

3D Printing: Effectively Utilizing the Markforged

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wait a minute, who are you?

- 971 Class of 2020
- Assembly Lead
- Joined the summer before Junior year
- Did a lot of 3D printing last year, i.e. starting prints at strange hours of the day and being Queen of the USB Drive



I Sure Hope You Know What 3D Printing Is

- Additive manufacturing
- Extrudes melted filament out of a nozzle in layers
- The material can be put down in any shape specified by a CAD file



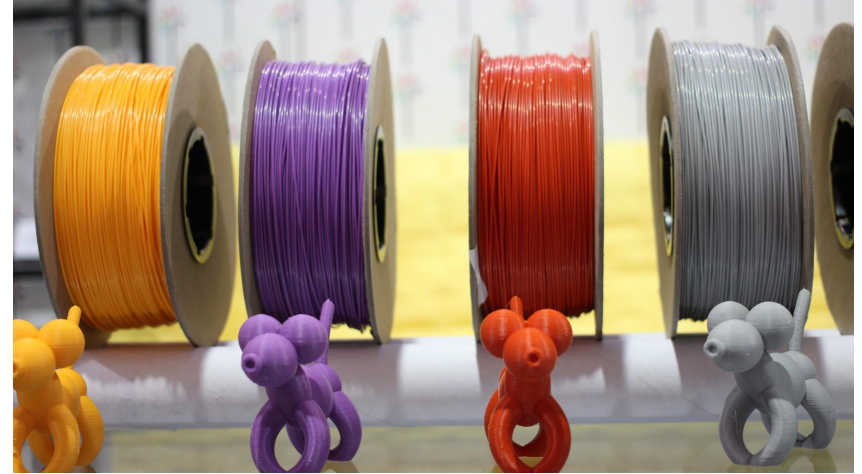
“Traditional” 3D Printing Has Upsides and Downsides

UPSIDES

- Entry-level CNC manufacturing
- Less restrictions on part shape
- Can make complicated parts in-house

DOWNSIDES

- Still takes hours to print small parts
- Traditional PLA material is not very strong and can make messy prints
- Size limited to printer bed



The Markforged

Desktop Mark Two



this bad boy...



Stronger Material, Stronger Parts

Markforged Onyx: combination of nylon and carbon fiber

- Super stiff
- More dimensionally accurate
- Clean prints with great surface finish

Kevlar: reinforcement material added between layers for even stronger parts



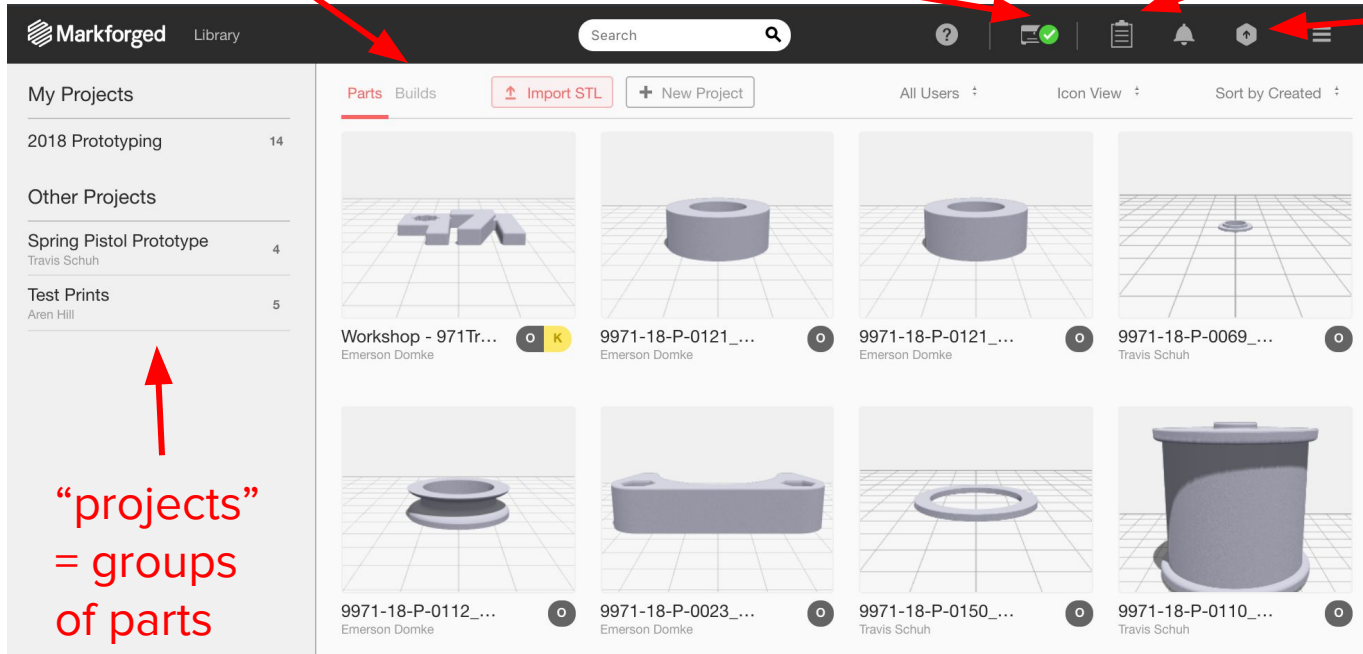
Eiger: Editing Part Properties and Starting Prints

see builds

what is the printer doing now?

printer history

import new part



↑
“projects”
= groups
of parts

Parts: imported
CAD files in STL
format

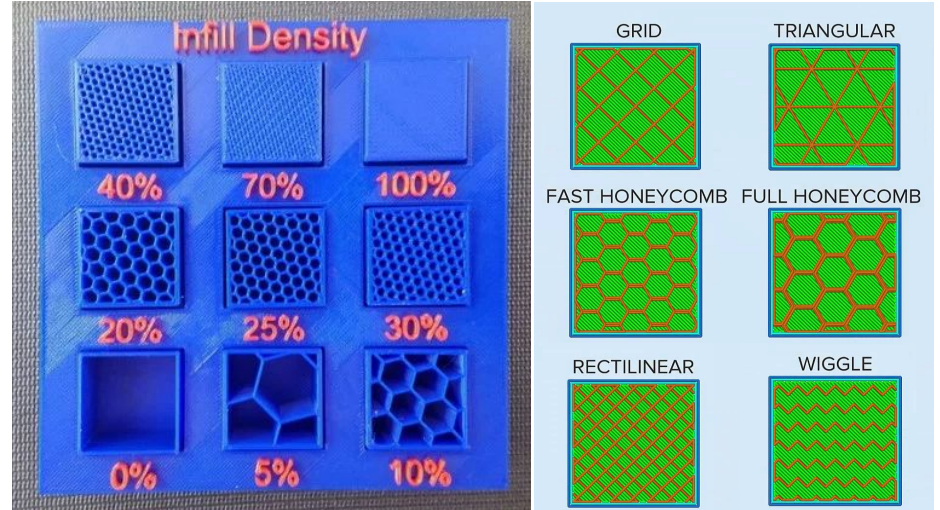
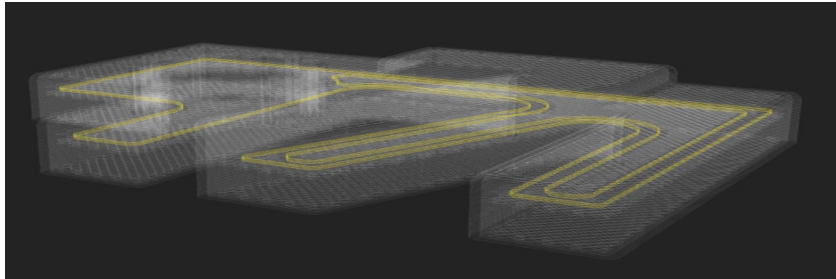
Builds: groups
of parts ready to
print



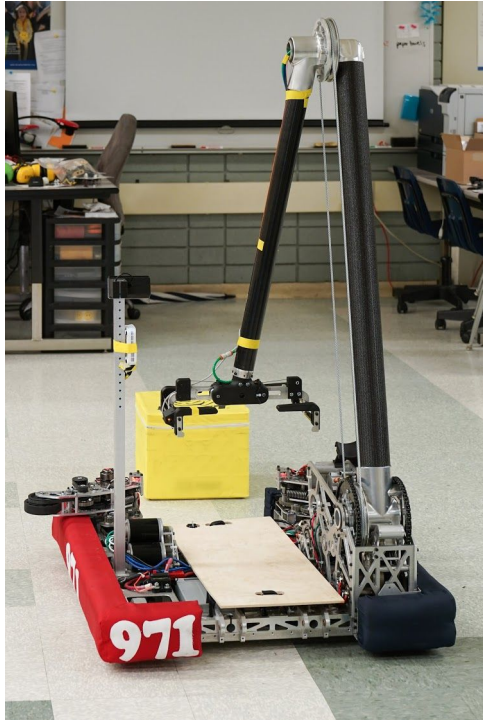
Change Infill Based on Part Purpose

Fill: can adjust shape and density based on the forces that parts need to withstand/exert

Reinforcements: Layers of Kevlar/
Fiber for extra strength



Example Part 0- fiber reinforcements



971-18-P-0108_Printed Claw Body
Emerson Domke

Get Support Visibility 2D 3D

Part Stats

Print Time	1d 18h
Onyx	215.33 cm ³
Kevlar	11.28 cm ³
Material Cost	73.21 USD

This model is displayed at lower resolution to ensure performance.


Warning
Some layers have thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.

Select one or more layers to view

Materials

Example Part 1- default fill

Finger_v1-Boss-Extrude1
James Doherty

Part Details 


Dimensions
164.0mm x 41.7mm x 25.4mm

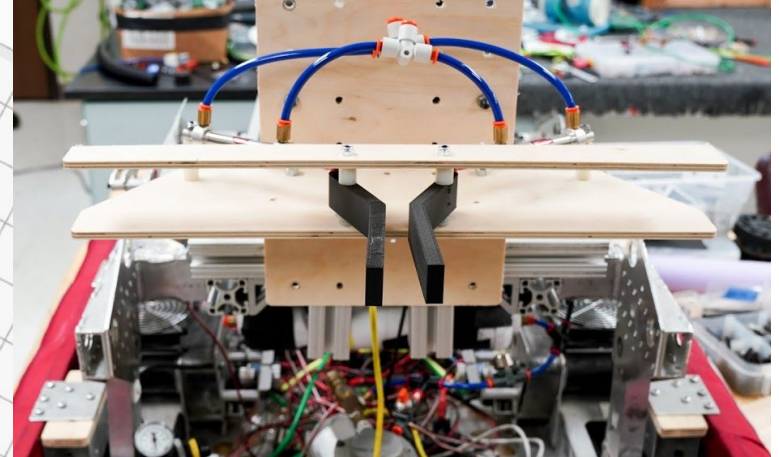
Print Time
2h 25m

Material Cost
4.77 USD

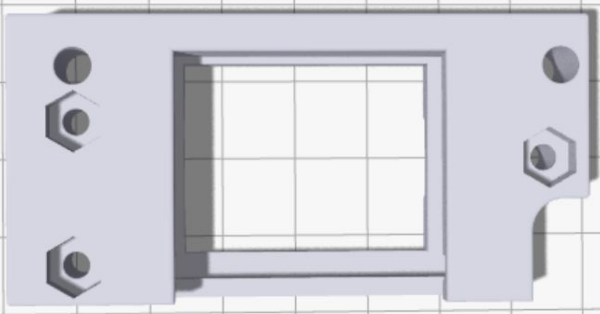
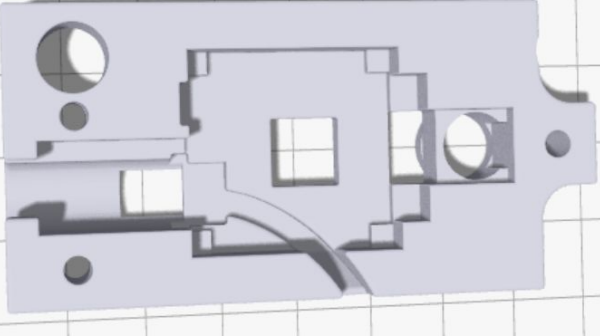
Final Part Mass
23.84g

Plastic Volume
20.21 cm³

Versions 



Example Part 2- heavy fill

JeVois Camera Mount Front V6 Travis Schuh	
Part Details ^	
Dimensions 35.0mm x 70.5mm x 12.1mm	
Print Time 3h 37m	
Material Cost 3.37 USD	
Final Part Mass 13.94g	
Plastic Volume 14.28 cm³	
Versions ^	



Example Part 3- heavy fill

Roller Suction Cup Lip 16 - Angled Flower Foam

Travis Schuh

Part Details

Dimensions

114.3mm x 114.3mm x 24.8mm

Print Time

11h 31m

Material Cost

12.96 USD

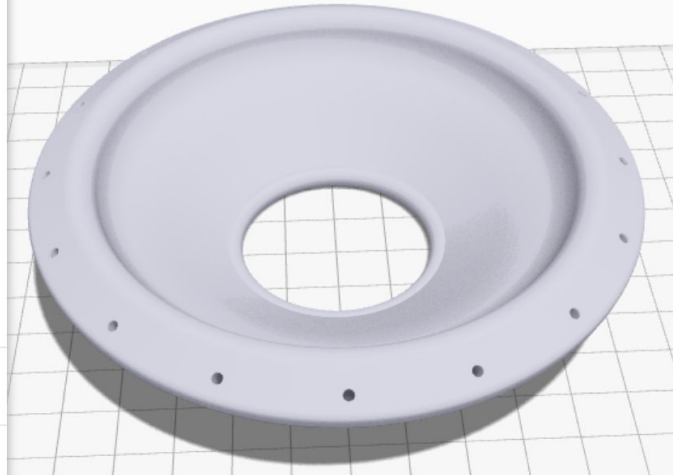
Final Part Mass

41.26g

Plastic Volume

54.87 cm³

Versions



Example Part 4- solid fill

971-19-P-0120_Timing Belt Clamp Top
Emerson Domke

Part Details ^

Dimensions
25.4mm x 65.8mm x 10.1mm

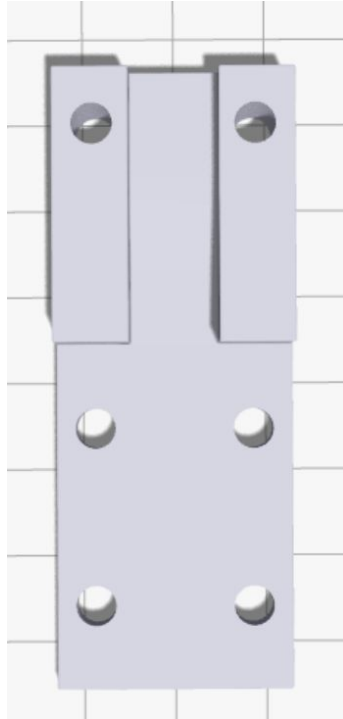
Print Time
1h 58m

Material Cost
2.25 USD

Final Part Mass
11.24g

Plastic Volume
9.53 cm³

Versions v



971-19-P-0118_Timing Belt Clamp
Emerson Domke

Part Details ^

Dimensions
50.2mm x 25.4mm x 6.4mm

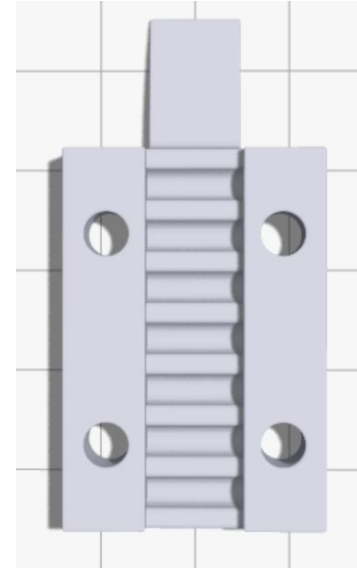
Print Time
1h 19m

Material Cost
1.23 USD

Final Part Mass
6.16g

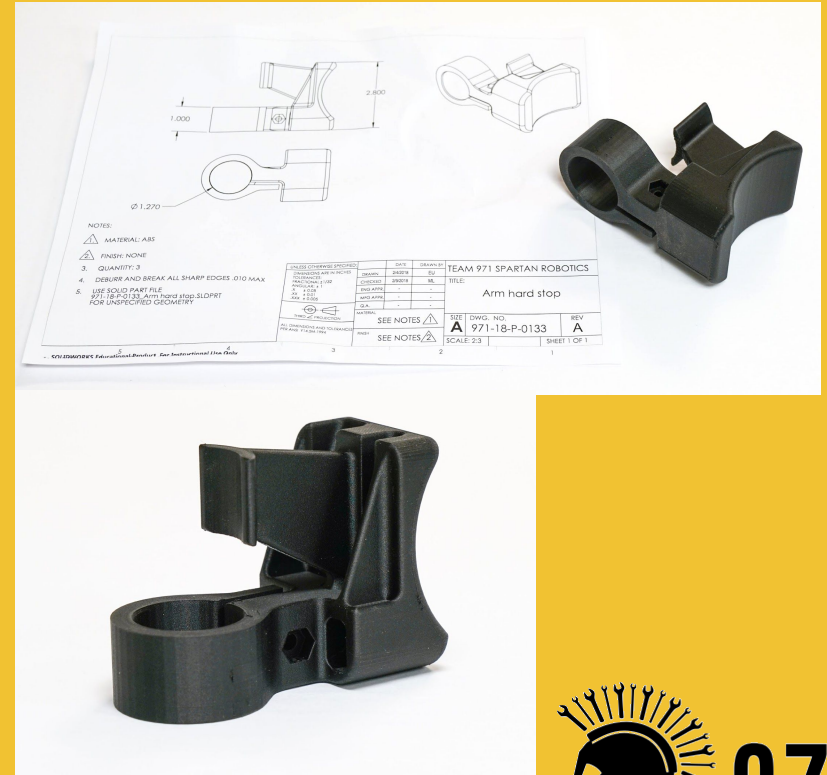
Plastic Volume
5.22 cm³

Versions v



Workflow

971's system for taking a part from CAD to assembly



CAD → Print

Preparing Parts for Printing

1. Export STL from Solidworks, import to Eiger
2. Work with part designer to set part fill and supports
 - a. Are you prioritizing strength or speed?
3. Using Fiber?
 - a. Where? How much?
4. Get checked by an Eiger account holder (Kayla, Travis, or Aren)



CAD → Print

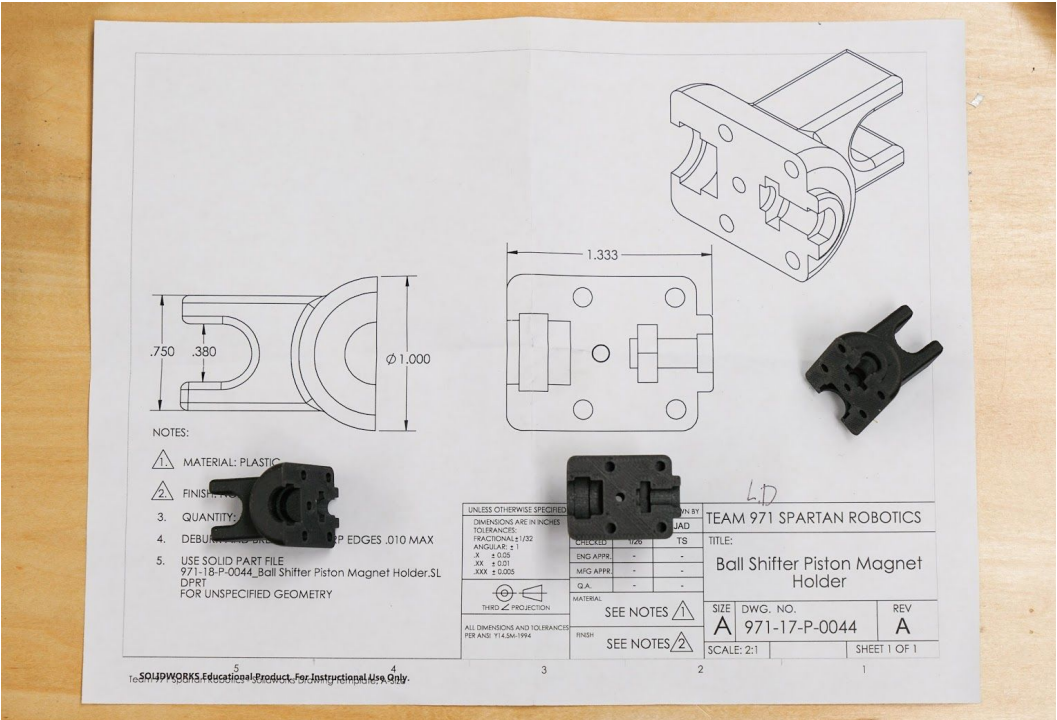
Printing a Finished Part

1. Clear/glue bed and start from Eiger or printer itself
2. When print is done, carefully take parts off the print bed
3. Remove any support & wipe off glue
4. Put in basket of printed parts to be kitted underneath printer



Drawings and Inspection

Give 3D printing the same level of care and organization as other manufacturing processes.



Optimization

MAXIMUM EFFICIENCY!
controlling factors that affect
print time



printing en masse

Basic Strategies for More Efficient Print Timing

Ideal print time: Instant.

Realistic print time: Hours. Many hours.

- Intentional part design
- Minimize printing supports by setting orientation
- Schedule prints



When To Print vs. When Not To Print

- How simple would the part be to machine?
- What material would be ideal?
- How large is it? Would it take too long to print vs. other manufacturing?



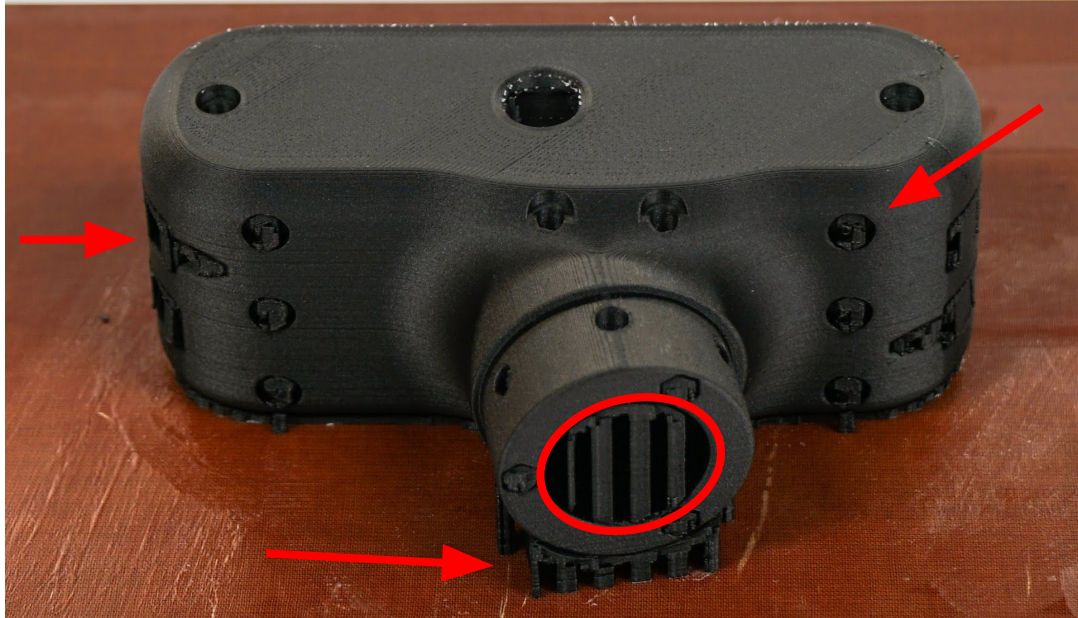
Intentional Part Design

- Keep supports in mind— don't add unnecessary floating edges or overhang
- Don't put material where it doesn't need to be. Take advantage of additive manufacturing!
- Add fillets/chamfers on edges for better strength and print quality



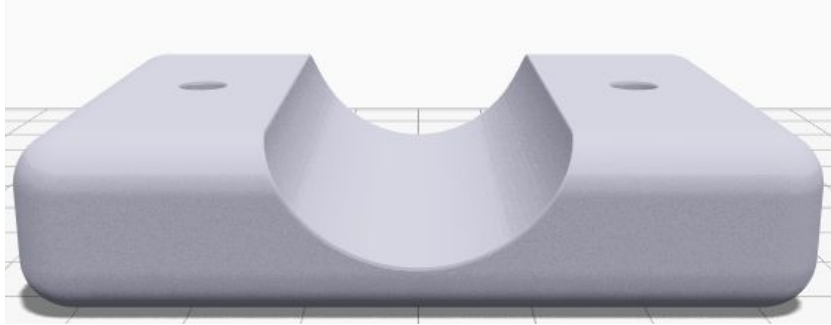
Printing Supports

Layers of material cannot be printed into thin air, so printers create scaffolding.

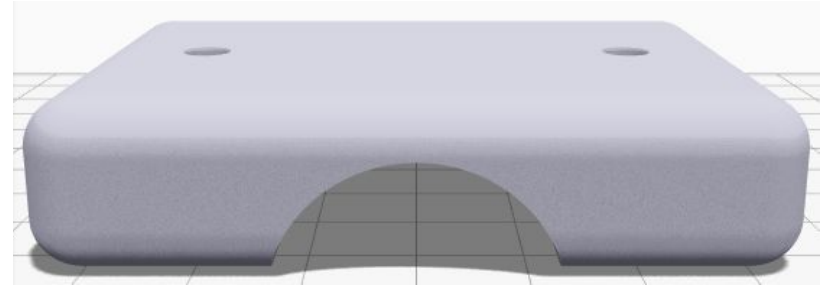


Print Orientation

Print time: 3h 53min



Print time: 4h 20min



Scheduling Prints to be Ready “Sooner”

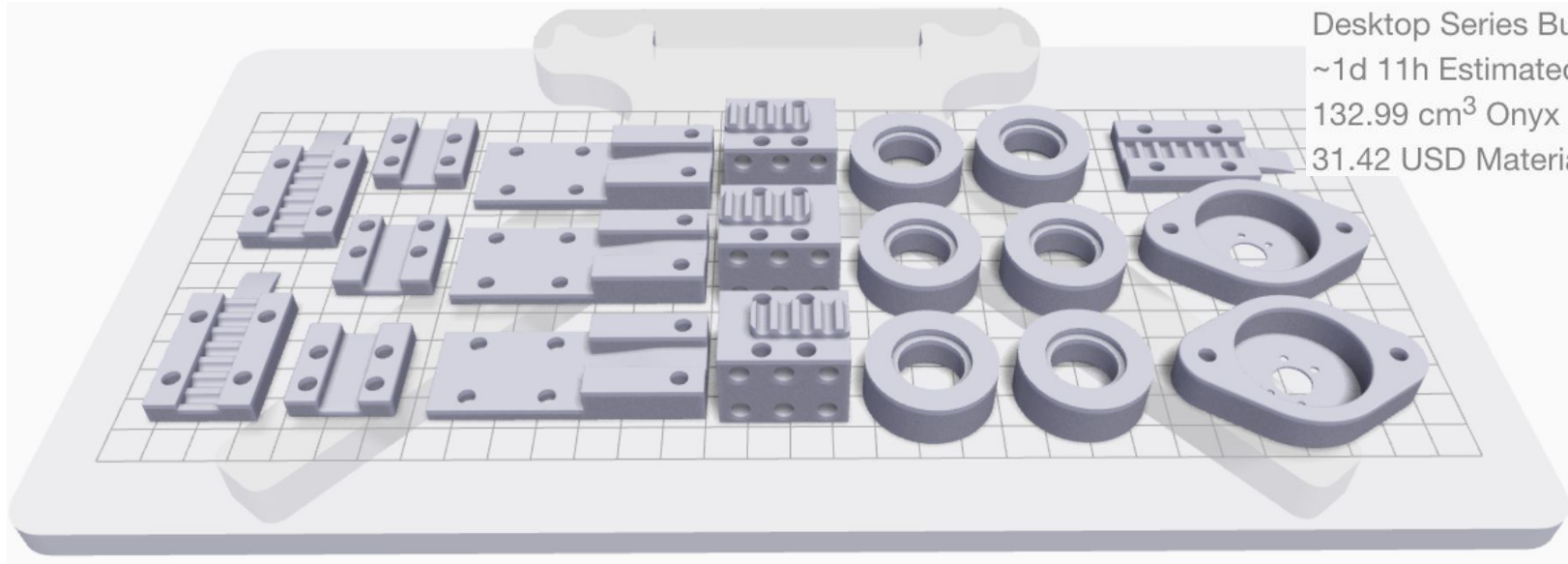
Best possible management means printers run during off times and have parts ready before/during meetings.

How to come close:

1. Prioritize parts
2. Know beforehand the estimated print/end times
3. Schedule parts on a spreadsheet
4. Strategically arrange Eiger builds
5. Leave one printer open for “panic prints”



Scheduling Parts into Eiger Builds



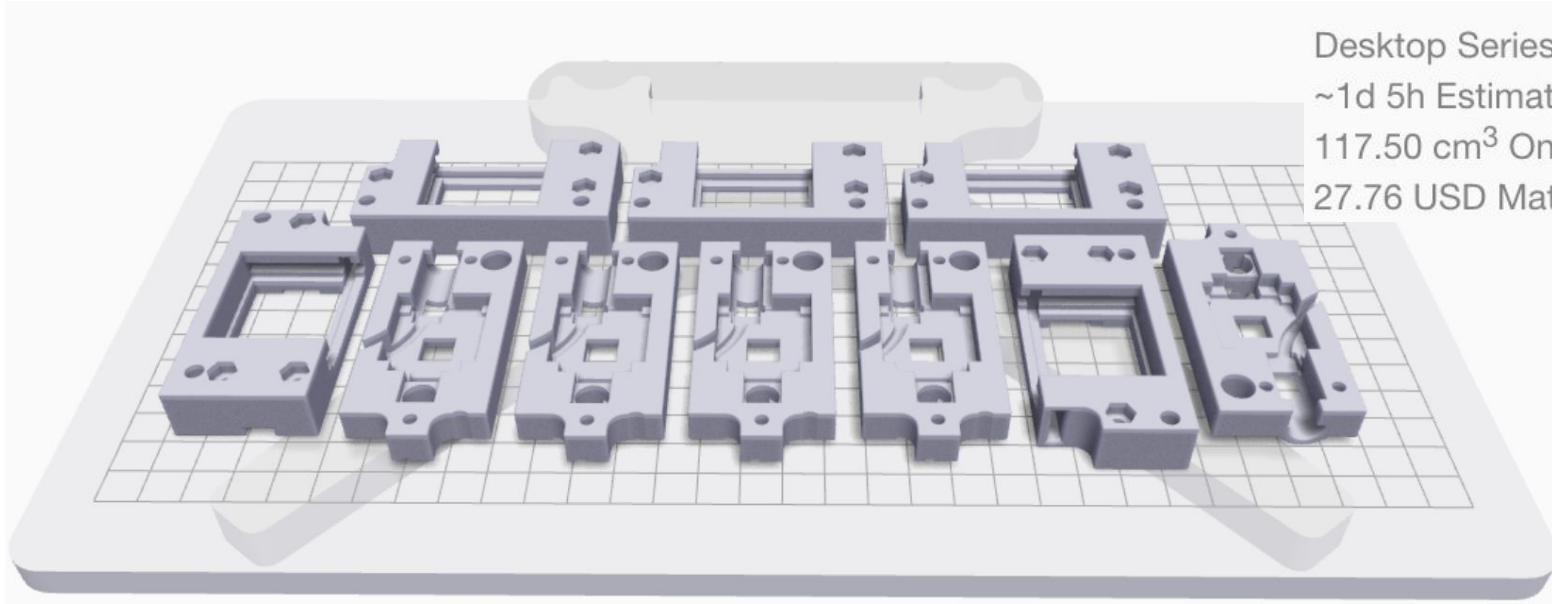
Desktop Series Build
~1d 11h Estimated Print Time
132.99 cm³ Onyx
31.42 USD Material Cost

Start time: 11pm Friday

End time: 10am Sunday



Scheduling Parts into Eiger Builds



Desktop Series Build
~1d 5h Estimated Print Time
117.50 cm³ Onyx
27.76 USD Material Cost

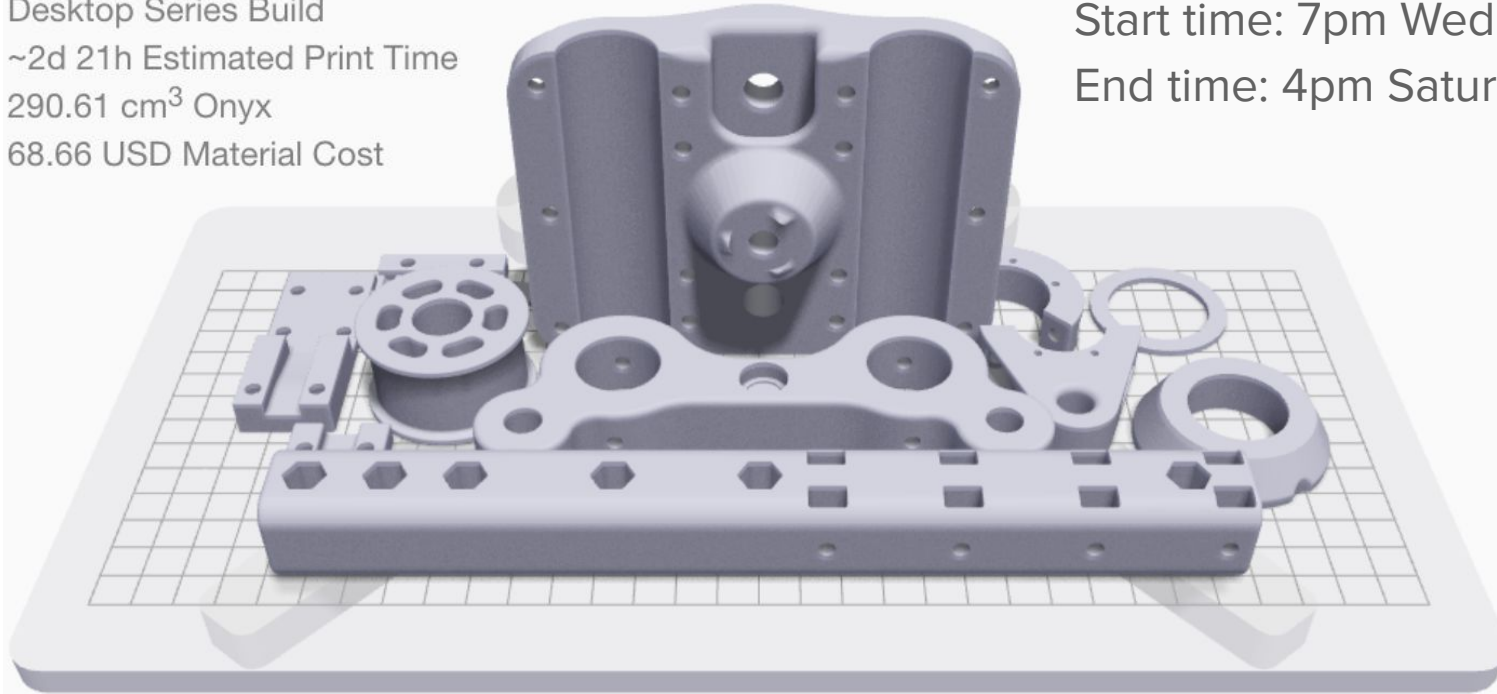
Start time: 1pm Saturday

End time: 6pm Sunday

Scheduling Parts into Eiger Builds

Desktop Series Build
~2d 21h Estimated Print Time
290.61 cm³ Onyx
68.66 USD Material Cost

Start time: 7pm Wednesday
End time: 4pm Saturday



Last Season's Scheduling Document

Part Name	Part #	Qty per robot	Total	Printed/Printing	Need to Print	Time to Print (hr)
Stage 1 Bearing Block	171	1	3	3	0	32
Slider Crossbrace2	202	1	3	3	0	10
Slider Crossbrace	201	2	6	6	0	2.5
Slider Crossbrace 2	225	2	6	6	0	1.5
Wrist Clamp2	66	1	3	3	0	22
Wrist Clamp1	40	1	3	2	1	27
Elevator Bearing Block 1	80	2	6	7	-1	10
Wrist Spacer	136	1	3	3	0	4.5
Elevator Bearing Support	153	2	6	6	0	3.5
Wrist Inner Spacer	175	1	3	2	1	2.5

finished

unfinished

has a spare

part deleted

ooh... ahh...



My Best Advice (sparknotes summary)

As long as you put glue on the bed, it is pretty hard to mess up Markforged prints.

- Establish and stick to an organizational system
- Design parts with 3D printing in mind
- Print heavier fill when parts should be stronger
- Orient parts to minimize printing supports
- Order parts by priority, and schedule builds to end at "convenient" times





Thank You!

