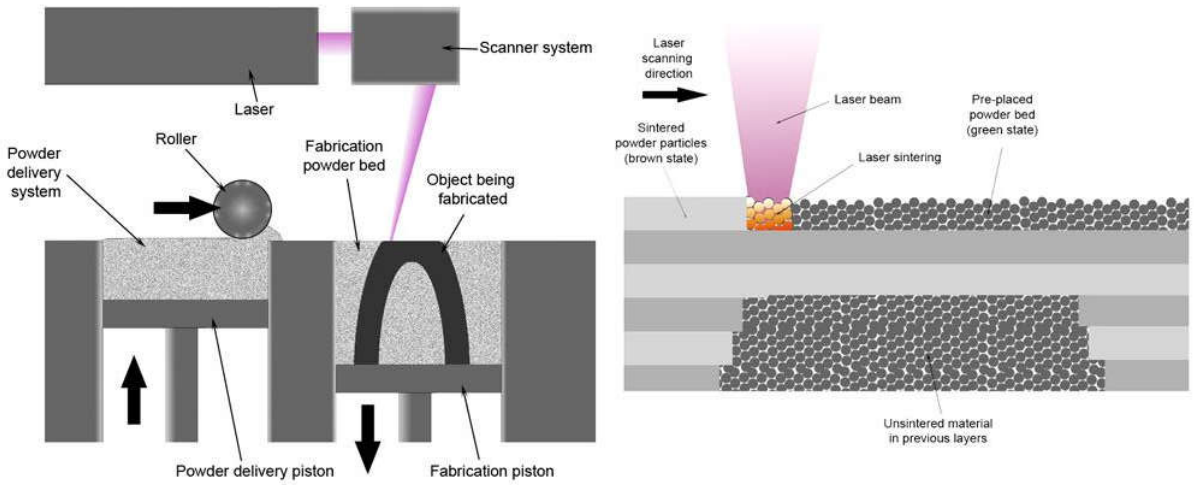


Image Source: https://upload.wikimedia.org/wikipedia/commons/3/33/Selective_laser_melting_system_schematic.jpg

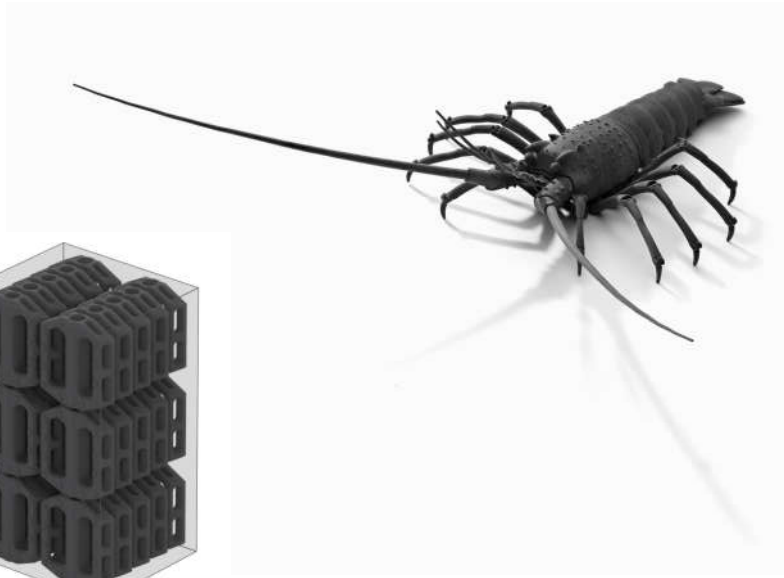
Best Material Properties

Self supporting technology

Ability to pack the build volume

Parts have no design constraints

SLS - Selective Laser Sintering



Pros

- Great materials (Nylon, TPU, PP)
- Good details and print quality
- No support marks to clean up
- Fewer design constraints

Cons

- Expensive
- Powder is messy, (metals) have health hazards
- Grainy Surface (glossy smooth hard to achieve)

// OTHER TECH TOOLS //
All the Fun Toys!

CNC Machining

(Subtractive Manufacturing)

Robots use sharp spinning cutting tools to remove material from chunks of material

Metal
Plastics
Ceramics

Laser Cutting

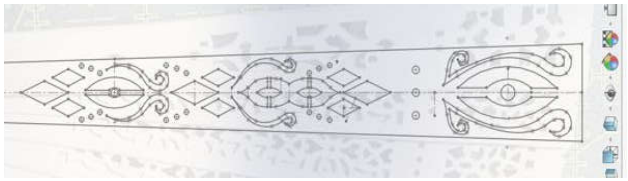
Glow Forge ~$4K

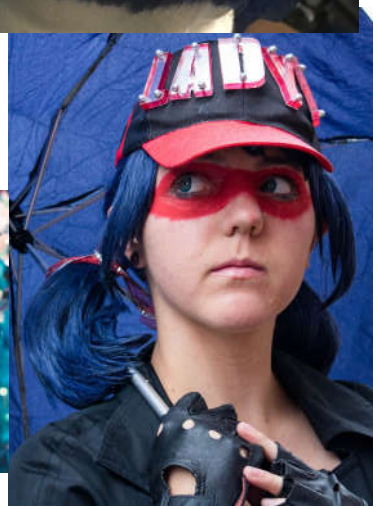
Commercial
`$10K-$100K

Fastest & lowest effort

Cuts Wood, plastics, felt, fabric, etc:
https://www.epiloglaser.com/how-it-works/laser-material-compatibility.htm

Not all plastics are safe to cut!!
No PVC or TEFLONS





Vinyl Cutting

Uses a blade to cut out from thin materials like paper, foam, fabric, plastic sheet and vinyl.

Use for materials that aren't good in a laser cutter

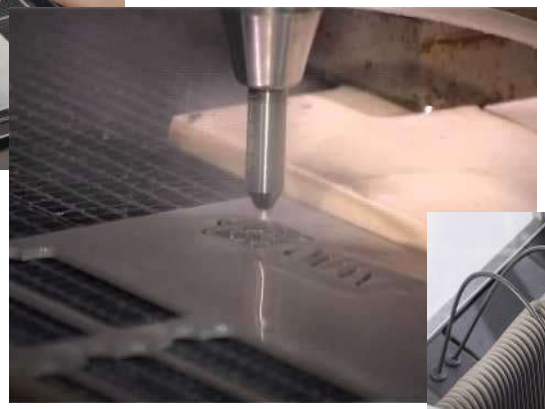
- Paper (will catch on fire)
- Vinyl = PVC ('C' in PVC = chloride → TOXIC)

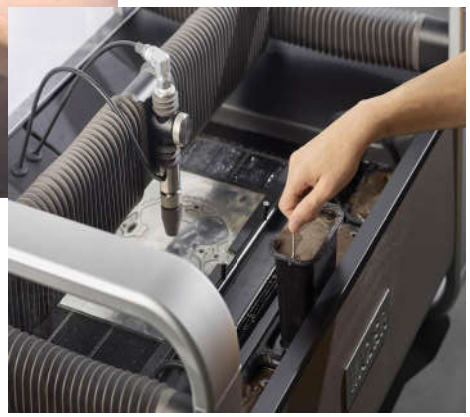
Cricut Maker ~ $400

Ex. @lulukohime's Lucina yukata

Water Jetting

High pressure water plus abrasive





Cuts all the difficult things

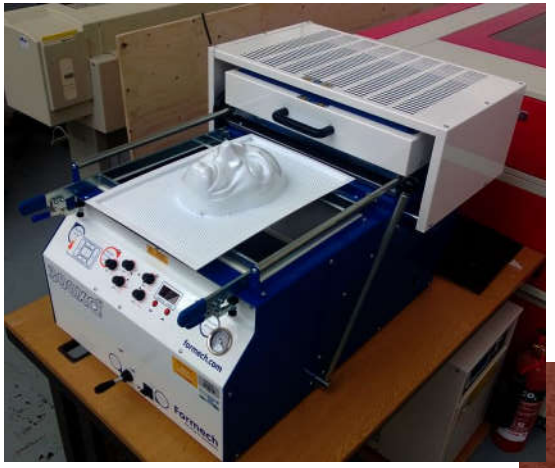
- Stone
- Metal
- Plastic
- Rubbers
- Ceramics

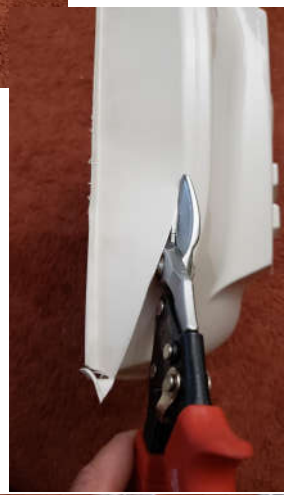
Thermoforming / Vacuumforming

Thermoforming
heating plastic sheets over molds
(or shaping by hand)

Heat gun + Worbla
https://www.worbla.com/

Vacuumforming
heating plastic sheets then
sucking them down over forms





Sheet plastic (ABS)
3D Printed Mold (High Temp)
Kitchen Oven (~400F)
Perfectly formed panels

// ACCESS TO TECH //

We Promise It's Not **That** Expensive

PRICE POINTS

Cheaper

More Expensive

Heat gun
(thermoforming)
~$20

Vinyl cutter
(~$100-$400)

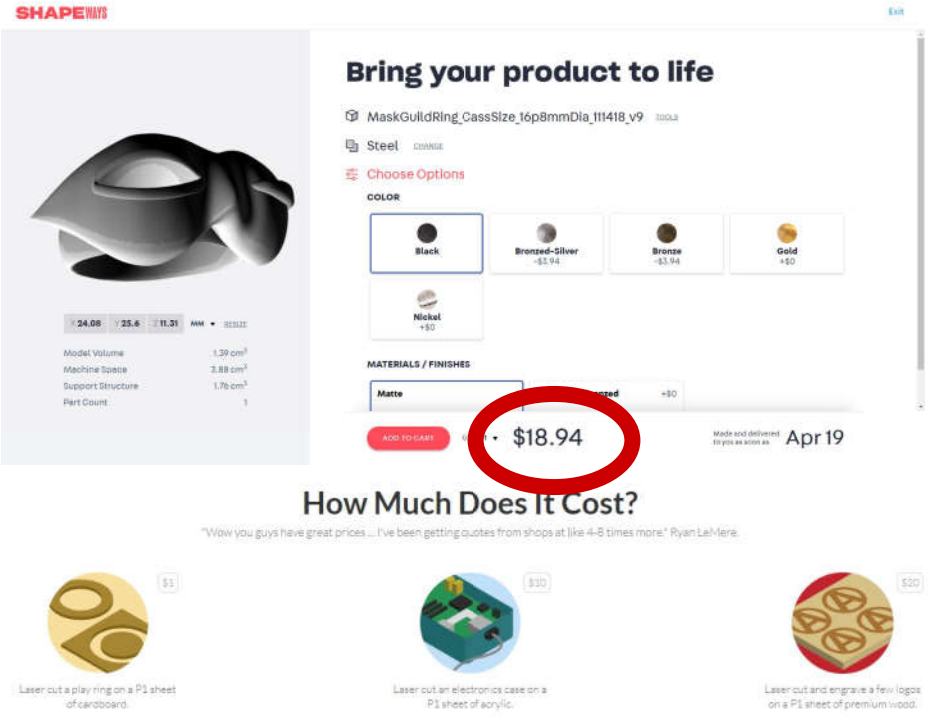
Self-assembly
3D FDM Printer
~$250

Form2 SLA Printer
~$3500

Glowforge Laser
Cutter
~$4000 (+some
for vent system)

SERVICE BUREAUS

shapeways



3D HUBS

Ponoko

PROTOLABS
Manufacturing. Accelerated.

MakerFleet

MAKERSPACES

- Machine shops & work spaces open to the public (usually for a fee)
- Learn to use equipment, take classes, etc.

Good list of New England Maker Spaces: https://thetakemagazine.com/new-england-maker-spaces/

BOSTON MAKERS
DESIGN • FABRICATION COMMUNITY

Artisan's ASYLUM

cambridge HACKSPACE

gather here and make something.

WHERE TO BUY STUFF

McMASTER-CARR®

adafruit

Applied Magnets
WWW.MAGNETALERS.COM
We sell strong magnets for less!

TNT COSPLAY SUPPLY

INVENTABLES™

TAP Plastics

Digi-Key ELECTRONICS

Reynolds Advanced Materials
www.reynoldsam.com

HARBOR FREIGHT TOOLS

// CONCLUSION //

If you learn *anything* today....

KEY TAKEAWAYS

- If you **plan it out first**, it will be **easier later on**.

  Do your homework (research your build)
  Sketch it out on paper
  Choose materials Wisely
  Use CAD to model parts (where it makes sense)
  Make all the things!
  Assemble
  Go to Con!

- Work smart, not hard: **buy parts** when possible.
- Pick the **right tools** for the job.
- Your build is more than the sum of its parts - **internals matter** as much as externals!

WANT MORE? // DOWNLOAD

http://tiny.cc/

2D3D-AB2019