

# 3D Printing PPE: A Three-Minute Face Shield Solution

**Elizabeth Bishop**

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# About me

## Elizabeth Bishop

- 2012 – 2017 MEng Mechanical Engineering
- 2016 – 2017 UAV Group Project
- 2017 – 2021 PhD in Large-Scale Additive Manufacturing (3D Printing)
- Maker in Residence at Warwick Engineering Build Space

 @LizBish94

 @WEDesignMake

 Elizabeth Bishop



# You may remember us from...



# Learning Objectives

## OBJECTIVE 1

Learn about the global maker's response to the COVID-19 crisis

## OBJECTIVE 2

Learn how Warwick University responded and helped using 3D printing

## OBJECTIVE 3

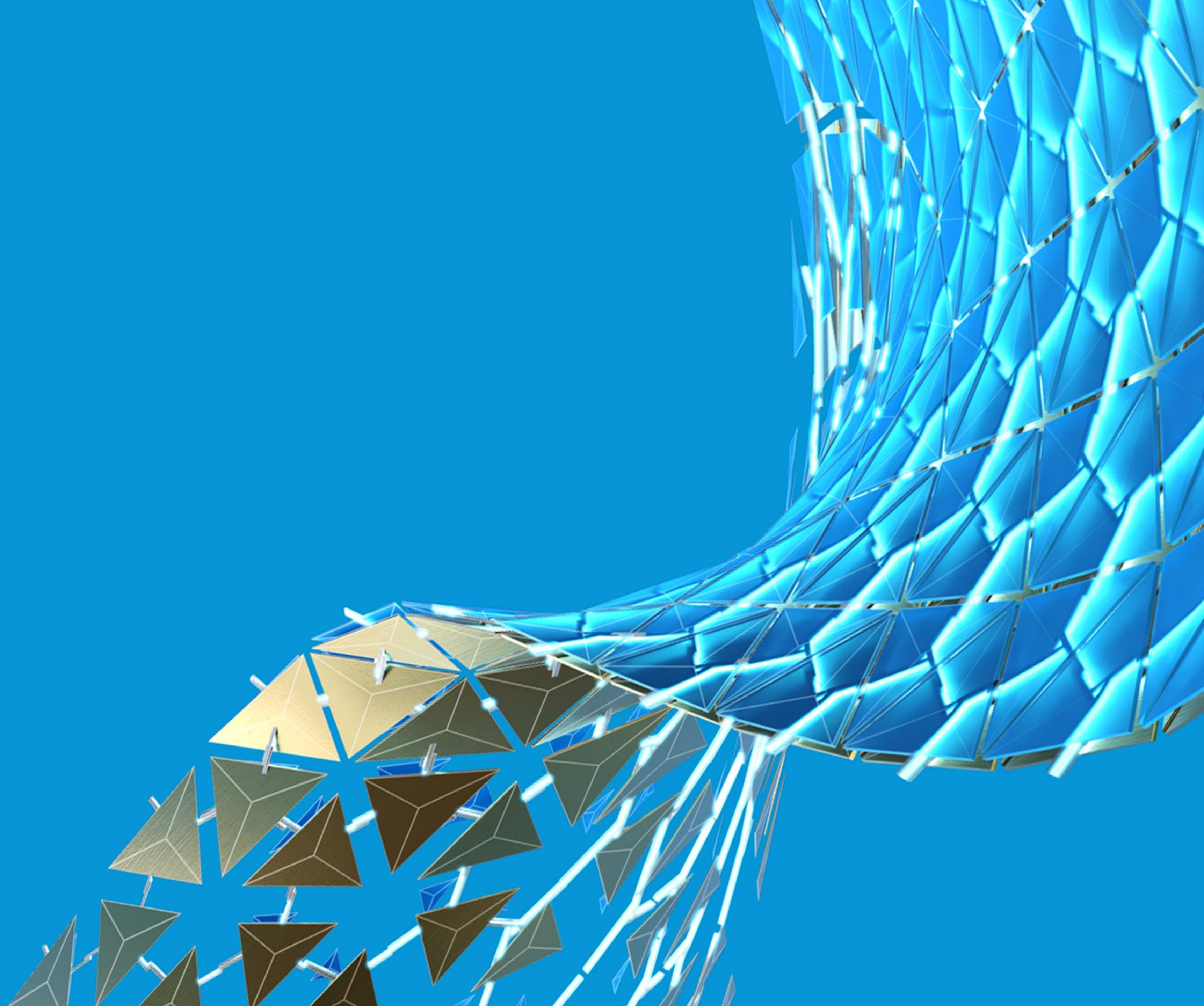
Learn how to print a PPE face shield in under three minutes

## OBJECTIVE 4

Learn about large-scale additive manufacturing



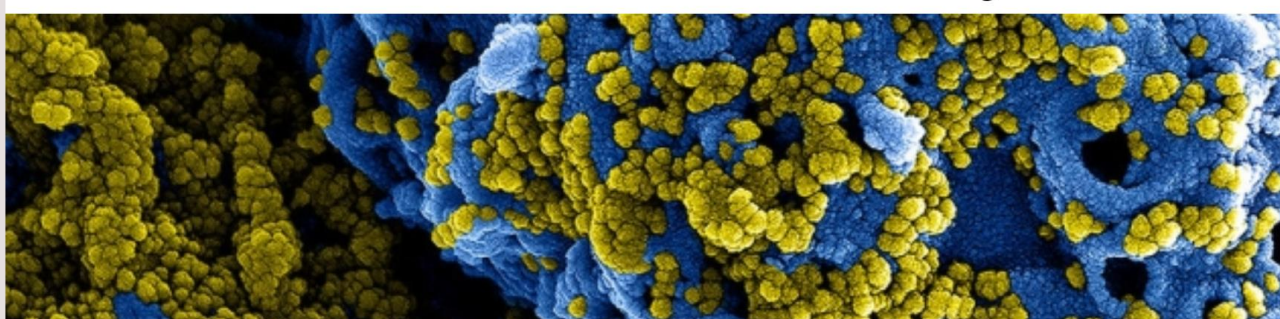
# Introduction







# WHO Declares Coronavirus a Public Health Emergency, Highlights Need to Support Countries 'Weaker Health Systems'



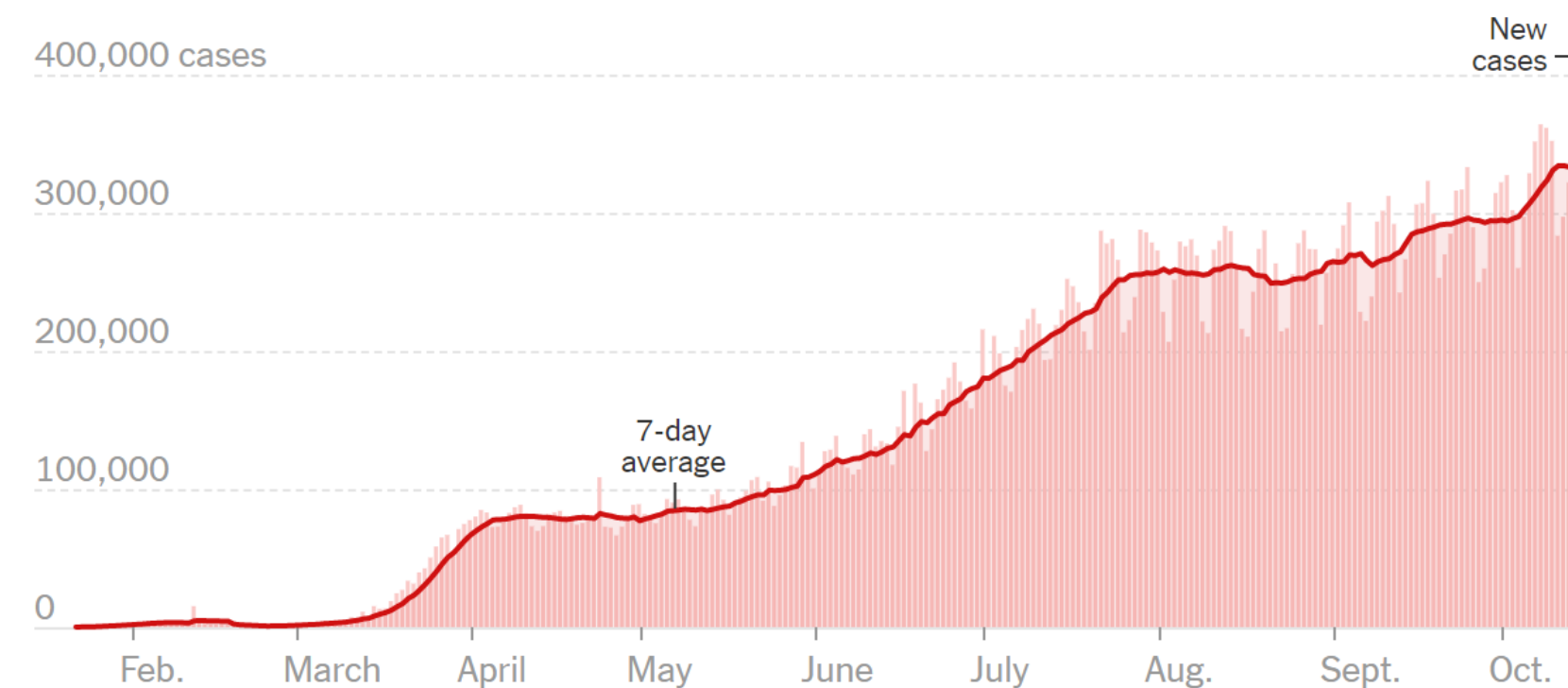
## Coronavirus: Nottinghamshire woman, 75, 'first positive test within UK'

25 August

Coronavirus pandemic

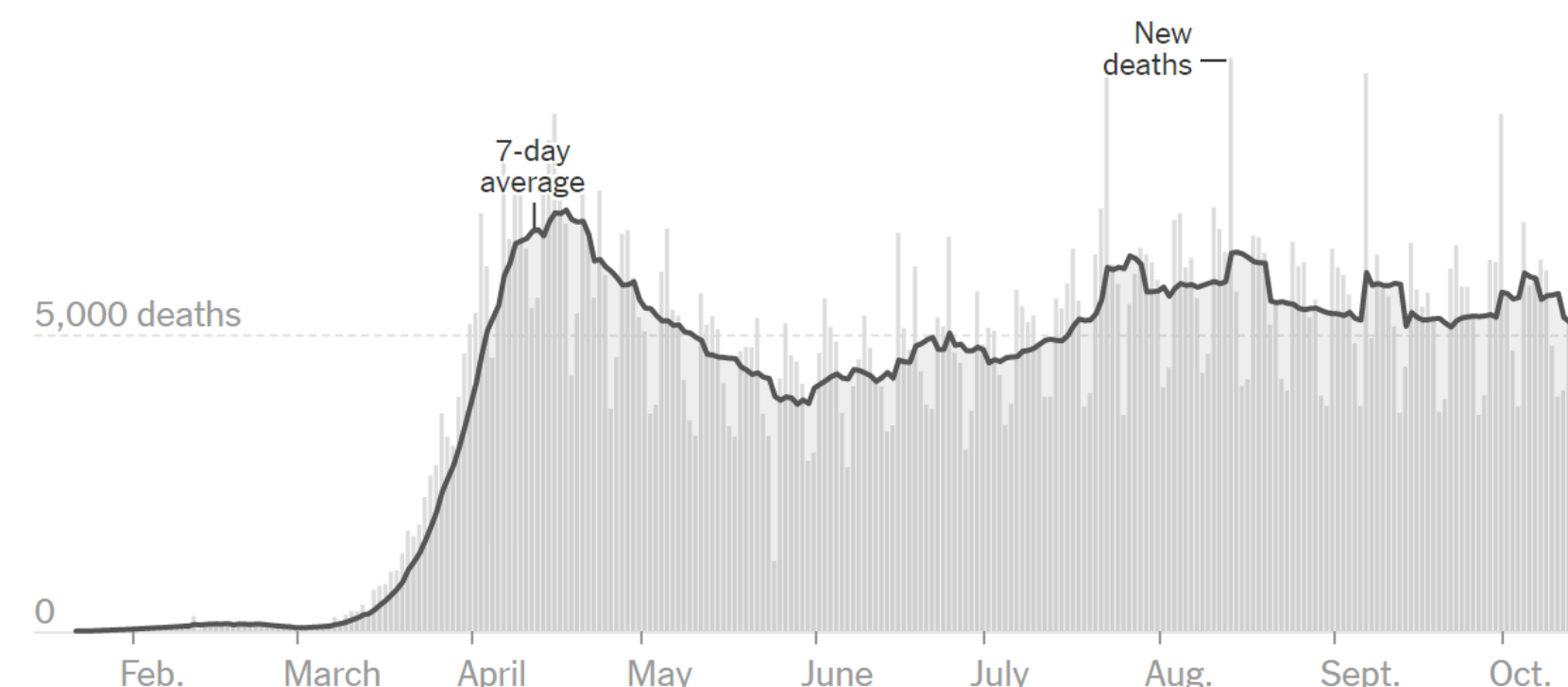


### New reported cases by day across the world



Note: The seven-day average is the average of a day and the previous six days of data.

### New reported deaths by day across the world



Note: Scale for deaths chart is adjusted from cases chart to display trend.

**GOOD HEALTH 10-PAGE SPECIAL**  
**Daily Mail**  
 THE GOOD NEWS? Newsagents to stay open - and CAN deliver the Mail to your door...  
**FREE DELIVERY FOR 6 WEEKS**  
 EXCLUSIVE: Queen bans Harry and Meghan from using 'Sussex Royal' brand  
**PM's historic stay-at-home plea to beat virus**  
**LOCKDOWN BRITAIN**  
 Astonishing restrictions on daily life ++ NO travel unless essential ++ Don't see friends or family ++ Only one exercise outing a day ++ Fines if you don't obey ++ Mass closures of shops ++ All for at least 3 weeks

**SUN**  
 FREE HOME DELIVERY FOR 12 WEEKS  
**HOUSE ARREST**  
 PM: Brits must stay home  
 Police fines up to £1,000  
 Gatherings over 2 banned  
 Only shop for basics

**The Guardian**  
 for six weeks Get the Guardian sent to your home, with no delivery charge  
 PM: 'Stay at home, this is a national emergency'  
 Johnson drastically restricts movement to combat coronavirus  
 Gatherings of more than two people in public to be prohibited  
 Police given powers to disperse groups and enforce lockdown

**Puzzles Plus**  
 Brilliant new puzzles section with four extra pages of teasers to keep your mind active  
**The Daily Telegraph**  
**End of freedom**  
 Public gatherings of more than two to be outlawed with threat of fines  
 All non-essential shops to be closed as restrictions imposed for three-week period  
 Scientists told Prime Minister the NHS faced collapse

**CORONAVIRUS CRISIS**  
 CRAMMED SCENES ON THE TUBE THAT PROVED MEASURES WEREN'T ENOUGH  
**BRITAIN ON LOCKDOWN**  
 PM SAYS STAY AT HOME  
 ALL GATHERINGS OF MORE THAN TWO BANNED  
 ONLY ONE FORM OF EXERCISE PERMITTED

**THE TIMES**  
 Alex Salmond: not Scotland's former leader cleared of sex charges  
**'You must stay at home'**  
 PM declares national emergency  
 Meetings of more than two banned



# Coronavirus: UK failed to stockpile crucial PPE

28 April

Coronavirus pandemic



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NHS

## What is the situation with personal protective equipment in the UK?

PPE - or the lack of it - has been one of the key issues making headlines since coronavirus reached the UK

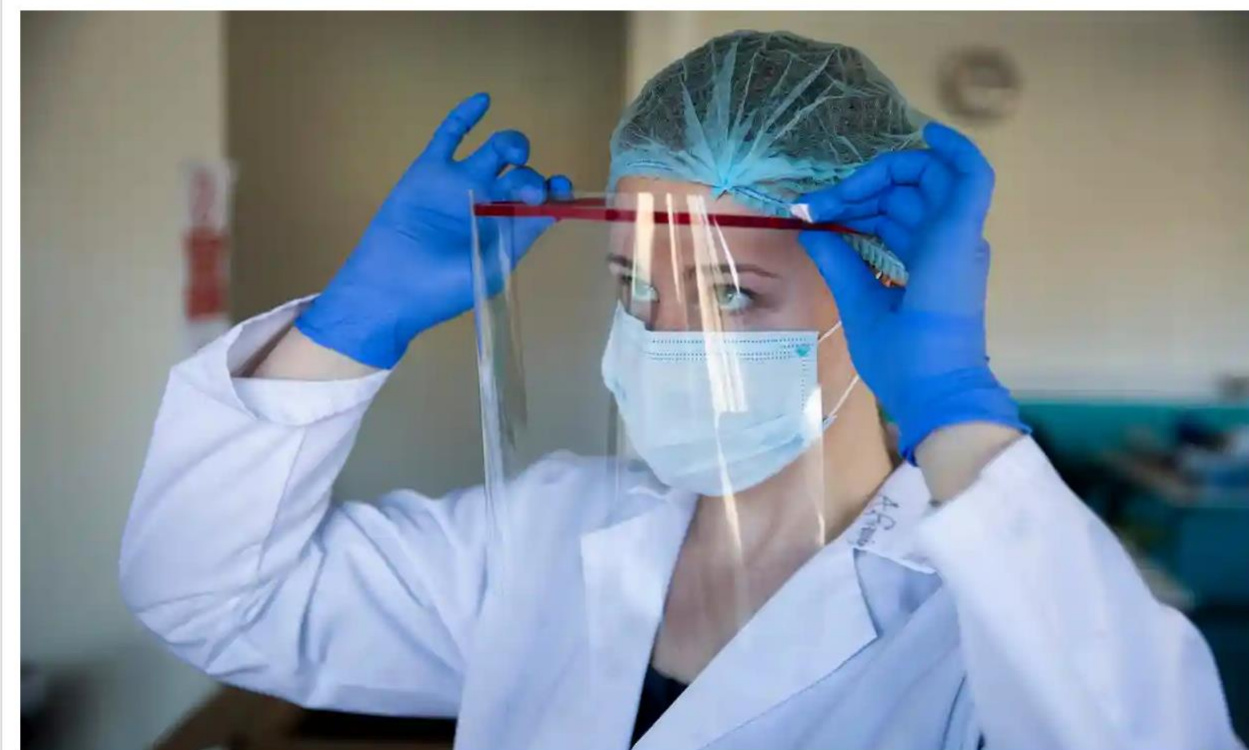
- Coronavirus - latest updates
- See all our coronavirus coverage

Haroon Siddique

Tue 14 Apr 2020 15:17 BST



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Student Ailsa Fleming checks a face shield at Edinburgh Shield Force, a pop-up factory manufacturing face shields for medics and nurses. Photograph: Murdo MacLeod/The Guardian

Since the coronavirus outbreak in the UK was first identified, the issue of

## Is there a PPE shortage, and how can NHS workers use it safely?

Personal Protective Equipment (PPE) is essential for frontline workers, but why is there a shortage in the UK?

By Laura Donnelly, HEALTH EDITOR

10 May 2020 • 12:35pm

Related Topics  
Coronavirus Q&A, Coronavirus, PPE, NHS, Face masks



# NEWS

Home Coronavirus US Election UK World Business Politics Tech Science Health Family & Education

Health

## Coronavirus: Has the NHS got enough PPE?

By Michelle Roberts  
Health editor, BBC News online

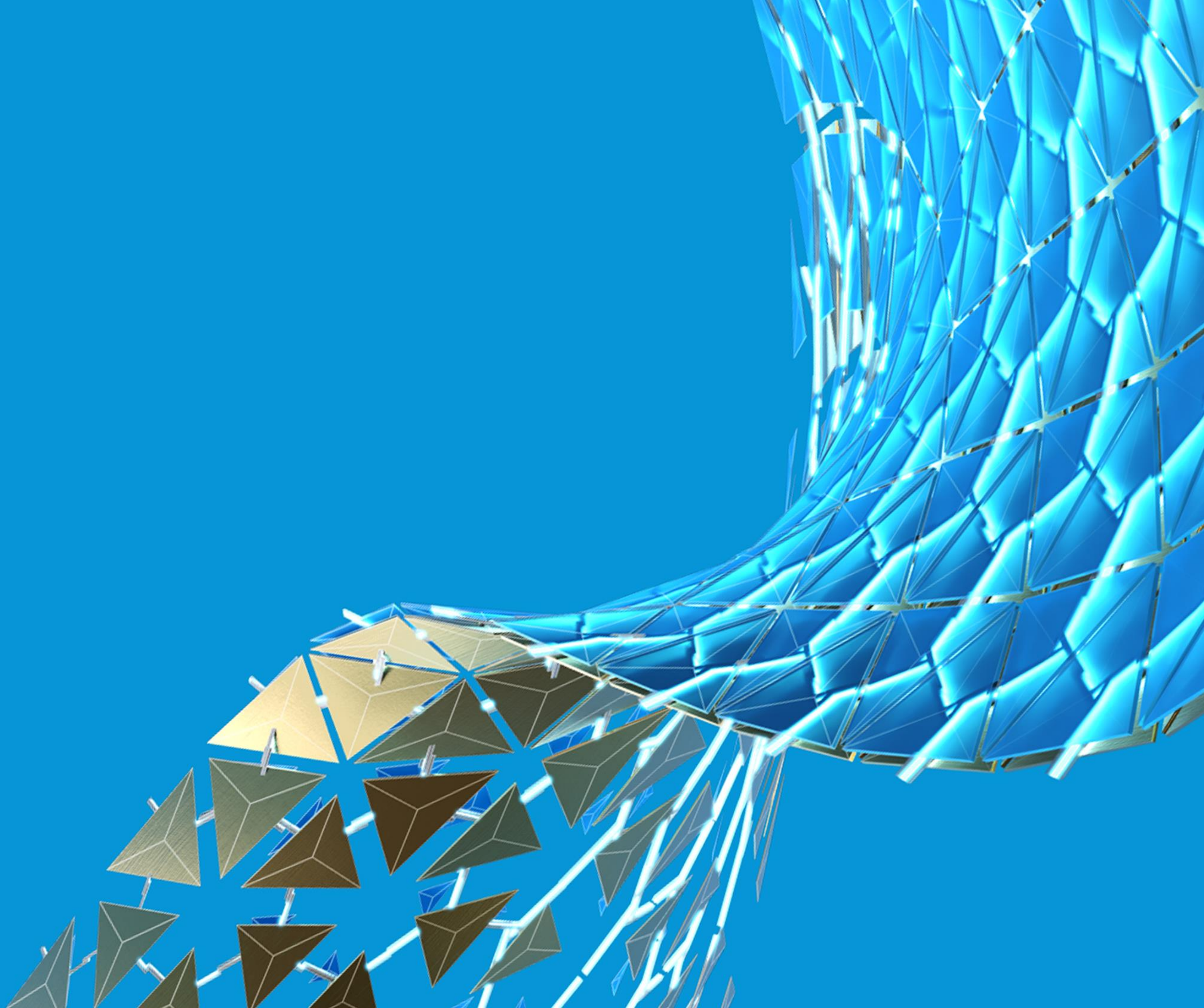
28 September

Coronavirus pandemic





# What is PPE?

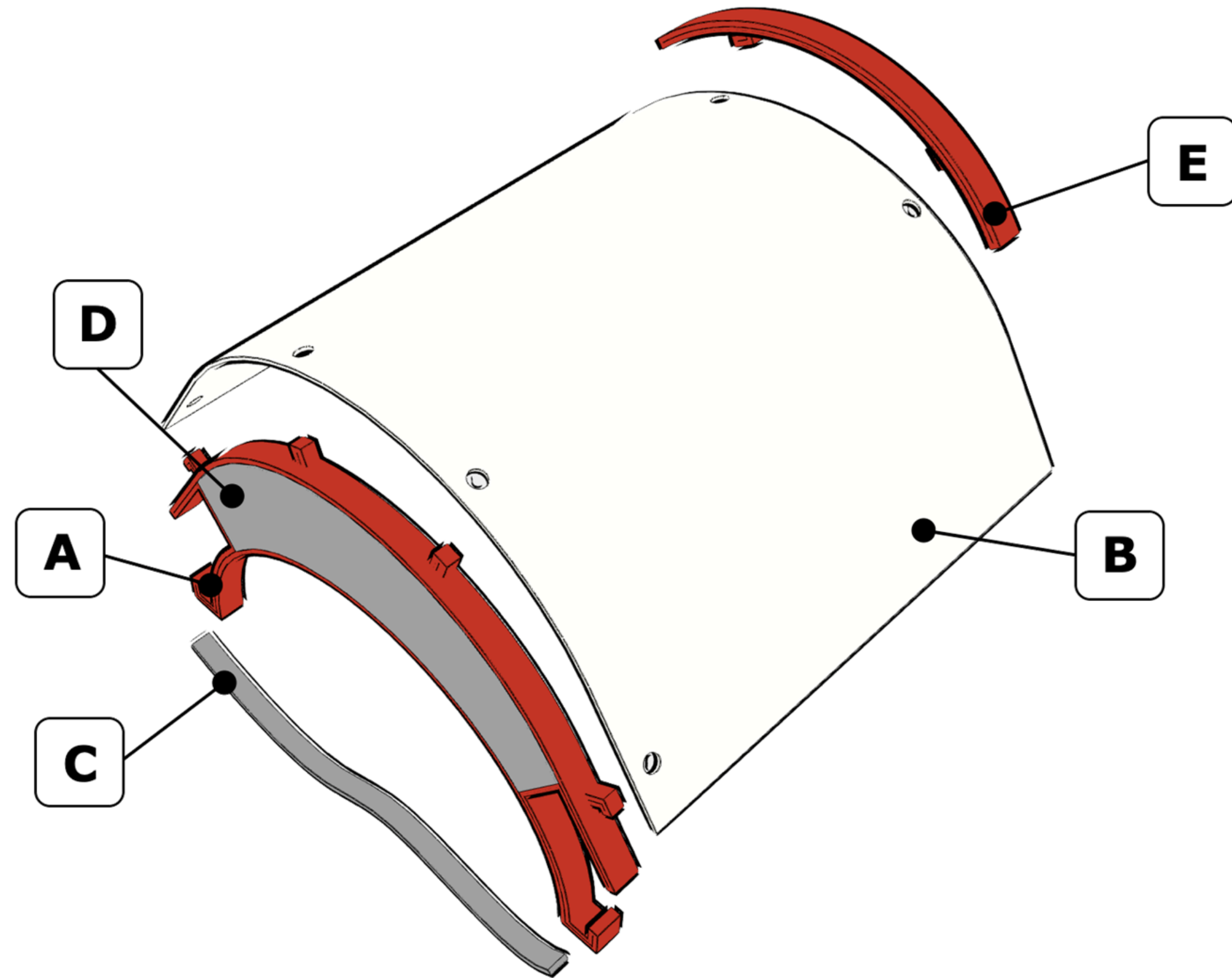




**PPE protects the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. It also includes respiratory protective equipment, such as face masks.**



# Face Shields



A – Headband

B – Visor/Lens

C – Strap

D – Optional foam insert

E – Optional bottom reinforcement piece

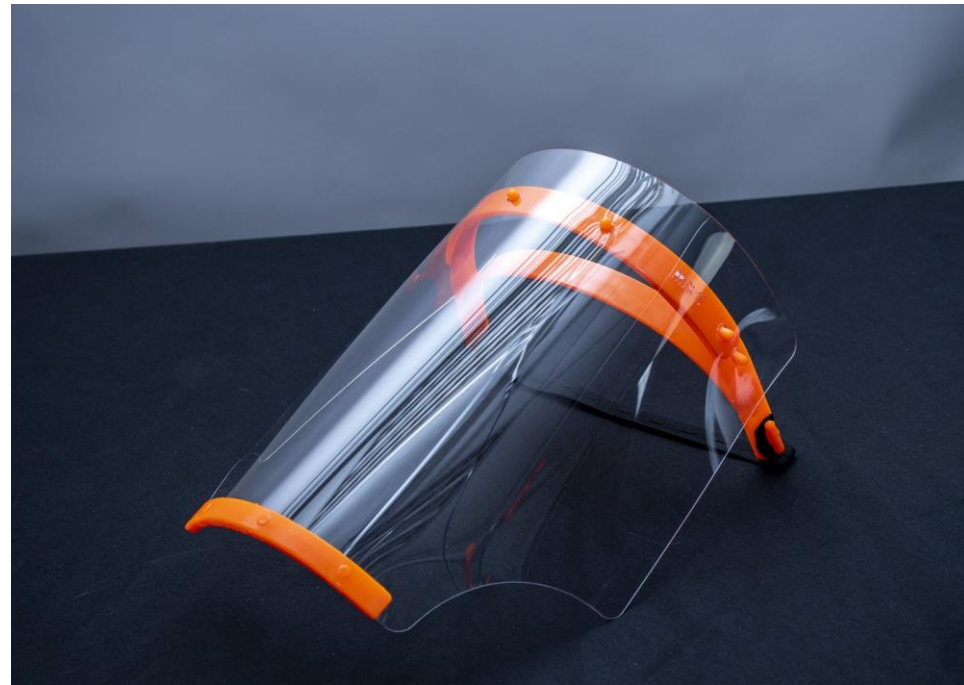


# 3D Printing Community Response





# Biggest Responders



## Prusa Research

Printed and donated almost 200,000 shields



## N3DPS

National 3D Printing Society, UK  
Established UK distribution network for individual's 3D printing PPE



## 3DVERKSTAN

Swedish distribution network for individual's 3D printing PPE

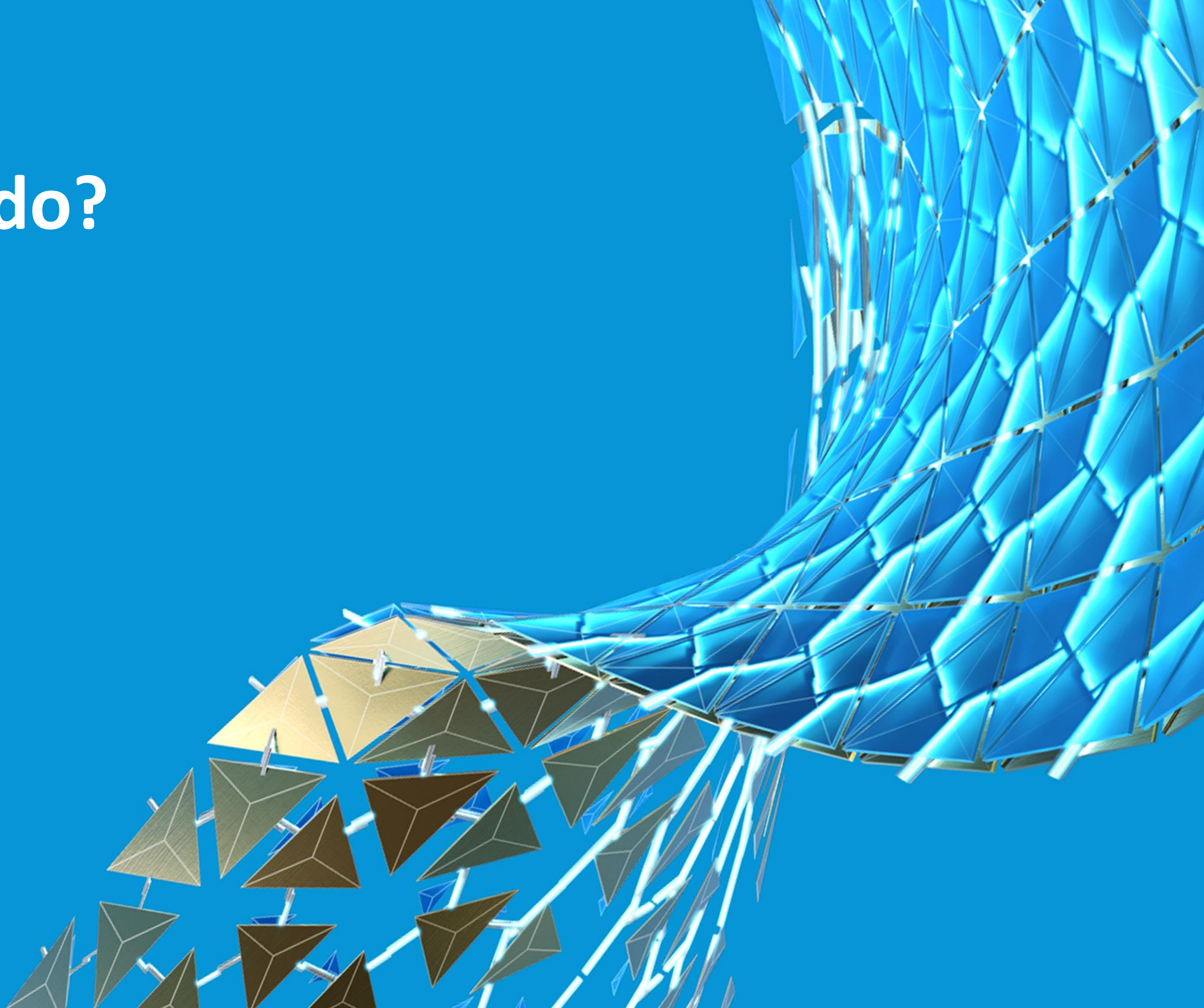


## Photocentric

Supplying NHS with 7.6 million face shields

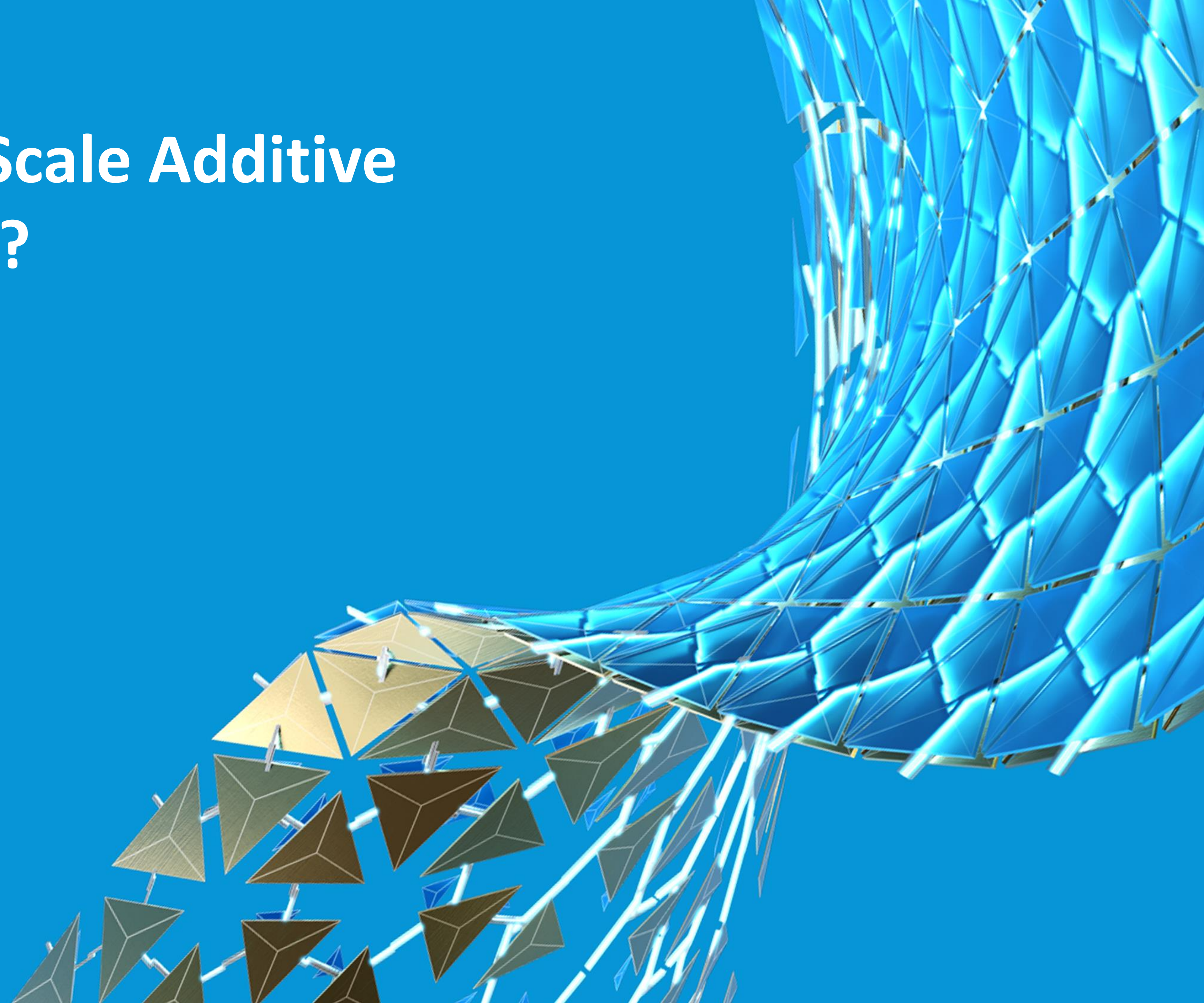


**What did we do?**





# What is Large-Scale Additive Manufacturing?





**The process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies**

ASTM 52900







# Large-Scale Additive Manufacturing



**DESKTOP SCALE**

*Ultimaker 3 Extended*



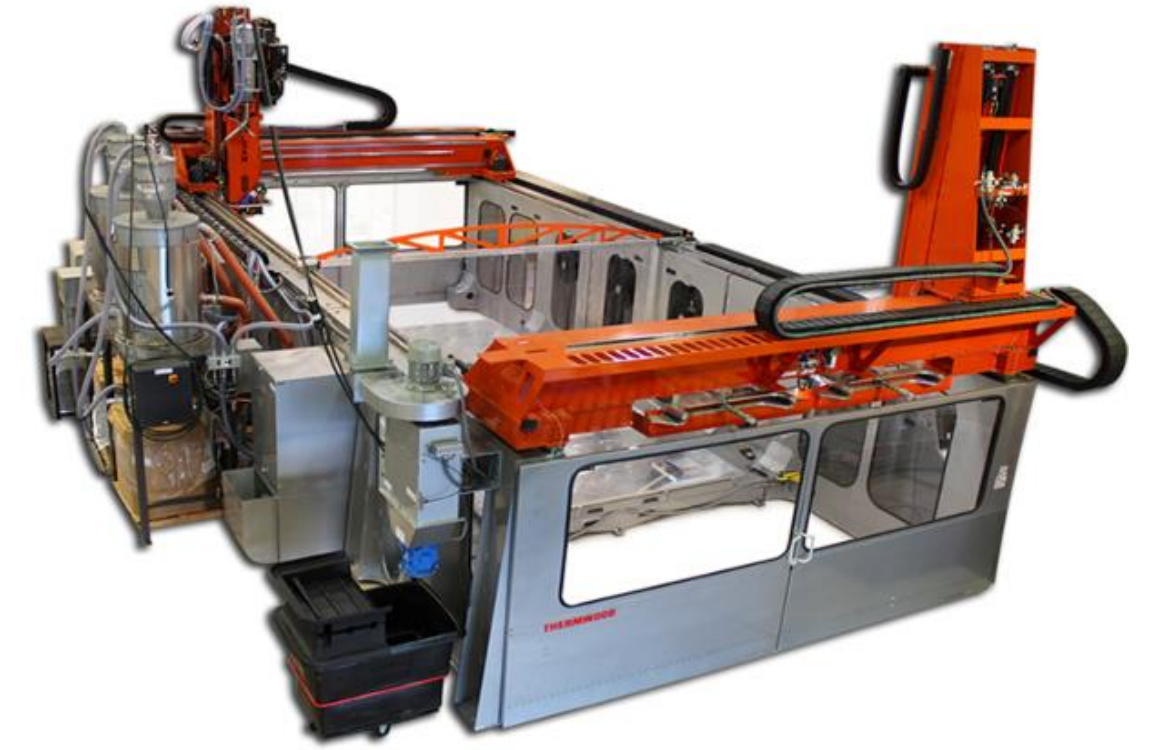
**LARGE-FORMAT**

*3DP WorkBench + E3D  
Extruder*



**LARGE-SCALE**

*3DP WorkBench + HFE (High  
Flow Extruder) 300*



**VERY LARGE-SCALE**

*Thermwood LSAM 1020*



# Advantages and Disadvantages

## Advantages

**High flow rate**

**Faster printing**

**Large-build volumes**

**Stronger parts**

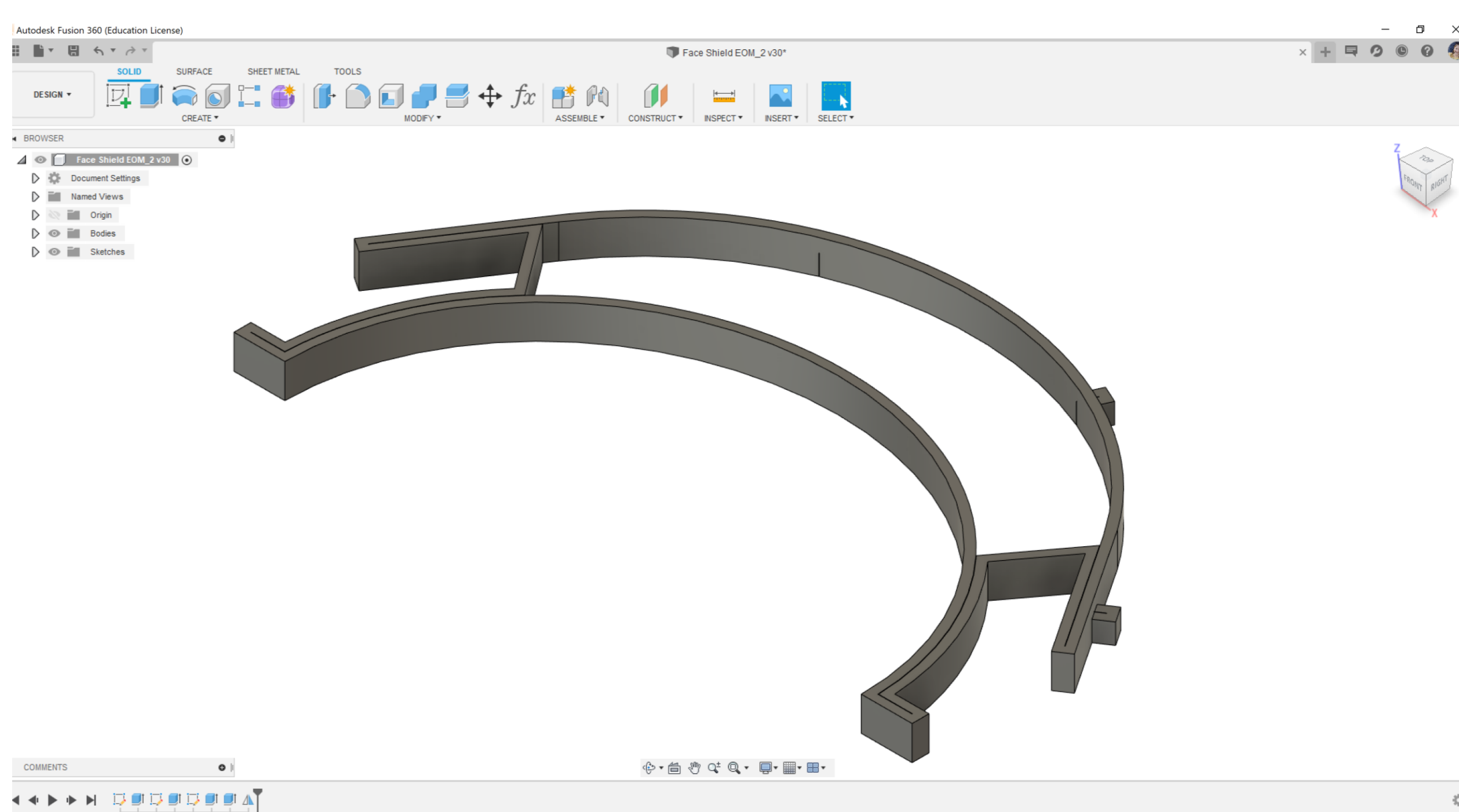
## Disadvantages

**Extrusion control more difficult**

- **More stringing**
- **Artefacts in part**

**Faster printing means more waste if it goes wrong**





## Designing in Fusion 360

**Parameter Driven**

**2.5 mm nozzle**



## First Test Print

**Printed in under 10 minutes**

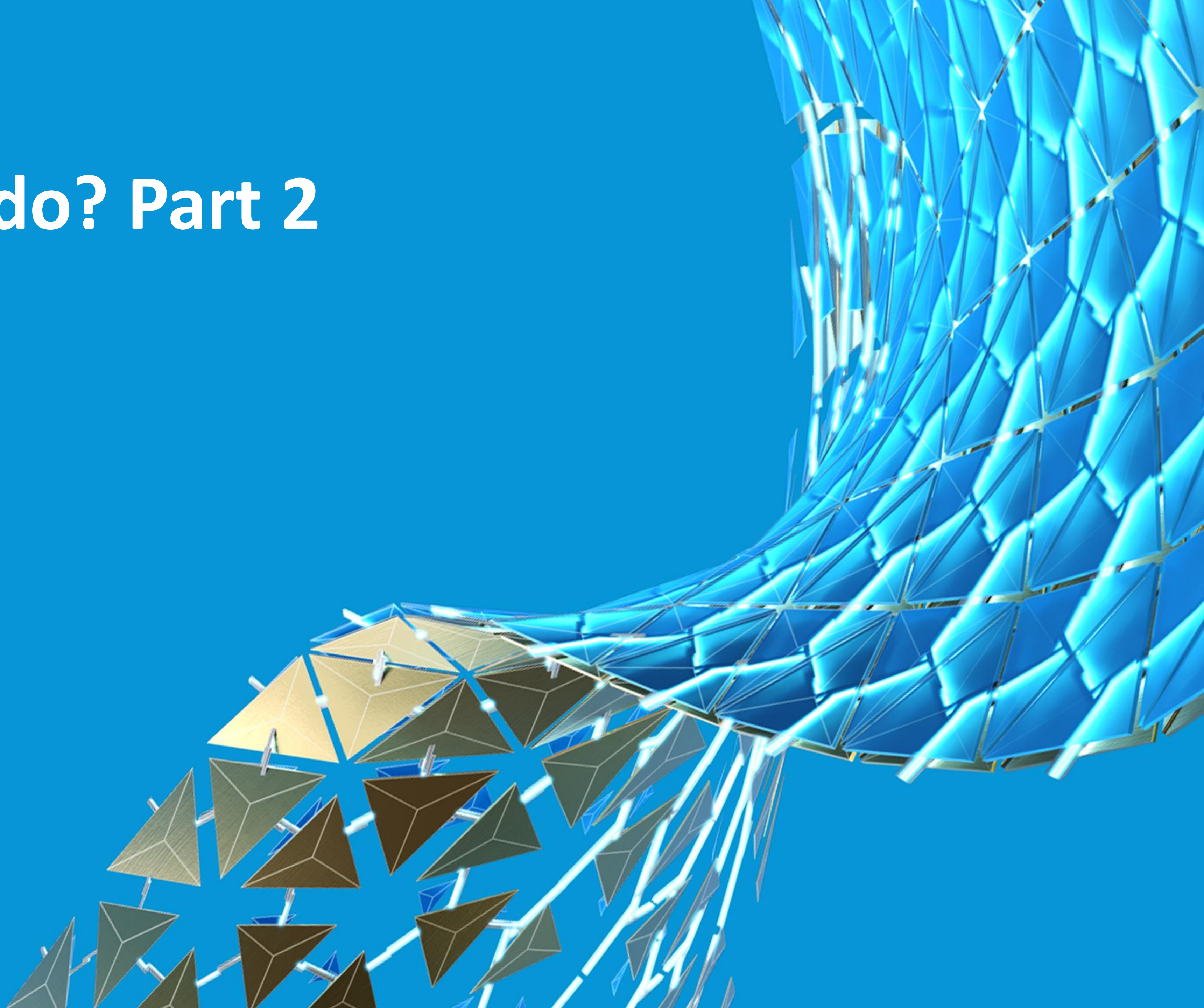
**Time saving of at least 1 hour compared to other designs**



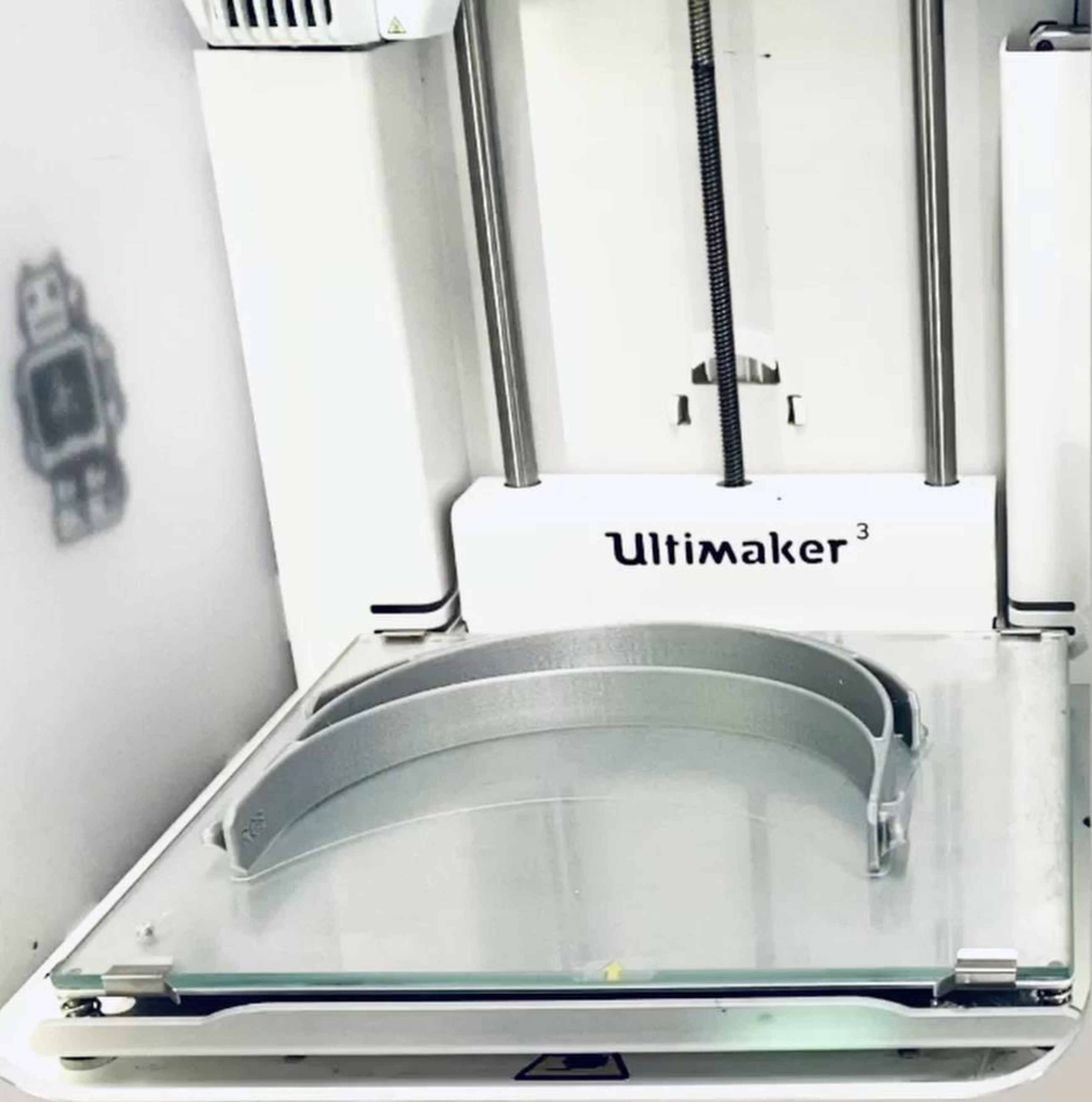




# What did we do? Part 2







WIFI USB

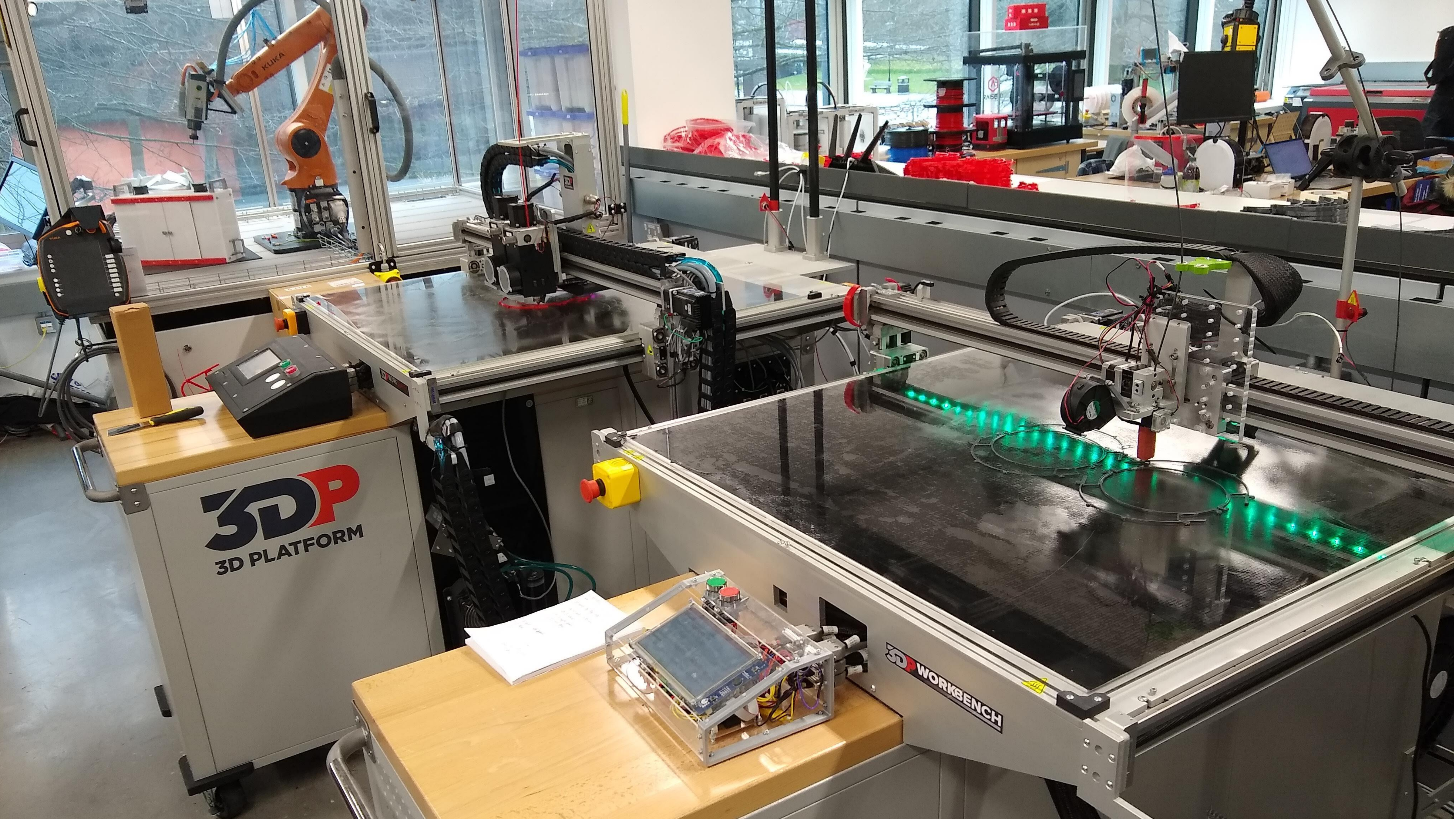
Print finished.  
Remove the print from  
the build plate.



WIFI USB

Print finished.  
Remove the print from  
the build plate.  
19°C



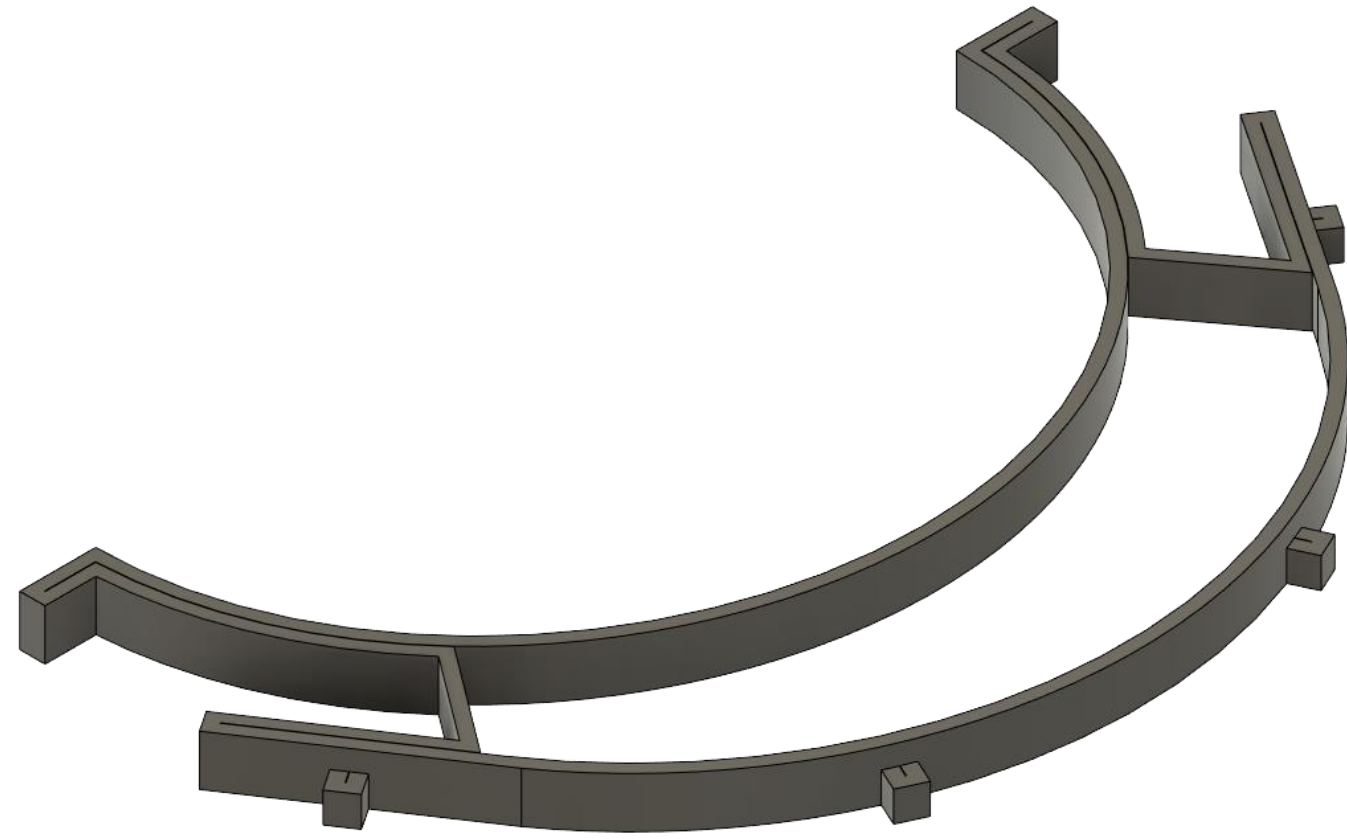


**3DP**  
3D PLATFORM

**3DP WORKBENCH**



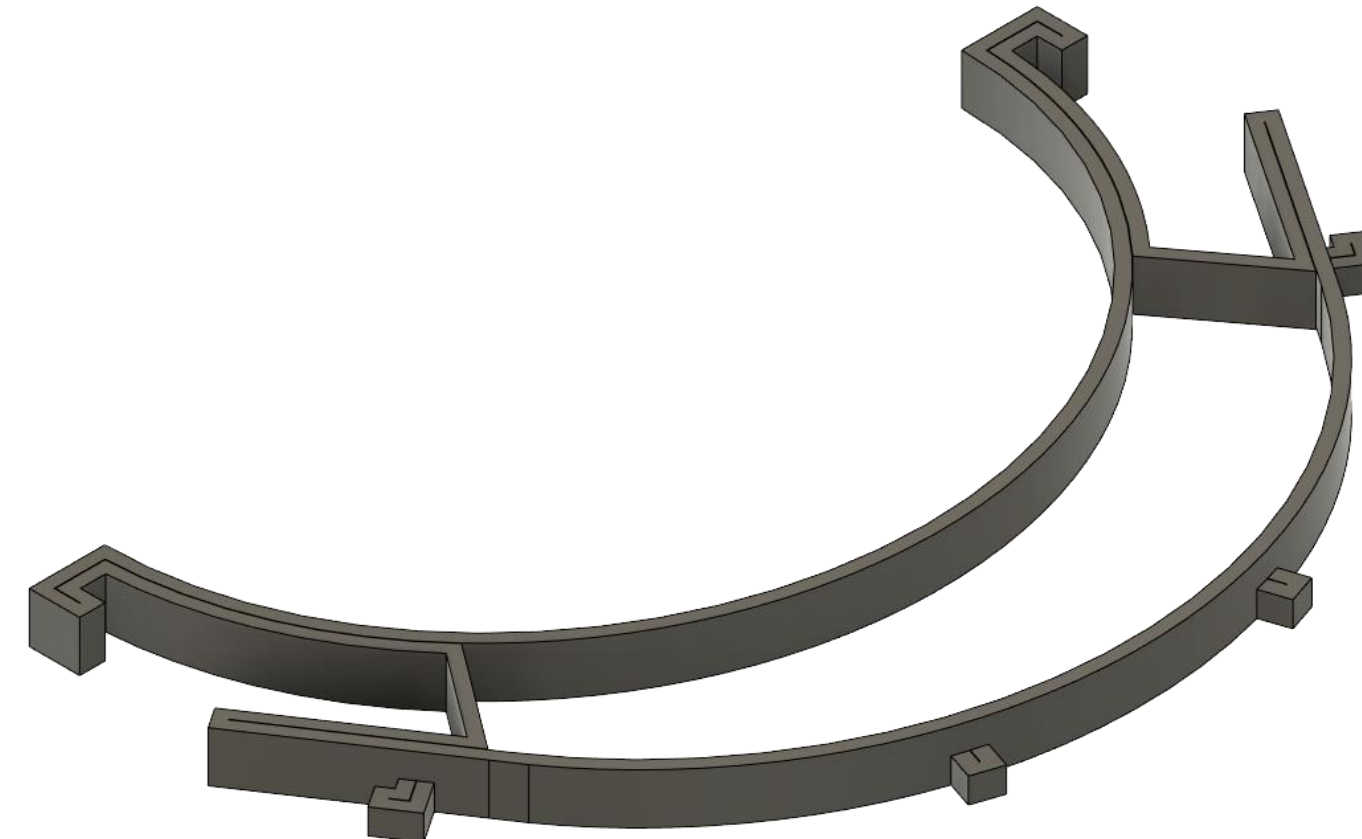
# Initial Design Iterations



**VERSION 1**

Attachment points too small

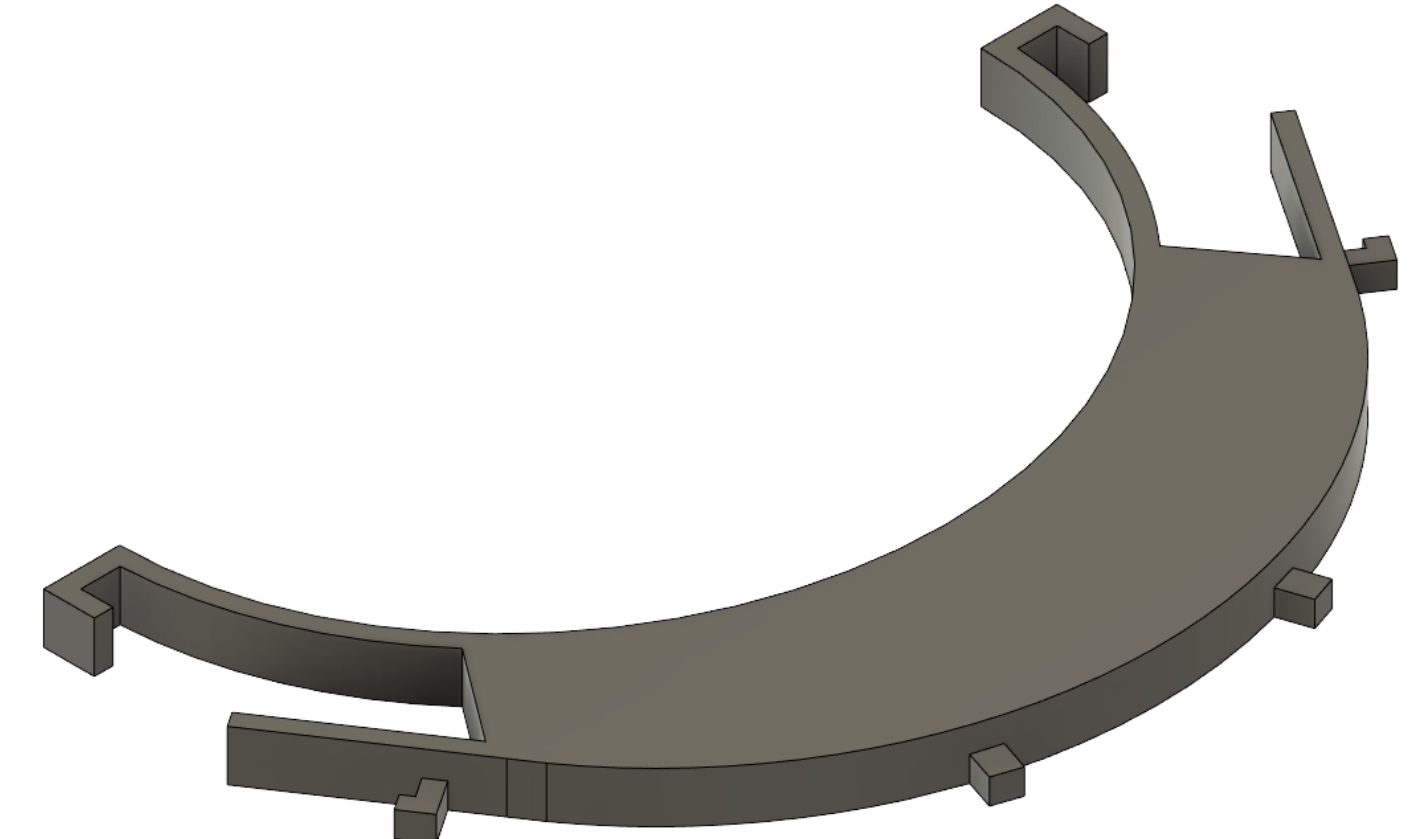
No where for strap to attach



**VERSION 2**

Added hooked outer attachment  
points for visor

Strap attachment designed

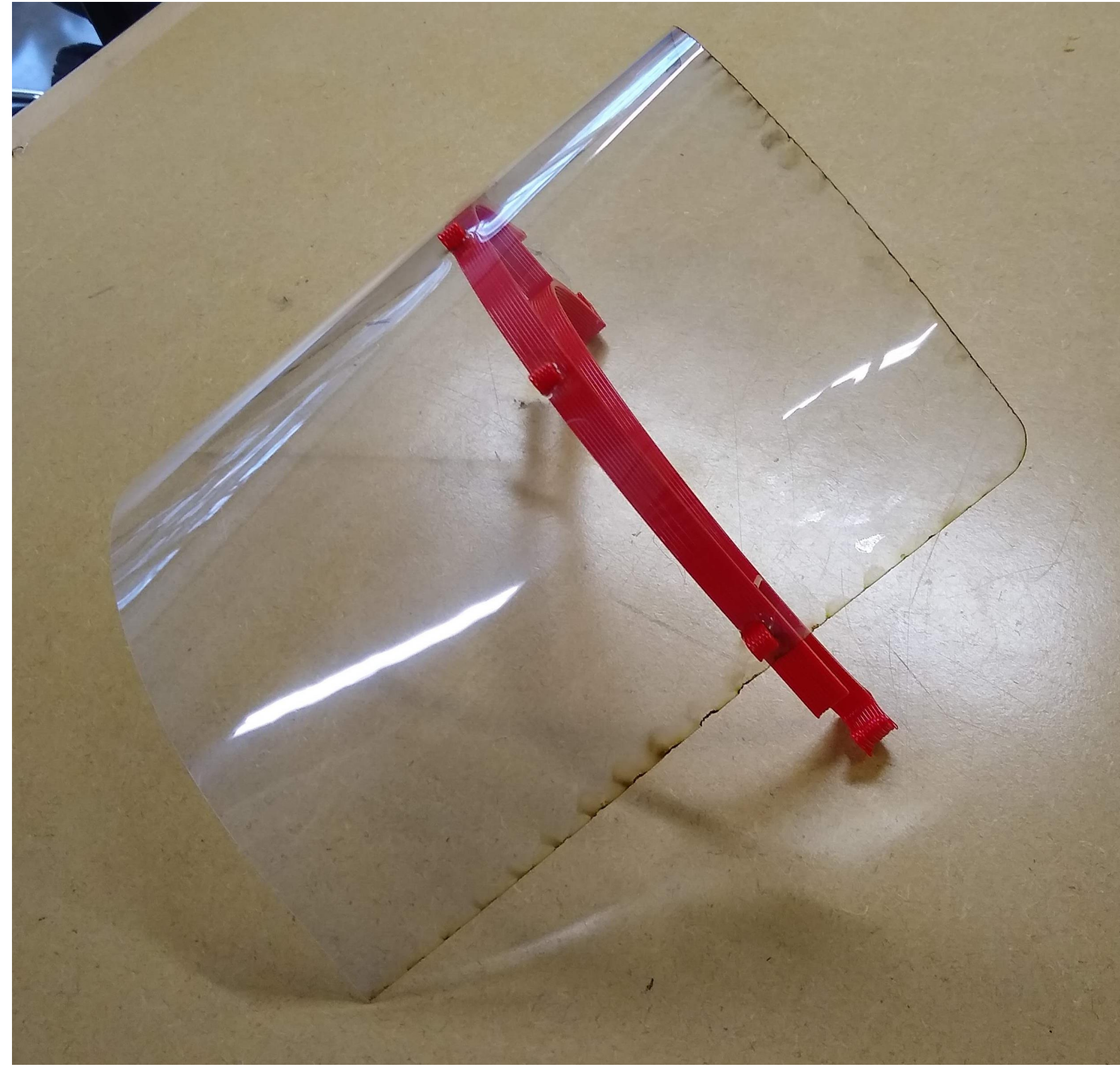


**VERSION 3**

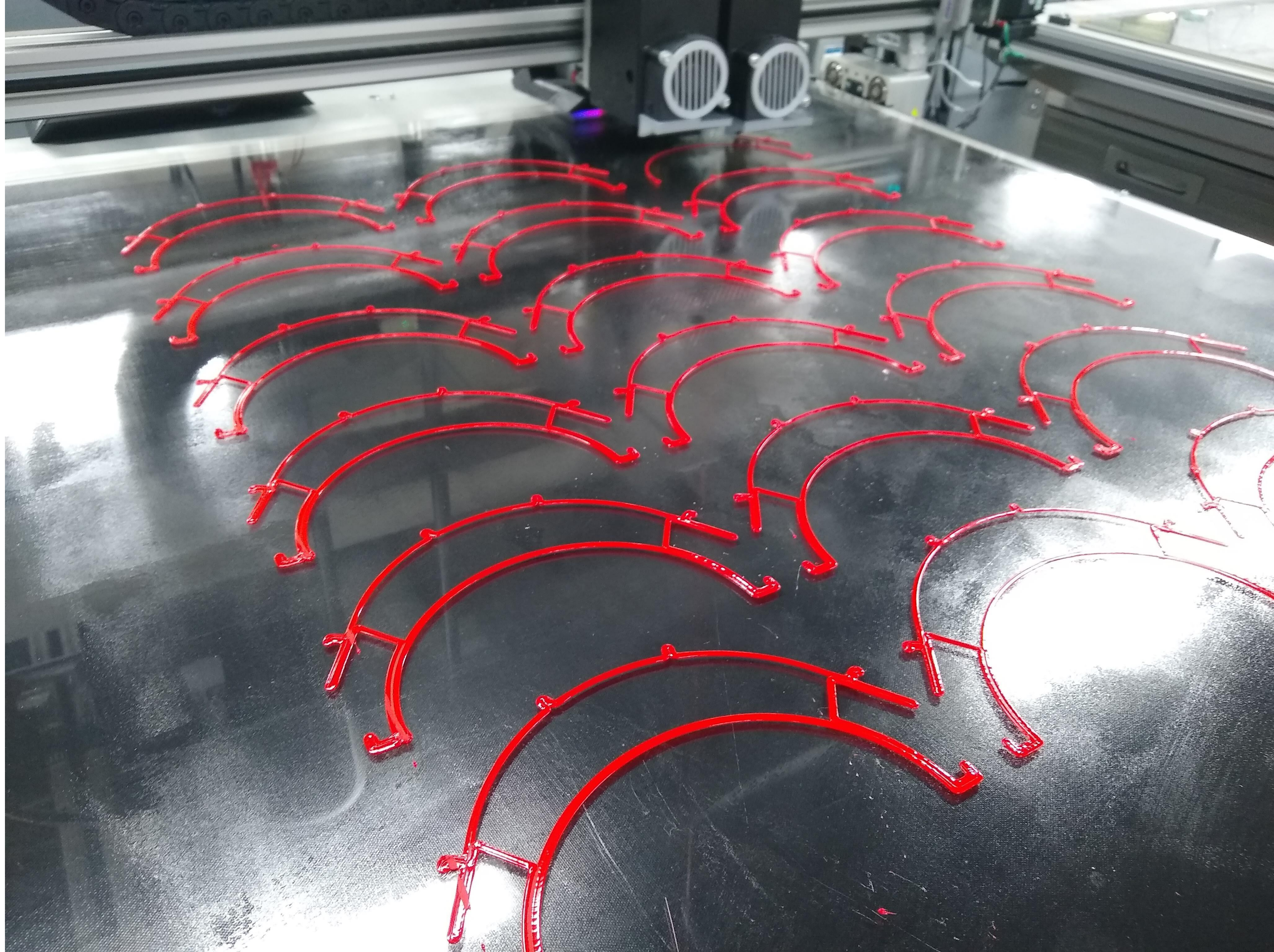
Redesigned for true vase  
mode



# Version 2

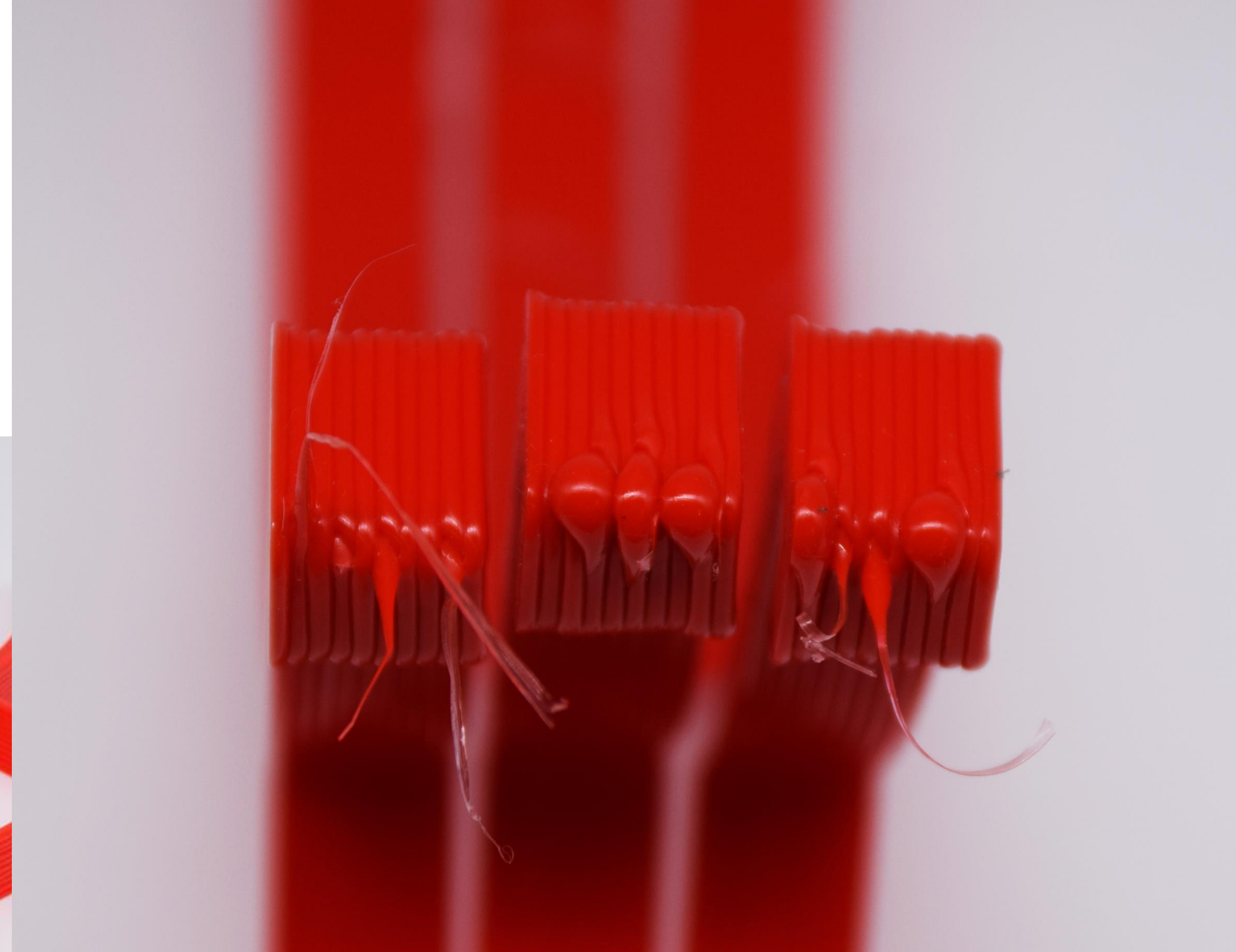






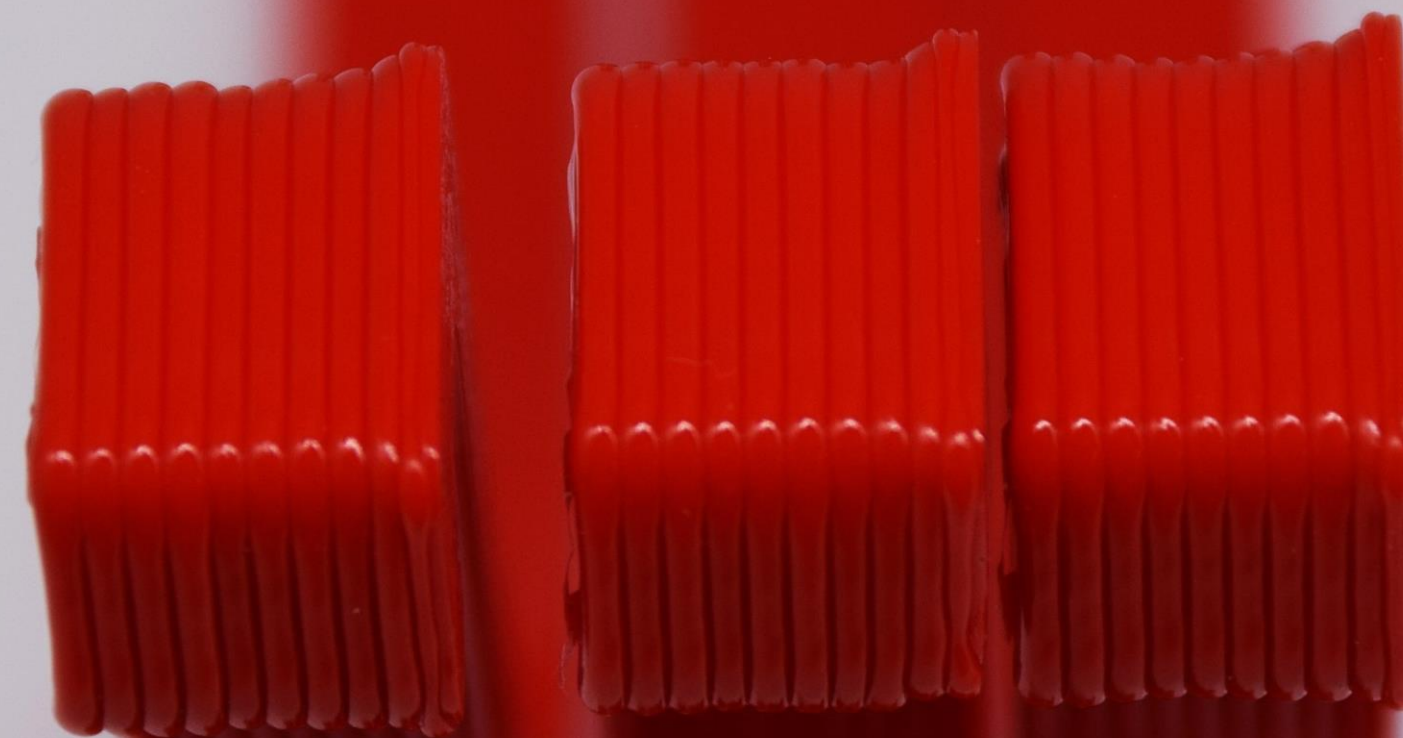
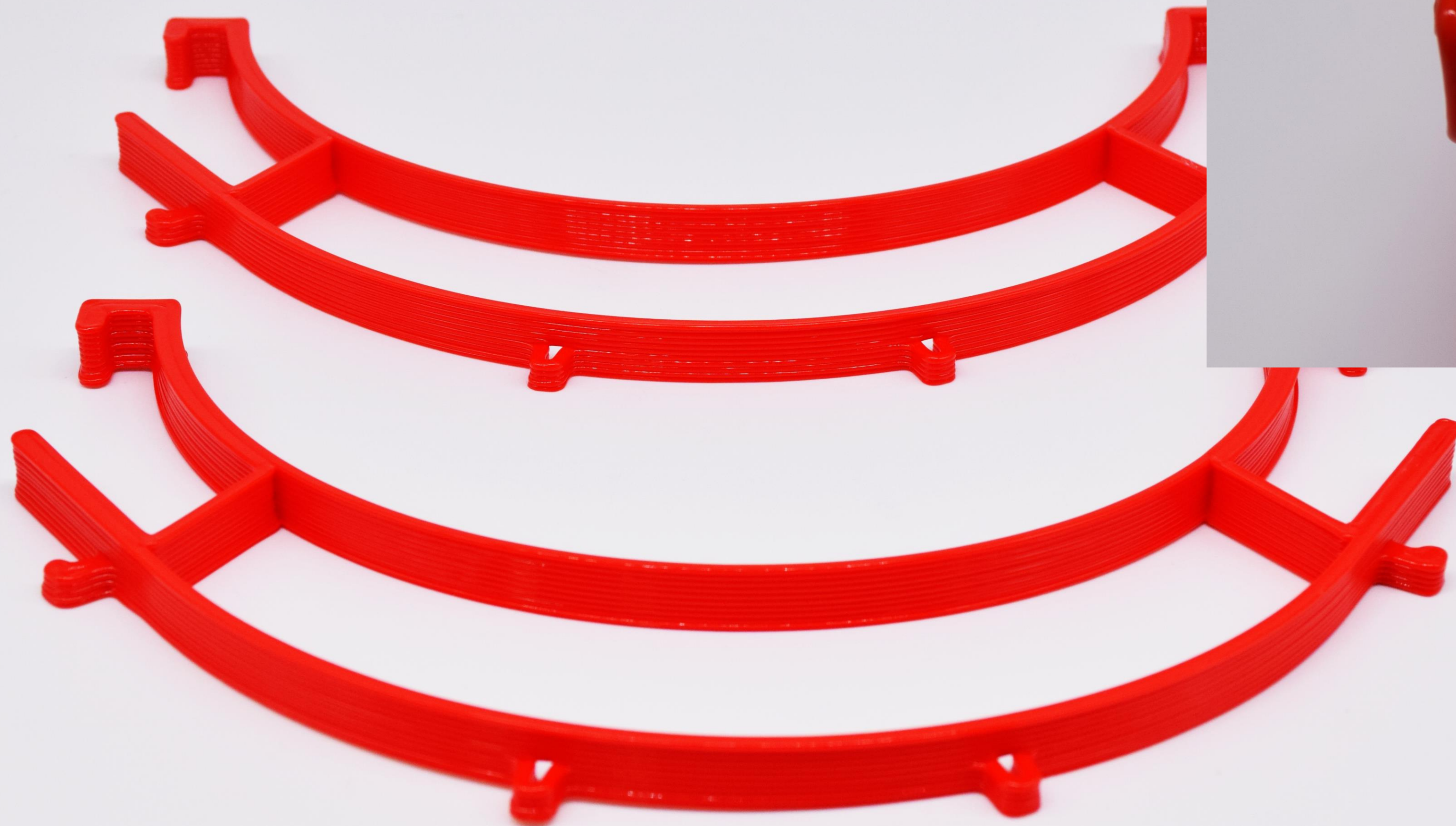


# Parallel Printing





# Sequential Printing





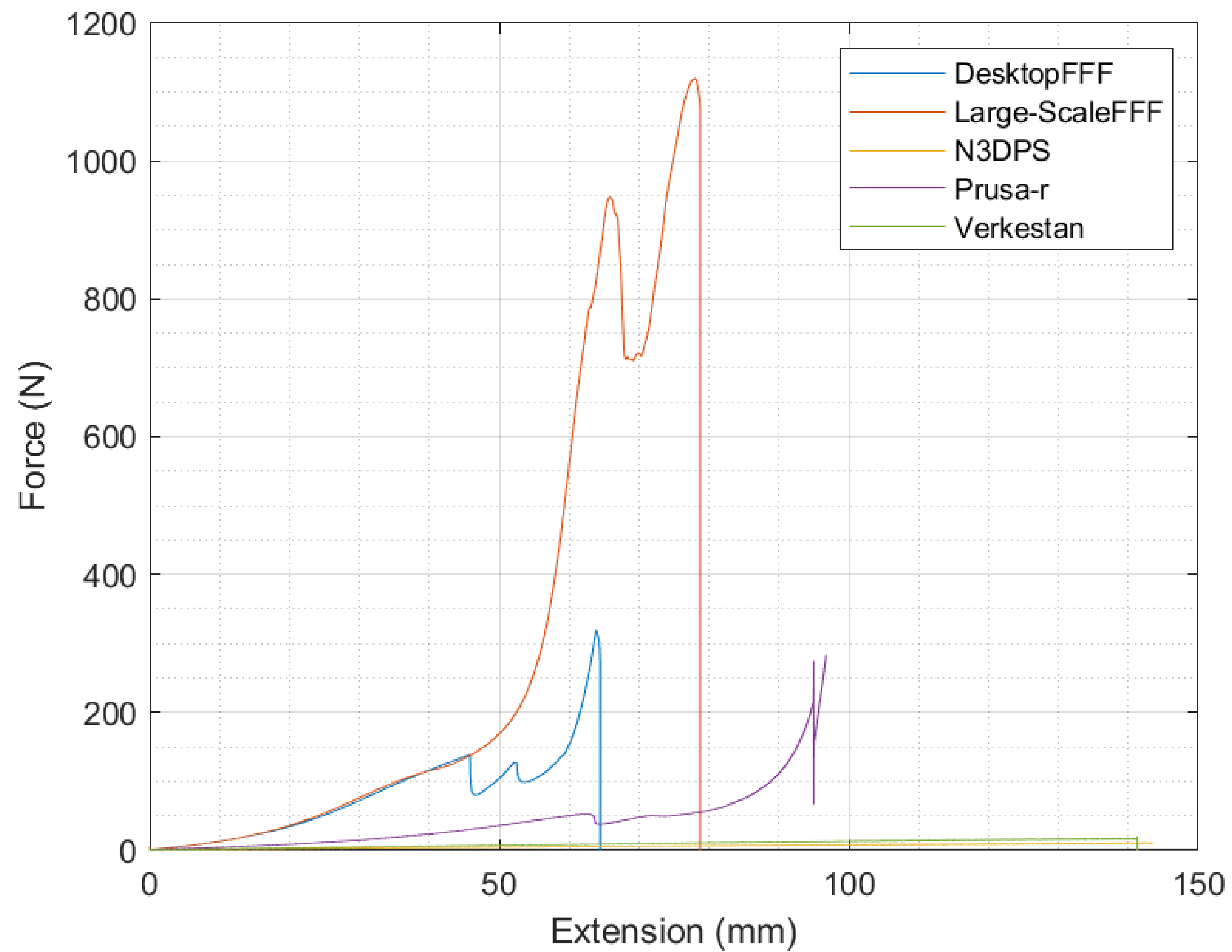
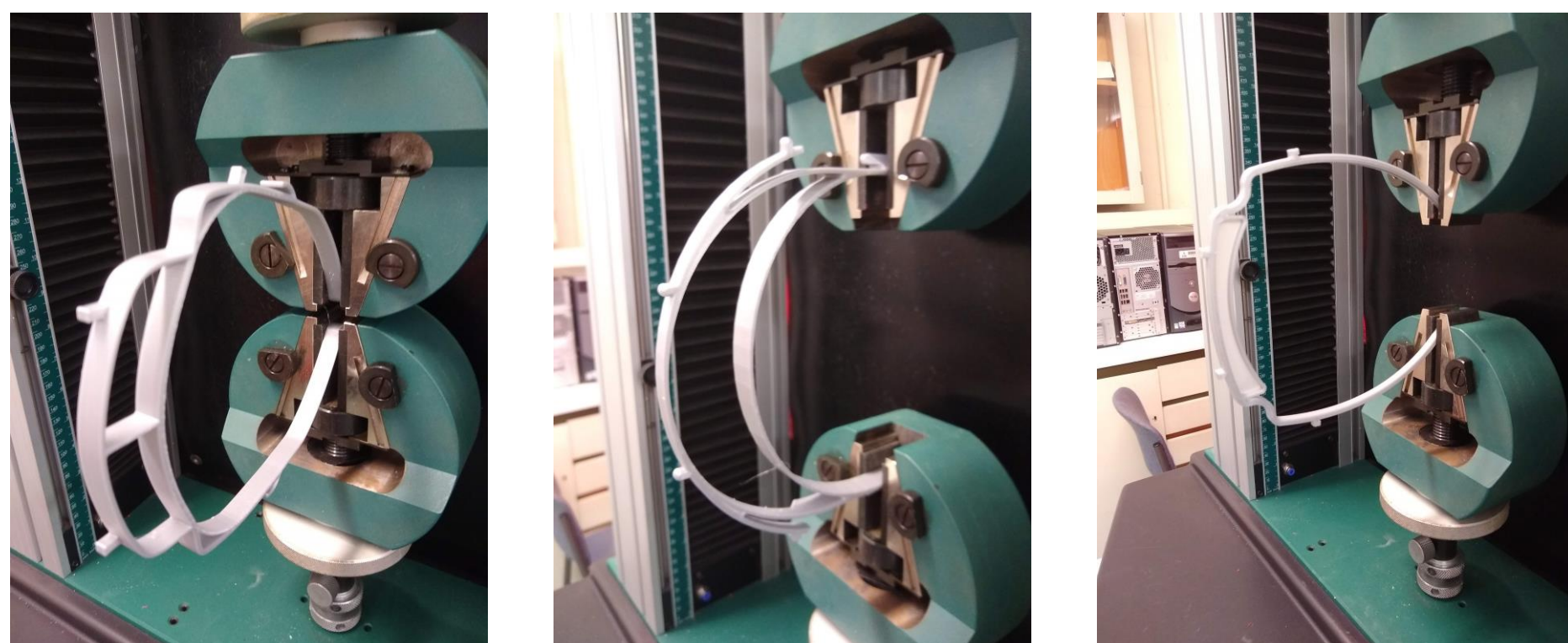
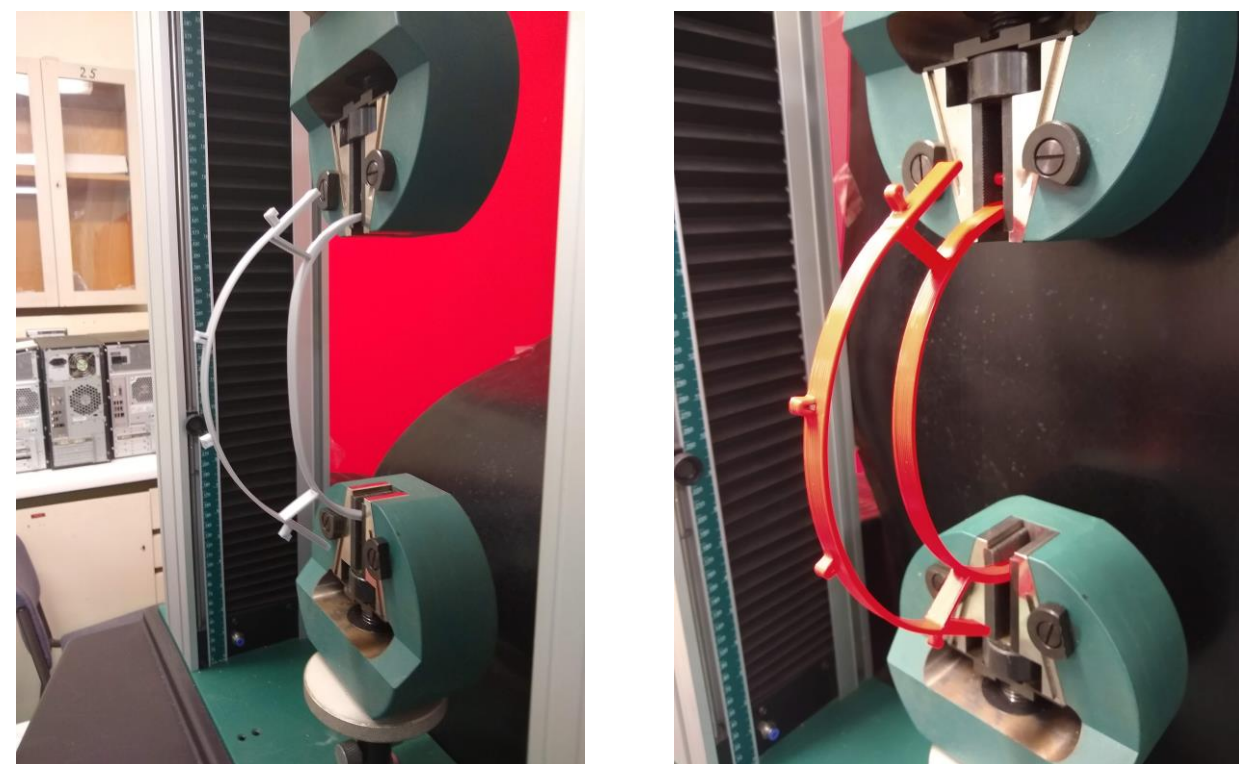
# 6<sup>th</sup> April

- Established successful print workflow
- Designed bottom reinforcement piece for large-scale
- Printing top ad bottom headband using 3DPs
- Production line set up
- Started distribution to the community free of charge
- Working flat out
- Using A4 report cover sheets with a 4-hole hole punch to create the holes
- Design with BSI for testing

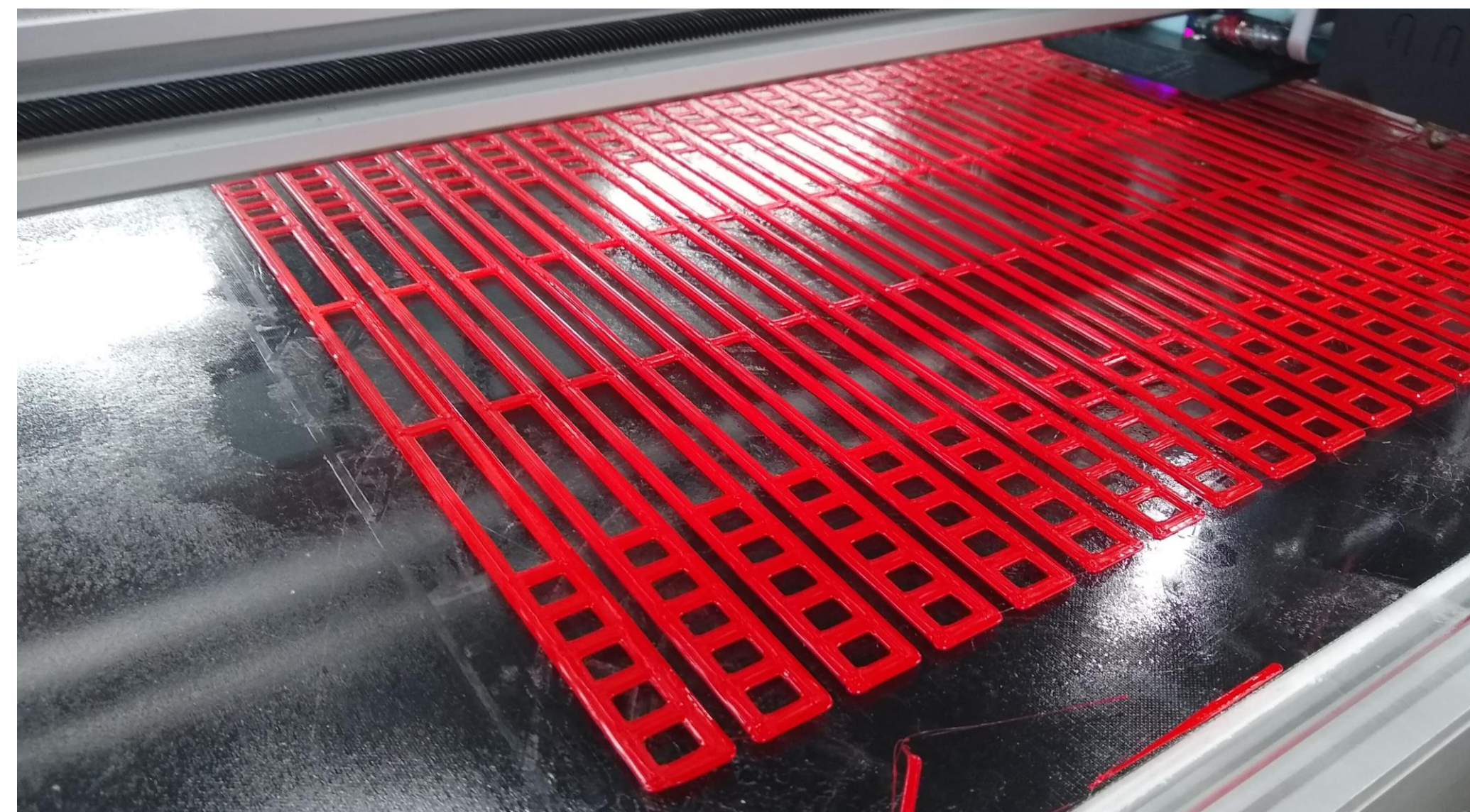
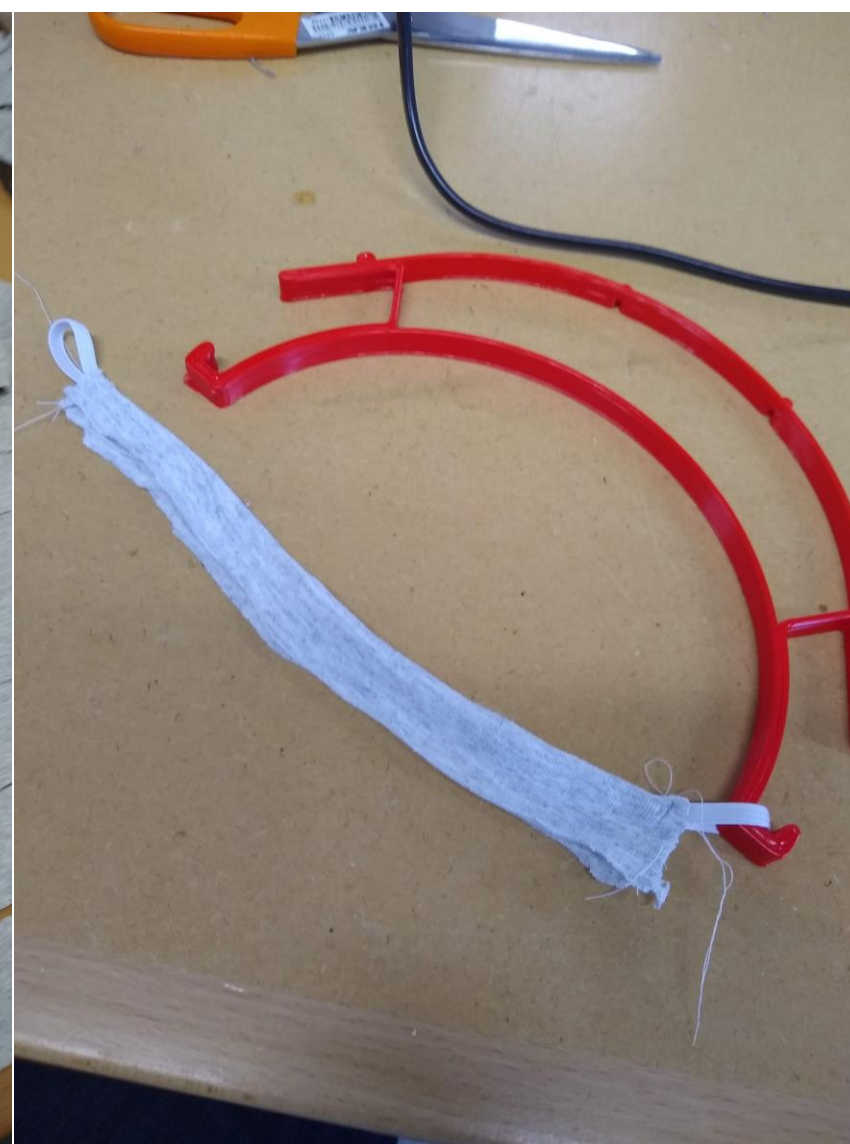
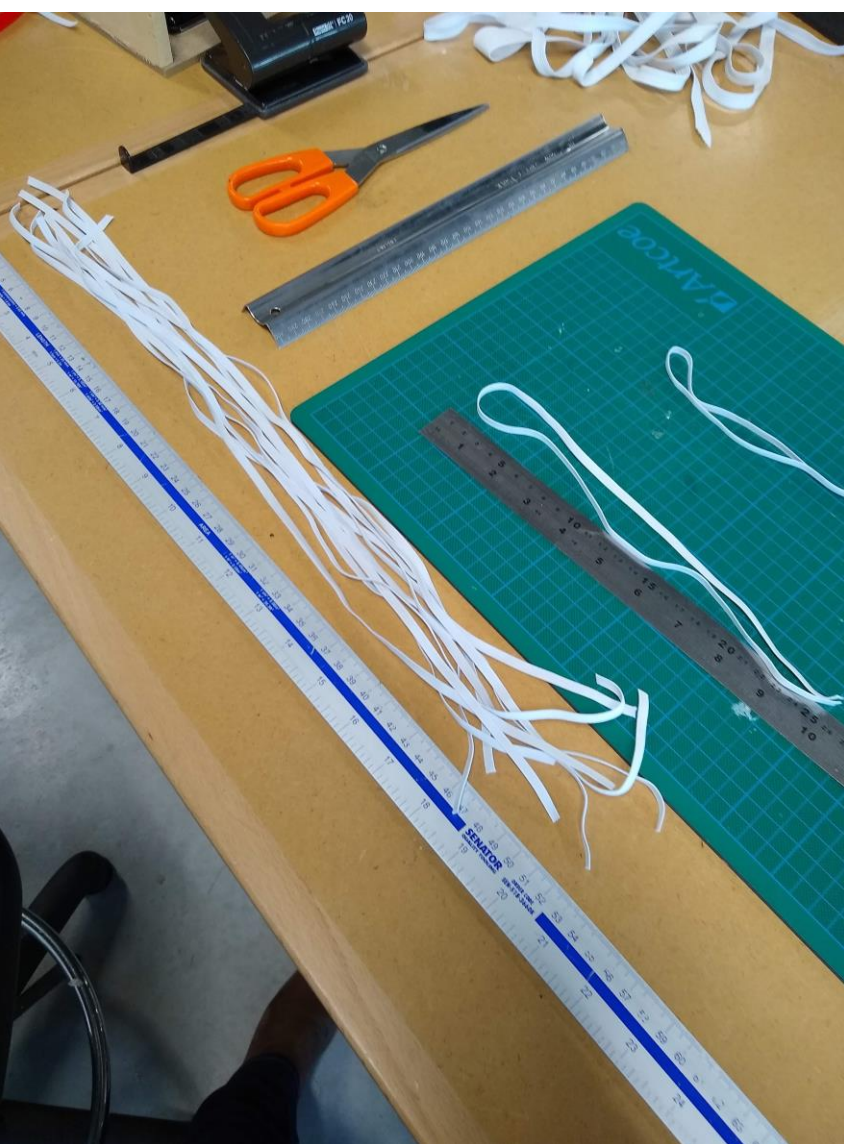




# Tensile Testing







## Elastic

**Slow to make**

**Hand skills**

**Using a sewing machine**

## 3D Printed Strap

**Print 64 in 1 hour**

**Formed hot off the bed into curve**

**Automated process**



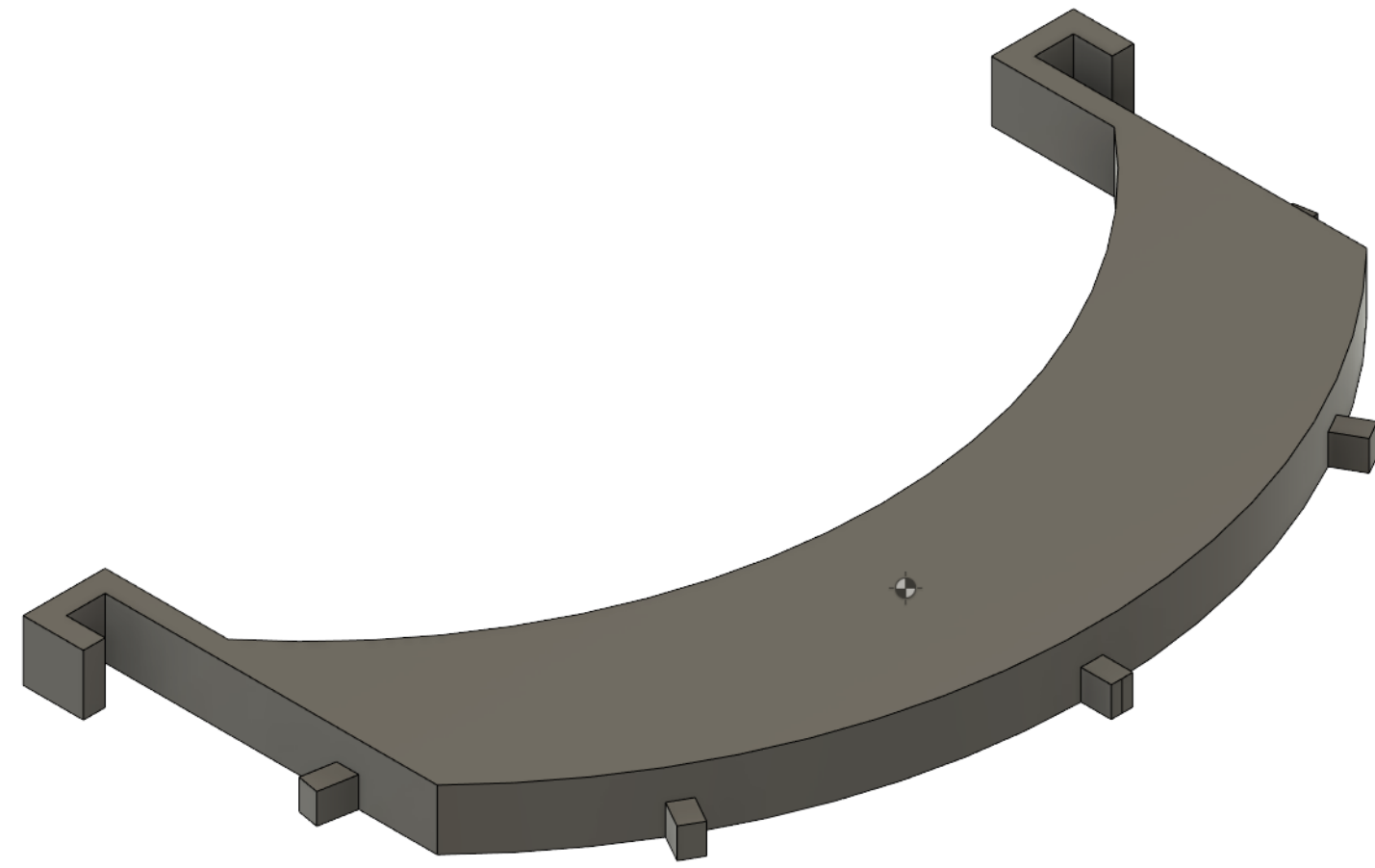
# BSI Testing

- Our A4 sheet just wasn't big enough
  - Needed to modify the headband to change the location of the visor
- Or
- Come up with a new supplier/solution for the visor

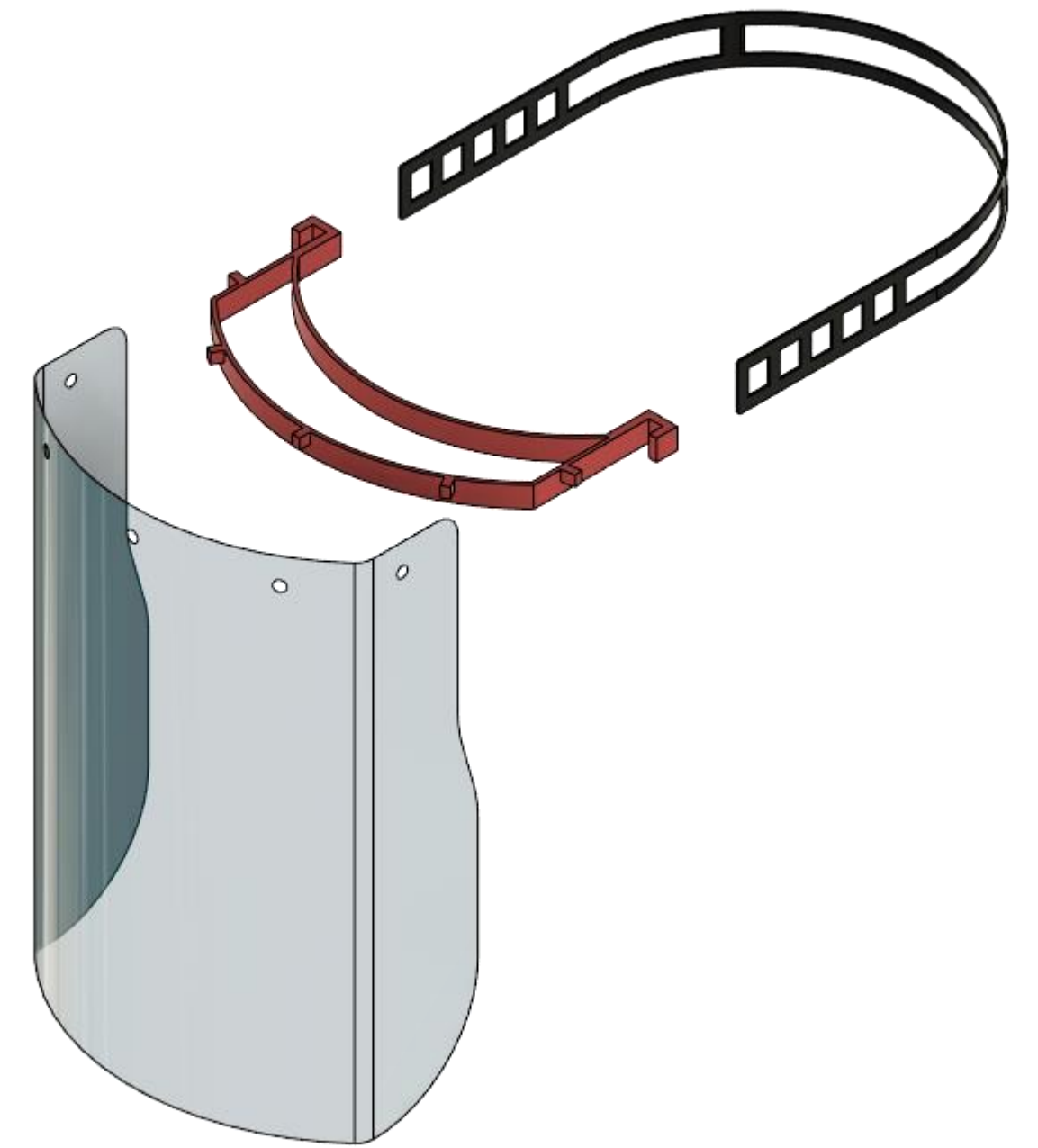
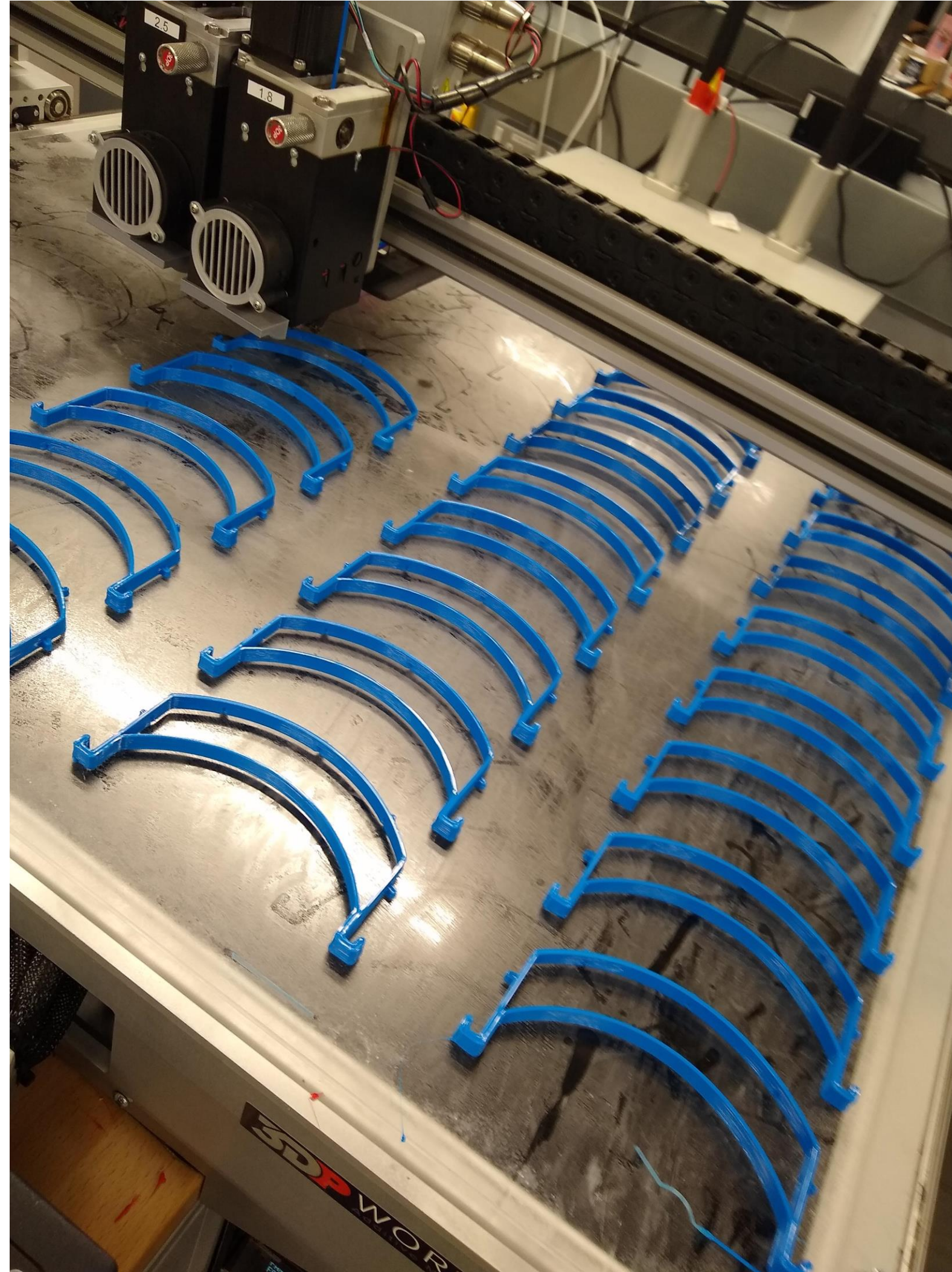




# Version 4



COMPLETE RE-DESIGN



NEW FACE SHIELD KIT



# Design Changes

- Narrower visor / more wrap
- Bottom reinforcement piece removed
- Longer visor
- 5 attachment points instead of 4
- Reduction in printing material
- Faster to print





# BSI Testing

- Our A4 sheet just wasn't big enough
  - Needed to modify the headband to change the location of the visor
- Or
- Come up with a new supplier/solution for the visor

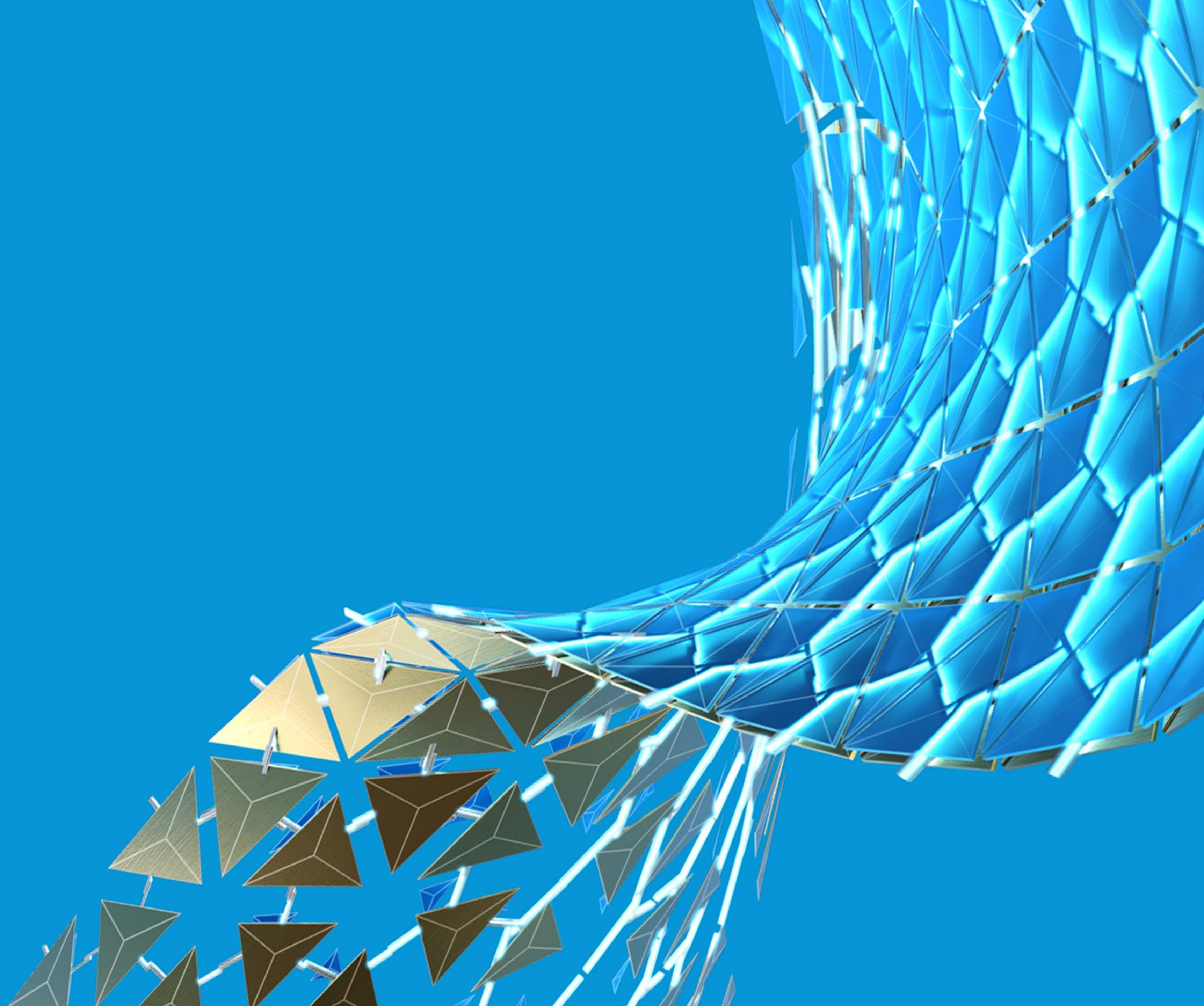




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# Conclusions





# Summary

## OBJECTIVE 1

Learn about the global maker's response to the COVID-19 crisis

## OBJECTIVE 2

Learn how Warwick University responded and helped using 3D printing

## OBJECTIVE 3

Learn how to print a PPE face shield in under three minutes

## OBJECTIVE 4

Learn about large-scale additive manufacturing



# Want More?

**REACH OUT ON MY SPEAKER / CLASS PAGE**

**READ MY PUBLISHED JOURNAL PAPER**

**BISHOP, Elizabeth G.; LEIGH, Simon James. Using Large-Scale Additive Manufacturing as a Bridge Manufacturing Process in Response to Shortages in Personal Protective Equipment during the COVID-19 Outbreak. International Journal of Bioprinting, [S.l.], v. 6, n. 4, p. 281, sep. 2020**

**<http://ijb.whioce.com/index.php/int-j-bioprinting/article/view/281/pdf>**

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**Stressing Out: Simulation Workspace in Fusion 360**

**Fusion 360 and 3D Printing: Tips and Tricks for a Successful Workflow**





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