



Citrus Circuits
Fall Workshop Series
Design with 3D Printers

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Overview



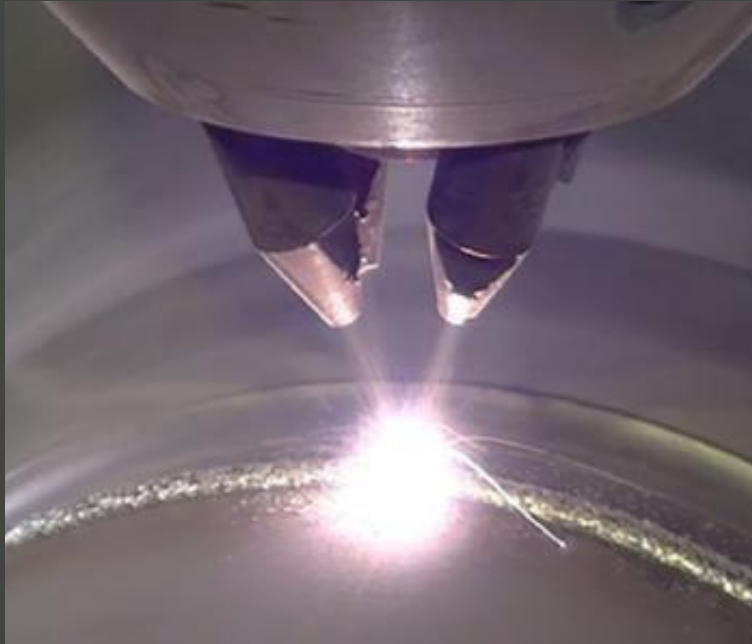
- 3D printing technology
- Physical limitations
- Printing toolkit
- Modelling tips
- Printing variables
- Examples in FRC

History



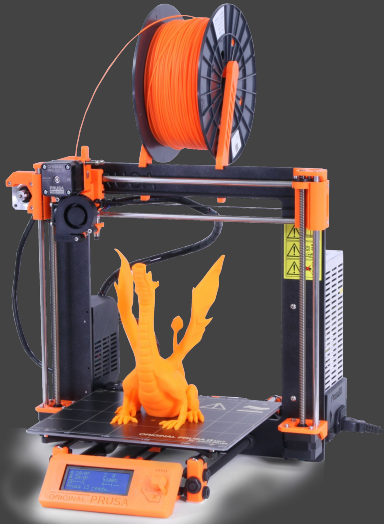
- Began in the 1980's in Japan using photopolymerization
- Mid 80s': Stereolithography STL format
- Late 80's FDM machines were created
- Early 90s: Laser Sintering (SLS and SLM)
- 2009: The patent on FDM expired

Types of 3D Printing



- Stereolithography (SLA)
- Fused Deposition Modeling (FDM)
- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)

Common Frc Printers



- FDM Printers
 - Prusa
 - MarkForged
 - MakerBot
 - Ultimaker
- SLA Printers
 - Formlabs



FDM VS SLA

- FDM
 - Wide range of printing Materials
 - Cheaper
 - Stronger Parts

- SLA
 - Higher Resolution
 - Smooth Surfaces



FDM

SLA

Common Materials



- ABS
- PLA
- Nylon

Detailed Material Properties

- ABS
 - Long life span
 - Hard
 - YS 7540psi
 - UTS 10600psi



Detailed Material Properties

- PLA
 - Stiff
 - Minimal warping
 - YS 7830
 - UTS 16500



<https://www.simplify3d.com/>



Detailed Material Properties

- Nylon
 - Flexible
 - Impact resistant
 - YS 14500 Psi
 - UTS 16000 psi

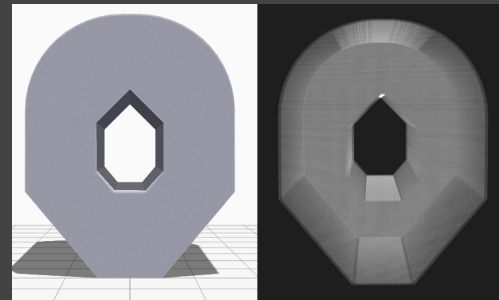
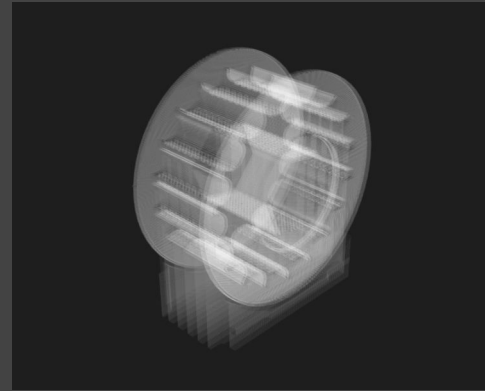


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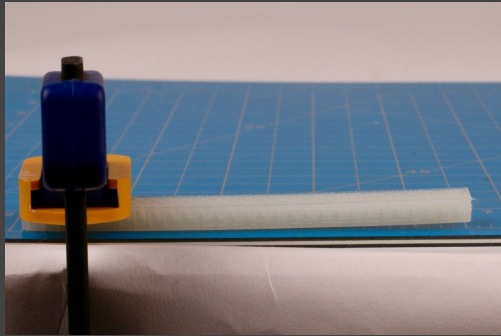
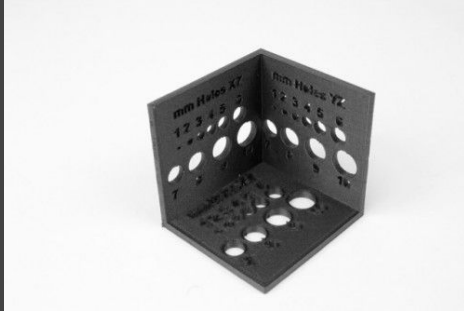


Physical Limitations

- Print surface
 - Prints must have 1 surface to contact bed
 - Solutions: Raise part, use brim
- Support material
 - Support material is needed for overhangs over 45°
 - Interior features are limited by what support material you can remove
 - Solutions: Pause prints, Add a roof

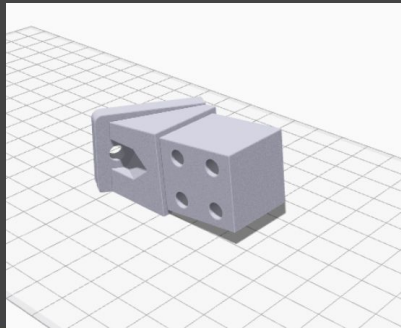
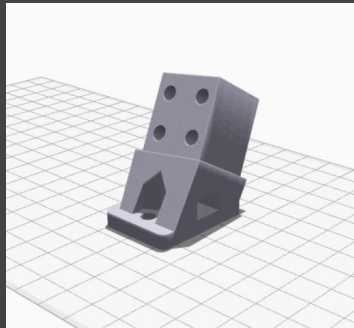
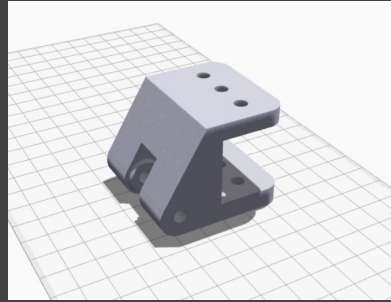
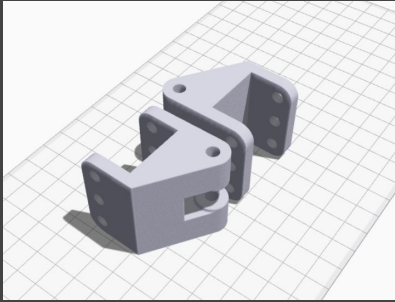


Physical Limitations



- Hole shrinking
 - Printed plastics naturally shrink after being extruded
 - Solutions: Oversize holes, unit tests
- Part warping
 - Shrinking can also cause warping on long parts
 - Solutions: Adhesive, brims, fillet vertical edges

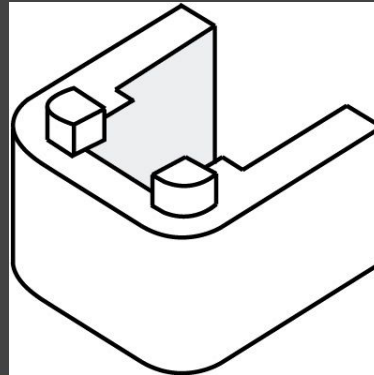
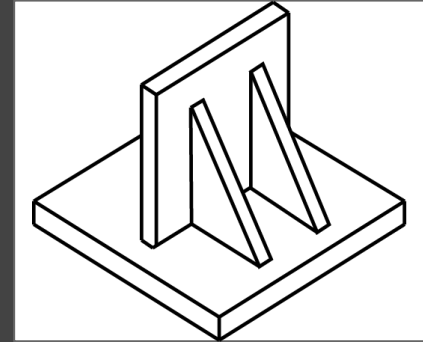
Physical Limitations



- Layer shear
 - Printed parts are anisotropic, and have limited layer adhesion
 - Solution: Smart part placement
- Material strength
 - All materials have limits
 - Solution: know the limits

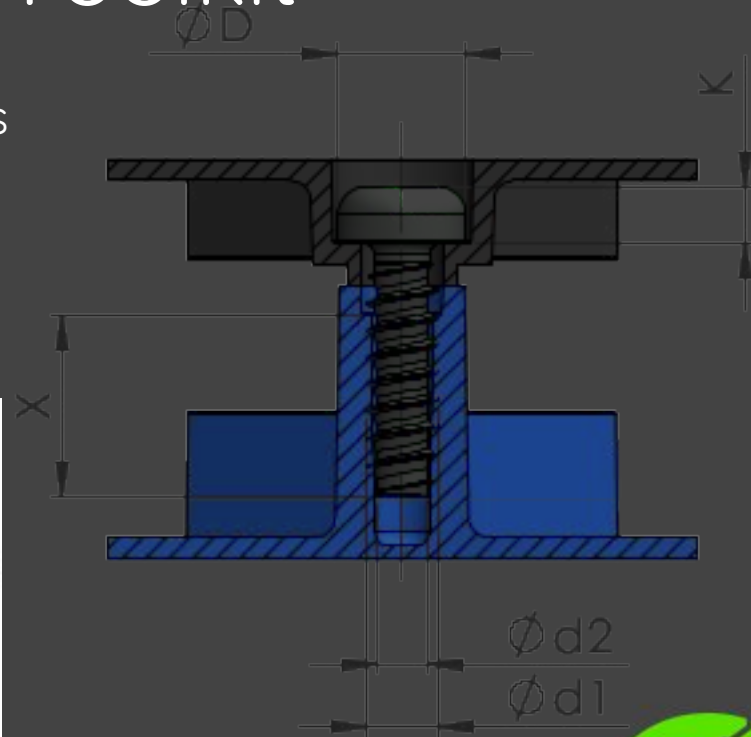
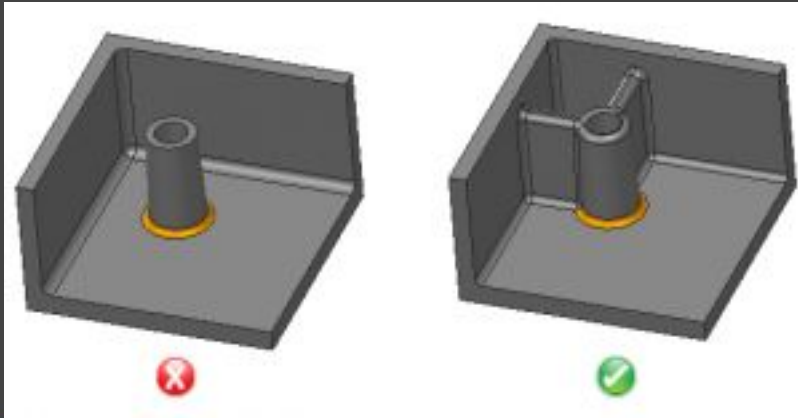
3D Printing Toolkit

- Ribs
 - Reduce material while retaining rigidity
- Lugs
 - For joined parts
 - Simple way to share shear forces

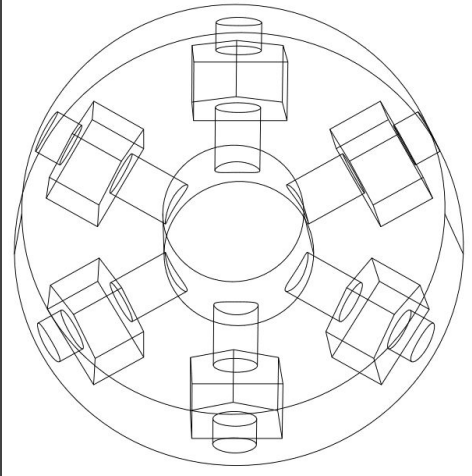


3D Printing Toolkit

- Boss
 - A mounting feature for fasteners
 - Used to join hollow parts
- Self-threading holes
 - When strength is not needed
 - Reduce size of hole, force screw



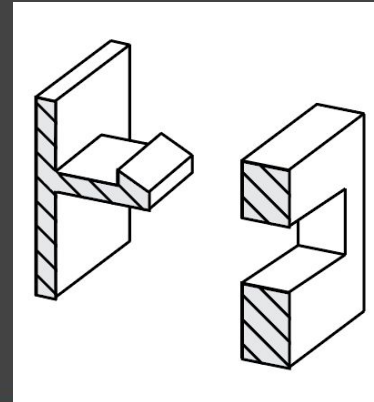
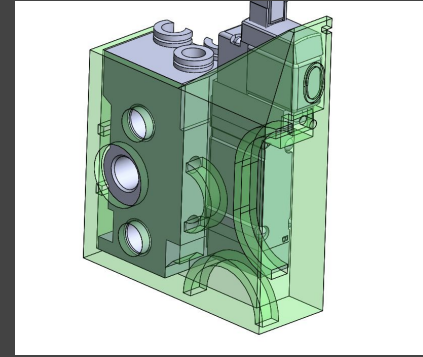
3D Printing Toolkit



- Inset nuts
 - When additional strength is needed
 - Glue in nuts
 - Pause print and insert
 - Using 2 parts, nuts can be added at weird angles

3D Printing Toolkit

- Zip tie paths
 - Strain relief or mounting
 - Limited by support material
 - Solutions: make roof $<45^\circ$, pause print
- Snap fits
 - Use material flexibility to make bendable snap
 - Limited use
 - Difficult to implement



3D Printing Toolkit



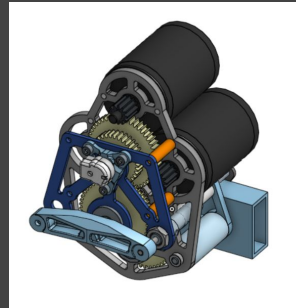
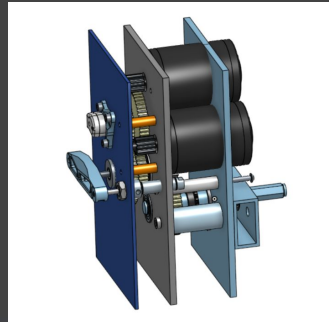
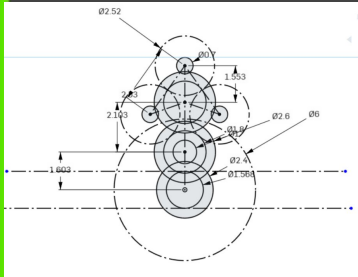
- Part fixtures
 - Used to mill complex parts
 - Could be used to pocket gears
 - Limited by strength
- Molded parts
 - Can include overmolded parts



Modelling Tips

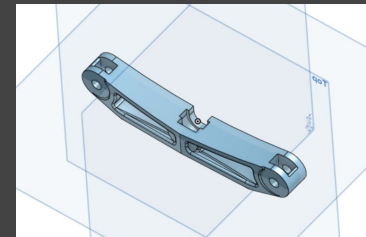
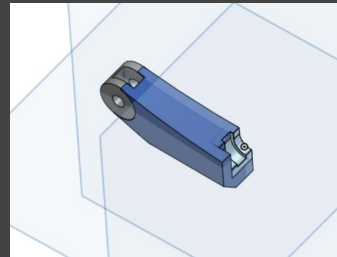
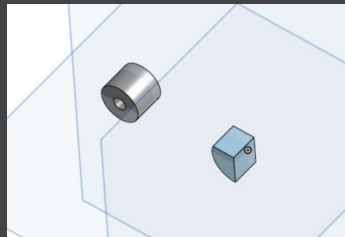
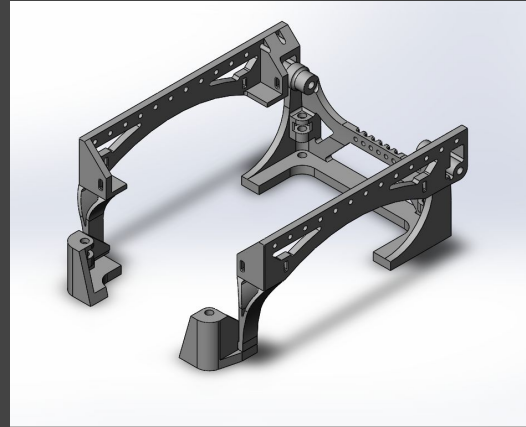
Group	Description	Typical Features	Notes
1-Ref	All Reference sketches and geometry, made available and visible to all features	Base Sketches, Reference Planes, Reference Axes	No Solid Features
2-Core	Base feature that determines the model's basic shape, extents, and dimensions	Extrude, Revolve, Sweep	Add Material
3-Basic	Marks the clear placement of various important cuts	Hole, Cut	Critical Holes and Features
4-Detail	Detail features that complete the shape	Extrude Cut	Typically Remove Material
5-Modify	Tile faces, replicate features, final features	Pattern, Mirror, Final Features	Modify Existing Geometry
6-Quarantine	Volatile features	Chamfer, Fillet	Largest First

- Resilient modelling
 - For complex parts, this idea becomes critical
 - Model the core first, then work towards the details
 - Prevents dependencies, makes editing easier

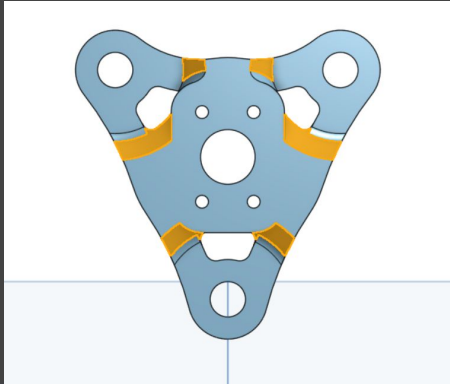
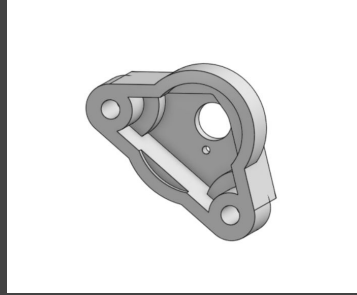
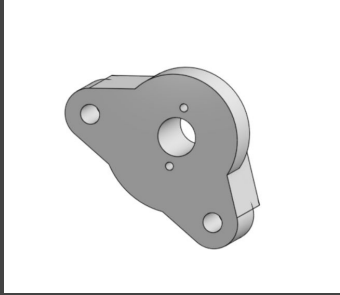


Modelling Tips

- Multibody parts
 - Allows you to model needed parts, then join them
 - Helps visualize what is needed and minimize size
 - Good for developing interconnected parts together



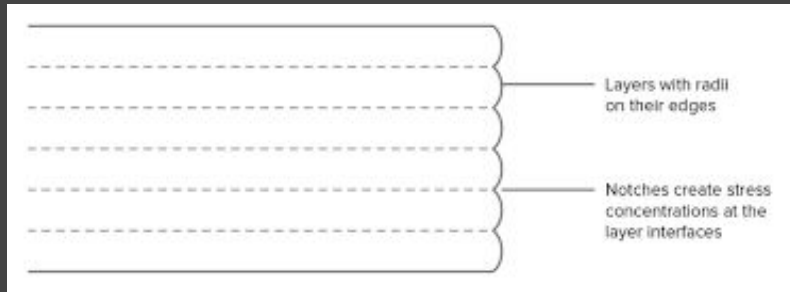
Modelling Tips



- Useful features
 - Features that aren't usually used, but are particularly useful
 - Shell - easily lighten parts
 - Loft - create smooth connections
 - Fillet - stronger angles

Printing Variables

- Layer Height
 - Thin
 - Increase print time
 - Better surface finish
 - Thick
 - Decreased print time
 - Increased chance of layer separation



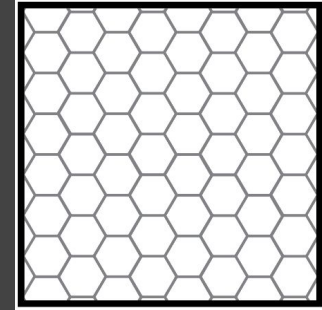
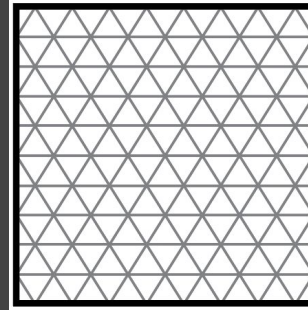
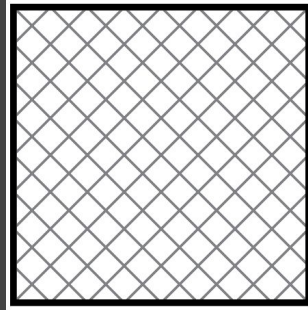
Printing Variables

- Wall thickness
 - Strengthens holes, outer profiles
 - Limited by thin feature thickness
 - Keep a multiple of nozzle thickness
- Infill
 - Increases overall strength of part
 - Directly proportional to weight and cost



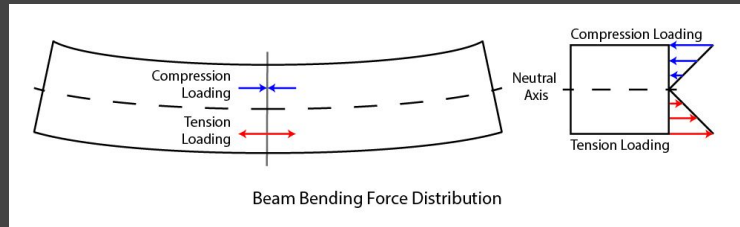
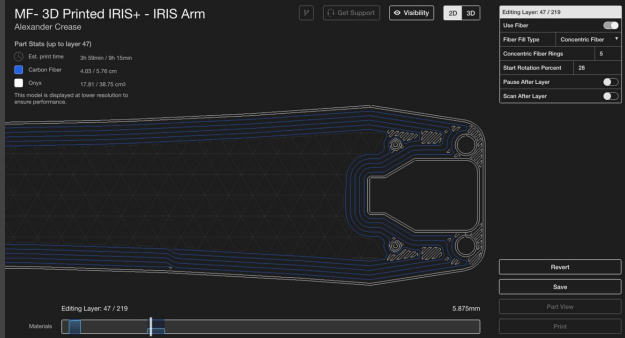
Printing Variables

- Infill pattern
 - Rectangular
 - Triangular
 - Honeycomb

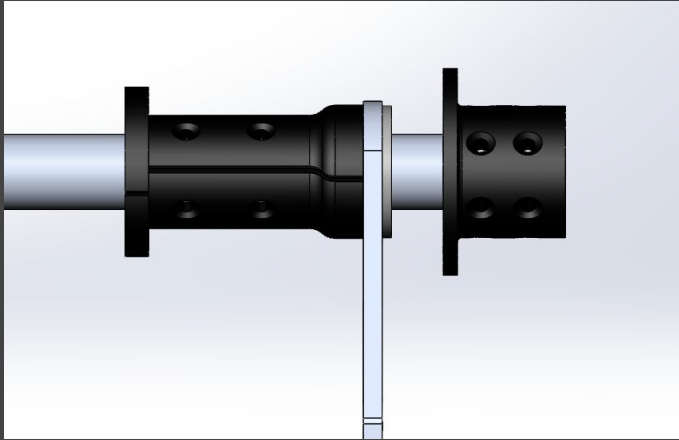


Printing Variables

- Reinforcement
 - Limited to high end printers
 - Concentric
 - Strengthens holes, hex profiles, etc
 - Layer
 - Sandwich panels
 - Define angles for reinforcement in one direction



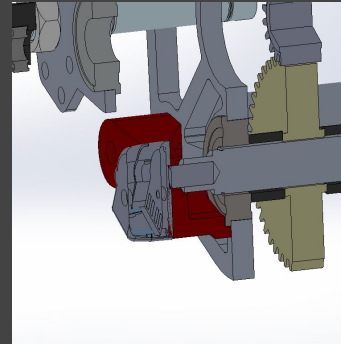
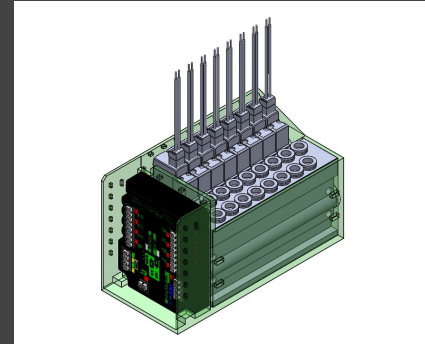
Printing in FRC



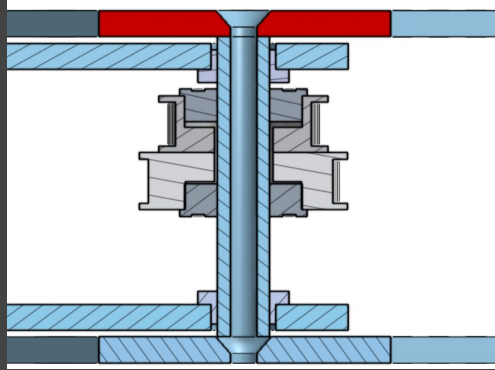
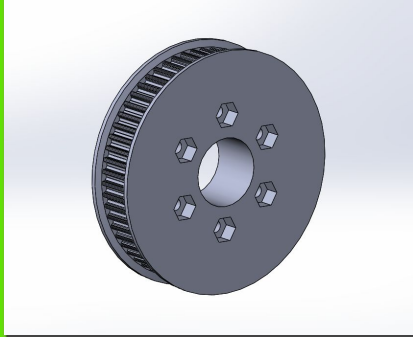
- Fast iteration
 - Printers make complicated parts almost as fast as other parts
 - Good for prototyping/testing later in the season

Printing in FRC

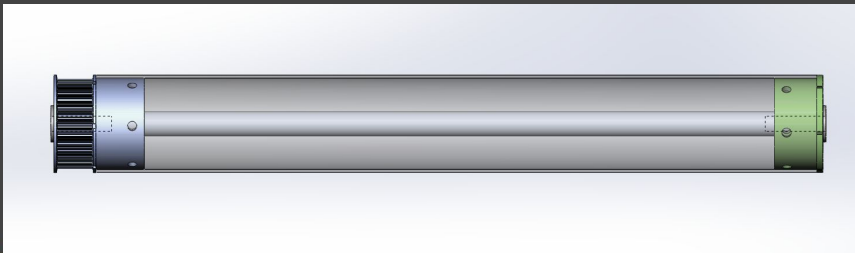
- Electrical mounts
 - Groups similar components
 - Built in strain relief
 - Reusable, easy to develop in offseason
- Sensor mounts
 - Get sensors in weird, awkward places with high accuracy



Printing in FRC

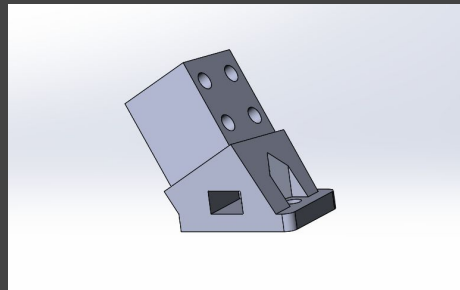
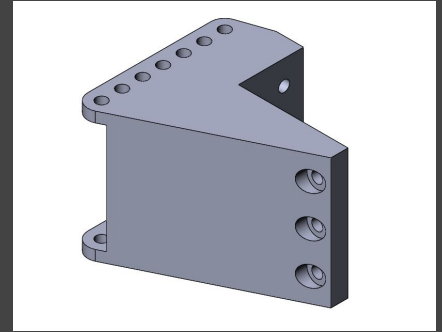
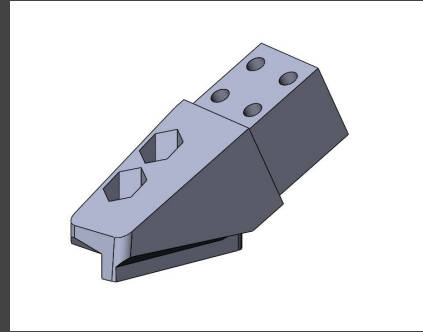


- Pulleys
 - Very lightweight
 - Effective at lower loads
- Dead axle plugs
 - Strong, efficient power transmission
 - Allows rotation around structural standoffs
 - Works well with pulleys



Printing in FRC

- Frame members
 - Printed blocks are a lightweight solution to join tubes in awkward locations
 - Works well combined with inset nuts





Citrus Circuits
Fall Workshop Series

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Thank You!

Questions?



Give us Feedback!

