Additive Manufacturing Technology and Trends

MCA Session Topic: CAM for CAD and MCA Ideation

6/23/25

Instructors:

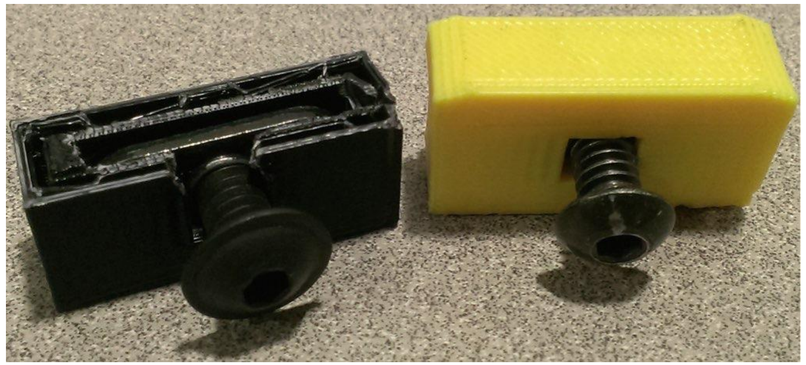
1. Alex Raymond Renner: arenner@iastate.edu
2. Sam Edwards: scedward@iastate.edu

VRAC DABL 3D Printing Differences

Machine	Size (x, y, z) (mm)	Speed (mm/s)	Material(s)	Software	Transfer Method (s)
Old Faithful	225, 145, 150	90	ABS	MakerBot Desktop	SD card
MakerBot 2X	246, 163, 155	~100	ABS / PLA * Dual extruder	MakerBot Desktop	SD card *Octoprint maybe
Voxelab Aquila S2	220, 220, 240	70 - 80	PLA, PETG, ABS, ASA, TPU	Cura	Octoprint
Ultimaker UM3	215, 215, 200	70 - 80	PLA, ABS, PVA *Dual extruder	Cura	Cura network print
Monoprice Maker Select V2	200, 200, 180	60	PLA, PETG	Cura	Octoprint
Creality CR6 Max	400, 400, 400	50	PLA	PrusaSlicer	Octoprint
Prusa XL	360, 360, 360	200	PLA, PETG, ABS	PrusaSlicer	PrusaLink
Creality K1	220, 220, 250	600	PLA, ABS	Creality Print	Creality print WiFi

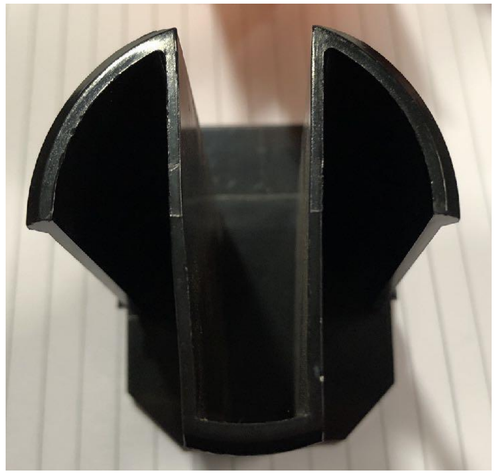
Design for Additive Manufacturing (DFAM) ?

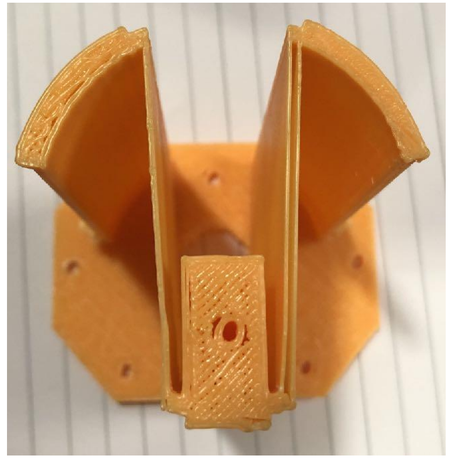
- Don’t print boxes or threads
- Use a printer to make it’s own parts
- Combine parts that need to function within your design
- If assembled with production part, make printed part tolerance higher

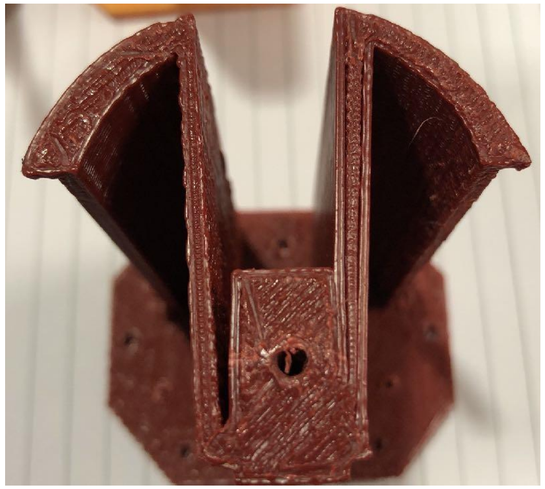


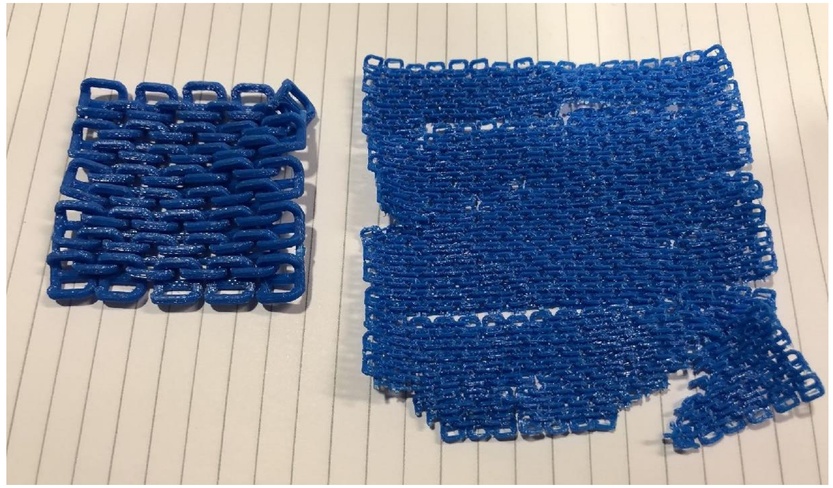
Design for Additive Manufacturing (DFAM) ?

- Can the size be modified to make it function nearly as well as traditional manufacturing method?
- Is 3D printing the only way to manufacture the part?
- Script the model to customize & ensure fit/function: [OpenSCAD]



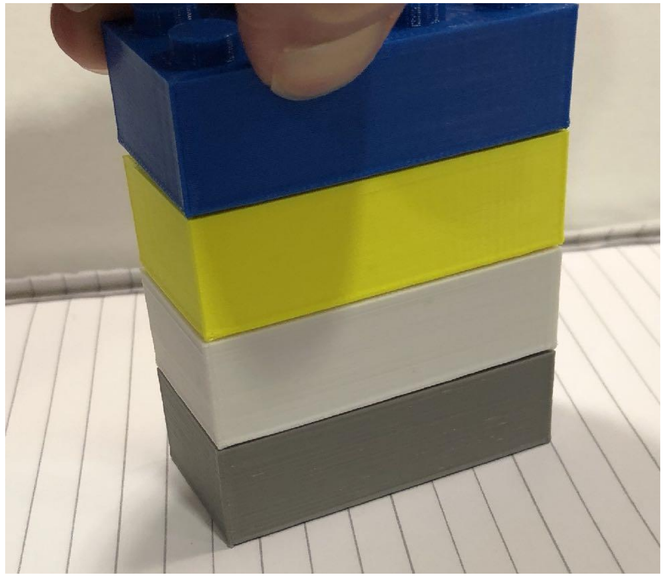


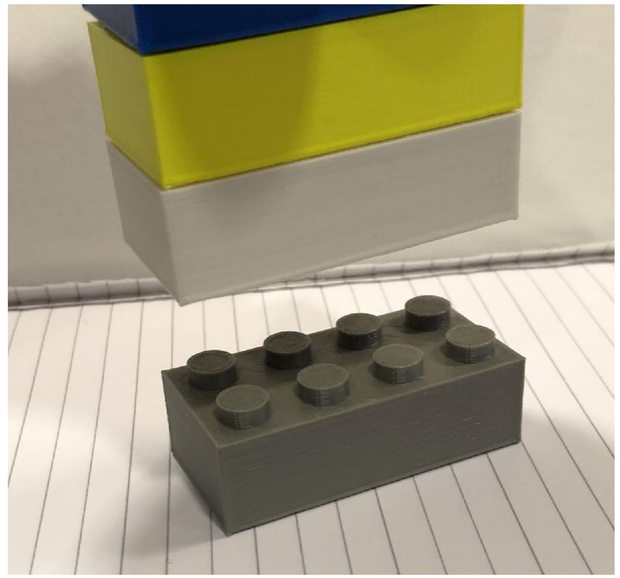




Design for Additive Manufacturing (DFAM) ?

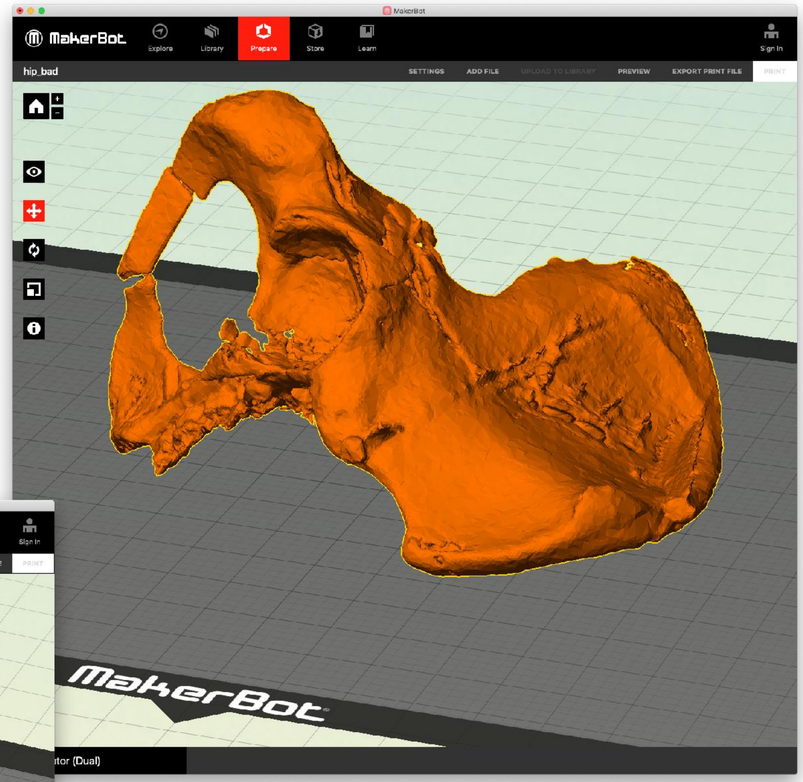
- All 300,000 were 100% inspected using non-destructive evaluation.
  - How many failed to print?
  - How many failed inspection?
- Nobody, has, can, or ever will print 2 parts that are exactly the same

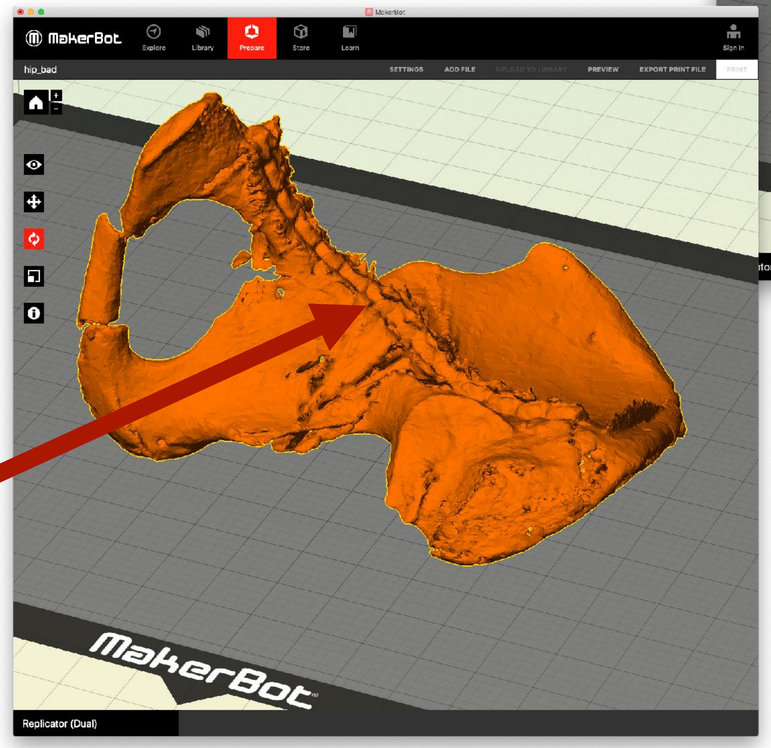




Part Orientation

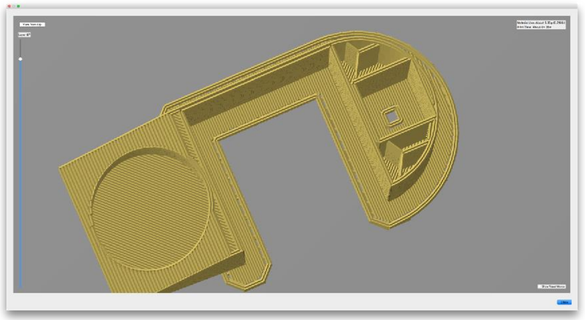
- Is there a best orientation?
- Software algorithms and experienced users can optimize choose “optimal” orientation”.
- How do we know if model is bad and/or when 2 disciplines are collaborating?
- Who knows (e.g., designer, 3D printing person, medical doctor)?

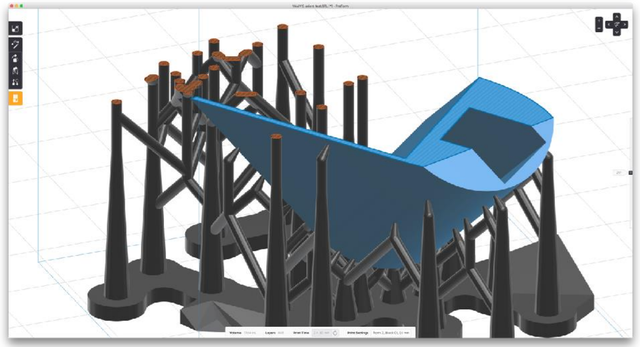


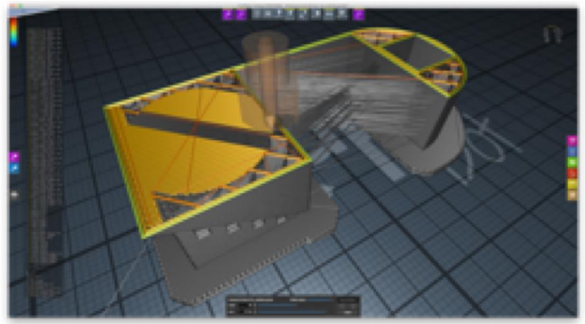


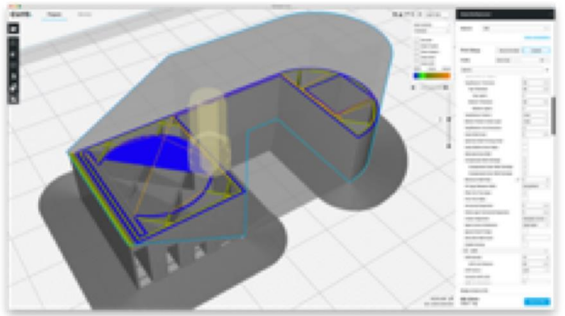
Print Preview Uses

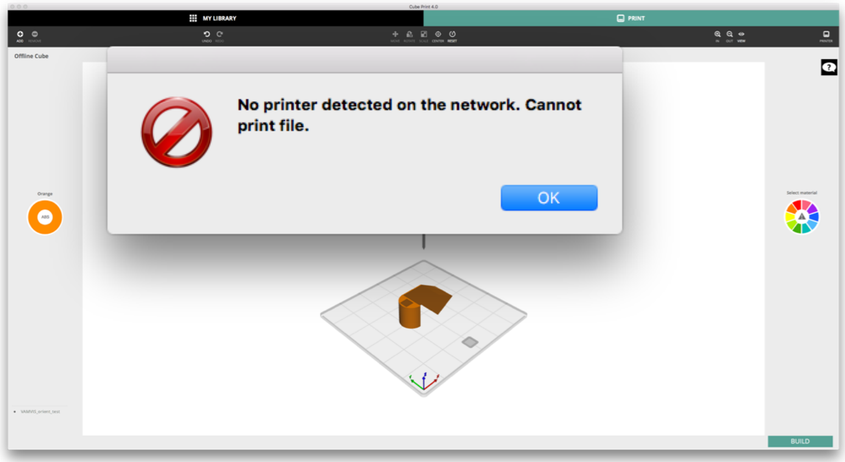
- Print time, material usage
- Support location and amount (may help orient the part)
- Print type for the part on a single layer
- If connection to printer required: to make system proprietary or to get real-time print info

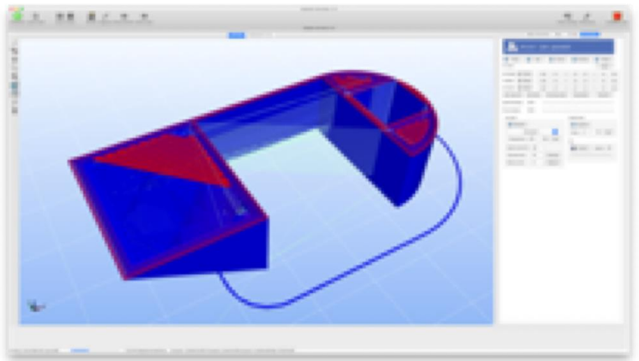








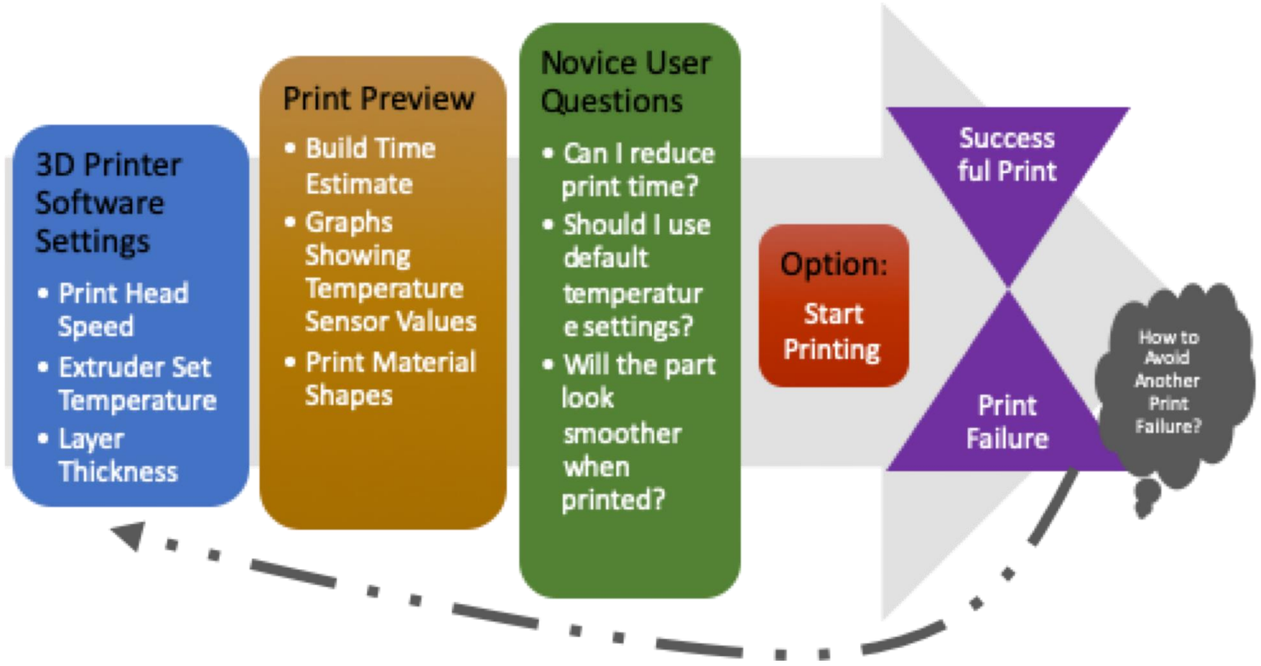




Print Previews Do Not Help Choose Settings

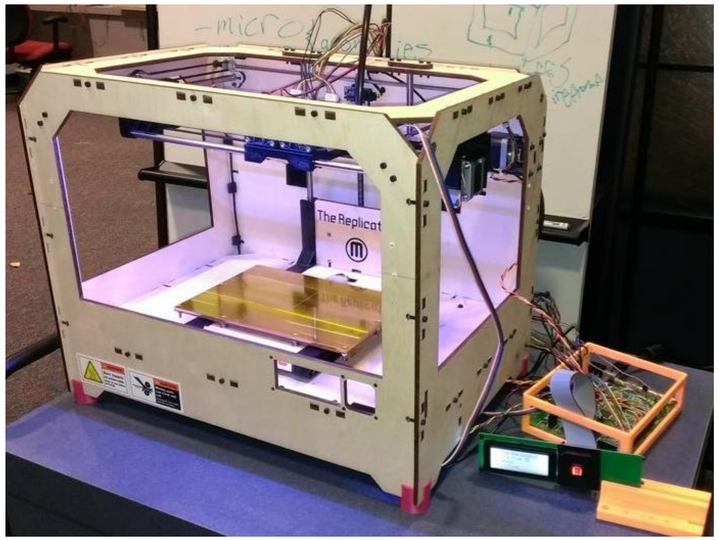
- If we had the Goldilocks Evaluation Matrix (GEM) it would show you the tradeoffs between print settings and part quality
- Without GEM we have to print parts, try modifying settings, and print again
- “Virtual Iterations” could be performed 1000s before printing 1 part

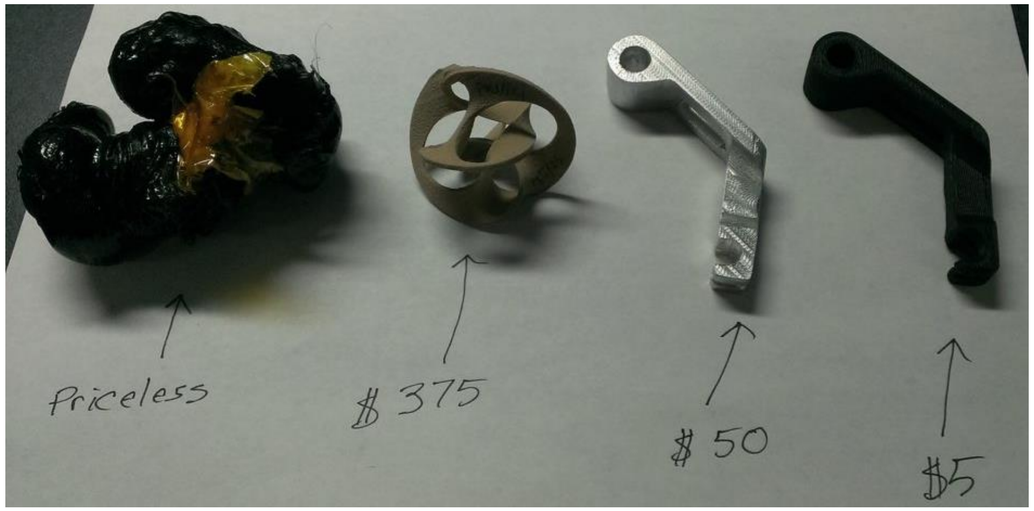
Per Layer Thickness	Increase Speed	Decrease Speed
Increase Extruder Temp	Yes or No?	Yes or No?
Decrease Extruder Temp	Yes or No?	Yes or No?



Training Levels

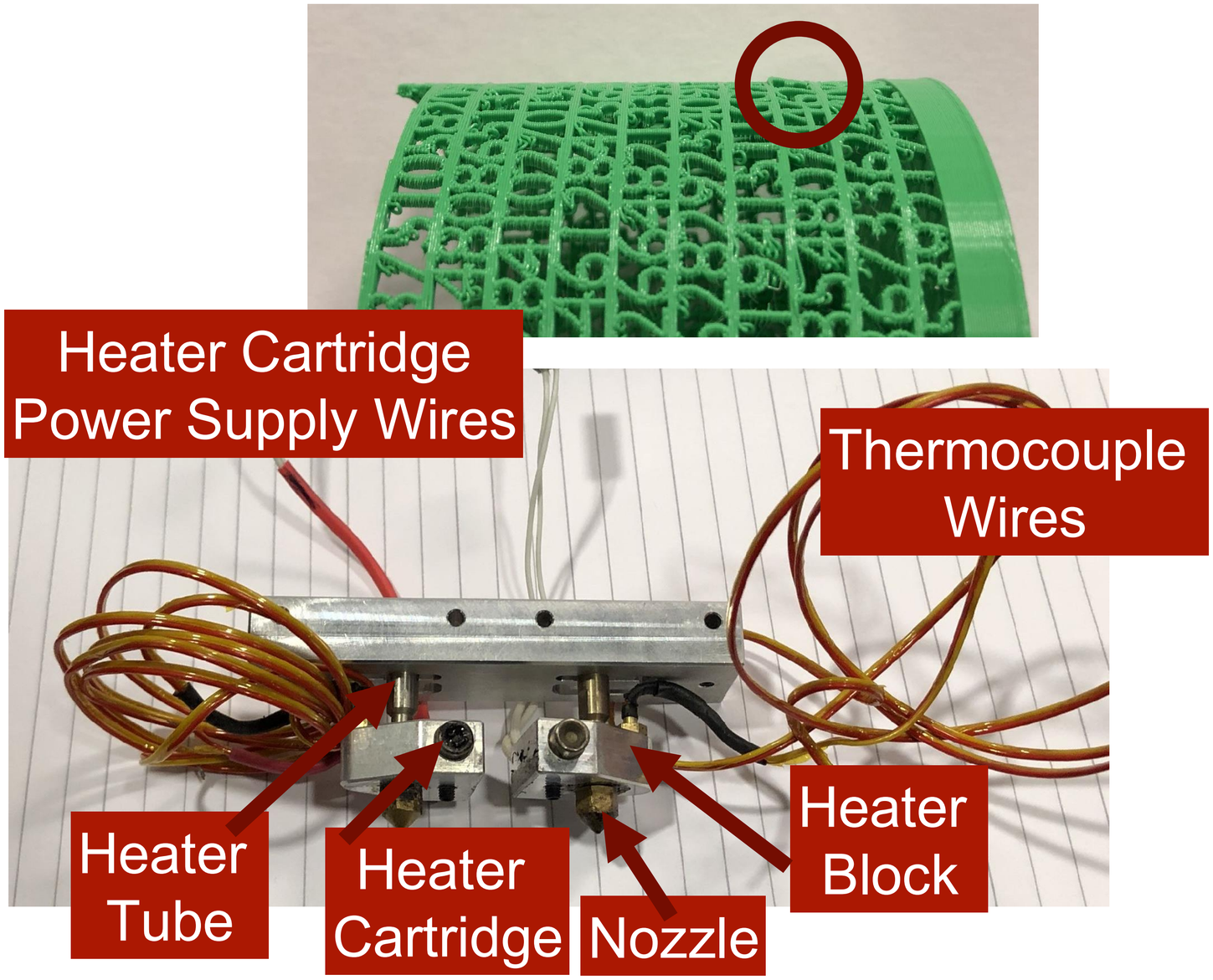
- Alex is the “Chief Operating Officer” of VRAC DABL 3D printing
- “VRAC Maker”: Sam
- “Trained Personnel”
  - 3D print deep dive REU interns?
  - Training needs?
- Print failures are priceless





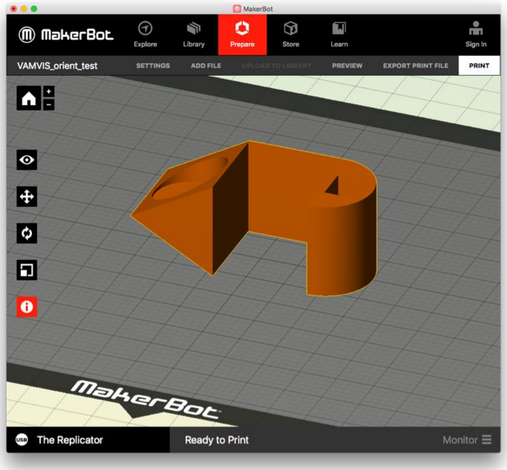
Limited Experience Still Print Cool Stuff

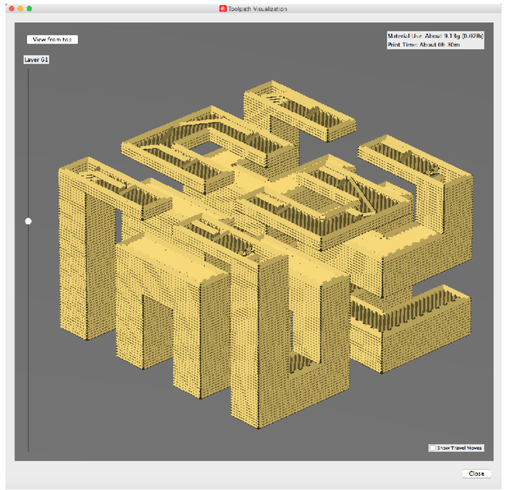
- Kate trained by Holly who was trained by Alex.
- Bottom up approach of learning the process effects at the road level helped learn how to make decisions about print settings.

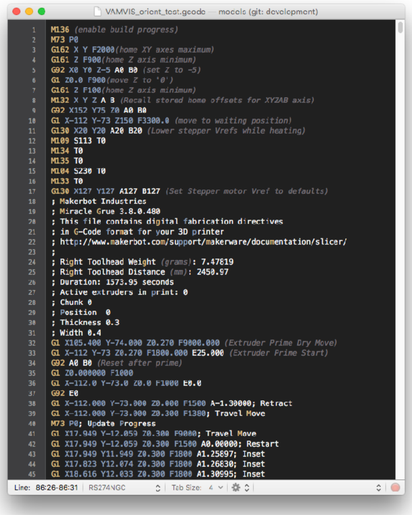


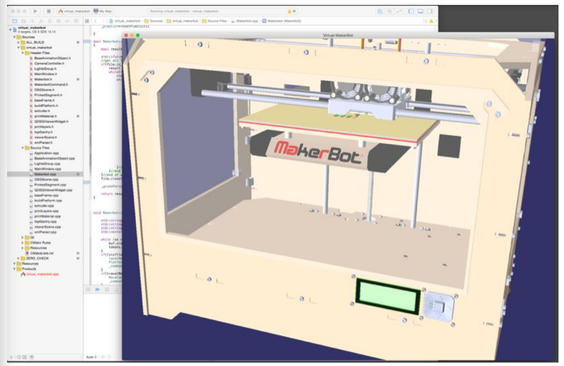
Preview vs. Simulate

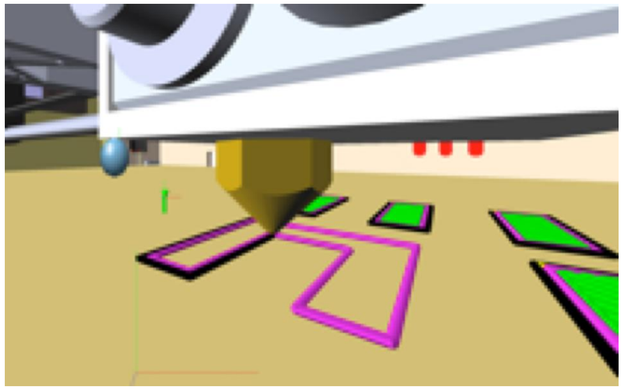
- Print Preview shows layers of ideally shaped 3D printed segments
- Simulation uses the machines instructions and provides inter and intra-layer visualization of the whole process





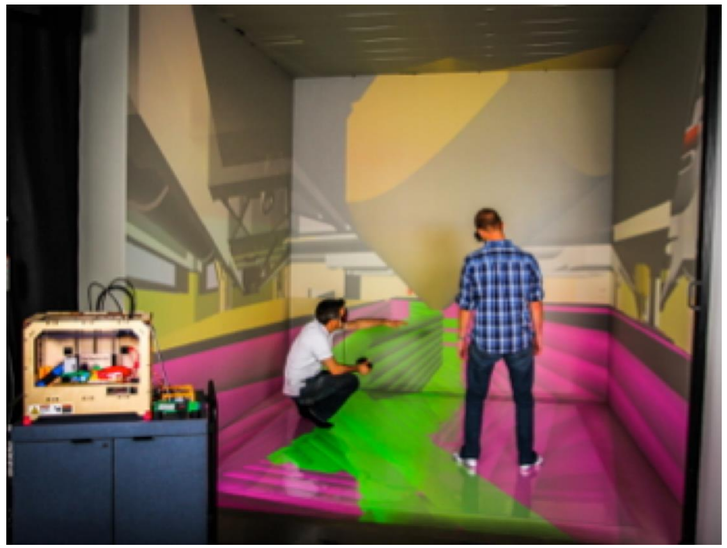






Virtual Additive Manufacturing Visualization Investigation and Simulation (VAMVIS)

- Alex Raymond Renner's PhD Research application
- Desktop (Qt), C6, and HMD
- Why the name:
- Using VR for AM
- 0.4mm nozzle (half thickness of piece of paper) can be visualized in C6 at much larger scale an investigated by more than one person at a time



VAMVIS's Thermal Process Simulation

- Any combination of 3D printer, software, and hardware
- Really??? How???
- Collect the information in the table for every print move from G-Code

Property	Symbol	Value	Unit
Software Set Temperature	T_s	230	℃
Envelope Temperature	T_∞	25	℃
Layer Thickness	L	0.3	mm
Print Speed: *Infill*	S_i	90	mm/s
Print Speed: *Insets*	S_s	90	mm/s
Print Speed: Outlines	S_o	40	mm/s
Print Speed: *First Layer*	S_f	30	mm/s

VAMVIS's Thermal Process Simulation

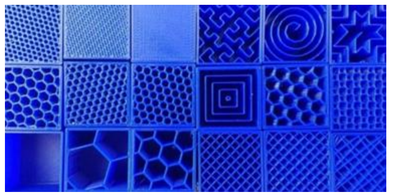
- Do some math for the roads' size (calculate volume/surface area)
- Account for print head speed changes and update frequency of the simulation app
- Include the roads' material properties in a fancy heat transfer analysis model (Lumped Capacitance assumptions)

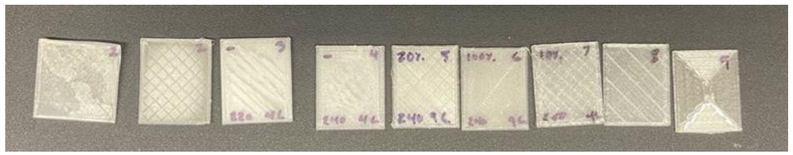
Property	Symbol	Value	Unit
Convective Heat Transfer Coefficient	h	0.000058	$\frac{W}{mm^2K}$
Characteristic Length	L_C	$\frac{V}{A_s}$	mm
Biot Number	B_i	$\frac{h(L_C)}{k}$	N/A
Alpha	α	$\frac{k}{\rho C}$	mm^2/s
Time	t	$\frac{1}{60}$	s
Fourier	Fo	$\frac{\alpha t}{(L_C)^2}$	N/A
Extruding Temperature	T_i	$T_\infty + (T_s - T_\infty)e^{(-Bi*Fo)}$	°C
Extruded Temperature	T_{i-1}	$T_\infty + (T_i - T_\infty)e^{(-Bi*Fo)}$	°C

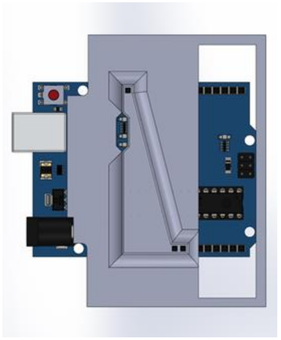
MCA Ideation

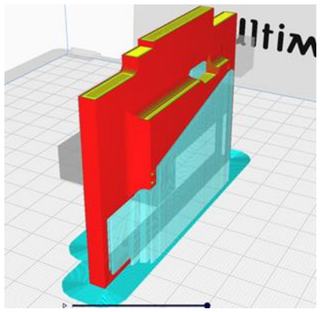
REU 2023

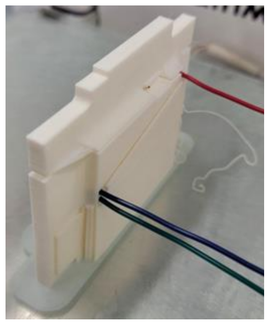
- Amy: 20% vs. 99% infill Ocarina
- Kris: material & print settings, most light through pinhole camera lens



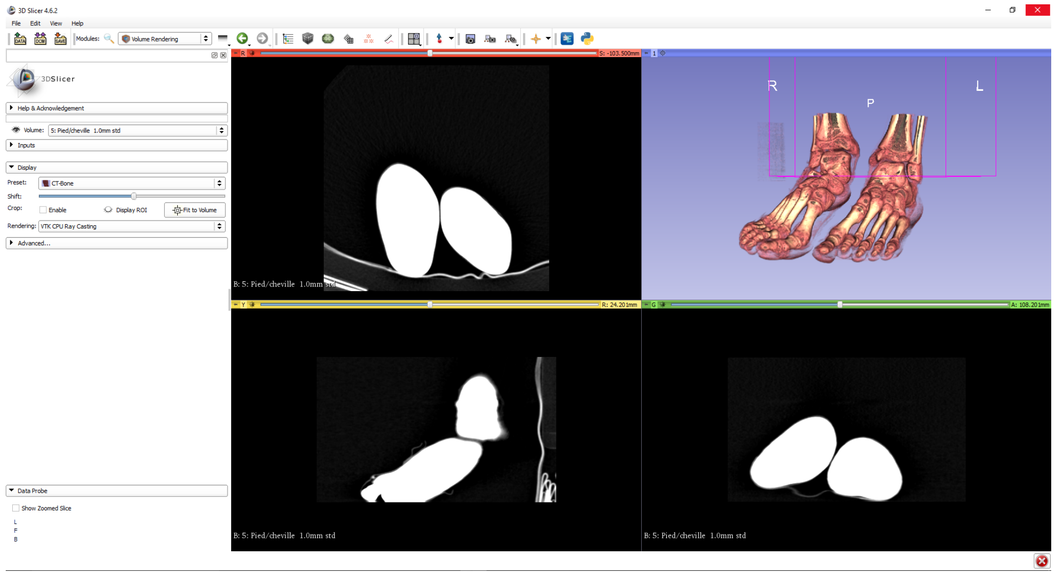








Train & Heal


3D Slicer 4.6.2
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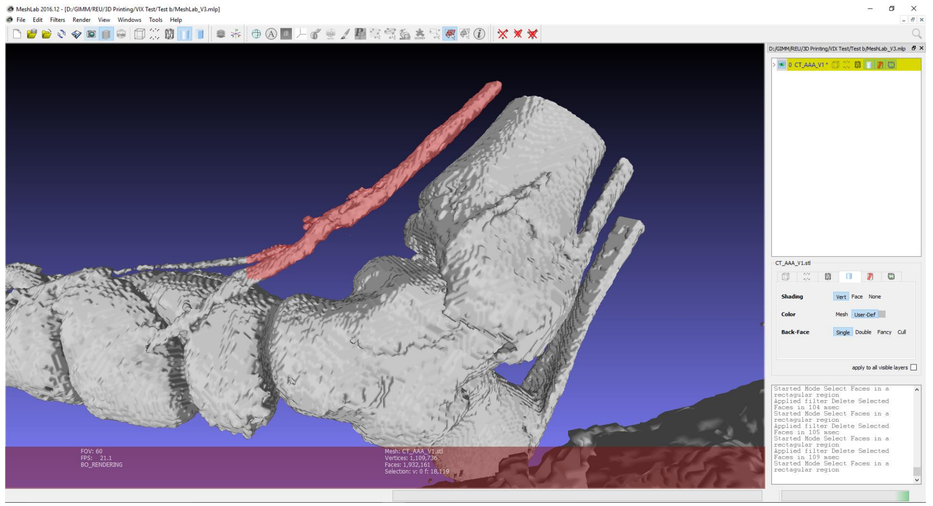
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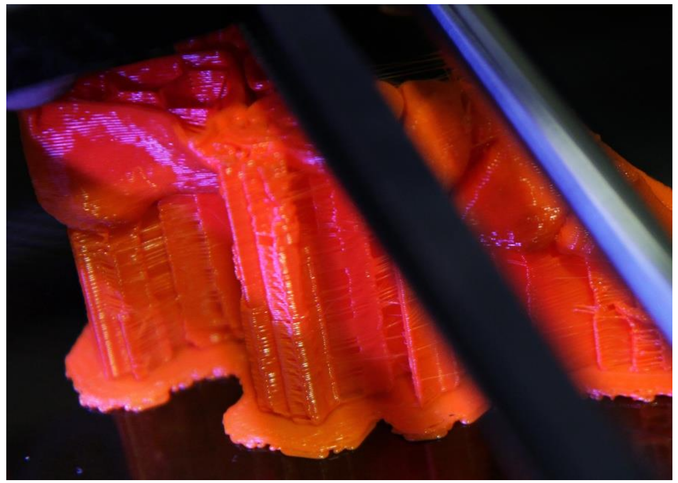
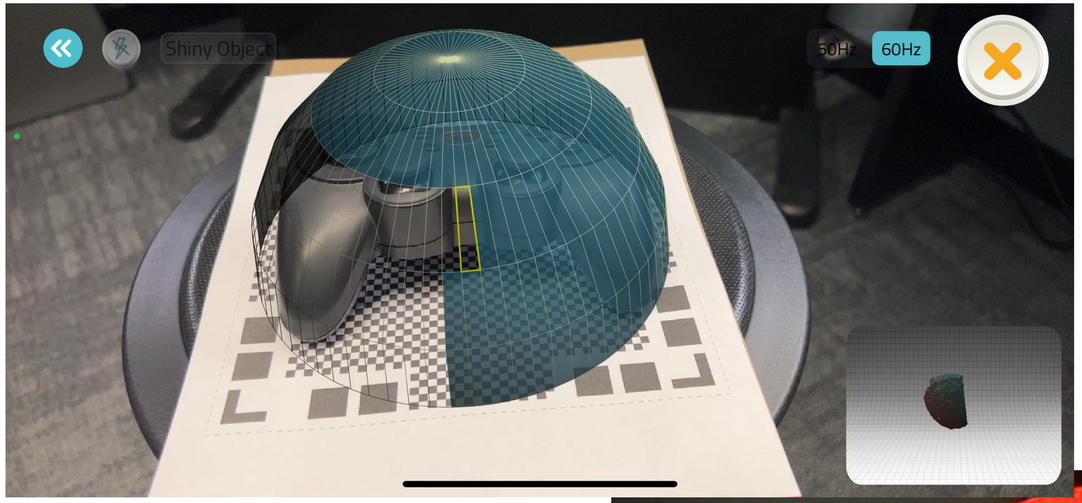
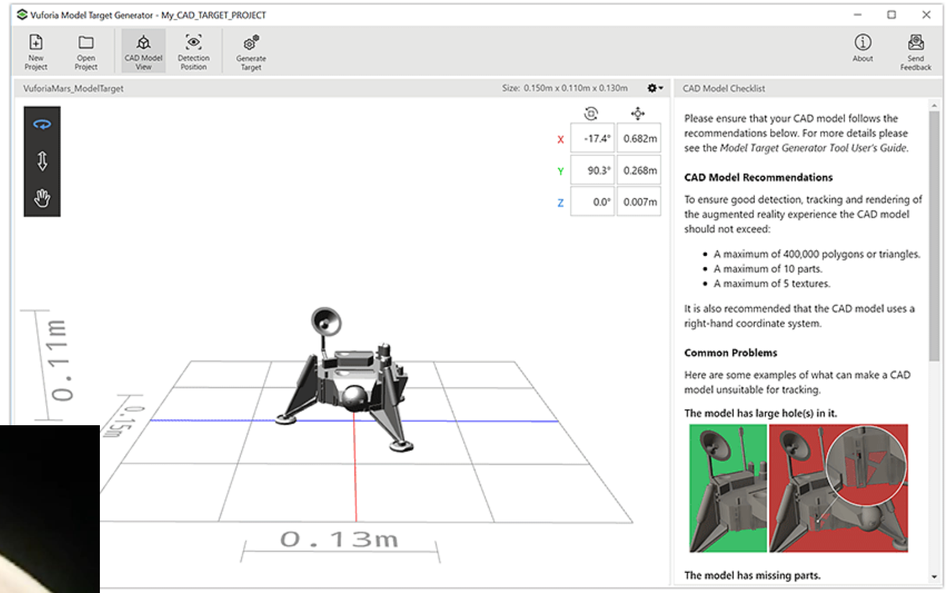
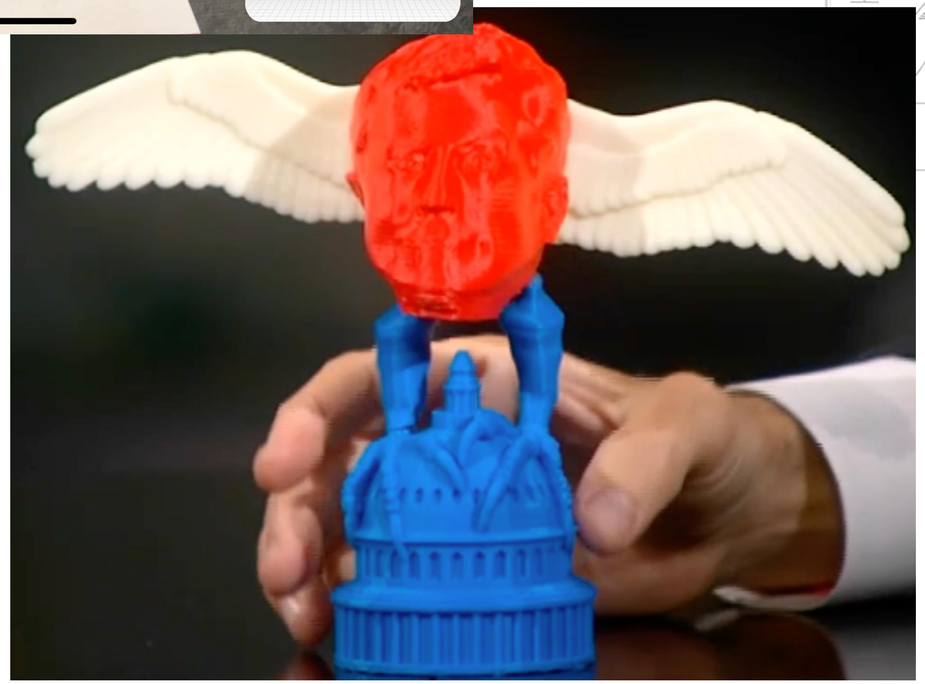


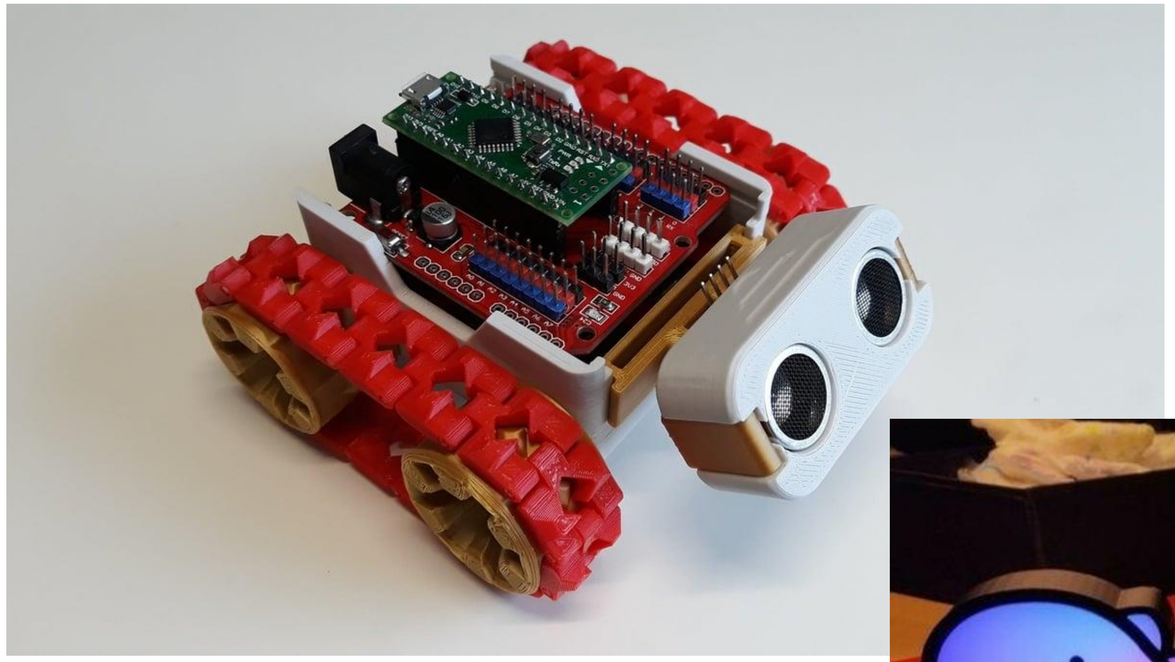
MCA: Replicate and Augment

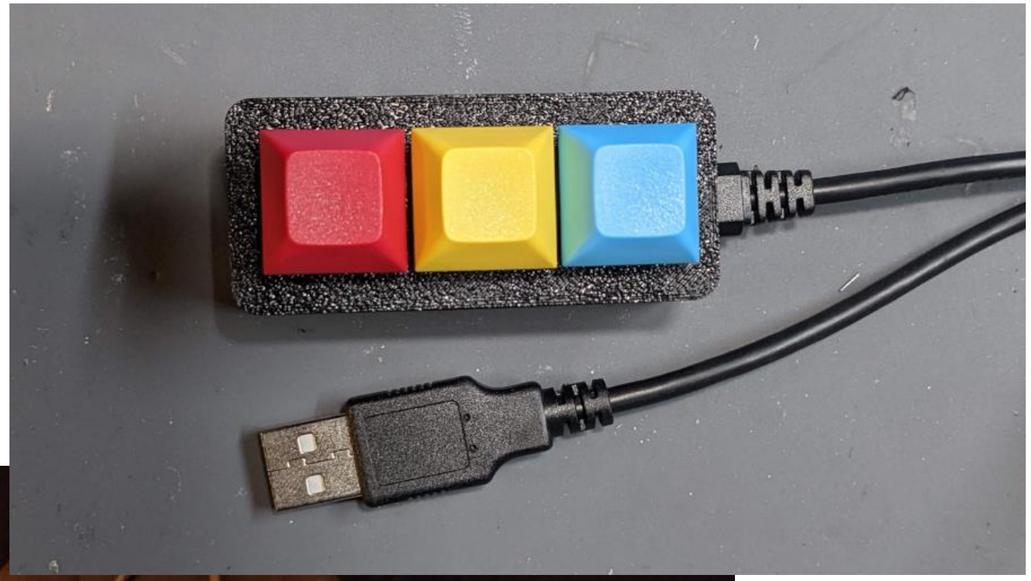


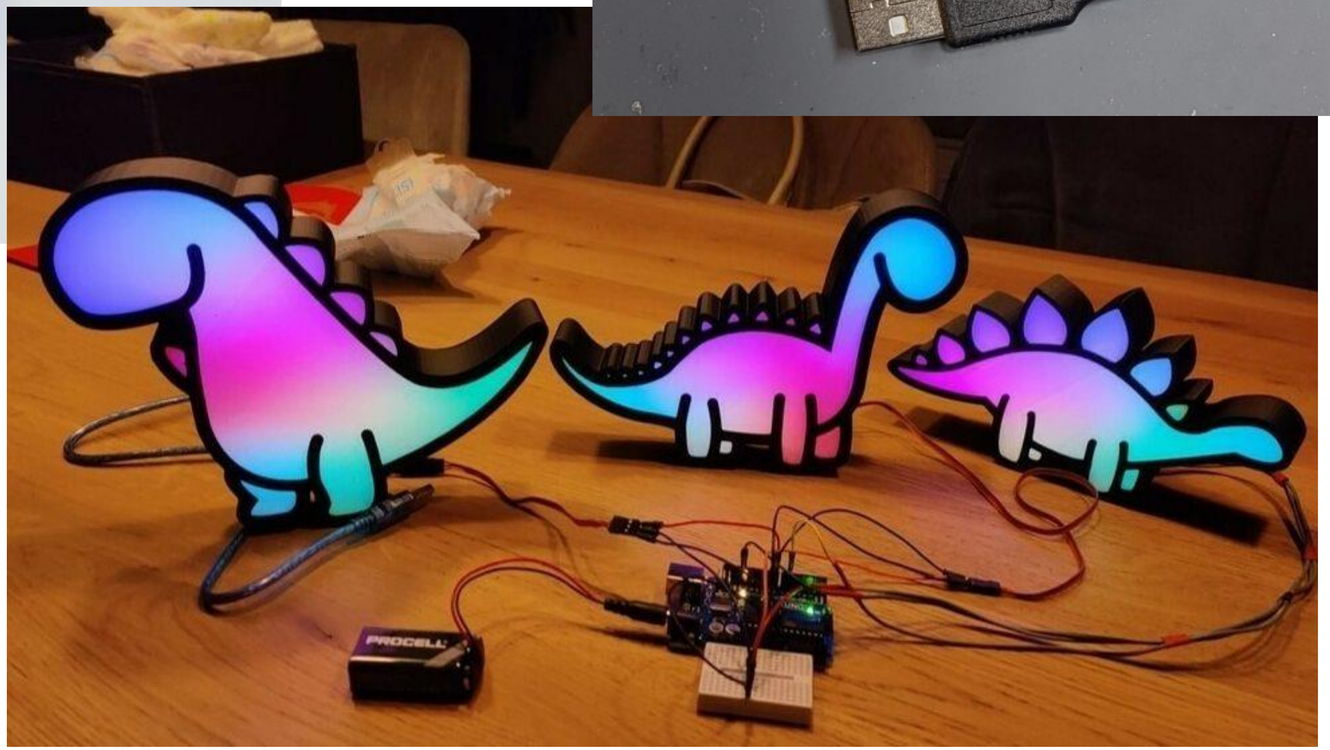




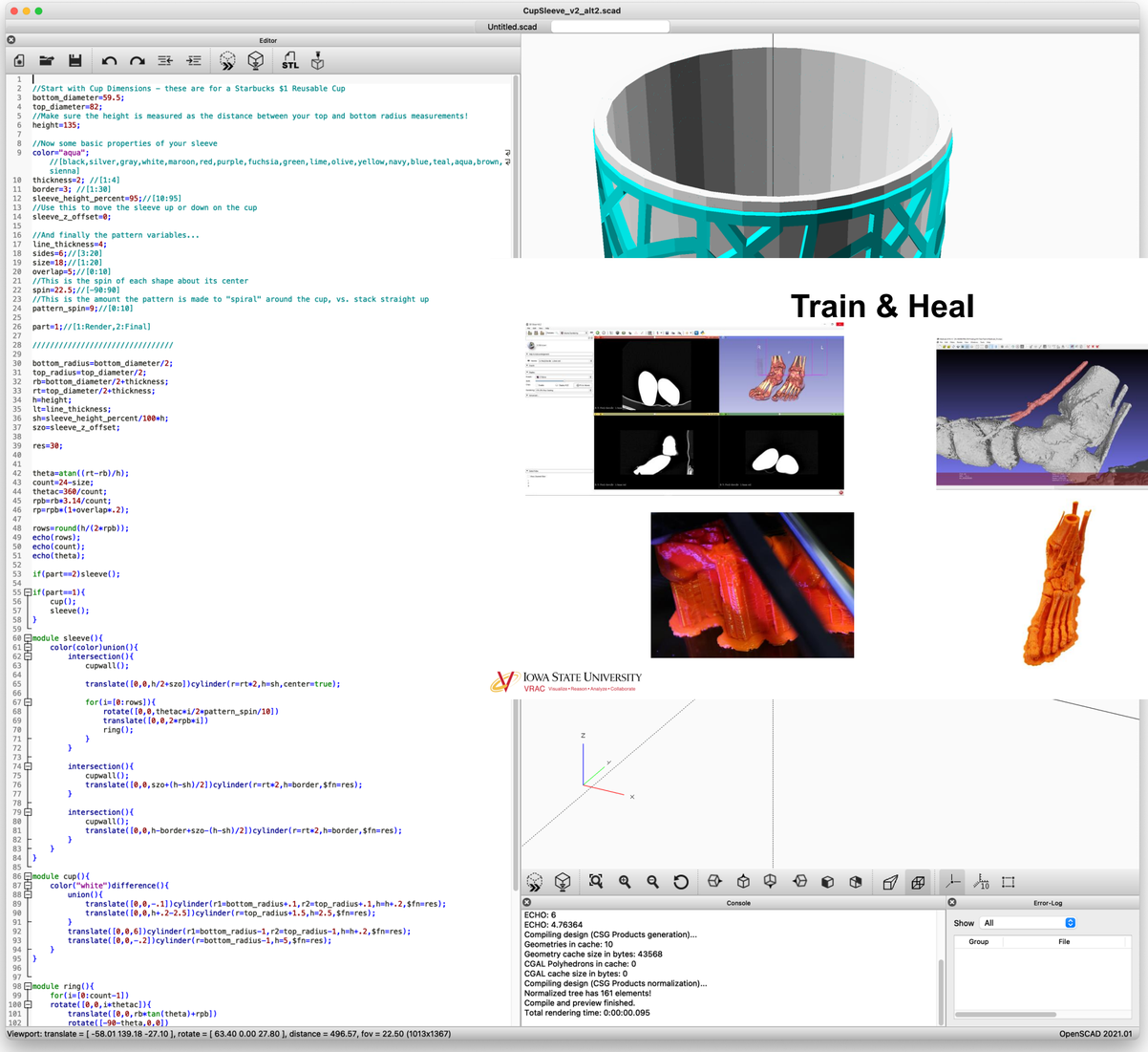
Electrify / motorize







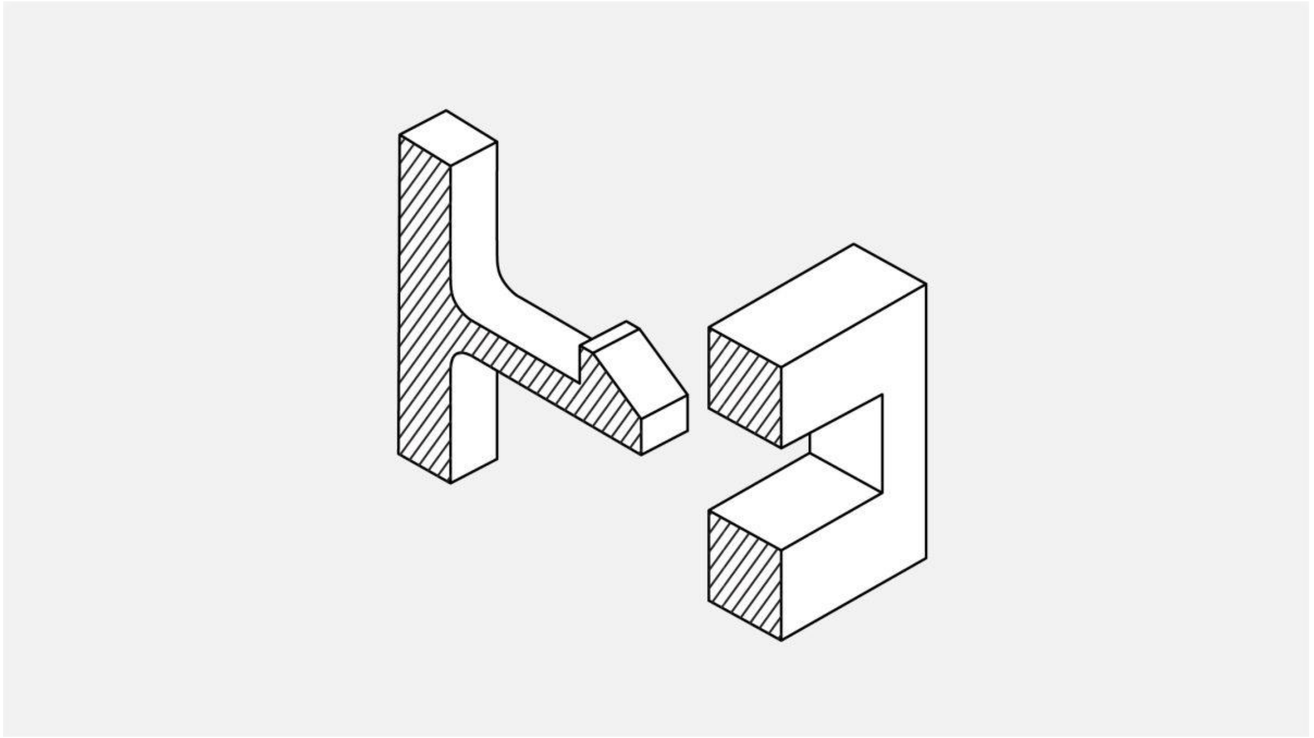
Script it



Train & Heal

IOWA STATE UNIVERSITY
VRAC Research Center

Connect it



Only 3D printers can make it