Design for Additive Manufacturing:
Adding true value to AM

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Creative Design and
Additive Manufacturing Lab

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND

A playground to explore and experience AM

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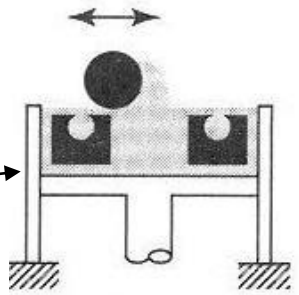
Why is DfAM so important?

- AM is probably the **most expensive manufacturing in the universe**. It is expensive because of its **slow speed** and **high machine hourly running c**osts.
- Because of these high costs of AM, we need to **increase value** through better functionality while, at the same time, **minimizing cost**, both of printing and post-processing
- But which aspects of **design** have the **greatest impact** on part cost?

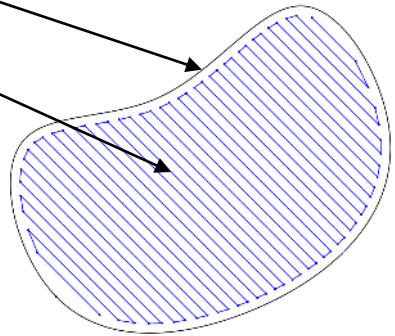
What design factors affect print time?

AM process step	Affected by design
Pre-processing and printing	
Clean the AM system	No
Purge the system of oxygen	No
Preheat the AM system	No
Print the parts	
Spread layer of powder (recoater time)	No
Laser scans the contour lines	**Yes**
Laser scans the interior hatch patterns	**Yes**
Remove build platform from machine	No
Recycle powder	No
Post-processing	
Thermal stress relief	**Yes**
Remove parts from build plate	No
Hot isostatic pressing	No
Remove support structures	**Yes**
Heat treatment	**Yes**
Shot-peening, surface machining, etc.	No
Inspection	No

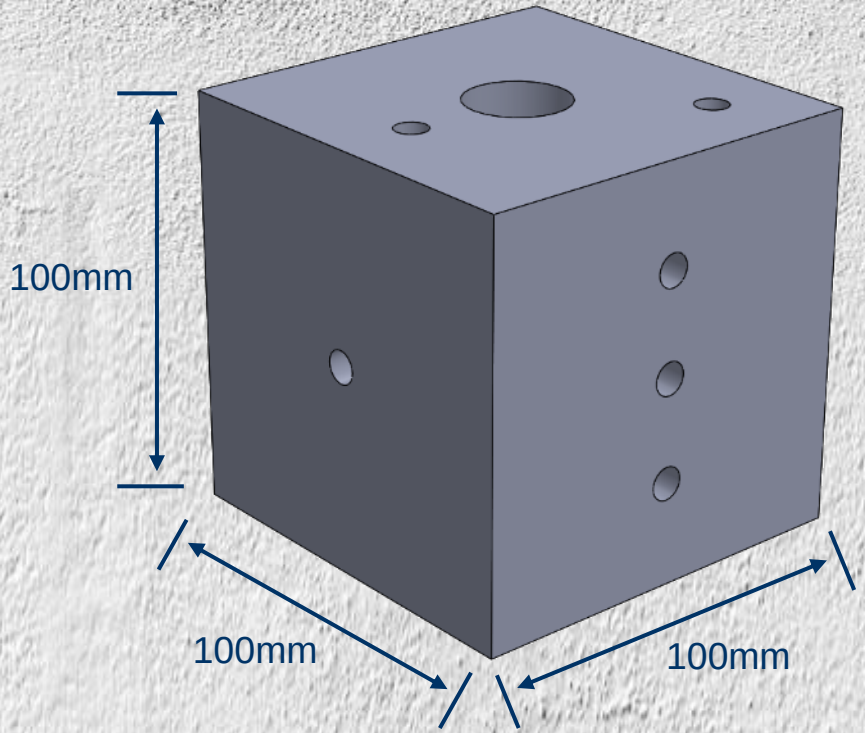
The printing process



If 100mm high
@ 50µ layers
= 2000 layers
@ 10 sec/layer
= 5.5 hours

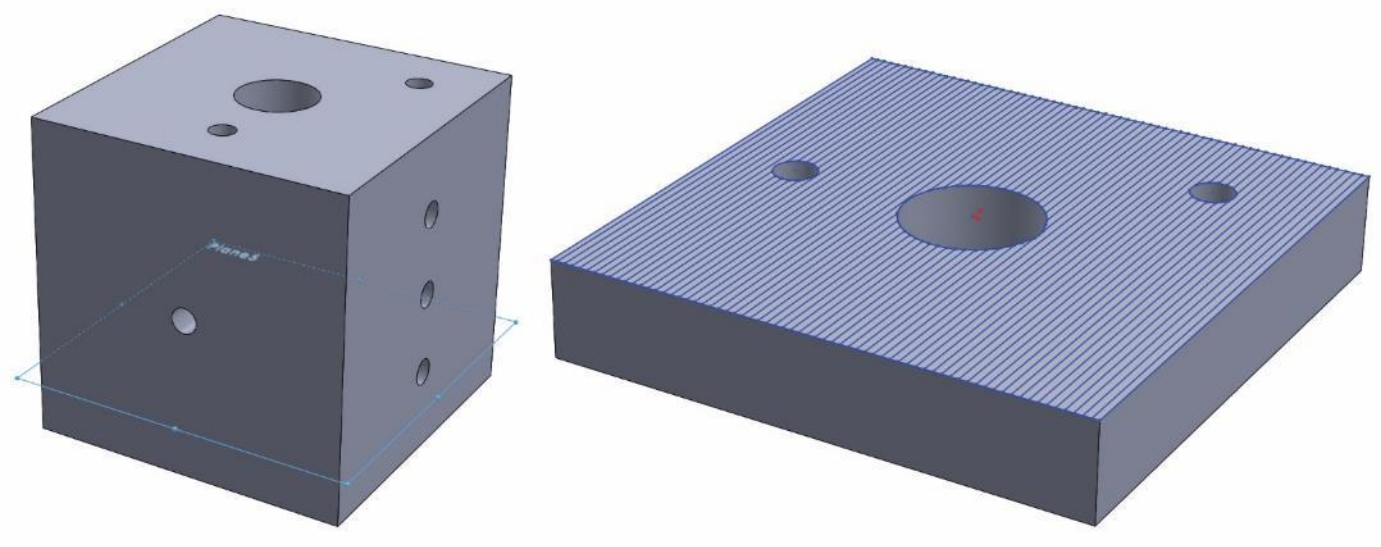


DfAM example: Redesigning a manifold



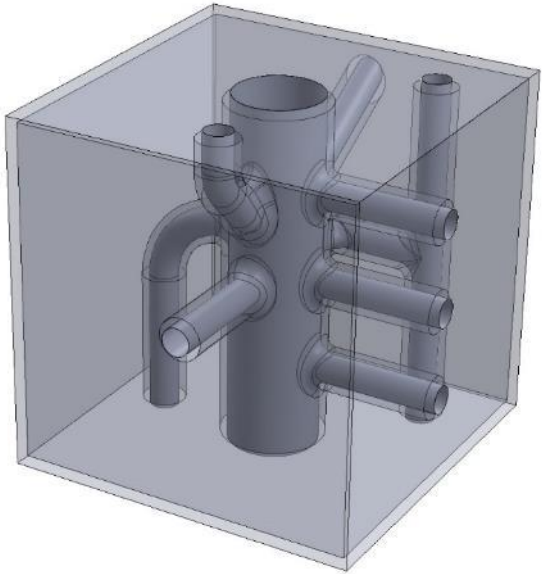
Why DfAM is a necessity not a luxury

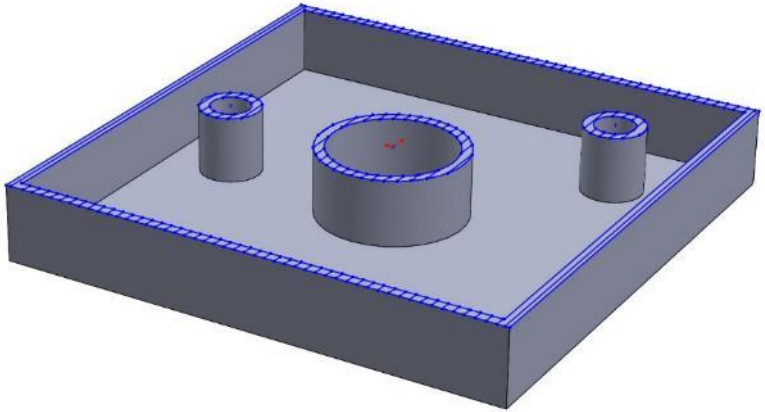
Solid block manifold: For 100mm x 100mm x 100mm, with 0.1mm hatch spacing, the laser has to travel over **100m of hatching** for each layer @ 330mm/s = 5 minutes = $5.421 of machine time per layer (@$65/hour machine time)



Why DfAM is a necessity not a luxury

Same design, shelled to 2mm wall thickness, each layer has less than **4.5m of hatching** = 13.6s hatch time = $0.24 per layer

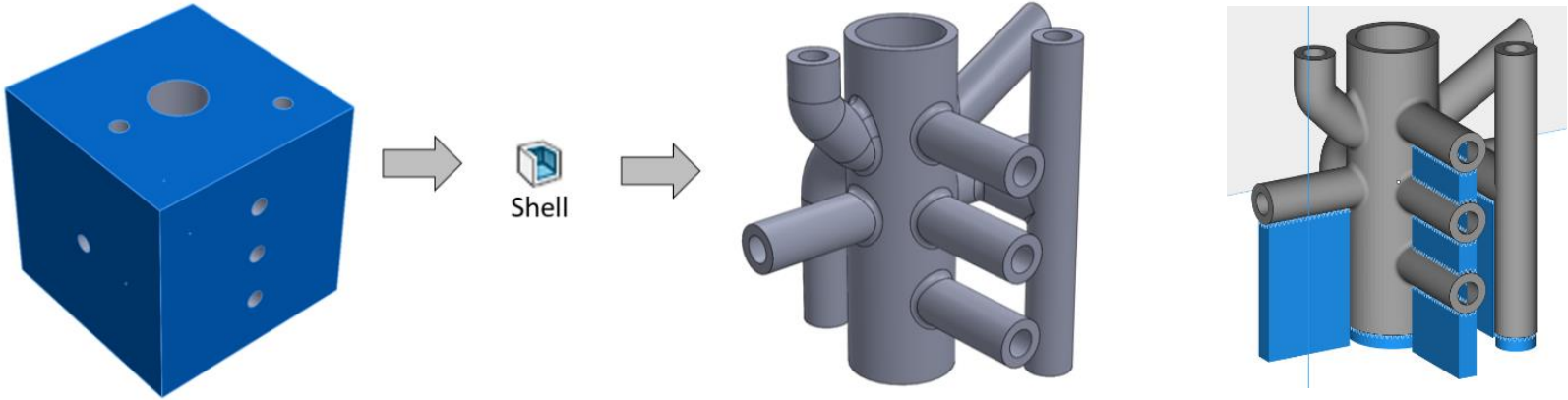


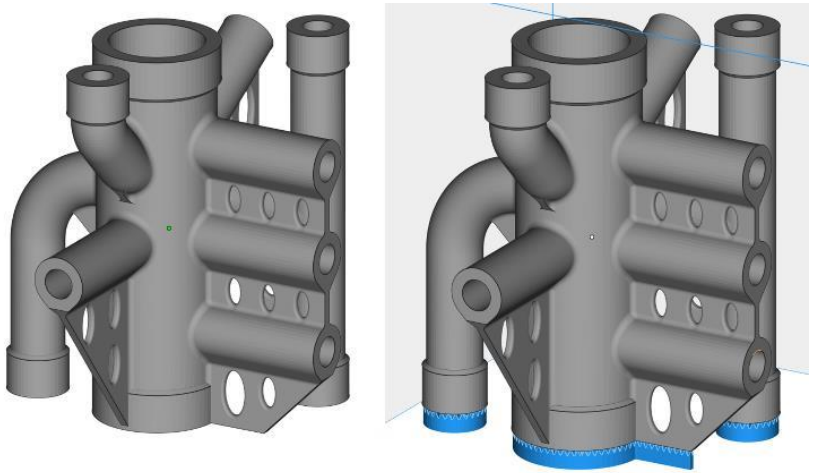


DfAM in 1 slide

1. Get rid of material! Reduce to only those features that have functionality.
   - Any unnecessary material just increases cost, causes more residual stress and therefore more supports and heat treatment.
   - Topology optimisation and lattices can be useful tools for this.
2. Take this opportunity to improve functionality (part consolidation?)
3. Now consider the most appropriate print orientation depending on what is important to you.
4. Run it through support generation software to see results.
   - Consider replacing temporary supports with permanent walls.
   - Consider changing the angles of features requiring support.
5. Fillet all sharp corners to avoid stress concentrations
6. Reiterate.

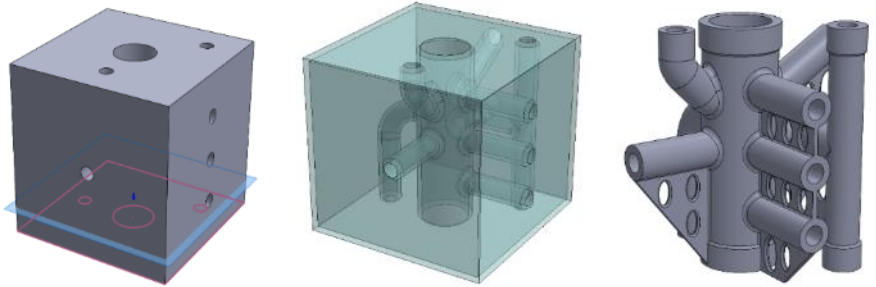
Why DfAM is a necessity not a luxury





Why DfAM is a necessity not a luxury

	Solid	Shelled	DfAM
Print times	191 hours	36 hours	19 hours
Material weight	7.411Kg	1.232Kg	0.558Kg
Material cost @ $70/Kg + 10% waste	$570.64	$94.86	$42.96
Bureau quotes for part in 316L Stainless	$15,293.82	$ 3735.12	$ 1986.25



Myth

Just hit print and you are done.

- The vast majority of 3D printing entails a large amount of post-processing.
- This can range from removing support material, to polishing, to machining, to coating, to heat-treating, to colouring, to sanding and painting, etc.

AM post-processing costs

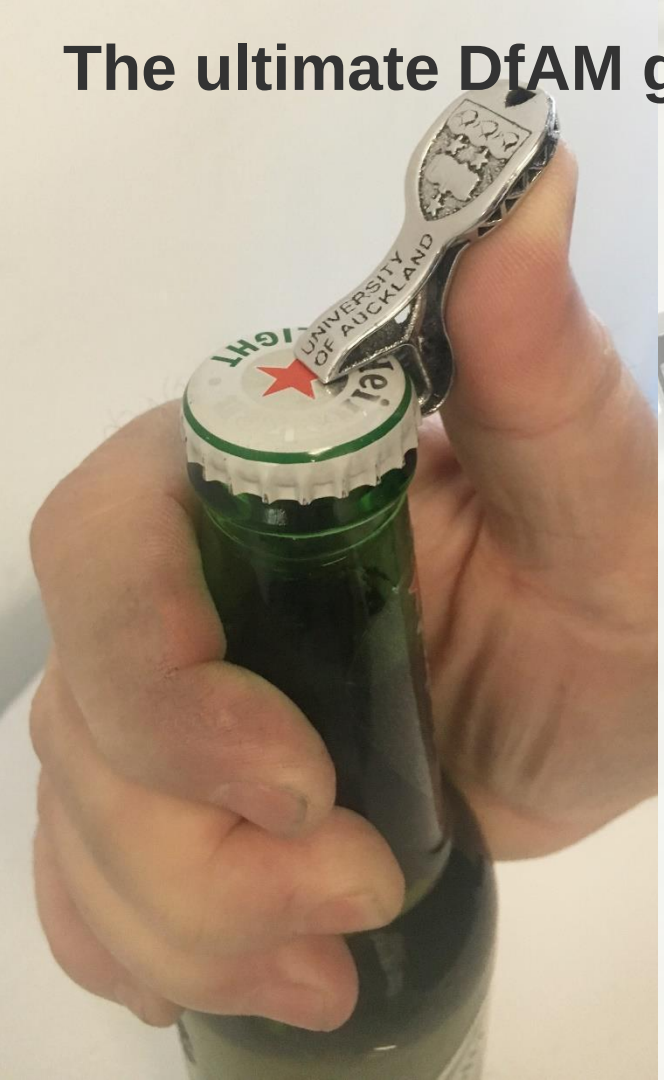
Service providers were asked, in 2017, what percentage of their part costs were attributed to printing vs pre and post-processing.

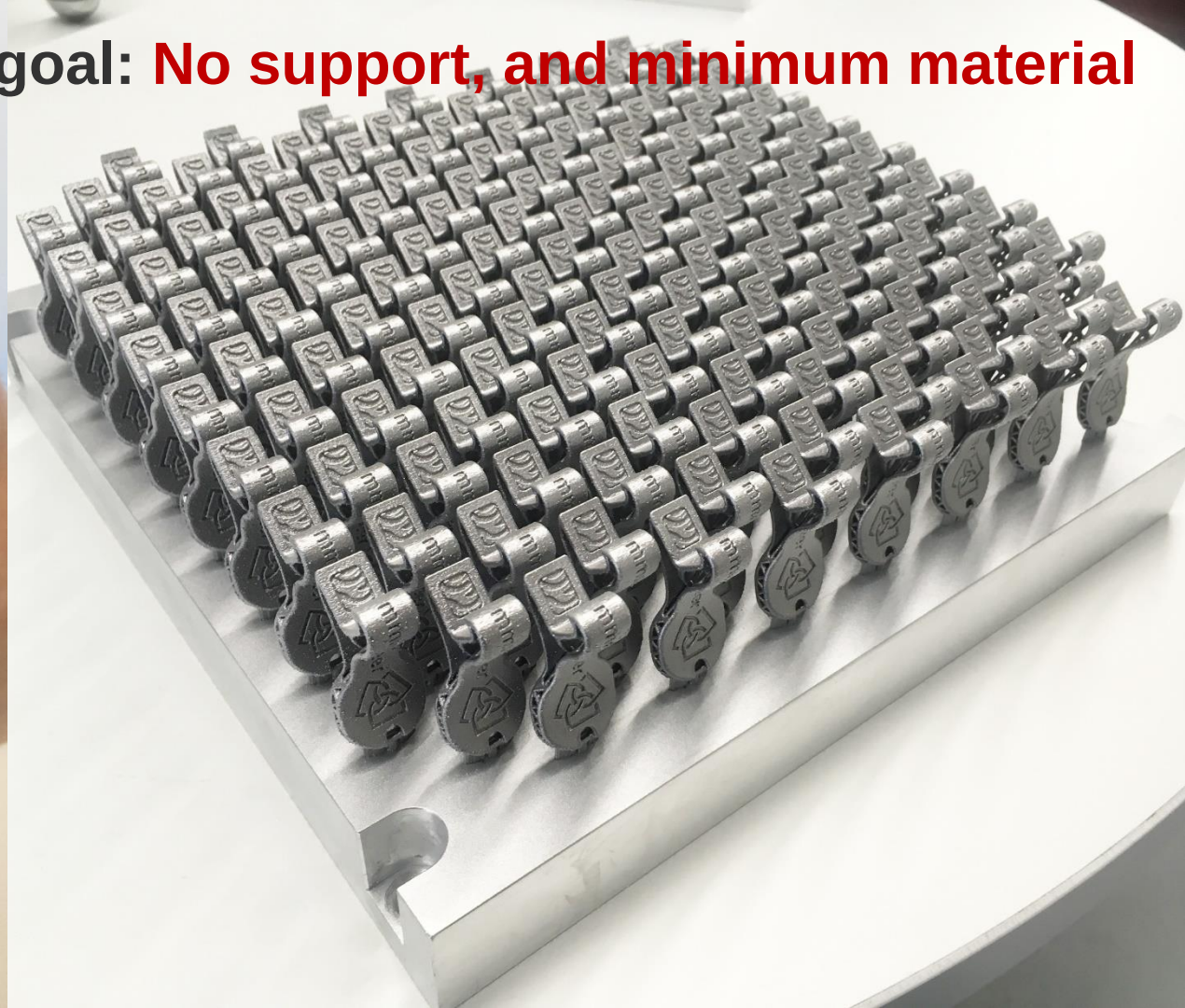
	Metal	Polymer	Both
Pre-processing	13.2%	10.9%	10.2%
Post-processing	31.4%	20.2%	27.0%
Total pre/post	**44.6%**	**31.1%**	**37.0%**
Printing	55.4%	68.9%	63.0%

Designing to minimize post-processing can have a serious consequence on price.

- 2 hours of file preparation in Magics
- 30 minutes of file preparation in EOS Software
- 2 hours of machine preparation
- 9 hours of printing
- 2 hours of machine cleaning & preparation for next build
- 3 hours of stress relief
- 30 hours of cooling
- 15 minutes of bench saw
- 4 days to remove supports
- 4 days of filing, sanding, and shot-peening

The ultimate DfAM goal: No support, and minimum material



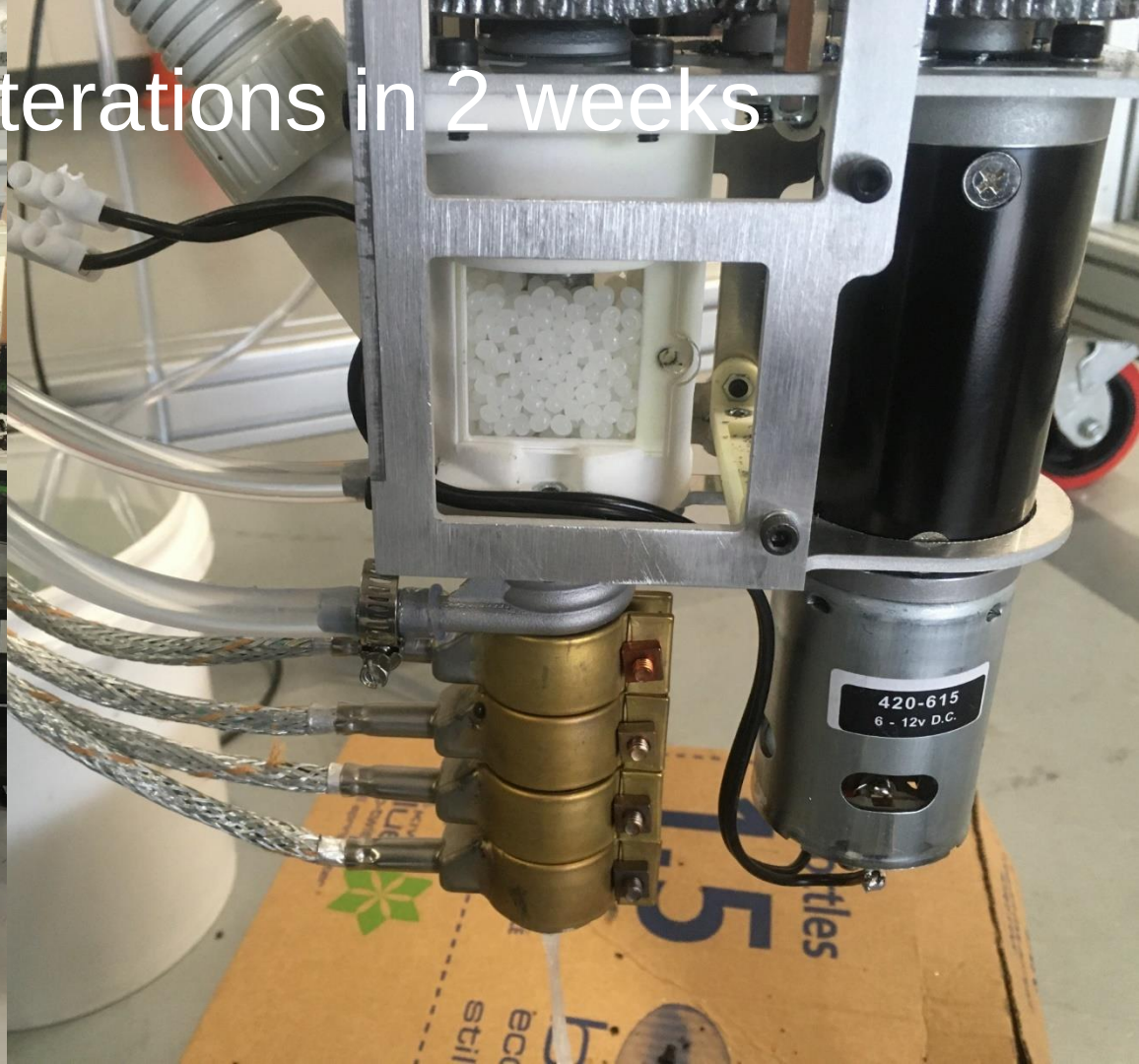


AM is all about adding value

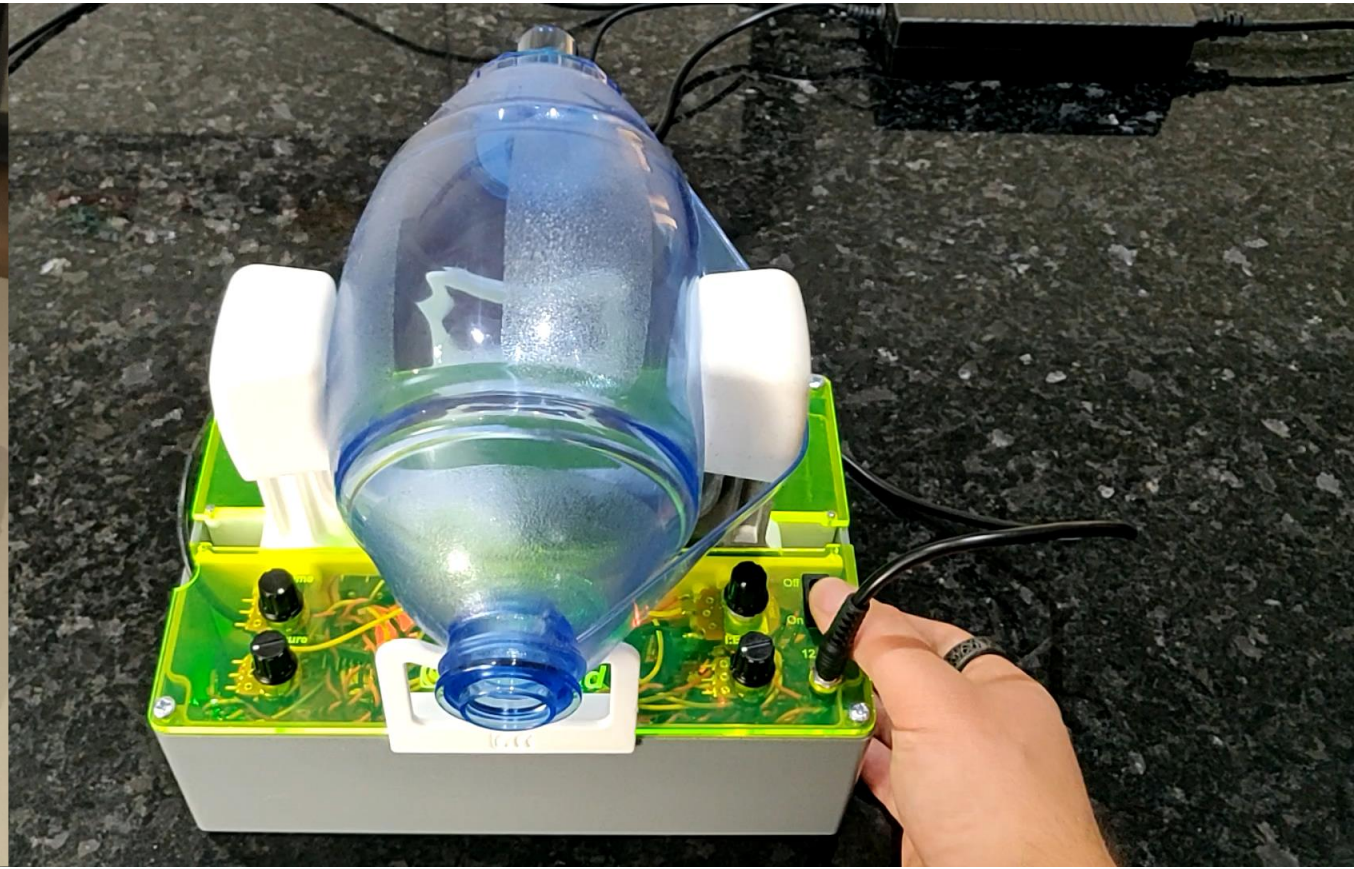
If you are using AM for production you must add enough value to overcome the high costs of the technology. This added value might come from:

- **Rapid product development**
- **Light-weighting**
- **Mass-customisation**
- **Increased efficiencies**
- **Etc.**

5 design iterations in 2 weeks



4 iterations in 2 weeks from start to working proof of concept



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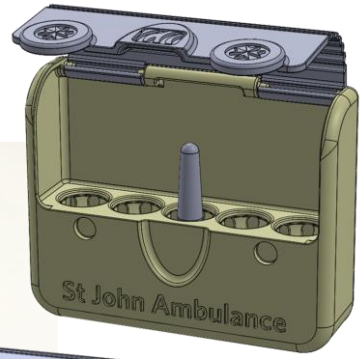
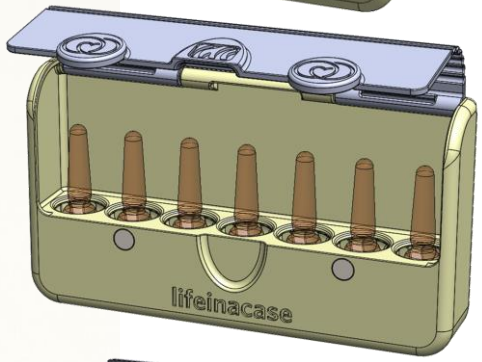
ABOUT US PRODUCTS MEDIA COVERAGE CONTACT

7 iterations in 4 weeks from start to working proof of concept

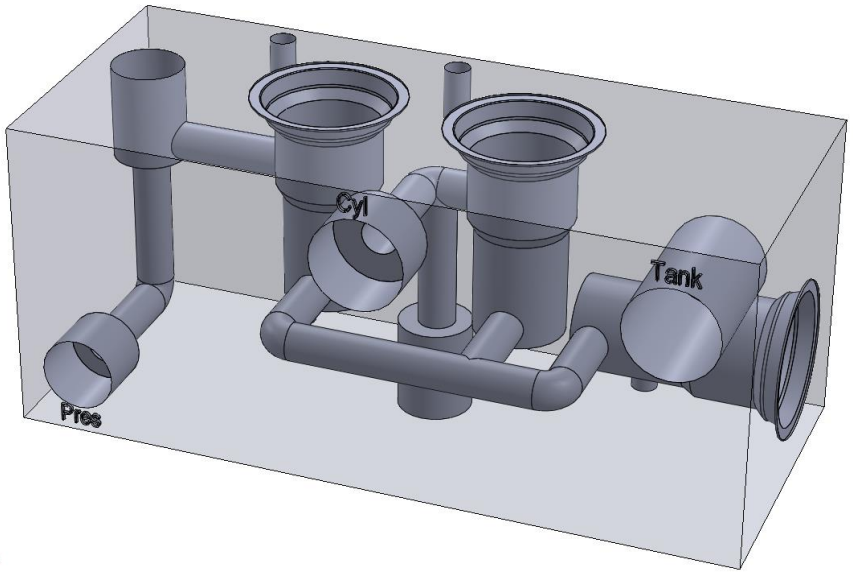
download (2).ics | Cast trial 1.cws | Show all

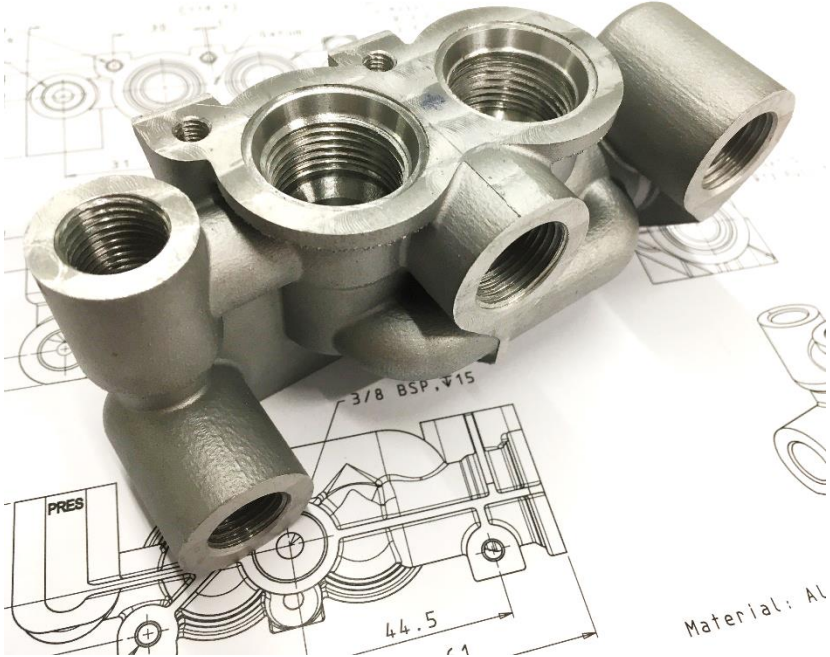
7 design iterations and 100 cases produced within 3 weeks of project start





Add value: Weight reduction





High pressure 600 bar hydraulic manifold with weight reduced by over 65%

45% weight saving over machined caliper

Courtesy of Taylor Grey and Jake Powell

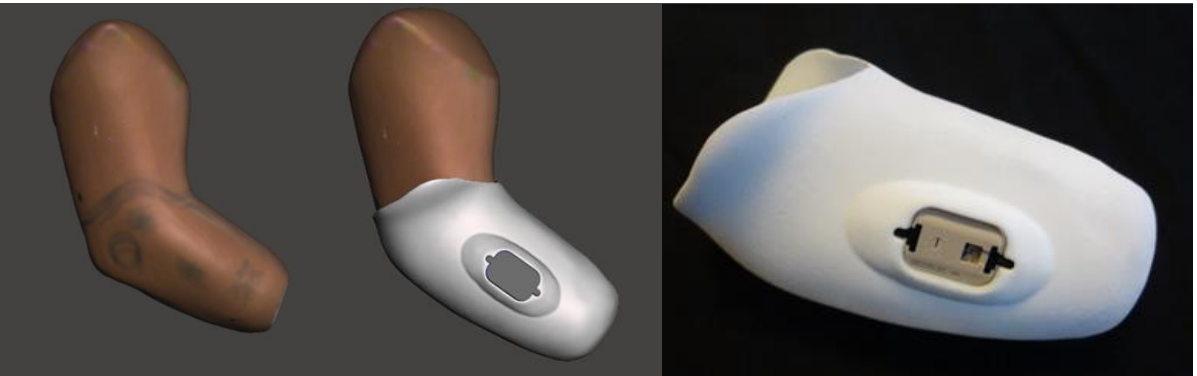

08:37
Close
Your Mask Fitter
bellus3D
Hide Face
08:37
Close
Your Mask Fitter
bellus3D
Hide Face

Mass-customisation: medical

The old-fashioned way

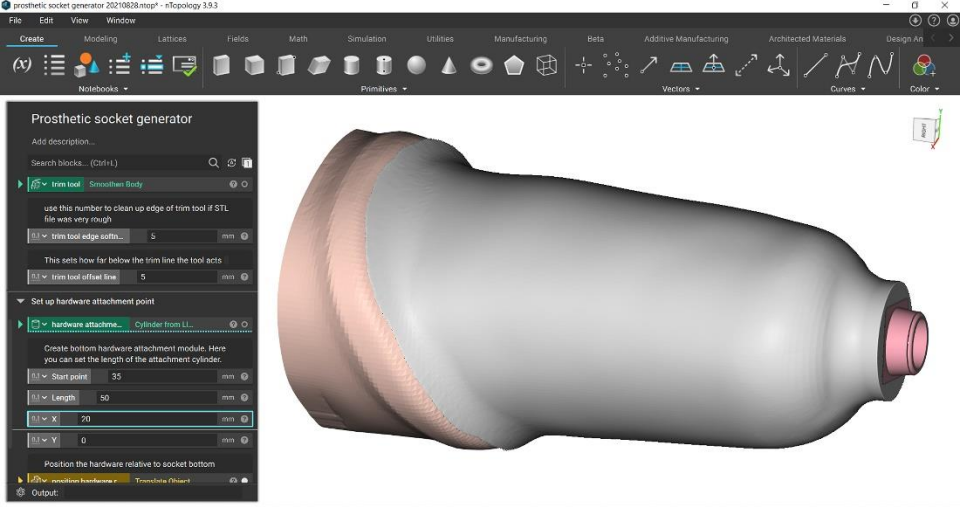
Custom prosthetic 3D printed for 2 ½ year old Neya
by Emelie Strömshed at Lund University

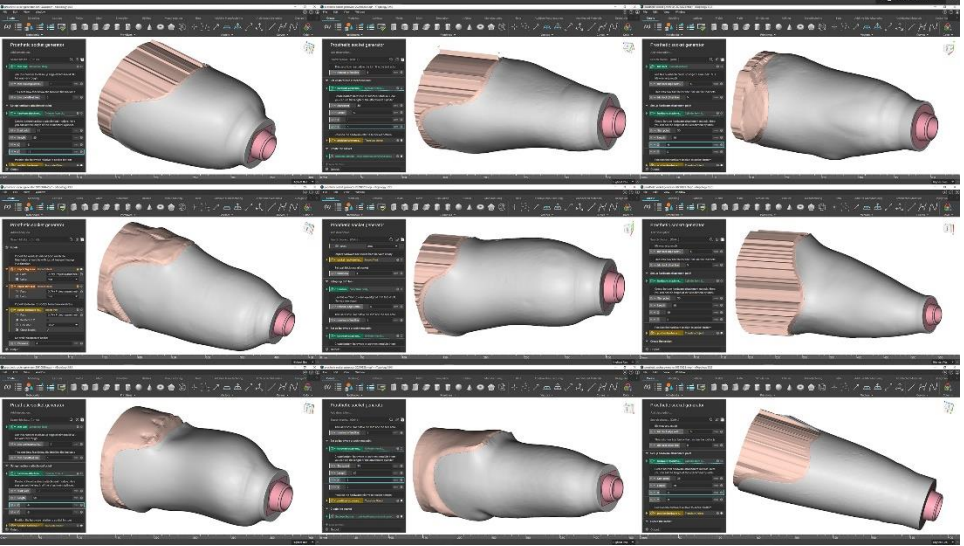
The little bit newer way



A new breed of design automation software

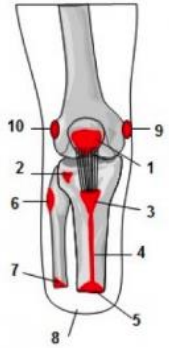
- Over the past few years, we have seen a number of new **design automation software packages**.
- These packages use a relatively novel form of CAD modelling – ‘implicit modelling’ – a light-weight method of **representing complex 3D objects using mathematical functions** to describe solid bodies, making it highly adaptable to **computational design, which is also formulae driven**.
- These packages allow the construction of ‘workflows’ that can be repeatedly used to easily create new instances of a design.
- Examples of these software systems include **nTopology, Gen3D,** etc.





Pressure sensitive and pressure tolerant areas of the TT stump

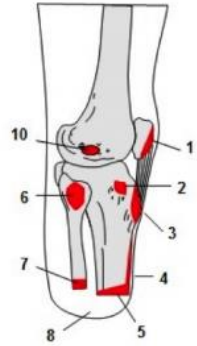
ANTERIOR VIEW



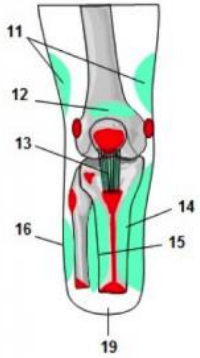
Pressure sensitive

1 - PATELLA
2 - LATERAL TIBIAL CONDYLE
3 - TIBIAL TUBEROSITY
4 - TIBIAL CREST
5 - ANTERIOR-DISTAL END OF TIBIA
6 - FIBULAR HEAD
7 - DISTAL END OF FIBULA
8 - DISTAL END OF STUMP WITH SURGICAL SUTURE
9 - MEDIAL FEMORAL CONDYLE
10 - LATERAL FEMORAL CONDYLE

LATERAL VIEW



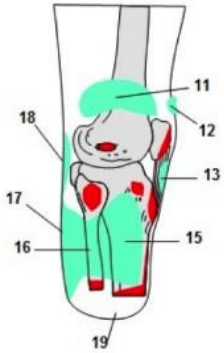
ANTERIOR VIEW



Pressure tolerant

11 - SUPRACONDULAR AREAS
12 - SUPRAPATELLAR AREA
13 - PATELLAR TENDON
14 - MEDIAL FLARE OF TIBIA
15 - LATERAL FLARE OF TIBIA
16 - LATERAL FLARE OF FIBULA
17 - POSTERIOR AREA OF THE STUMP
18 - POPLITEAL AREA (GENTLY!)
19 - DISTAL END OF STUMP FOR TOTAL CONTACT SOCKET
(NO PRESSURE, CONTACT ONLY!)

LATERAL VIEW



prosthetic socket generator II 20210831.ntop - nTopology 3.9.3

File Edit View Window

Create Modeling Lattices Fields Math Simulation Utilities Manufacturing Beta Additive Manufacturing Architected Materials Design An

Notebooks Primitives Vectors Curves Color

prosthetic socket generator II

Add description...

Search blocks... (Ctrl+L)

flare width 20mm mm

create and position hardware mount

hardware mount Translate Object

move X 6mm mm

move Y 0mm mm

position hardware Translate Object (1)

Finish things off

create the final socket

socket with flare Boolean Subtract

add the hardware mounting point

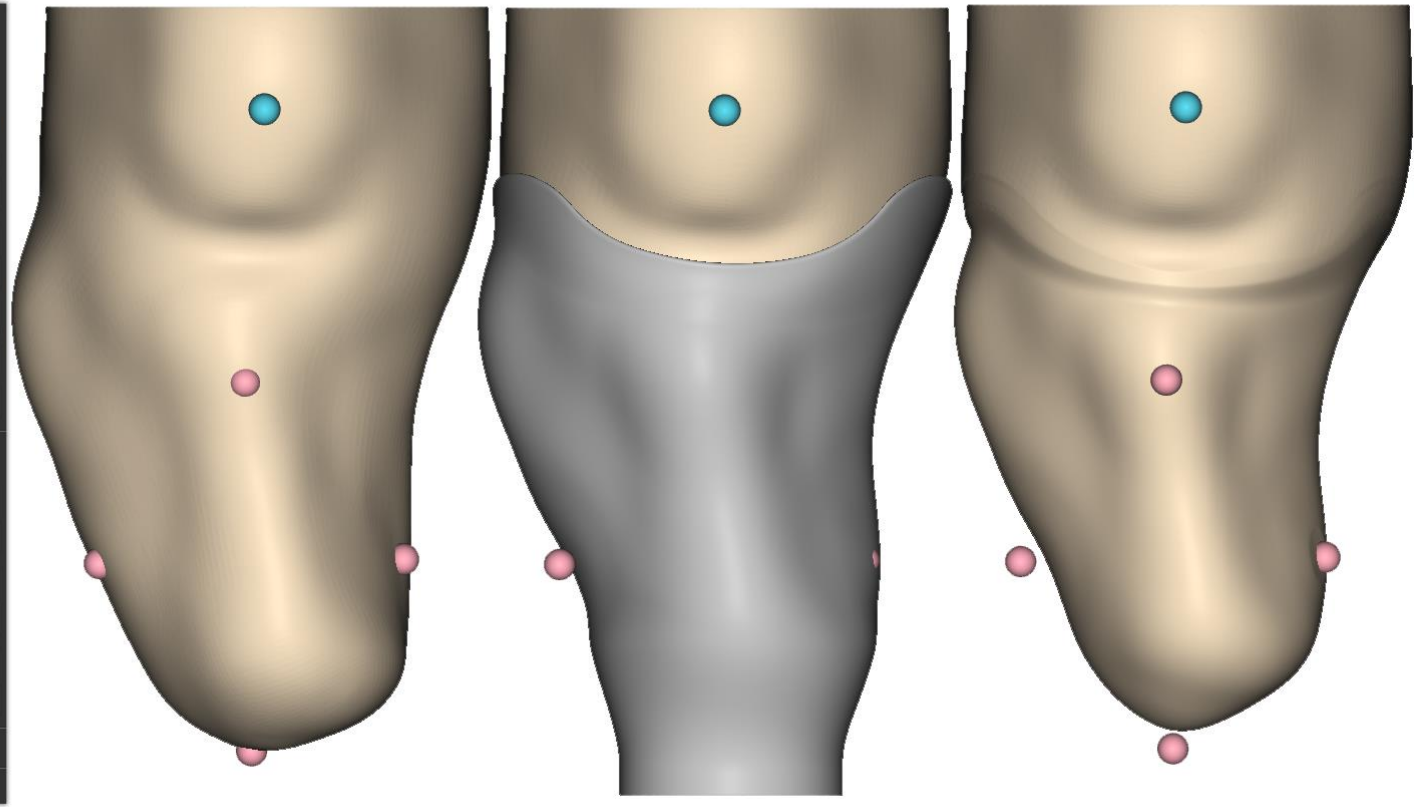
socket with hardwar... Boolean Subtract

create uncompressed limb in socket

limb in socket Boolean Subtract

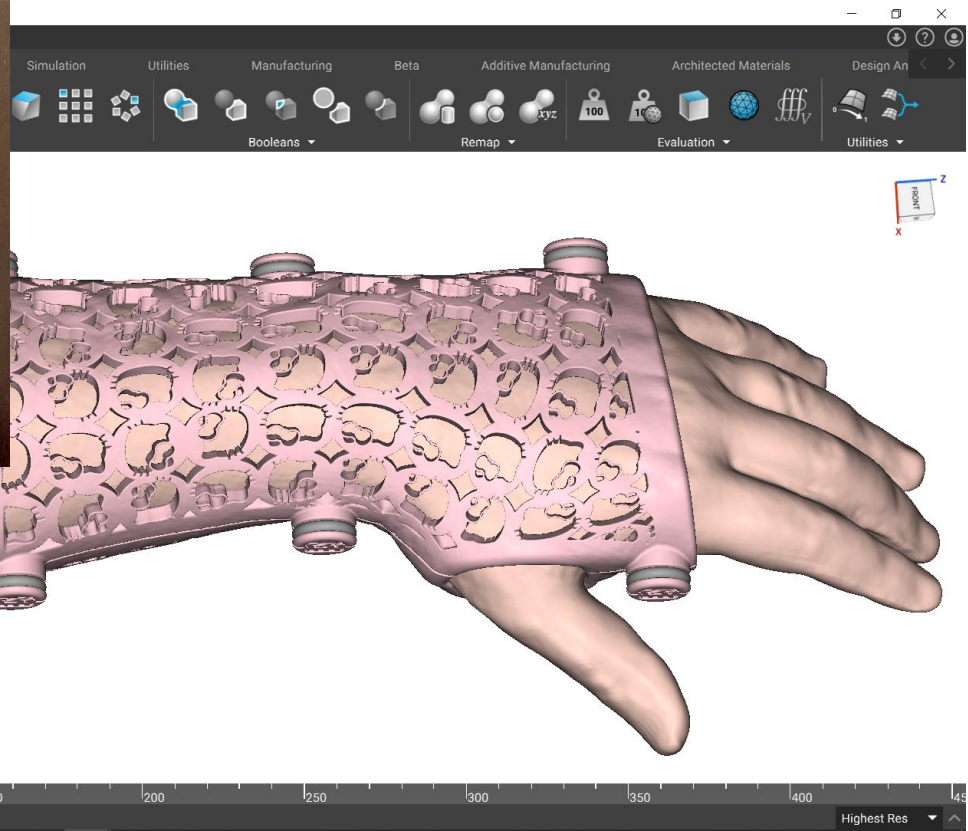
New Section

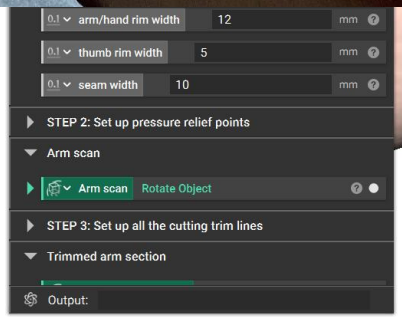
Output:



0 mm 50 100 150 200 250 300 350 400 450 500 550

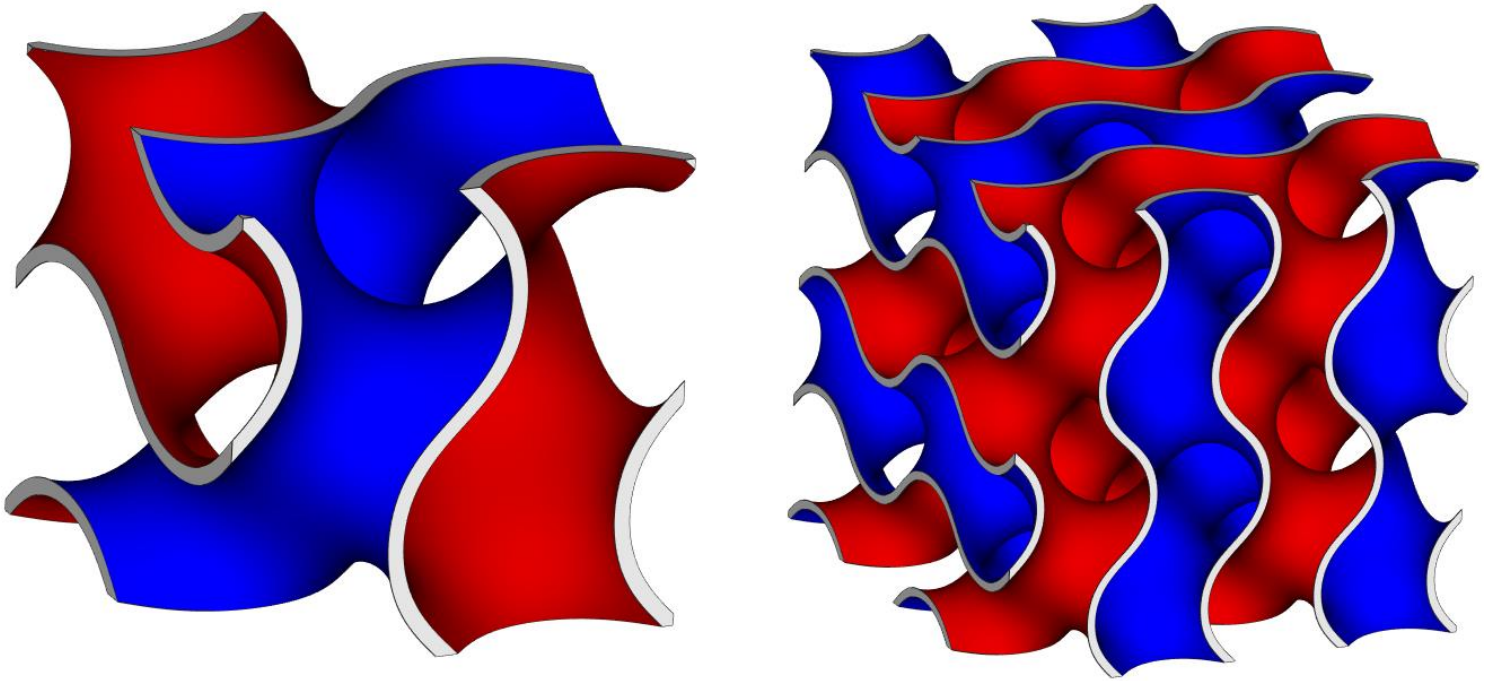
Highest Res

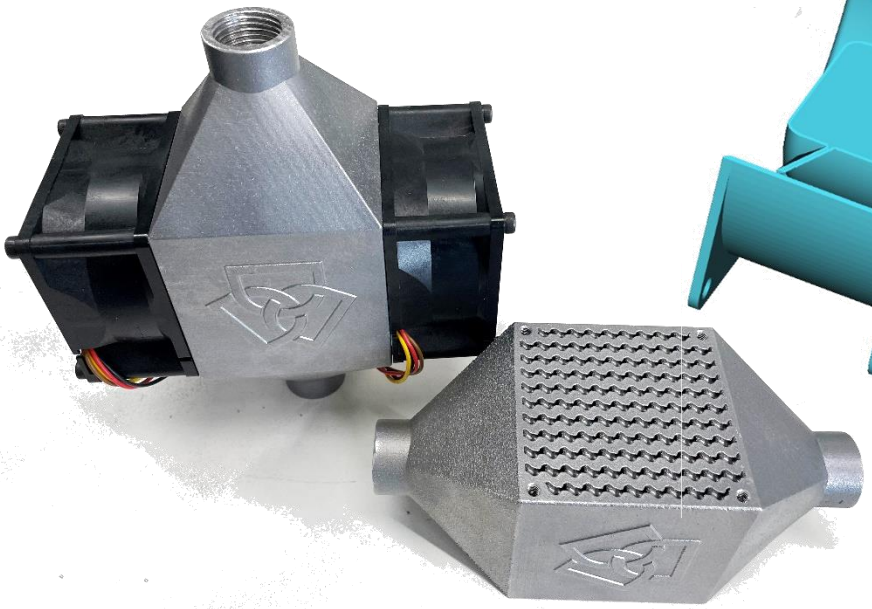

Simulation
Utilities
Manufacturing
Beta
Additive Manufacturing
Architected Materials
Design An
Booleans
Remap
Evaluation
Utilities
FRONT
Z
X

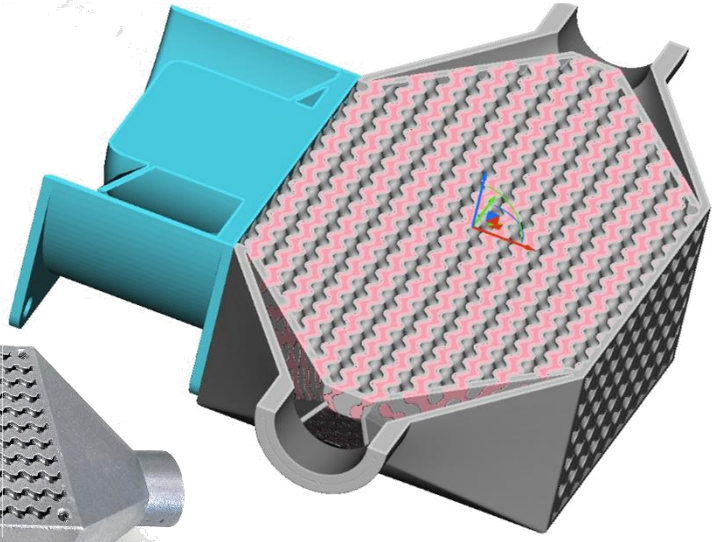

arm/hand rim width
12
mm
thumb rim width
5
mm
seam width
10
mm
STEP 2: Set up pressure relief points
Arm scan
Arm scan
Rotate Object
STEP 3: Set up all the cutting trim lines
Trimmed arm section
Output:

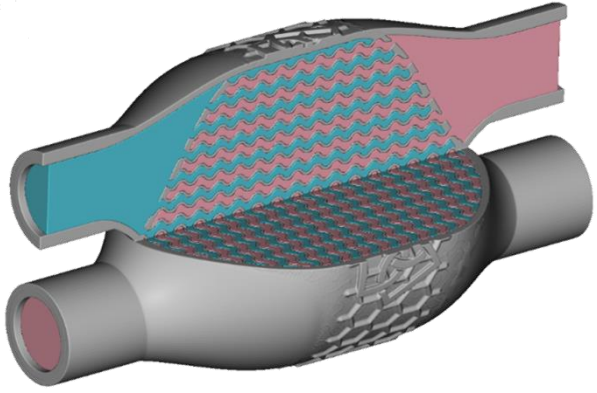
0 mm
50
100
150
200
250
300
350
400
Highest Res

Funky lattice structures and heat exchangers



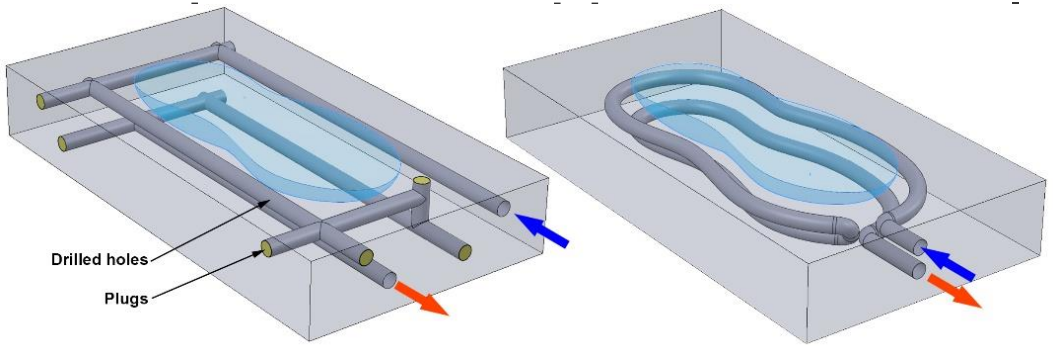


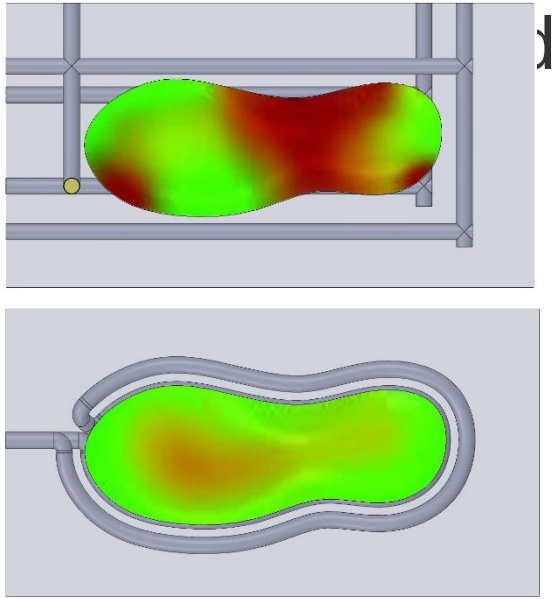




AM for injection molding

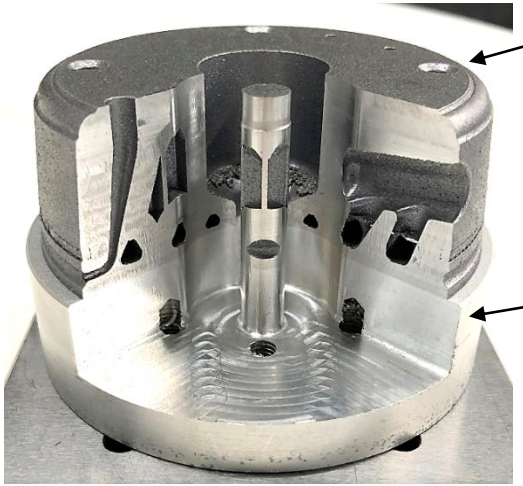
- Because of the complexity allowed by AM, we can print **conformal cooling channels** in injection molding tools.
- This can improve cycle time by





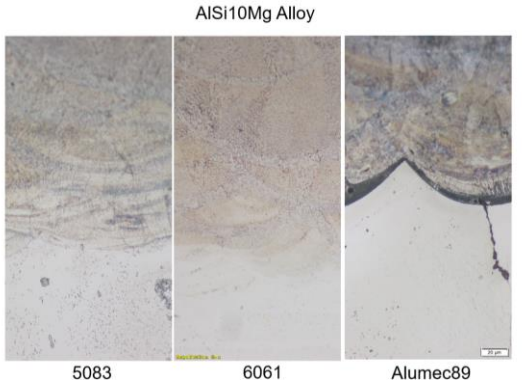
Hybrid AM Tooling

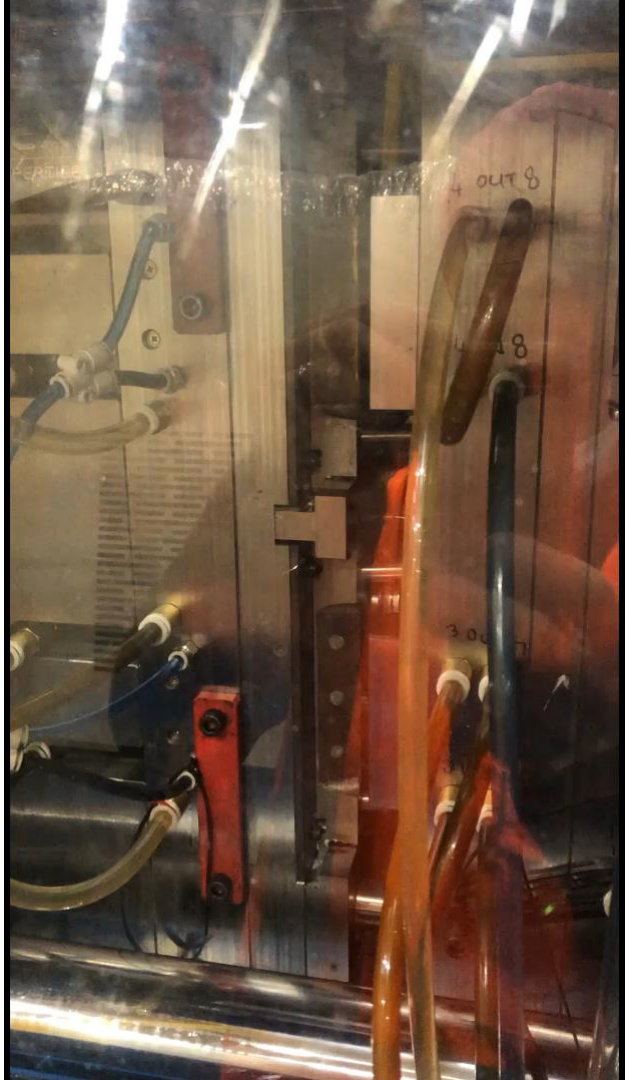
- Our PhD student, Simon Chan, is investigating printing hybrid AM injection molding tools with conformal cooling channels
- Aim is to make AM tools cost-comparable, but with faster cycle times than conventional injection molding tools
- Investigating both aluminium and maraging steel tools



Interesting part of tool, with conformal cooling channels so adds enough value to print

Boring lump of metal so expensive to print




4 OUT 8

Entrepreneurship can be fun!

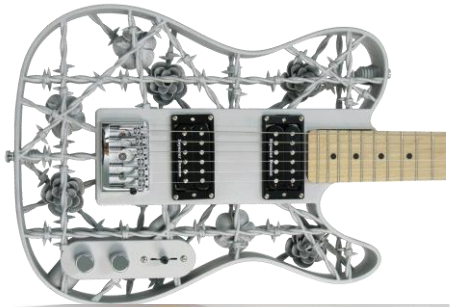
- Began as trial of technology in 2011.
- Evolved into side business over the following 2 years.
- Sold rights to 3D systems for 2 years in 2014.
- Regained rights in 2016.
- 90 guitars produced to date, 75 sold.
- Driven by passion rather than business (but the extra income is nice).

DfAM can be fun!





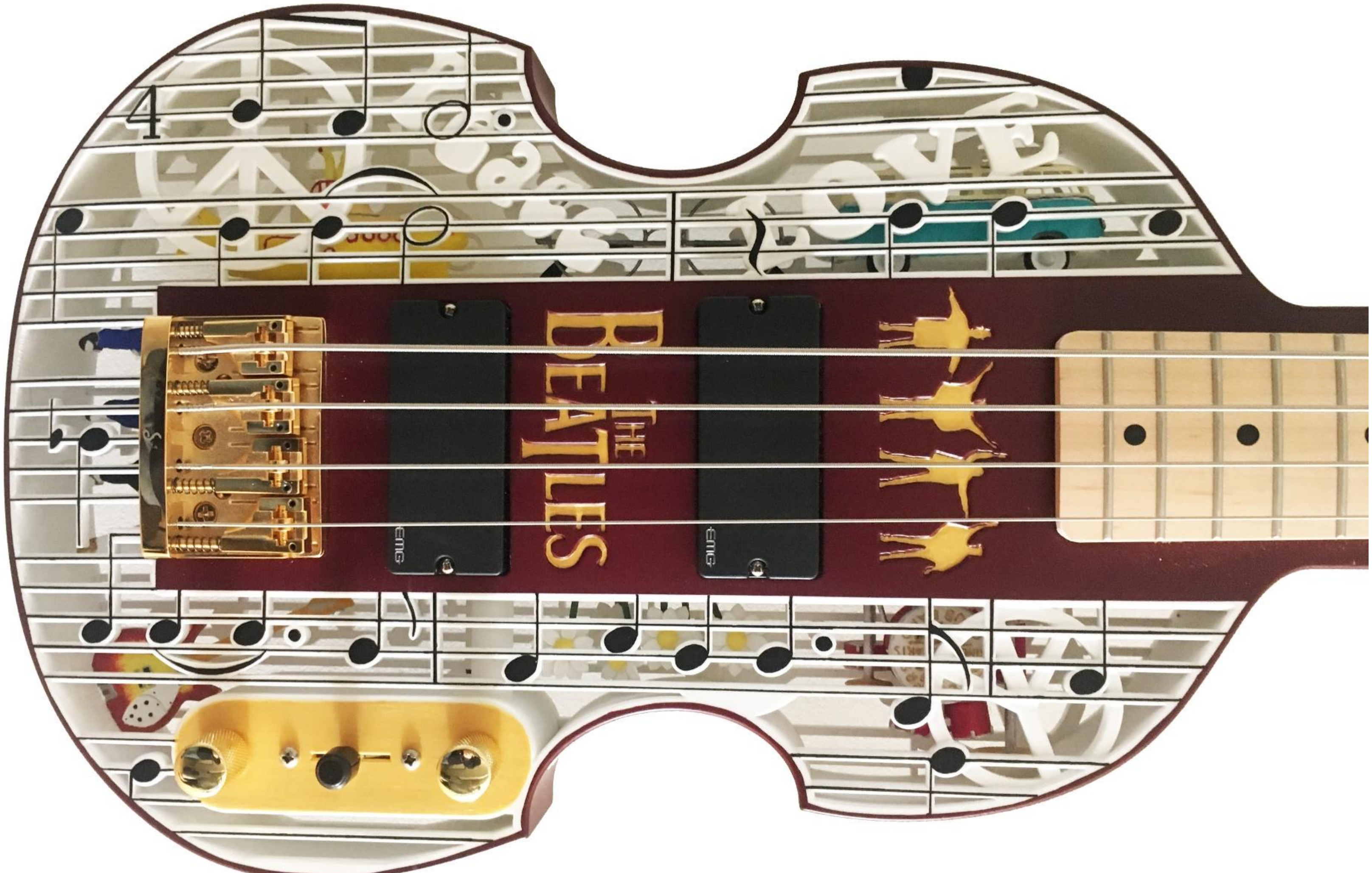








Seymour Duncan
Seymour Duncan

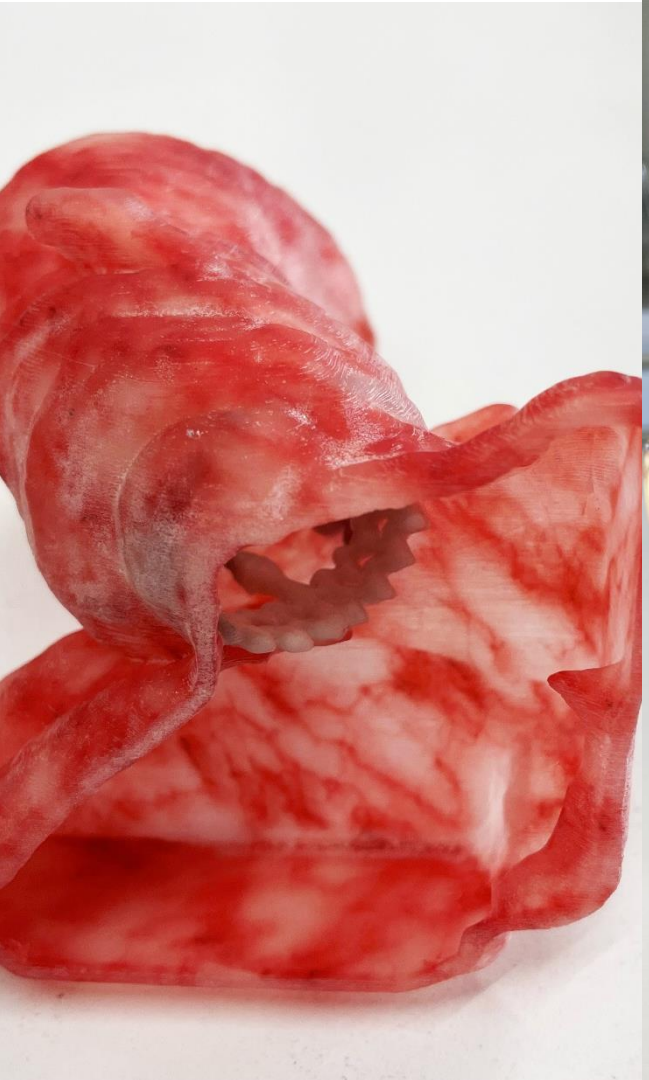

THE BEATLES
EMG
EMG

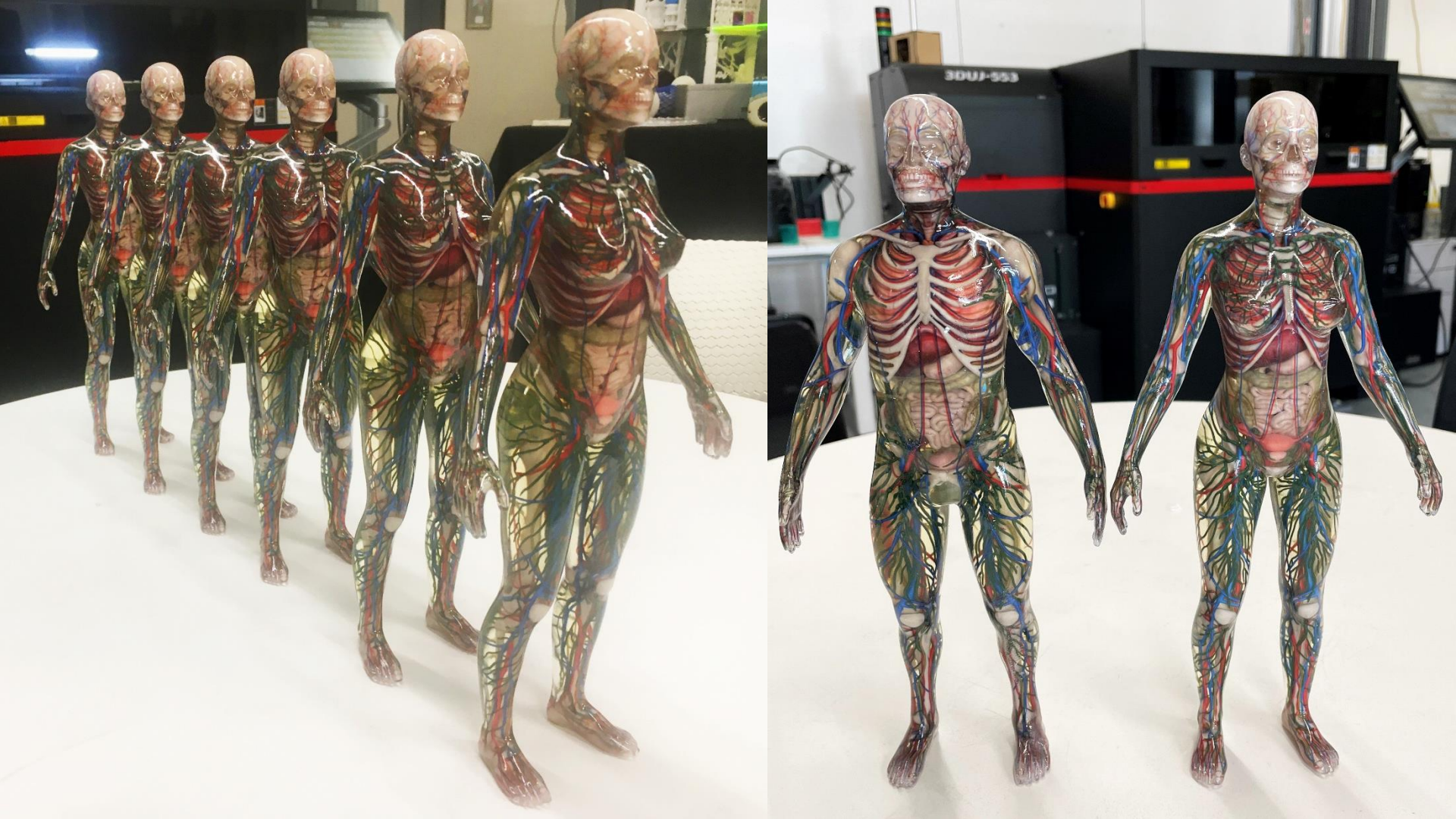

EMG
EMG


Seymour Duncan
Seymour Duncan


Seymour Duncan


Seymour Duncan

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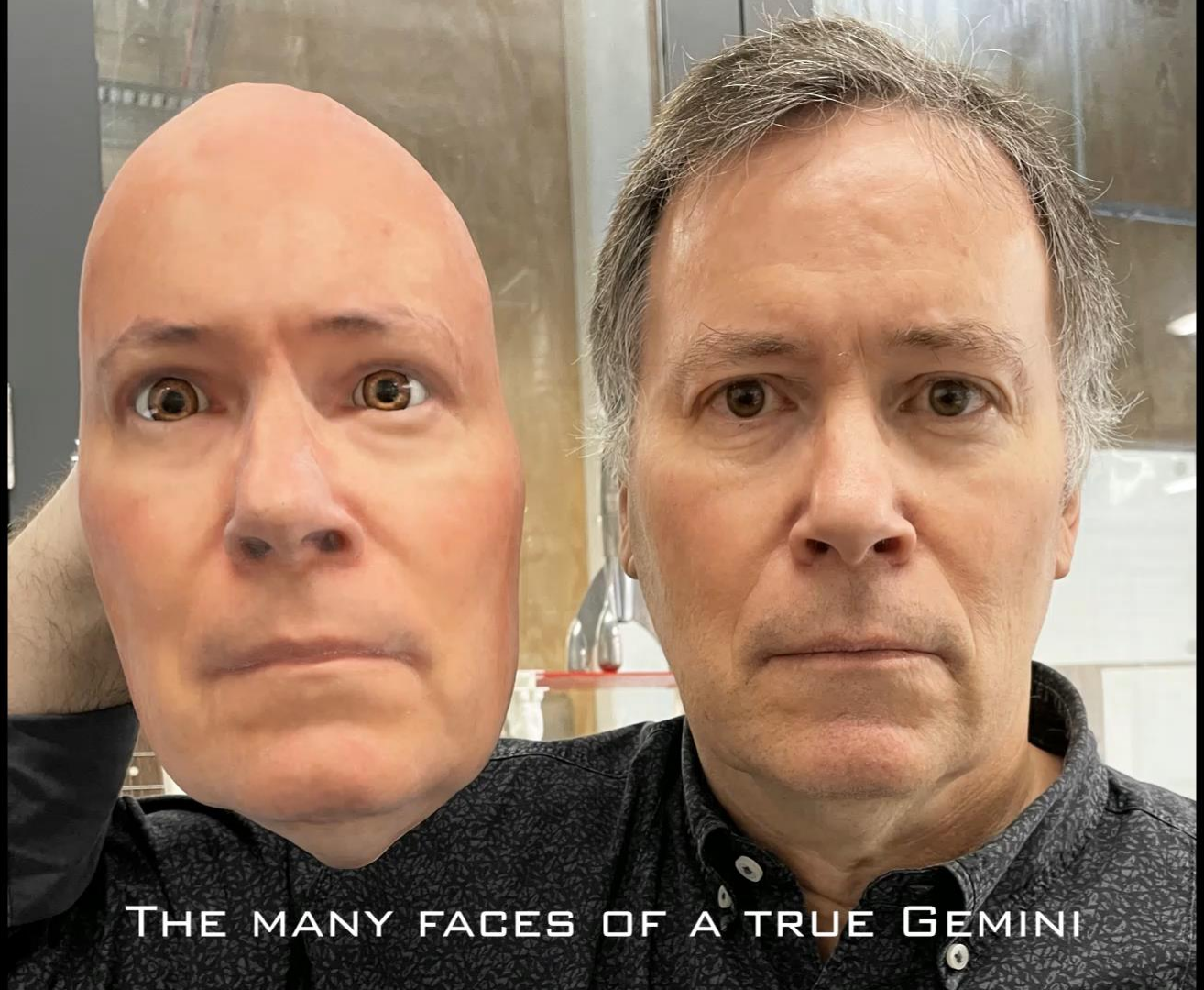
The many faces of a true Gemini

So what's missing?

- We need **more materials**, **better surface finishes**, and **certifiable** processes
- We need **design tools** that will allow us to design safe products that are **optimized for AM**.
- We need to update our engineering and design education programs to include **design for AM**.


3D Printing is amazing…
So have fun with it!
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Creative Design and Additive Manufacturing Lab
F*CK ME THAT'S HOT SAUCE