SCUTTLE™ 3D Printing Guide

Last revised 2022.10.28

This Guide Contains:

PRINTING SETUP
- Properly orienting parts for printing
- Suggested printing parameters for getting started

MATERIAL SELECTION
- Engineering characteristics of popular plastics
- Resources to learn from experienced printing teams

PRINT EXAMPLES
- Test prints with parameters
- Printed parts sets with parameters

Printing Setup

Orientation & Supports

▶ We design our parts for Fused Deposition Modeling (FDM) without supports

   ▶ The **twist bracket** is an exception

   ▶ **Holes**: small holes don't need supports and large holes have a teardrop shape

   ▶ **Overhangs** are designed at 45 degrees or taller.

   ▶ **Parts thickness** is constrained to avoid bulk material

   ▶ Design-for-manufacturing is implemented

▶ The Version Number indicates print orientation.

   ▶ Version should be upright

   ▶ Debossed text begins printing 6mm from base of part
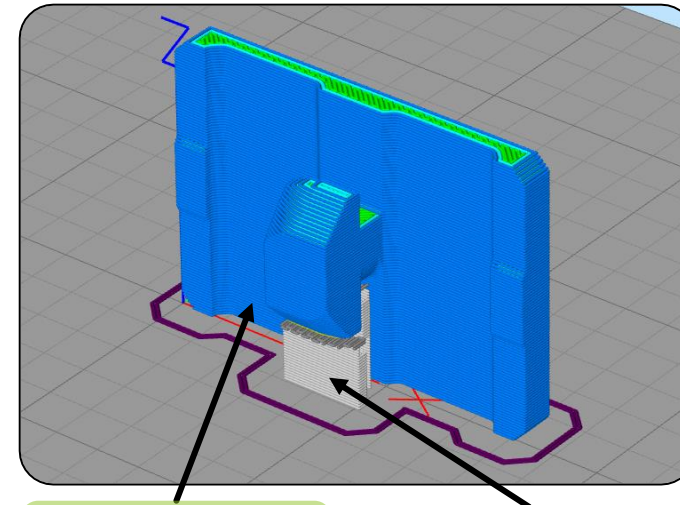
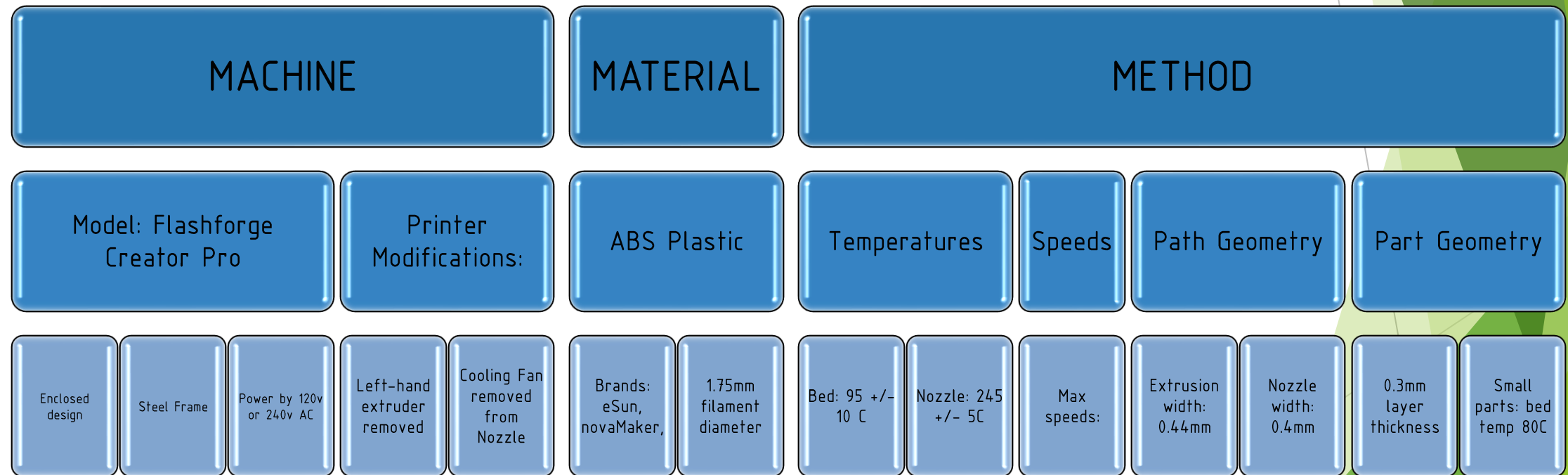SCUTTLE Twist Bracket in slicer software.

Printed Supports
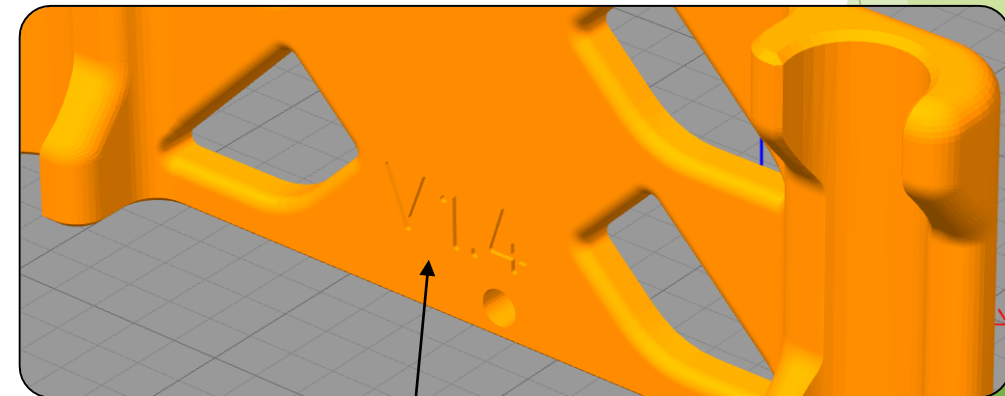
Model version indicates upright orientation

Standard Settings

- ▶ Our typical print settings in the general scope which can be applied across various:
  - ▶ slicer softwares
  - ▶ slicer versions
  - ▶ printer models
  - ▶ CAD variations

MACHINE		MATERIAL	METHOD			
Model: Flashforge Creator Pro	Printer Modifications:	ABS Plastic	Temperatures	Speeds	Path Geometry	Part Geometry

Enclosed design	Steel Frame	Power by 120v or 240v AC	Left-hand extruder removed	Cooling Fan removed from Nozzle	Brands: eSun, novaMaker,	1.75mm filament diameter	Bed: 95 +/- 10 C	Nozzle: 245 +/- 5C	Max speeds:	Extrusion width: 0.44mm	Nozzle width: 0.4mm	0.3mm layer thickness	Small parts: bed temp 80C

Settings Snapshot 2022.07.29

▶ Example of fine-tuning changes from our standard settings

▶ May occur as printer wears, with changed filament brands, or with environmental change (room temp, etc).

▶ DM Changes from 07.29 standard:

- ▶ Extrusion Ratio – 103%
- ▶ start point acceleration distance: 10mm
- ▶ minimum speed: 20mm/s
- ▶ Path Width – 0.44mm
- ▶ Bridge: NO
- ▶ Min extrusion speed: 20mm/s
- ▶ slow down first few layers: 0
- ▶ use random start points

- ▶ infill style: 3D infill
- ▶ overlap perimeter: 15%
- ▶ pre extrusion speed: 20mm/s
- ▶ margin: 3mm
- ▶ shell print order: anti overrush decel
- ▶ cooling fan control: always OFF
- ▶ Enable Pre-extrusion: OFF

Material Selection

Interesting data that compares 3D printing materials

What you can learn:

1) How do the popular materials differ?

2) What drives the selection of materials for a design engineer?

3) How does my material impact printing effort?

MATERIALS – Preferred Materials

- ▶ We prefer ABS, followed by PETG.

- ▶ ASA is a popular derivative of ABS formula used by industrial printing brands

- ▶ In engineering, one material is not better than another, but we focus on the key properties for our design application.

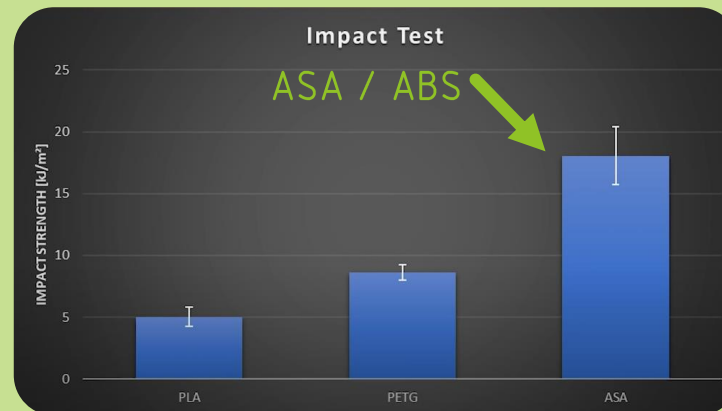- ▶ For SCUTTLE mechanical parts **and their failure modes**, ABS properties excel.

Heat Performance

Source: CNC Kitchen tests on youtube
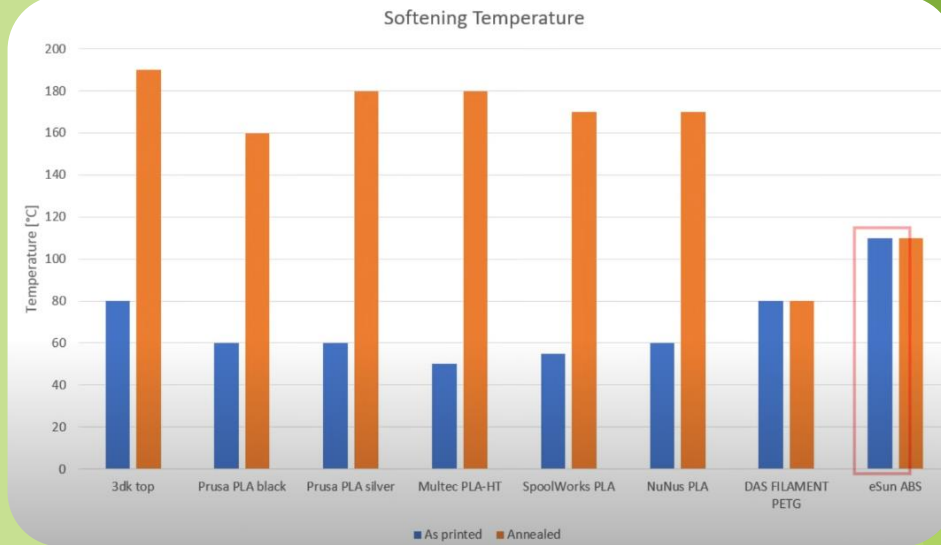
**Mechanical Performance**

Source: CNC Kitchen tests on youtube
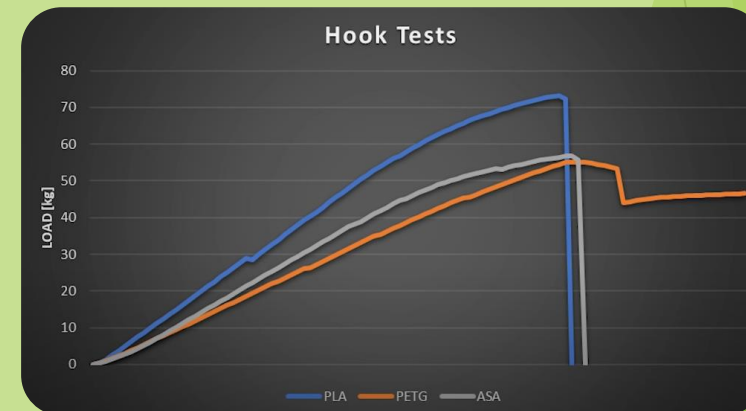
MATERIALS – Impact Performance

▶ Discussions of materials often highlight tensile strength and omit a common failure mode, which is impact. PETG, while more maker-friendly for printing, underperforms in impact resistance.

Impact Resistance

Regardless of drawbacks, PETG maintains popularity among makers. It is easier to achieve successful prints in comparison with ABS.
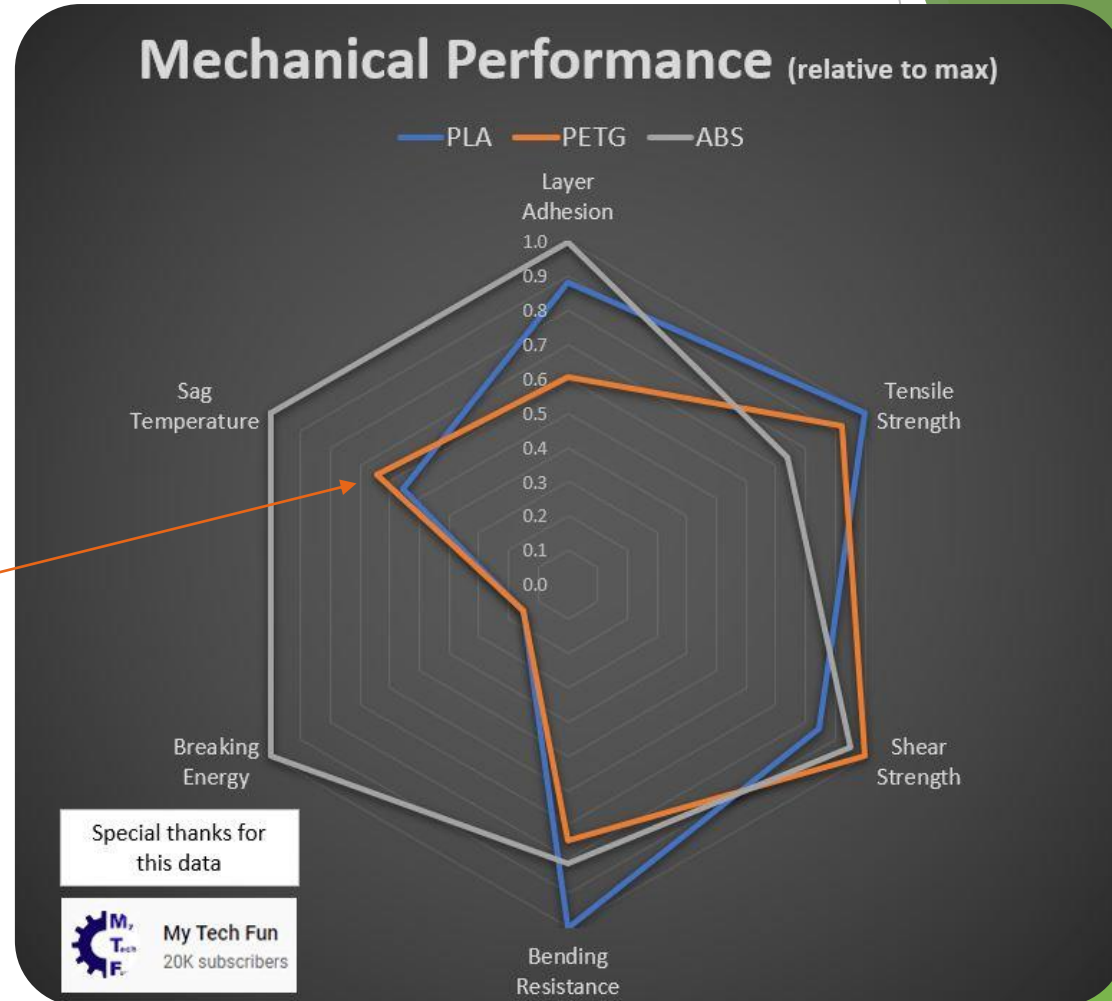
Video Explanation for this data

Hatchbox3D.com Embraces ABS

"Industries as varied as automotive and toy-making use acrylonitrile butadiene styrene (ABS) for its durability and formability. These properties also make ABS filament a solid choice for 3D printing whether for commercial applications or household objects.

Because **ABS plastic is stronger and better withstands impacts** than PLA materials, ABS filament is a better choice for objects that will bear structural loads or will be handled frequently. The base ABS material is translucent so adding pigments creates ABS filaments in a wide range of colors, like our popular black ABS filament. ABS objects can also be kid-safe.
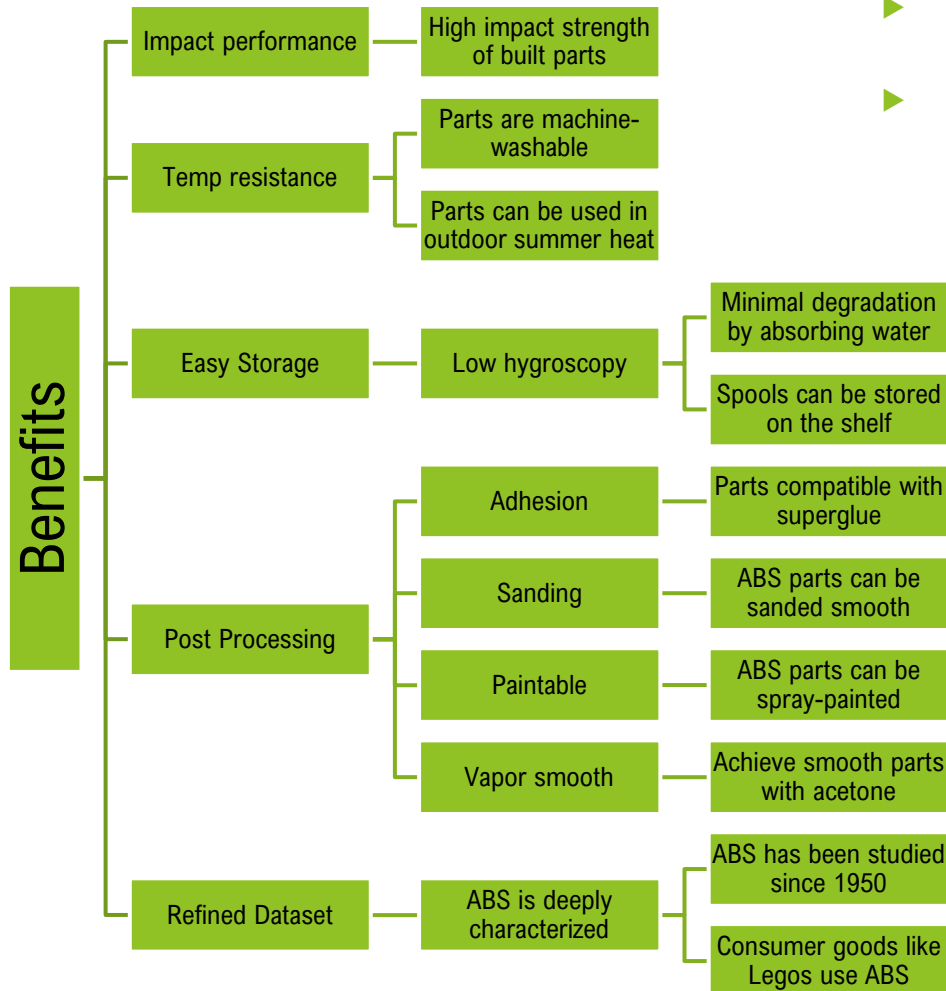
ABS will work with all but the cheapest FDM 3D printers because, while the ideal ABS print temperature is relatively low, the material requires a heated bed and an enclosed print volume. These temperature management features prevent adhesion and layer separation issues caused by ABS's tendency to contract when cooling. ABS produces fine details and **works with post-processing techniques** such as acetone smoothing.

Strength, durability and temperature resistance are why you will see ABS materials used in the automotive and medical device industries. These material properties are also why people choose ABS 3D printer filaments. With fine surface details, a variety of color options and post-processing techniques like solvent welding and acetone smoothing, ABS 3D printing lets you create objects that will withstand day-to-day use."
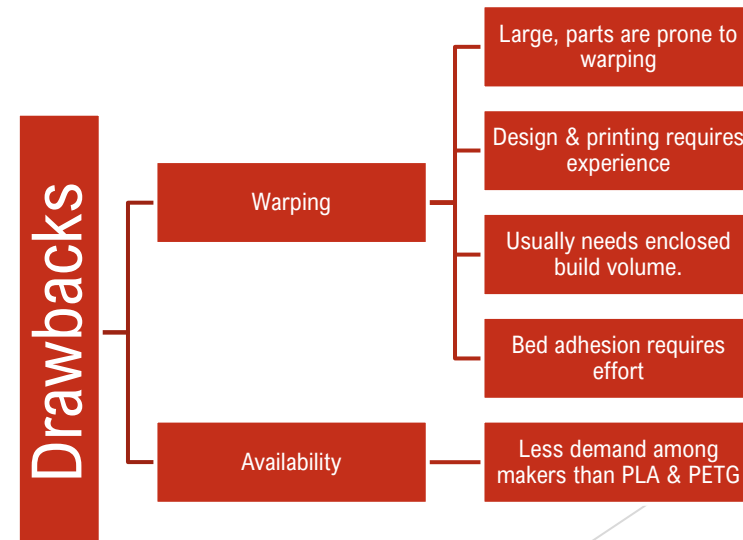
HATCHBOX®
YOUR CREATIVITY. OUR TOOLS.

Materials: ABS Pros & Cons

Benefits

- Impact performance
  - High impact strength of built parts
- Temp resistance
  - Parts are machine-washable
  - Parts can be used in outdoor summer heat
- Easy Storage
  - Low hygroscopy
    - Minimal degradation by absorbing water
    - Spools can be stored on the shelf
- Post Processing
  - Adhesion
    - Parts compatible with superglue
  - Sanding
    - ABS parts can be sanded smooth
  - Paintable
    - ABS parts can be spray-painted
  - Vapor smooth
    - Achieve smooth parts with acetone
- Refined Dataset
  - ABS is deeply characterized
    - ABS has been studied since 1950
    - Consumer goods like Legos use ABS

▶ Consider these qualities *relative to the most popular 3D filaments on the market*

▶ How to interpret:

  ▶ "These are subjective comments with a logical translation. Take a case where the designer is choosing a filament based only on ONE quality. Then, if the property is listed under Benefits, ABS is the best choice. If the property is listed under Drawbacks, ABS is not the best choice." —David M

Drawbacks

- Warping
  - Large, parts are prone to warping
  - Design & printing requires experience
  - Usually needs enclosed build volume.
  - Bed adhesion requires effort
- Availability
  - Less demand among makers than PLA & PETG

We solve drawbacks with design methodology and printing best practices.

Printing Sets

Benchmarks for printing key parts in pairs or common sets required for building the SCUTTLE Robot Kits.
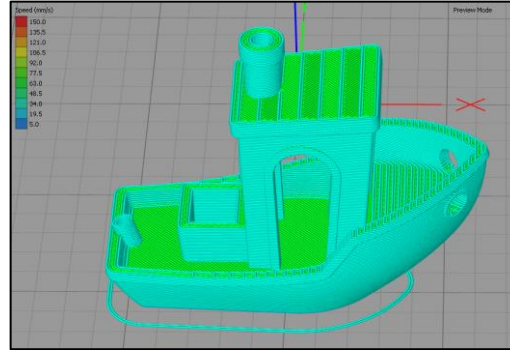
What you can learn:

1) How fast can the parts print in good quality?

2) How do settings deviate for outlier parts?

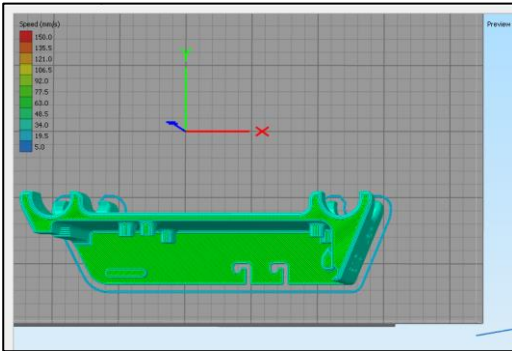3) How are parts usually oriented on the bed?
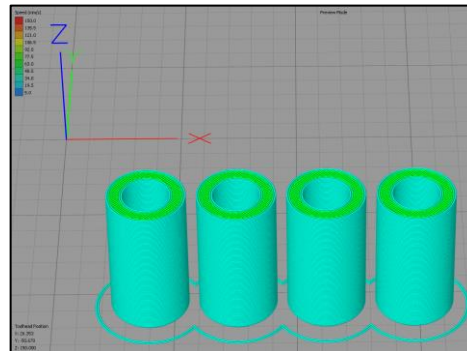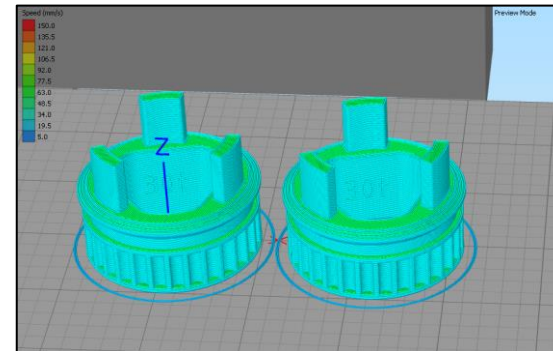
Print Tests

whlBrkL66

Benchy__45m
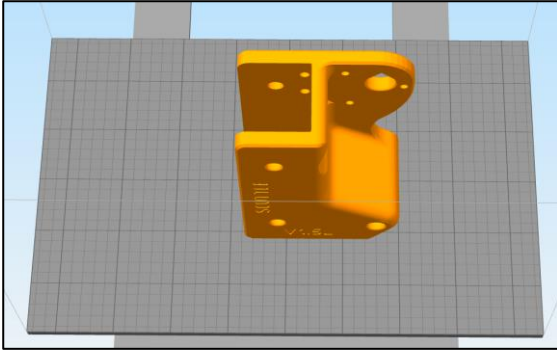
Param	WhlBrkL66	Benchy_45m	cpuBrkt	Spacers	pulyWhl
Speed(mm/s)	65	60	65	60	50
Outline(%)	60	50	50	50	50
Bed Temp	85	85	100	85	100
Extr Temp	245	245	245	245	245
Infill (%) / perimeters	35/2	raised temp improved warp	35/2	35/2	35/2
Plastic	Hbx ABS	HBX ABS	ABS_BMT	HBX ABS	ABS_BMT
Extr Width (mm)	0.40	0.40	0.44	0.40	0.44
Layer thick (mm)	0.3	0.30	0.3	0.30	0.3
Time (h:mm)	3:23	0:45	1:54	0:49	1:50

CpuBrkt

Spacers

pulyWhl

Print Sets
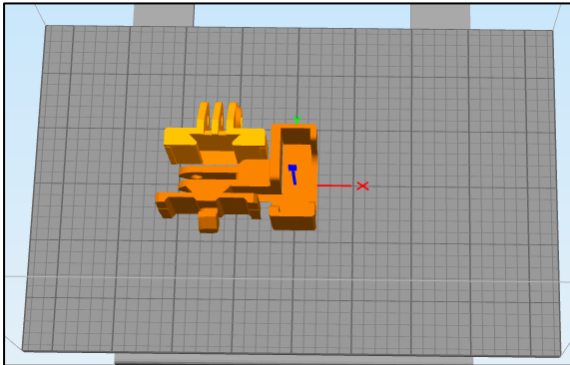
cameraSet

encdrPair
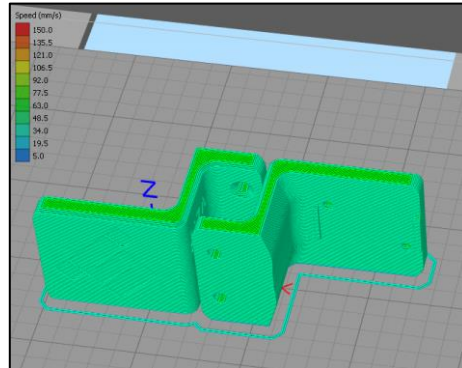
Param	CameraSet	encdrPair	KickStand_t2	rodBrktSet2	WhlBrk Pair_v1.5
Speed(mm/s)	60	60	60	65	60
Outline(%)	50	50	100	60	50
Bed Temp	85	90	85	90	85
Extr Temp	235	250	235	250	235
Infill(%) / perimeters	35 /2	35/2	35 / 3	35/2	35/3
Plastic	Hbx ABS	ABS	Hbx ABS	BUMAT ABS	Hbx ABS
Extr Width (mm)	0.40	0.40	0.48	0.40	0.40
Retraction (mm)	2.0	2.0	2.0	0.3	
Time	1:26	0:47	1:08	1:18	7:22

Kickstand_t2
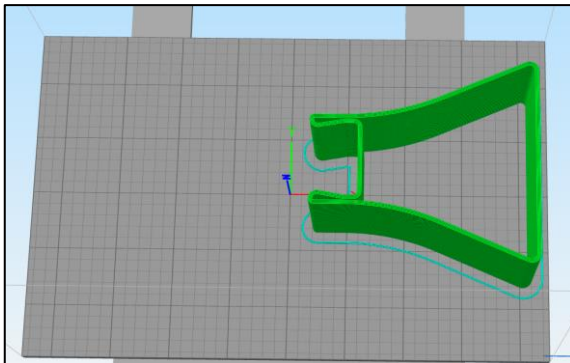
WhlBrkPair__v1.5
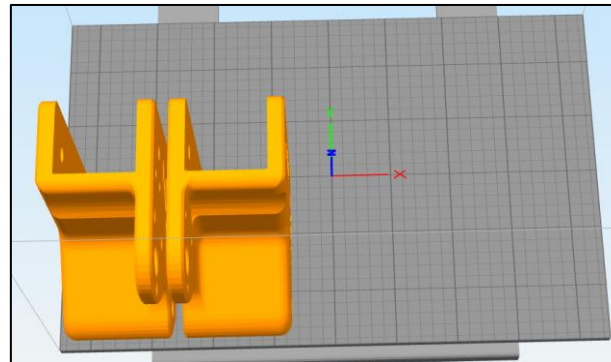
rodBrkSet2
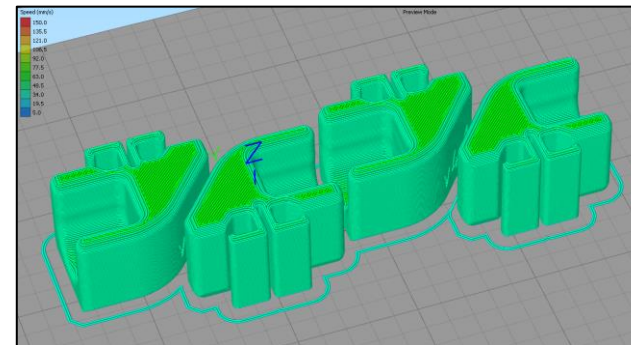
Print Sets

batBrkt

mDriverBrk
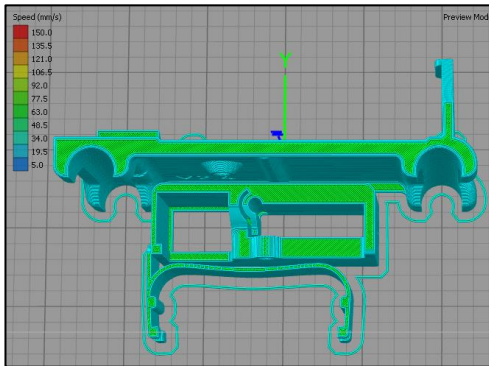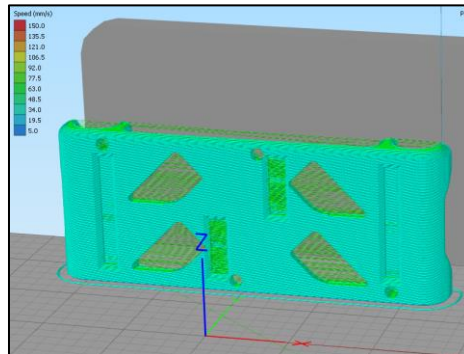
Param	batBrkt	mDriverBrk	camSet2	mPulley_v3	pulleySet3
Speed(mm/s)	60	60	60	40	40
Outline speed (%)	40	50	50	60	50
Bed Temp	85	85	85	85	85
Extr Temp	245	245	245	245	245
Infill (%) / perimeters	35/2	35/2	35/2	35 / 2	35 / 2
Plastic	HBX abs	HBX ABS	HBX ABS	HBX ABS	HBX ABS
Extr Width (mm)	0.44	0.40	0.40	0.44	0.44
Layer thick (mm)	0.3	0.30	0.30	0.25	0.25
Time (h:mm)	3:23	1:17	1:24	0:29	2:55
Outline overlap (%)	20	20	Retr vert lft: 0mm	30	20
Extr ratio	100			103 %	

camSet2

mPulley_v3

pulleySet3

Print Sets
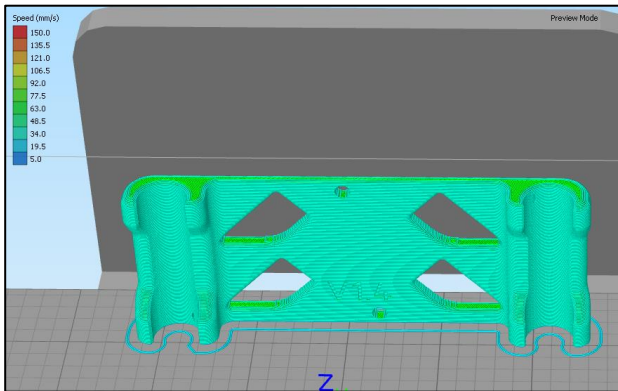
Param	mtrDrvBrkt1	Kckstand_t3	whlBrktSet_t2	mtrDrvBrkt_t2	camSet3
Speed(mm/s)	65	65	65	65	65
Outline(%)	50	100	50	50	50
Bed Temp	90	105	100	100	100
Extr Temp	245	245	245	245	245
Infill (%) / perimeters	35/2	35/2	35/2	35/2	35/2
Plastic	BMT ABS	GZMO GRN	BMT_ABS	BMT ABS	GZMO GRN
Extr Width (mm)	0.40	0.48	0.44	0.44	0.44
Layer thick (mm)	0.30	0.30	0.3	0.30	0.30
Time (h:mm)	1:09	1:03	6:38	1:09	1:18
Outline overlap (%)	20		20	20	20
Extr ratio		1.00	1.00		1.0
OTHER Layer1 Spd Layer 1 Ht	35%	35%	35%	35% 100%	

mtrDrvBrkt1

kickstand_t3
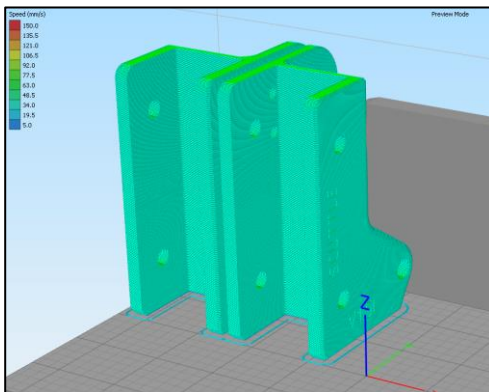
mtrDrvBrkt1

mtrDrvBrkt_t2
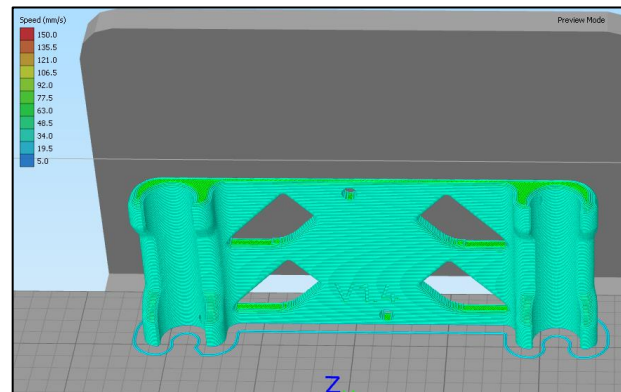
camSet3
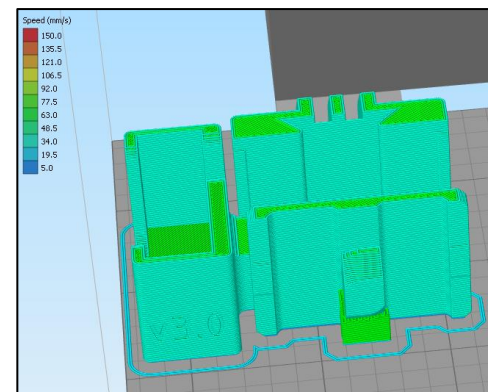
Print Sets

whlPuly2
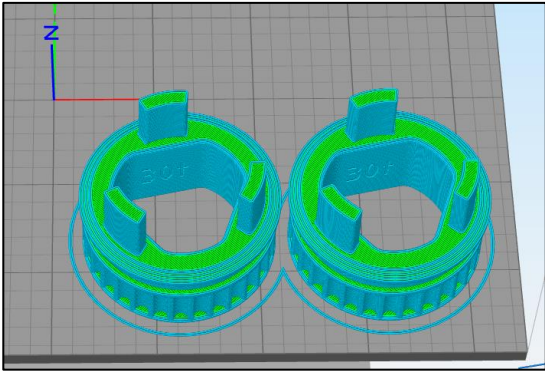
item

whlPuly__v3.3
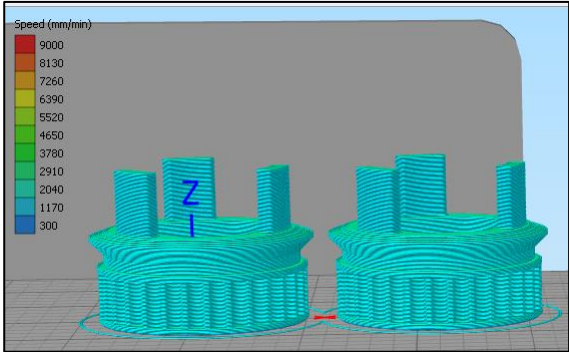
placeHolder

Param	whlPuly2	whlPuly_v3.3			
Speed(mm/s)	65	50			
Outline(%)	30	50			
Bed Temp	90	100			
Extr Temp	245	245			
Infill (%) / perimeters	35/2	35/2			
Plastic	GRN_GZM				
Extr Width (mm)	0.44	0.44			
Layer thick (mm)	0.30	0.3			
Time (h:mm)	1:55	1:47			
Outline overlap (%)	20	20			
Extr ratio		100%			
OTHER Layer1 spd	35%				

placeHolder