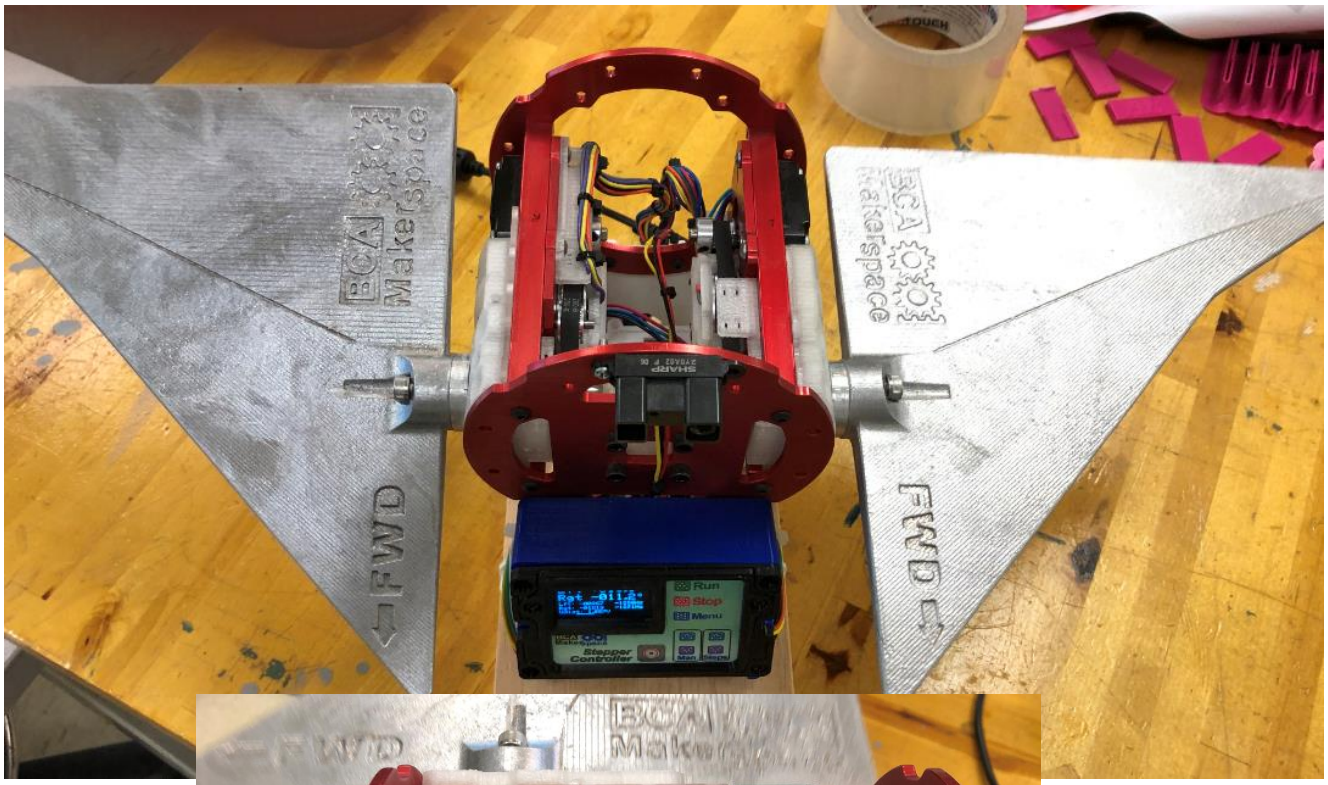
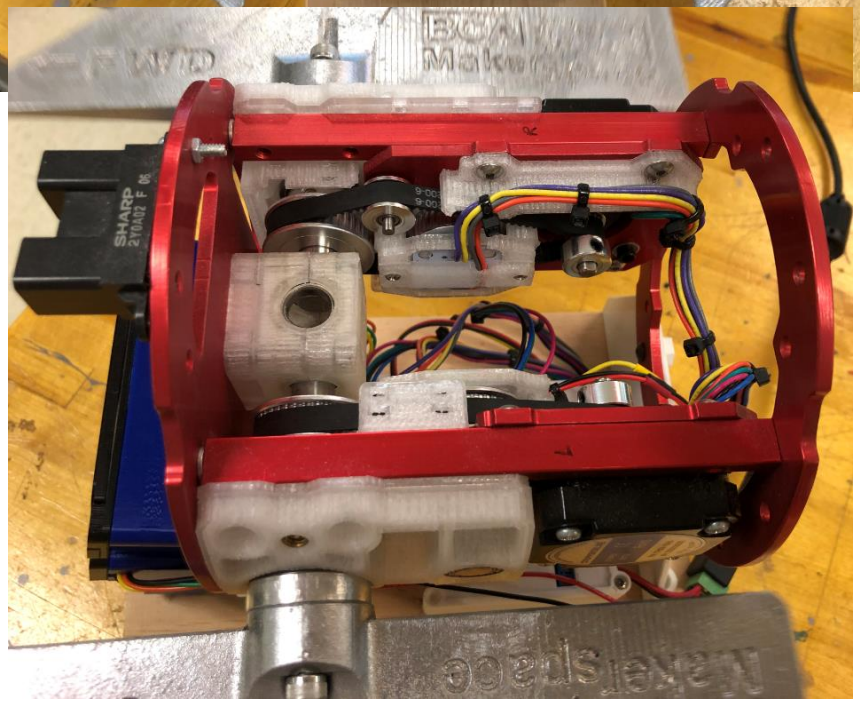
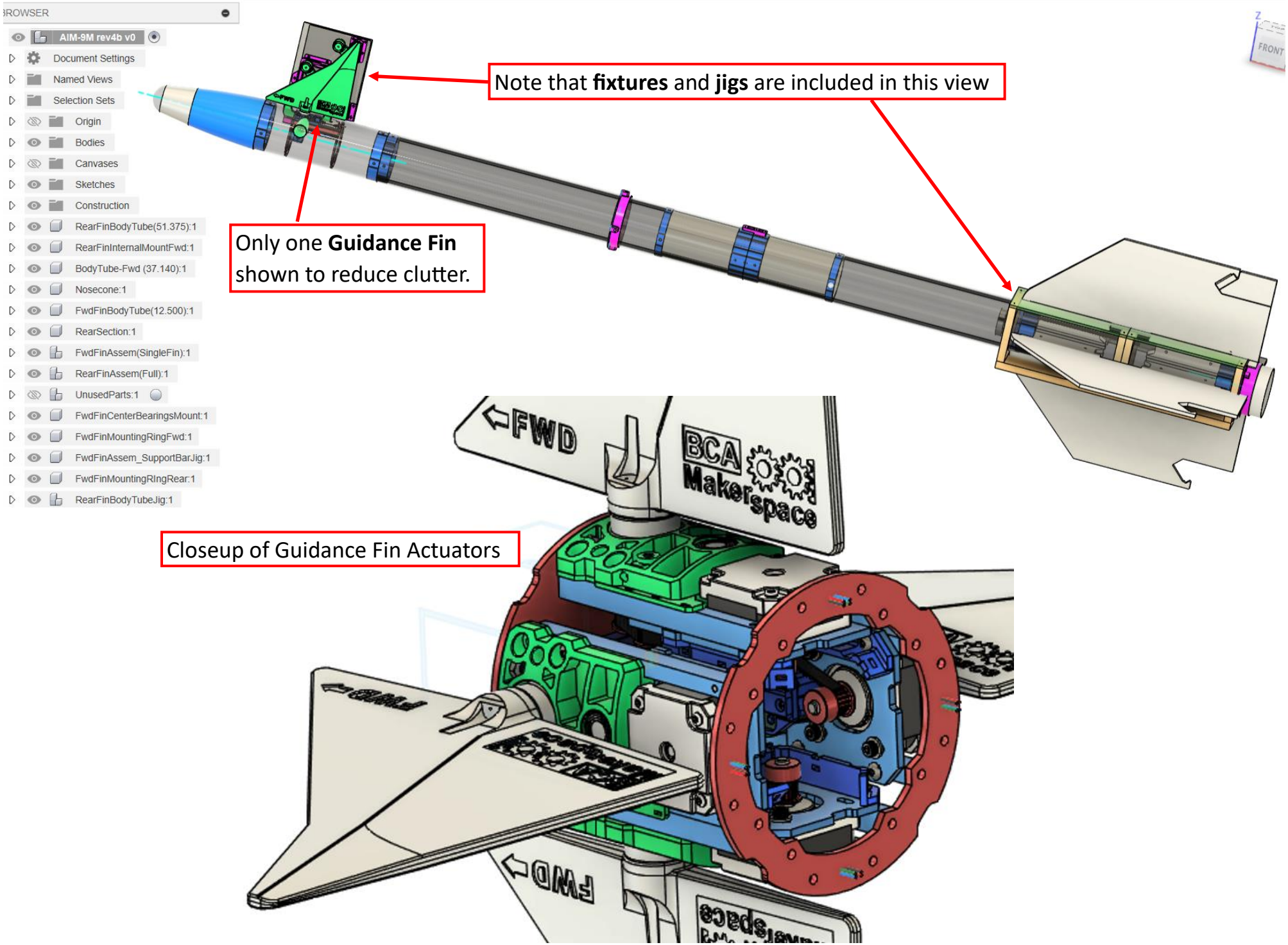
Design and fabrication of AIM-9 (Sidewinder) guided missile using Fusion and 3D printing, aluminum casting, and CNC machining



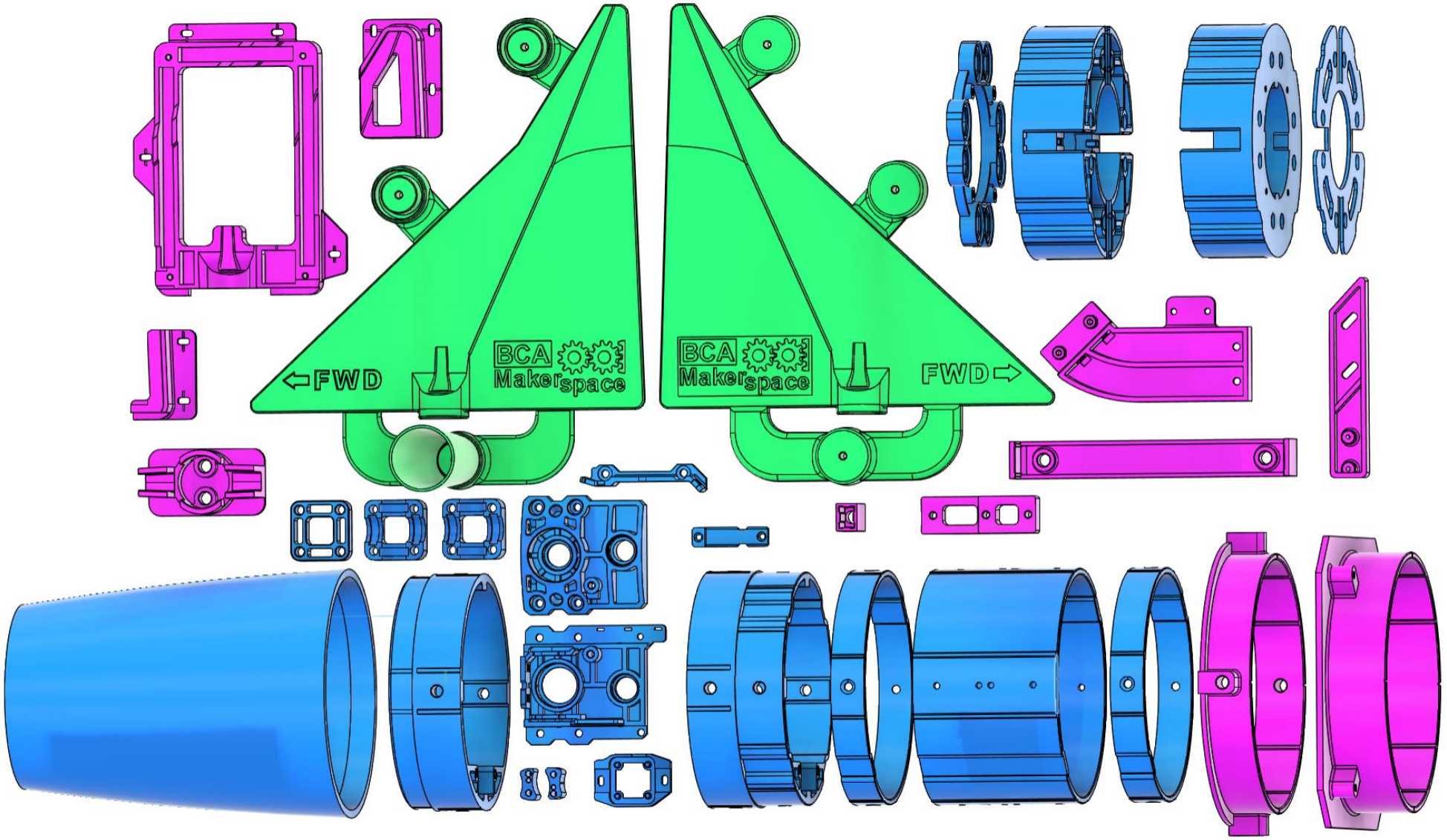


Contents

Full design in Fusion (warhead assembly censored)



3D Printed Parts (all blue and violet parts were printed on a $250 Monoprice Maker Select 2)

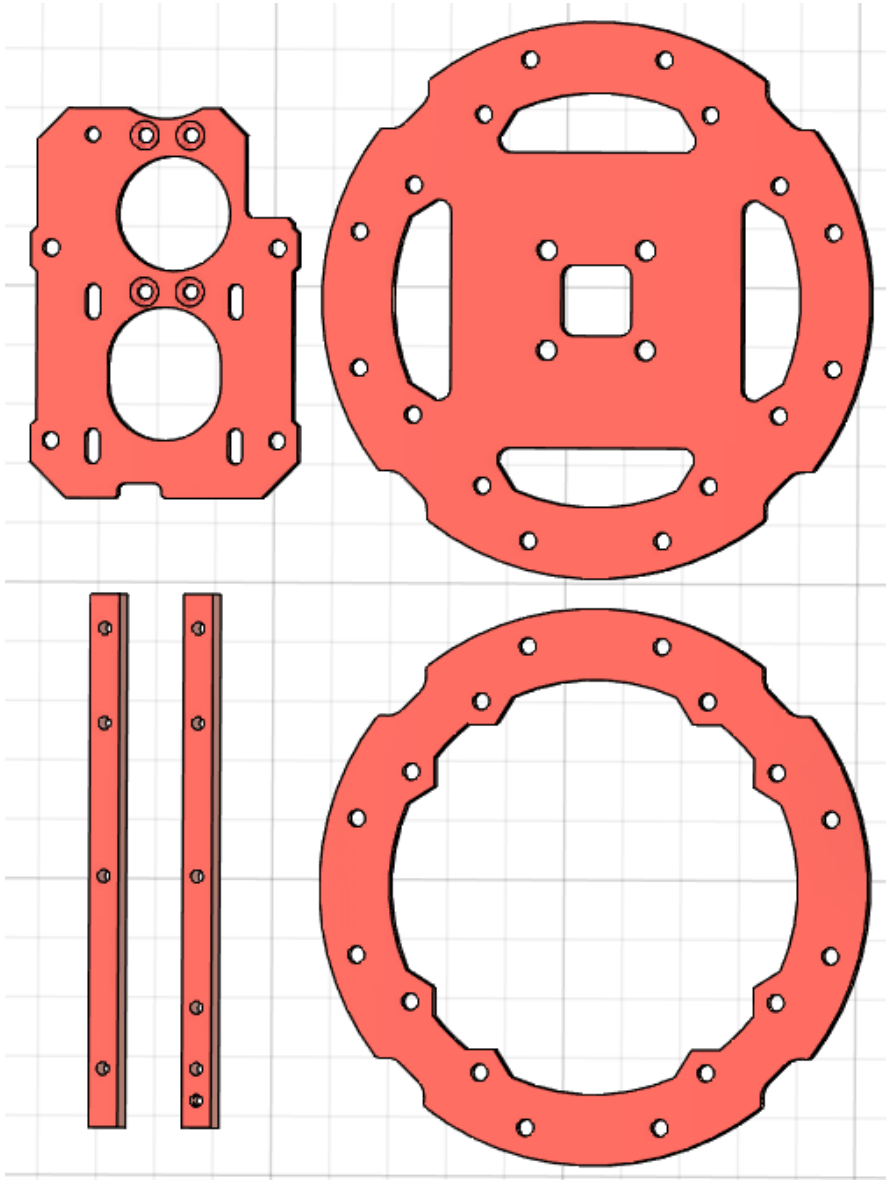


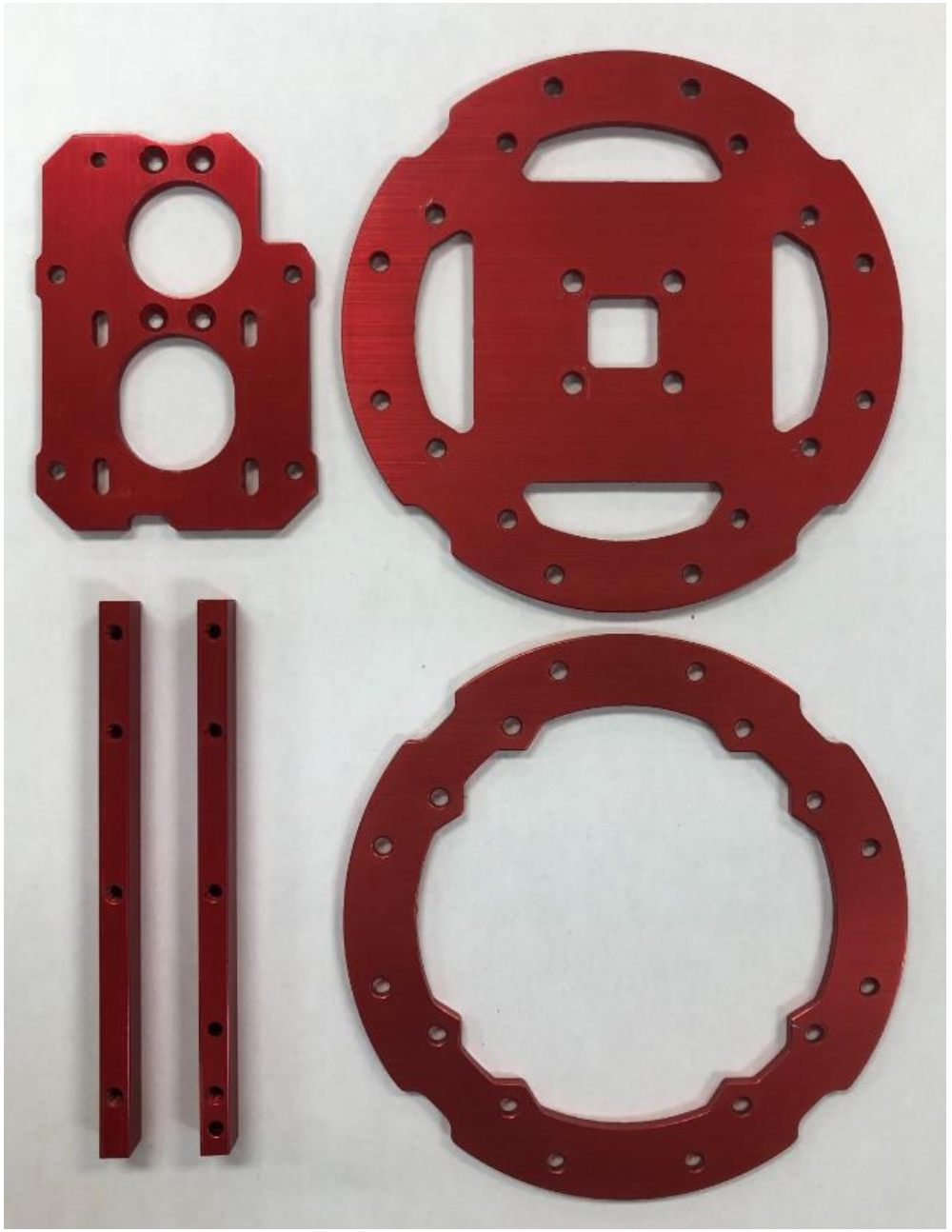
Blue parts are components of missile

Green parts **(fins)** are patterns for sand casting aluminum fins

Violet parts are fixture and jig tooling components to aid manufacturing

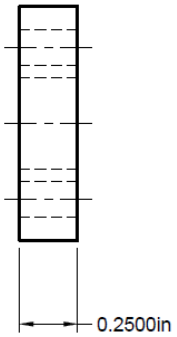
CNC Milled Parts with Anodized Finish

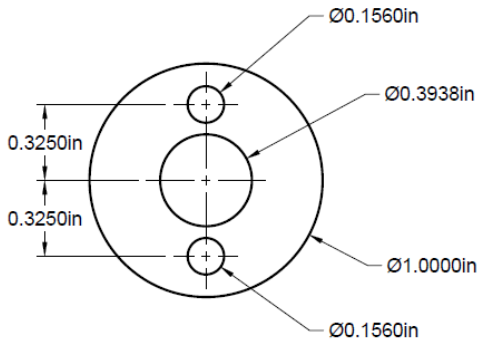


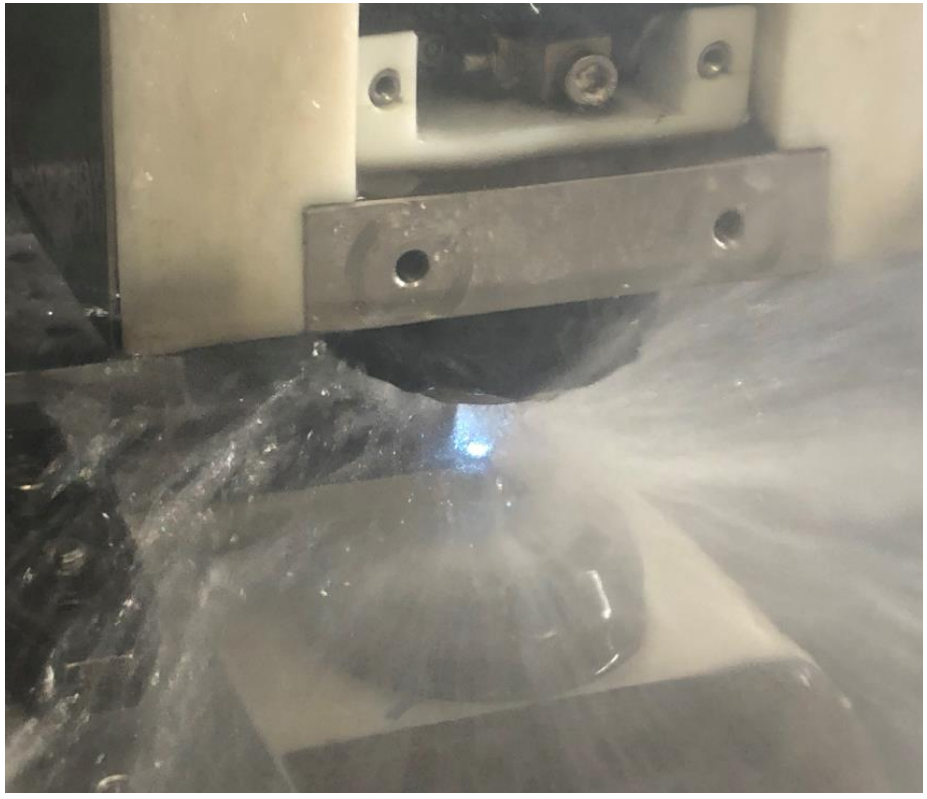


Wire EDM cutting of fin to shaft coupling

Small part cut with big machine (O1 tool steel)

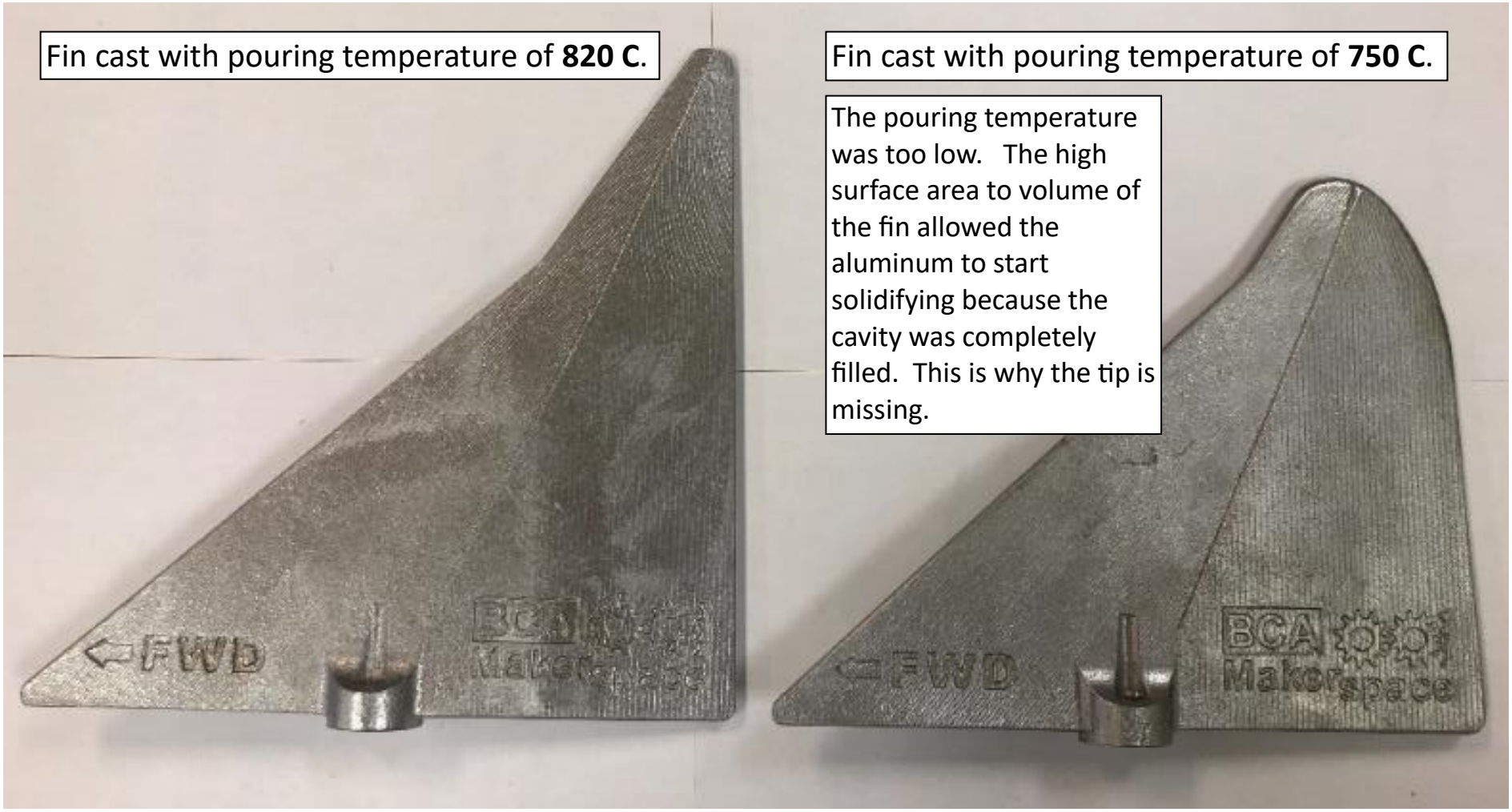




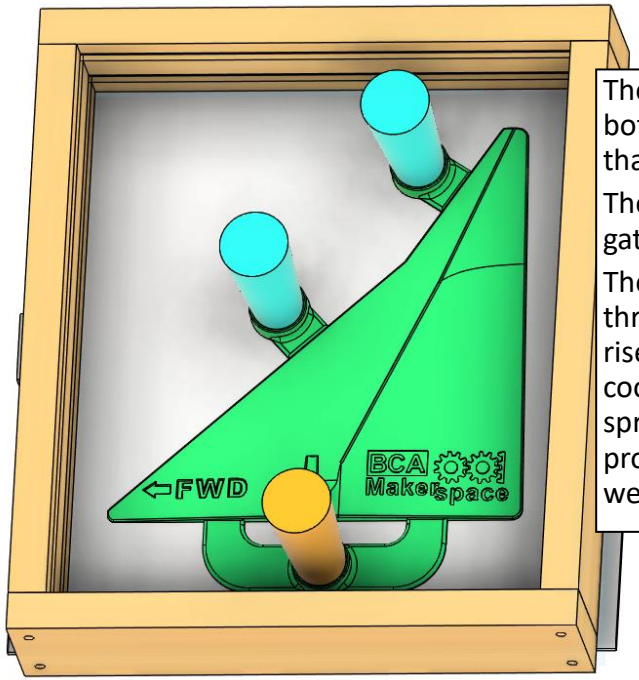


Guidance fins from sand casting aluminum from VW Jetta

The timing belt slipped on my Jetta resulting in valve damage. Aluminum parts were removed to be later casted.



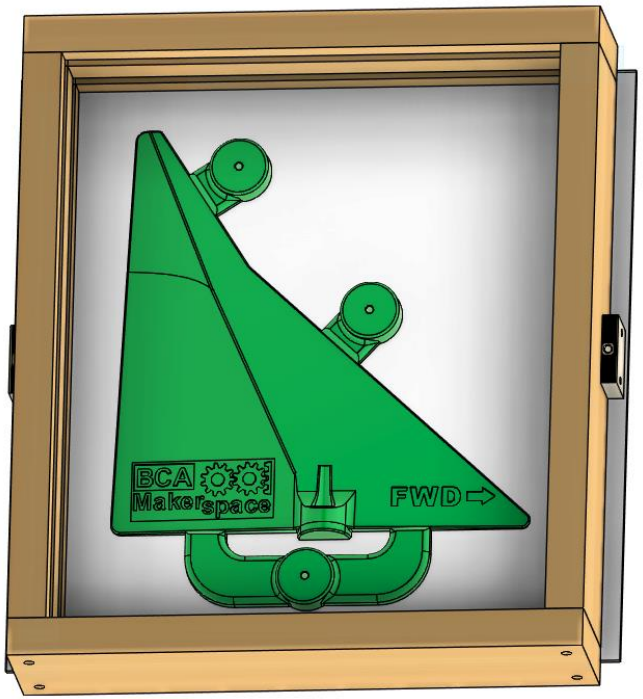
Split pattern sand casting process

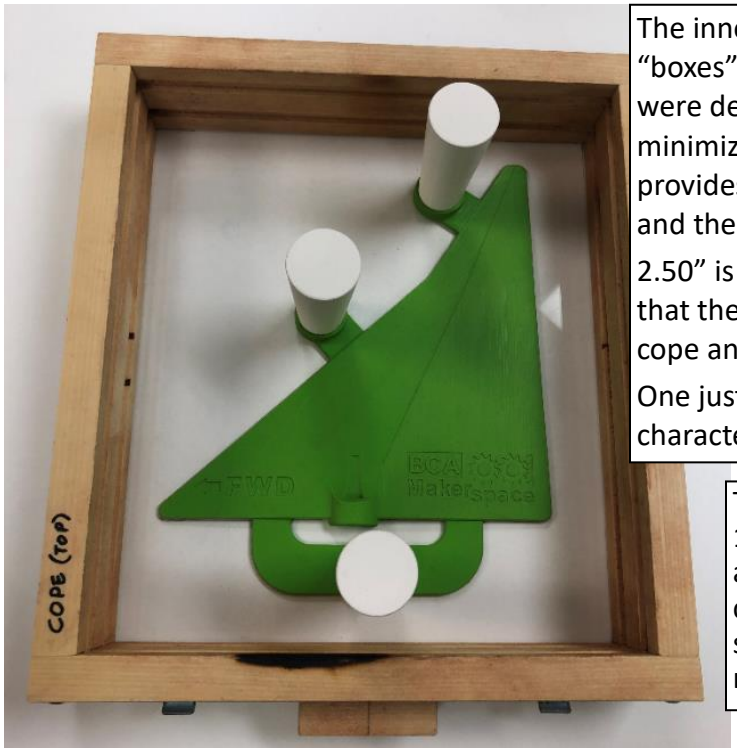


The orange cone extending up at the bottom forms the sprue. This is channel that the aluminum is poured in.

The aluminum then flows through the gating into the lower half of the fin.

The aluminum continues flowing through the fin cavity and then up the risers (blue cones). As the aluminum cools (and shrinks) the aluminum in the sprue and risers acts as a reservoir to provide extra aluminum. Two risers were used because of the size of the fin.





The inner dimensions of the cope and drag "boxes" are 9.75" x 11.50" and 2.50" deep. They were designed with these dimensions to minimize the amount of sand. The 9.75" x 11.50" provides an adequate spacing between the part and the wood to prevent the wood from burning.

2.50" is an adequate amount of depth to ensure that the sand doesn't fall out when opening the cope and drag.

One just goes by experience with the characteristics of the sand.

The half fin pattern is glued to a 1/8" sheet of acrylic with sprue and riser cones attached. The cope is placed on the acrylic sheet and casting sand is rammed around the pattern.

Petrobond sand is rammed into both the cope and drag. This sand is oil based and made for casting.

30 lbs were purchased costing about $100. A good source for the sand and general casting supplies is pmcsupplies.com

Sharpened hanger wire is then pushed into the sand in places for venting holes. The sprue and riser cones are then carefully removed. The cope is then turned upside down to remove the pattern.

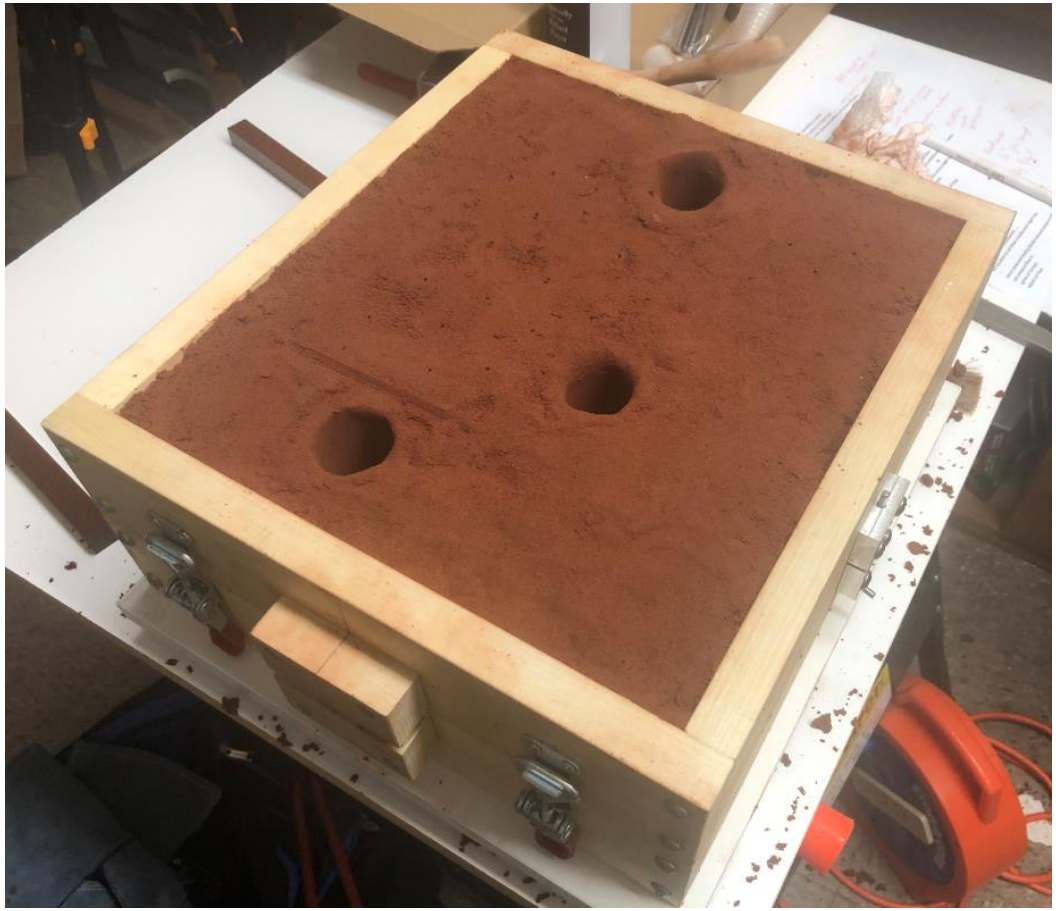
The same is done with the drag accept the drag has no sprue or risers and no vent holes are created.

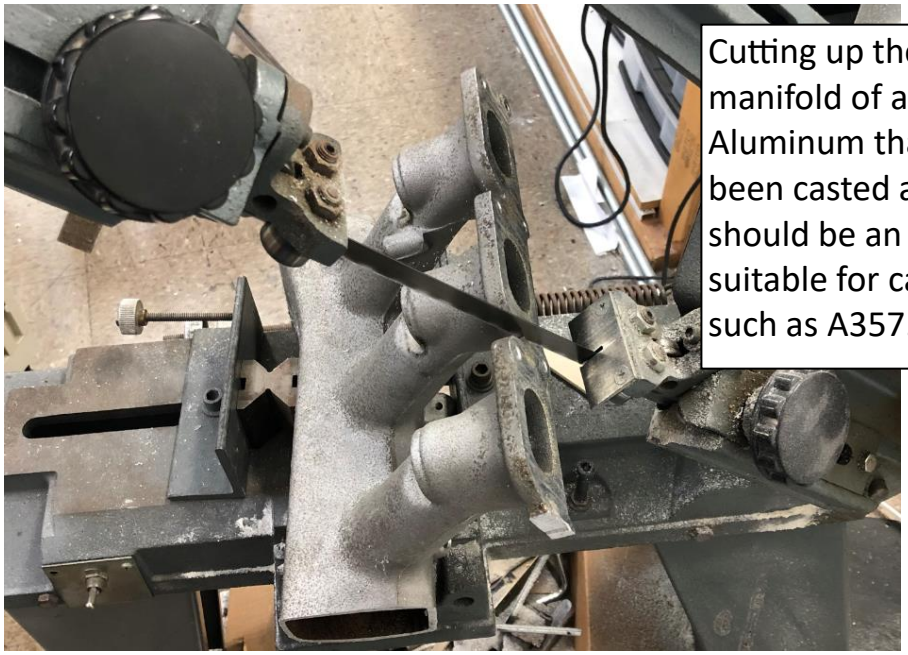
The cope and drag are then closed and secured together.

Pins are placed in the registration blocks to ensure proper alignment of the cope and drag. These pins also entended into the acrylic sheets of the patterns to maintain their alignment with the cope and drag.

The goal is to ensure the best alignment of the resulting cavities so half of the casting is not shifted.

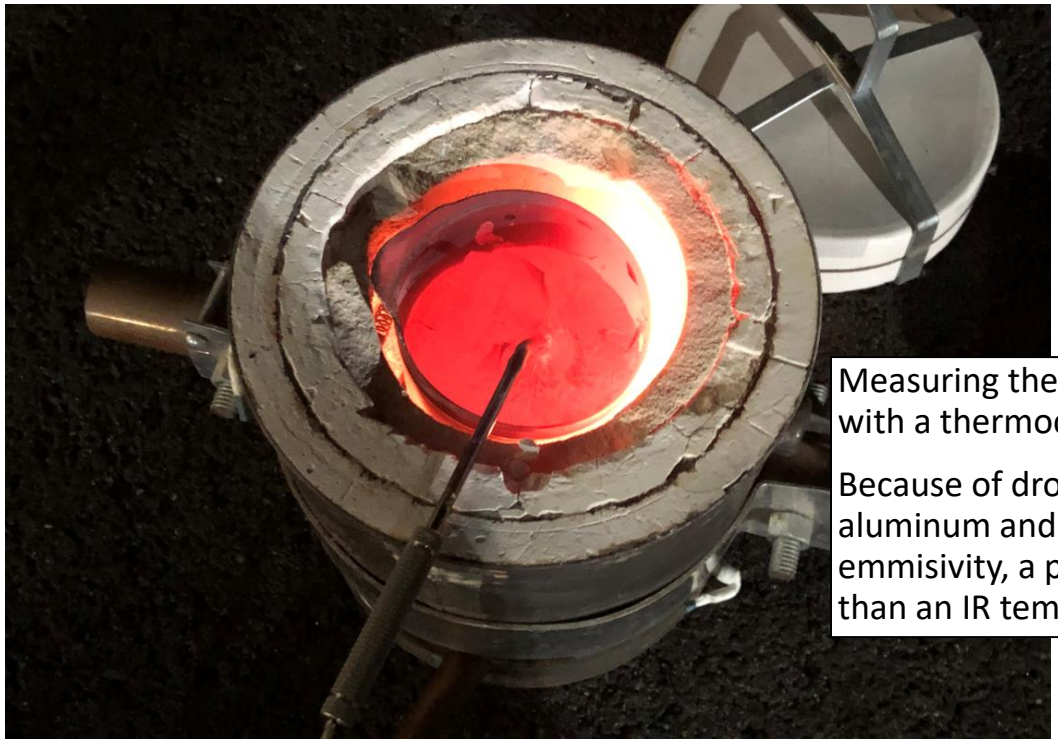
The bottom of the cope after the sprue and risers were pulled from the top, the cope is flipped over and the pattern is removed.





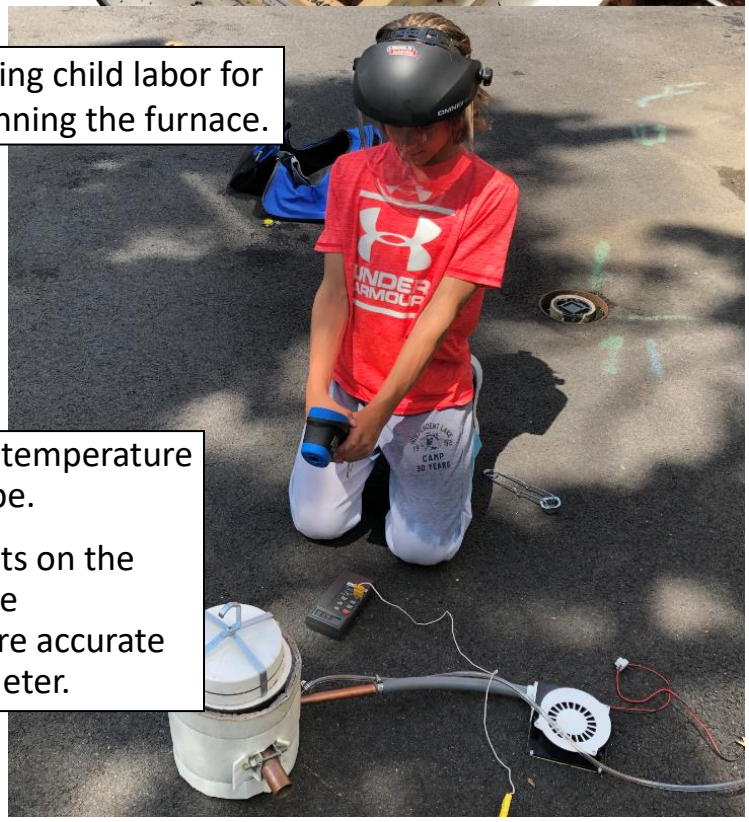
Cutting up the intake manifold of a VW Jetta. Aluminum that has been casted already should be an alloy suitable for casting, such as A357.

Using child labor for ramming casting sand.



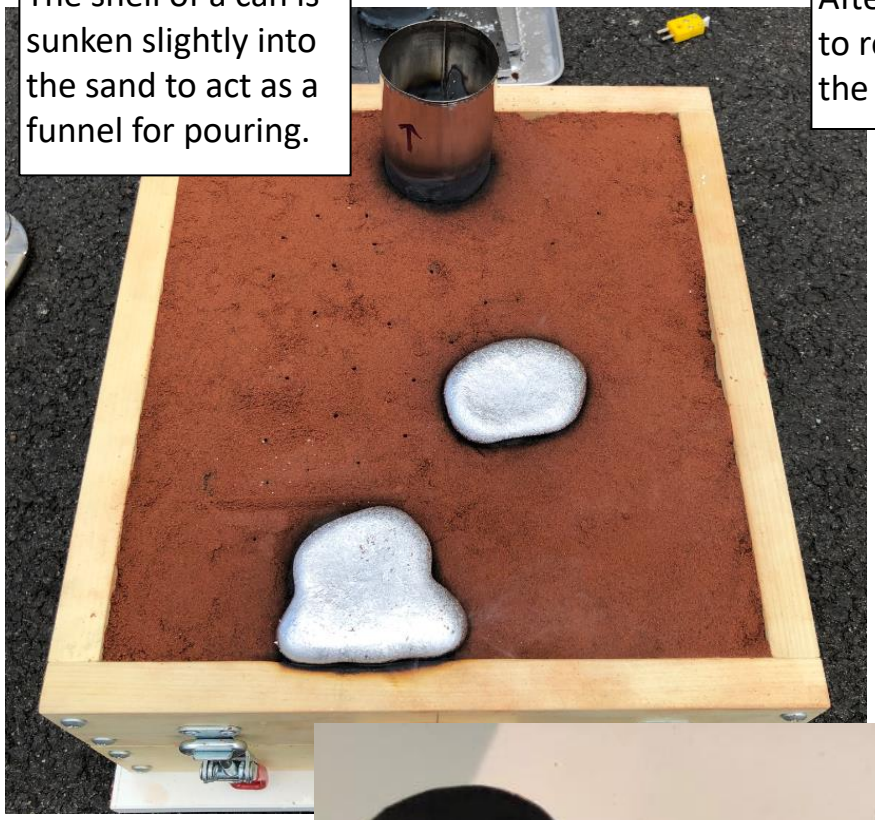
Measuring the aluminum temperature with a thermocouple probe.

Because of dross that floats on the aluminum and the variable emmisivity, a probe is more accurate than an IR temperature meter.



Using child labor for running the furnace.

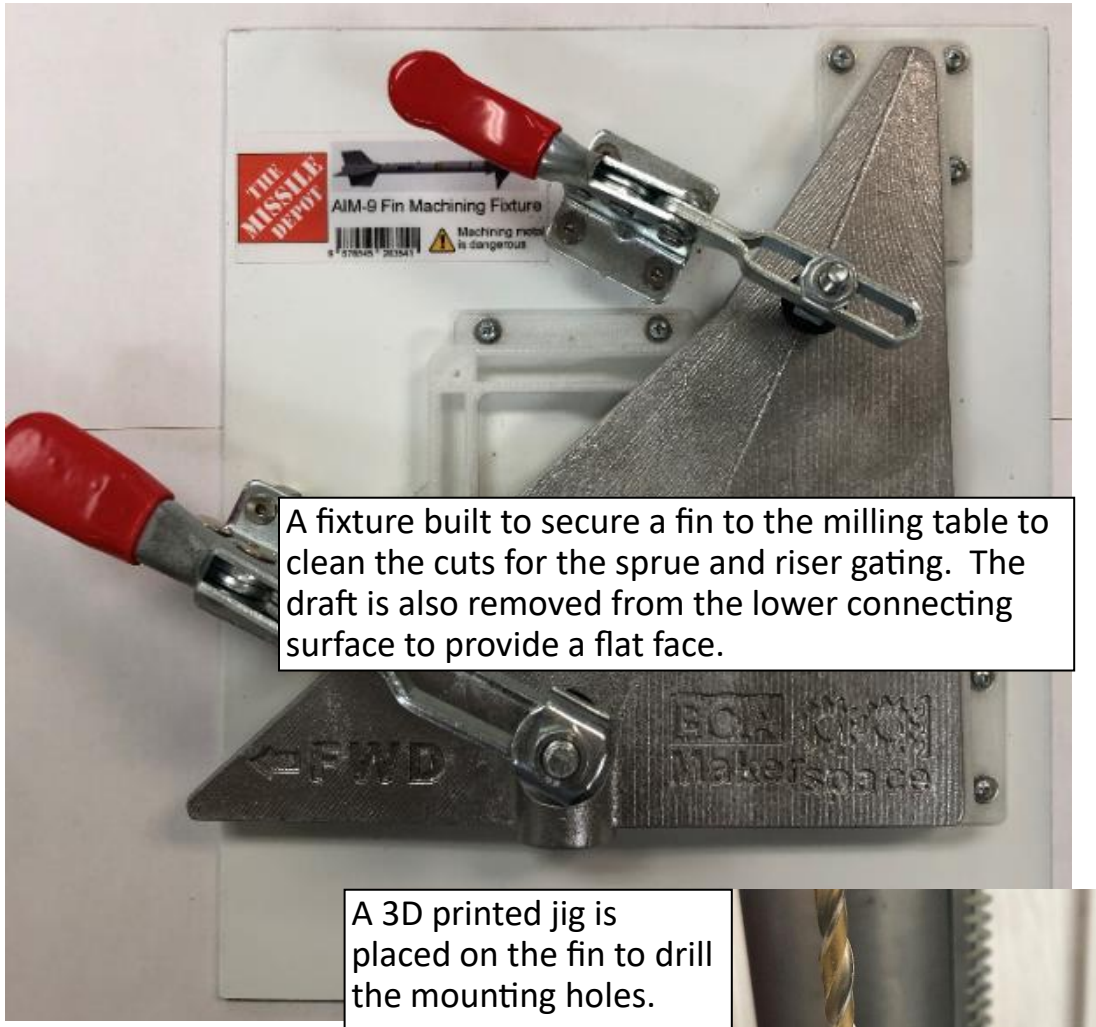
The shell of a can is sunken slightly into the sand to act as a funnel for pouring.



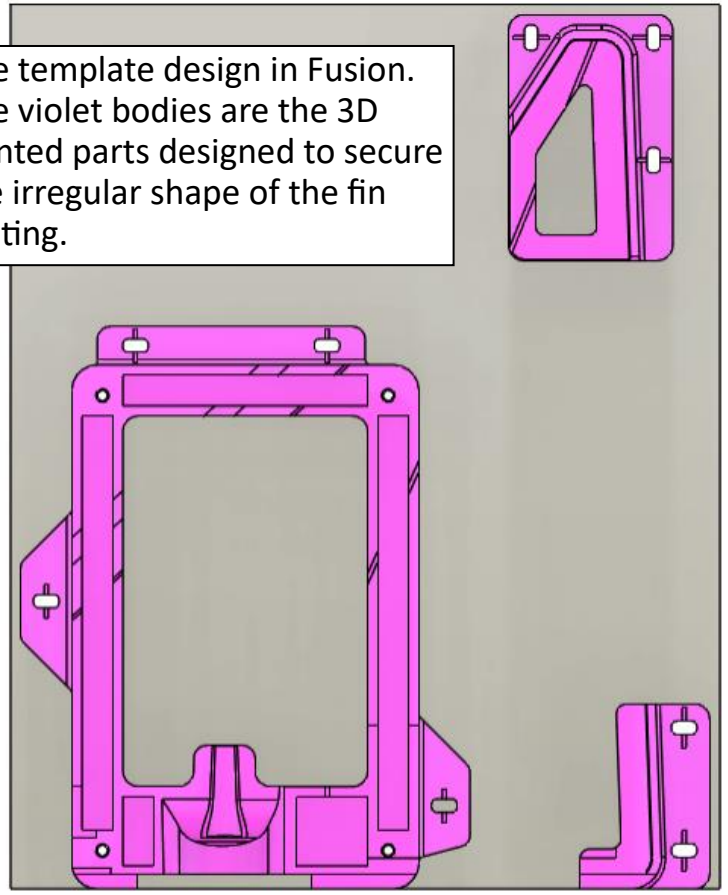
After a few hours of cooling, the fin is dug out. This is done carefully to remove any burnt sand to be discarded. A foundry would reuse all the sand and perform a “mulling” operation to “refurbish” the sand.

The casting with the sprue, gates, and risers still attached. They will be removed with a bandsaw.

Machining of fin casting

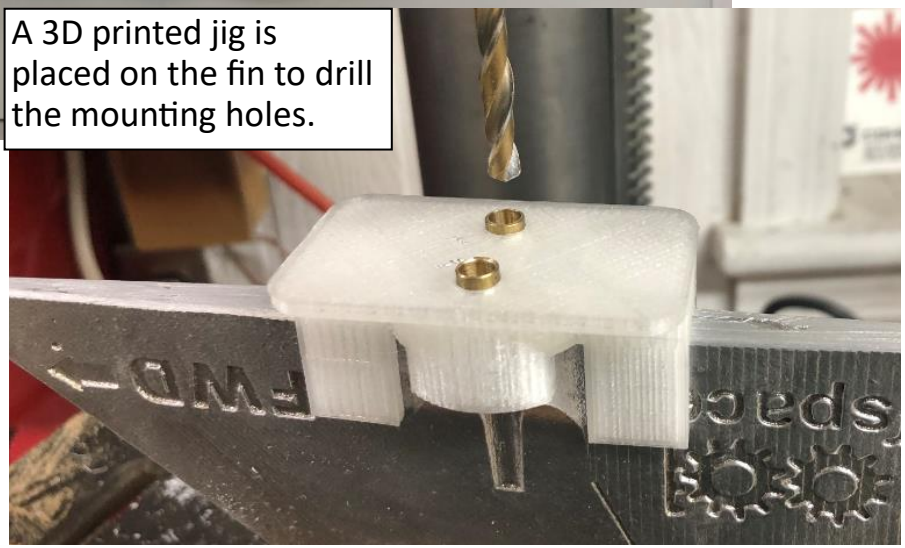


A fixture built to secure a fin to the milling table to clean the cuts for the sprue and riser gating. The draft is also removed from the lower connecting surface to provide a flat face.

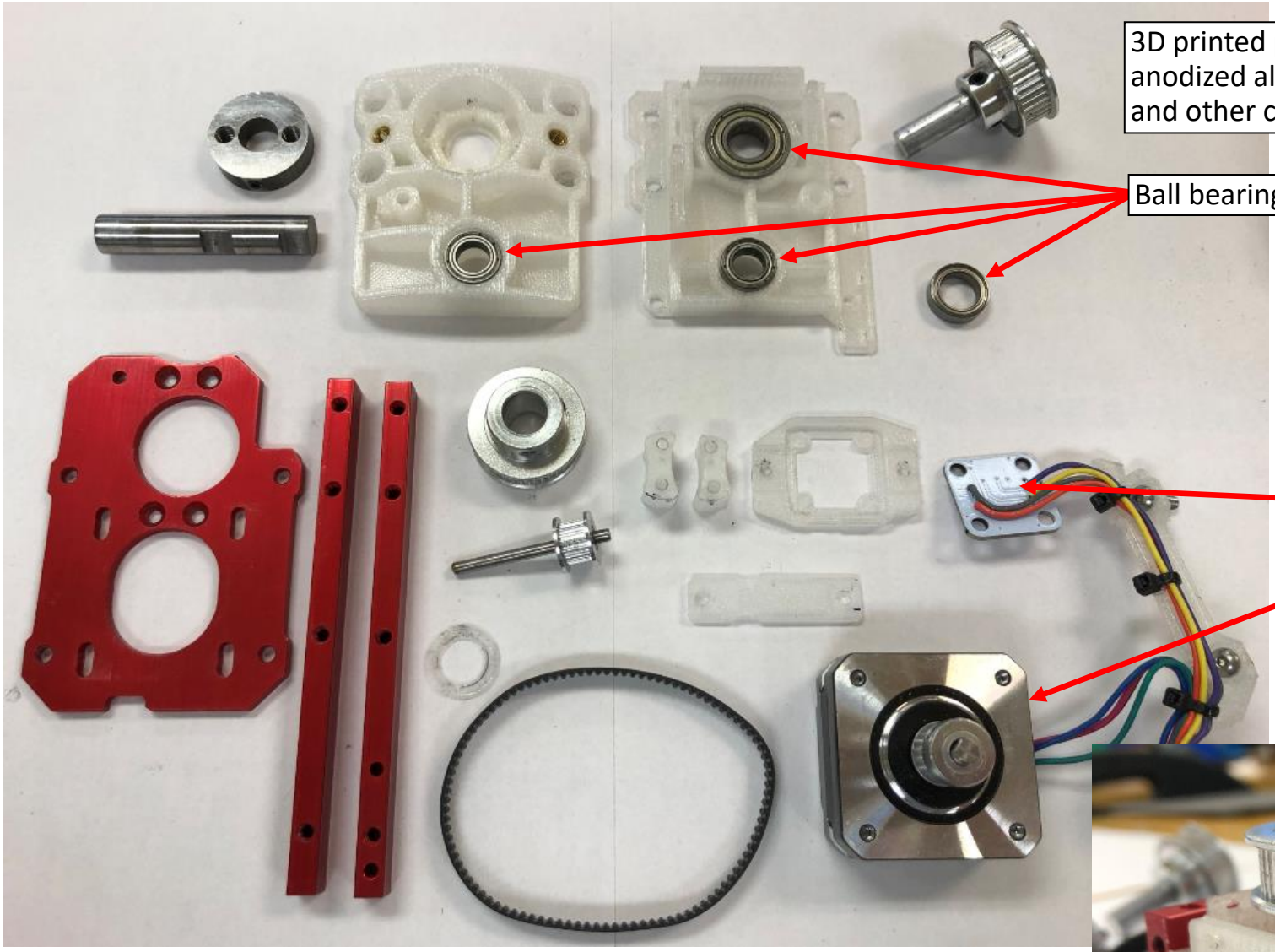


The template design in Fusion. The violet bodies are the 3D printed parts designed to secure the irregular shape of the fin casting.

A 3D printed jig is placed on the fin to drill the mounting holes.



Fin Guidance Actuator (disassembled)

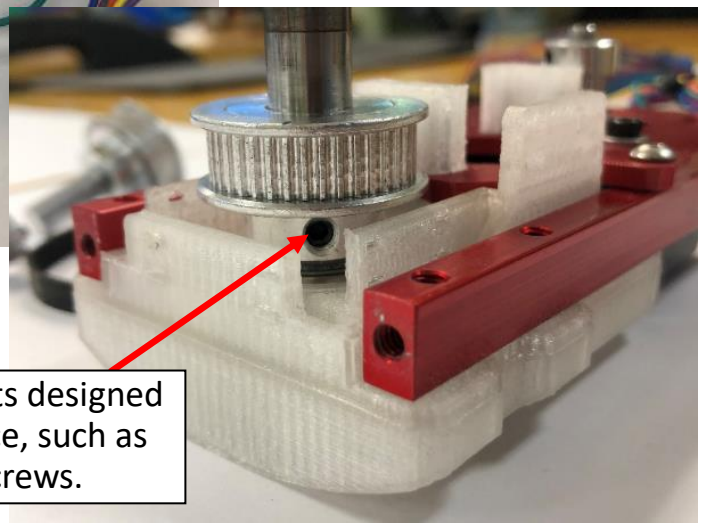


3D printed parts (clear/white), anodized aluminum parts (red), and other components

Ball bearings

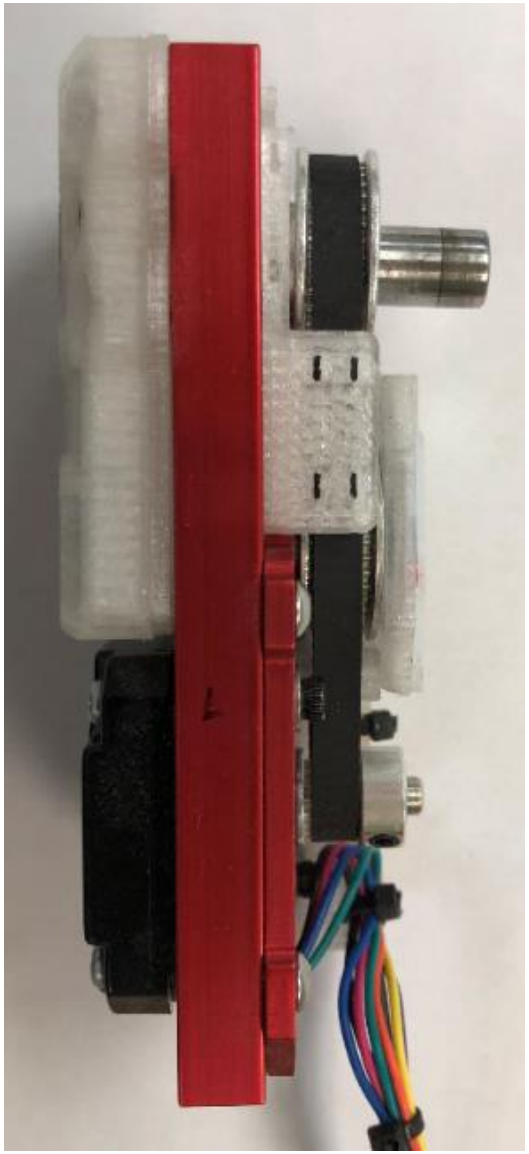
Magnetic position sensor

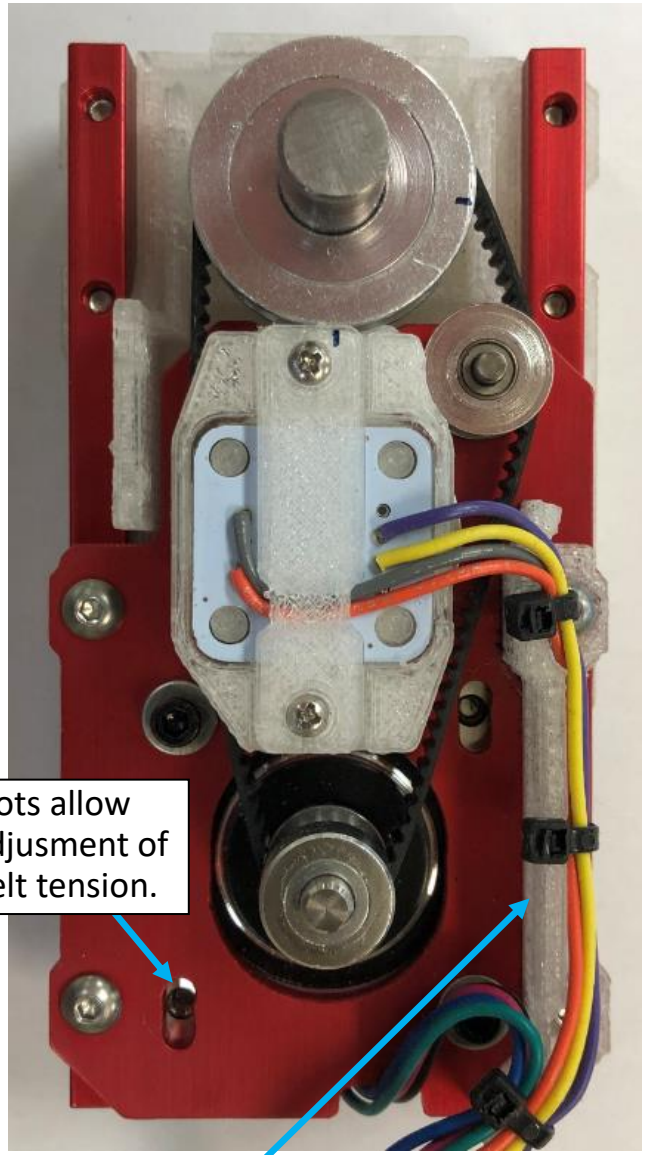
Stepper motor



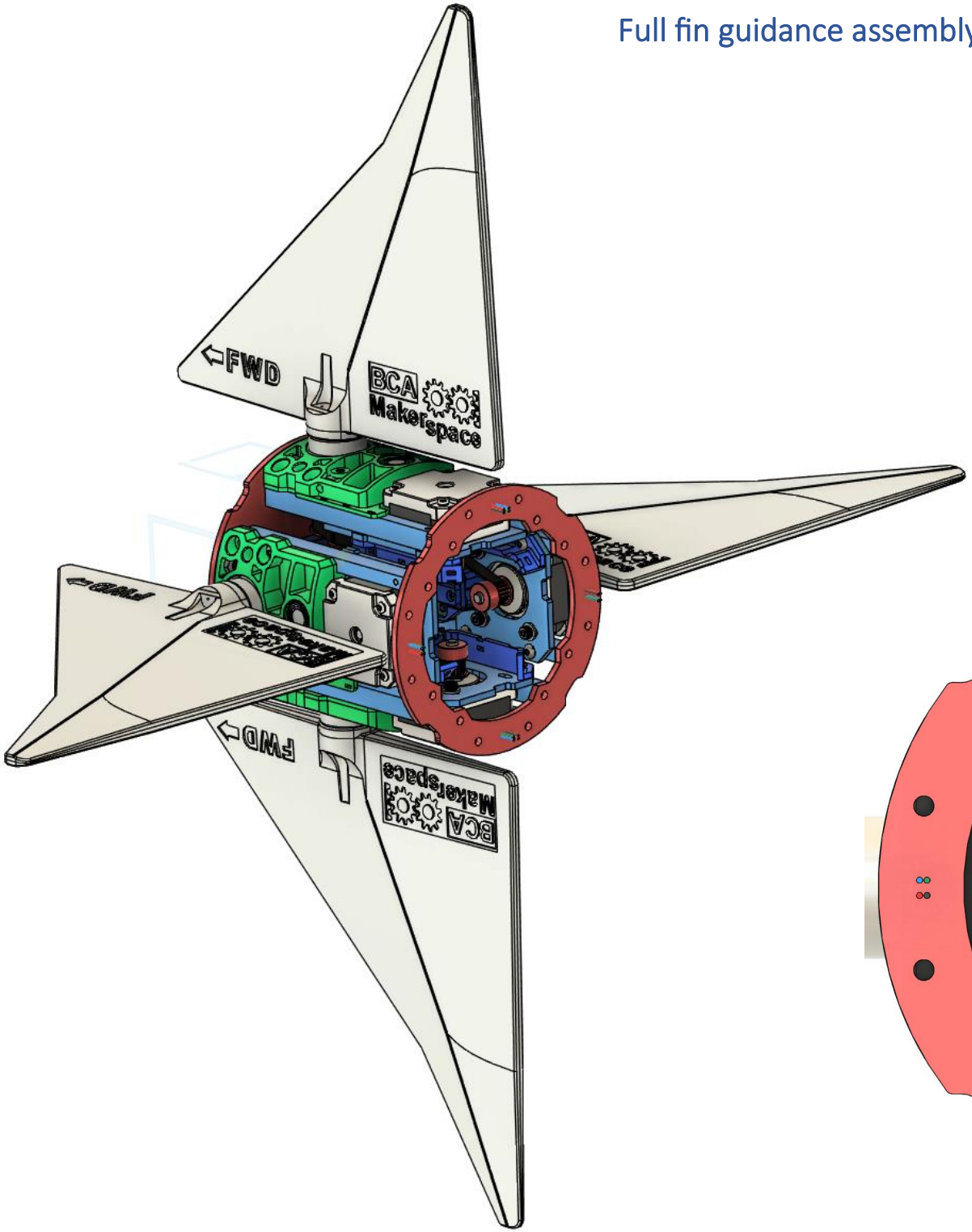
3D printed parts designed for tool clearnce, such as access to set screws.

Fin Guidance Actuator (assembled)



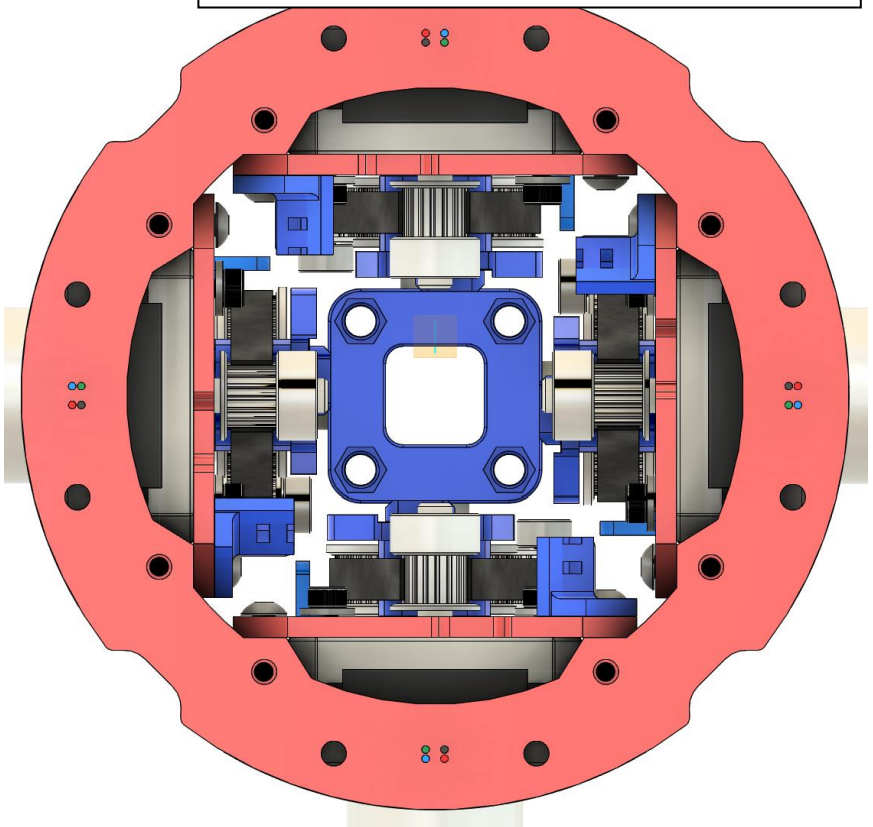


Full fin guidance assembly

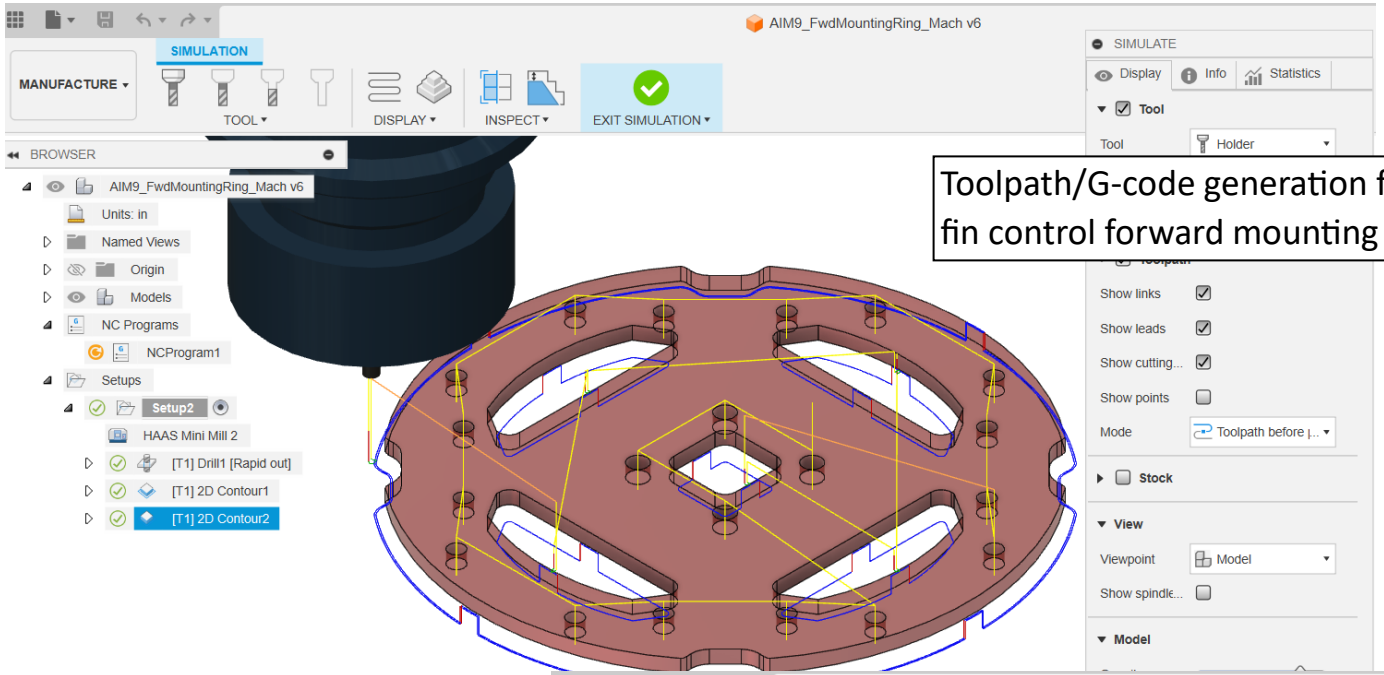


Rear view of full fin guidance assembly.

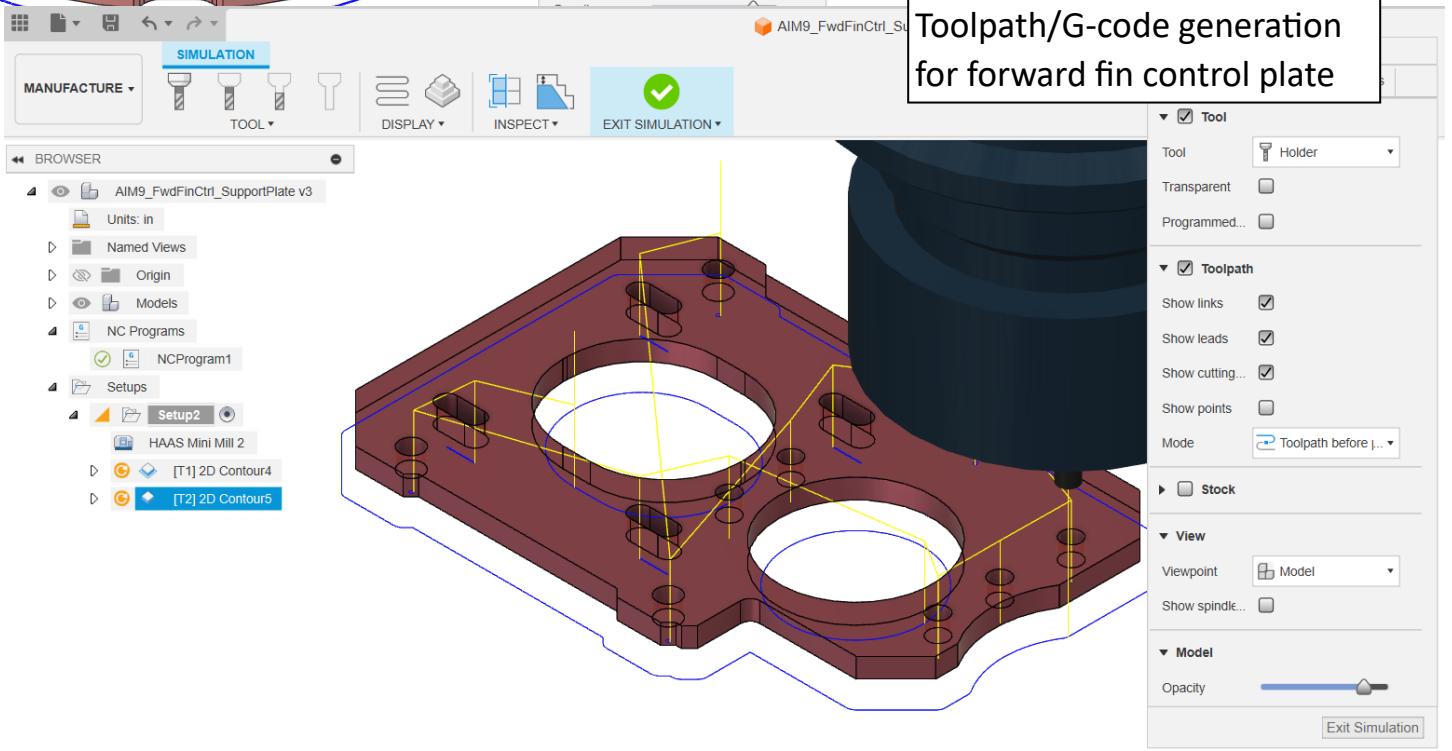
The individual actuators were designed to fit together with clearance between them.



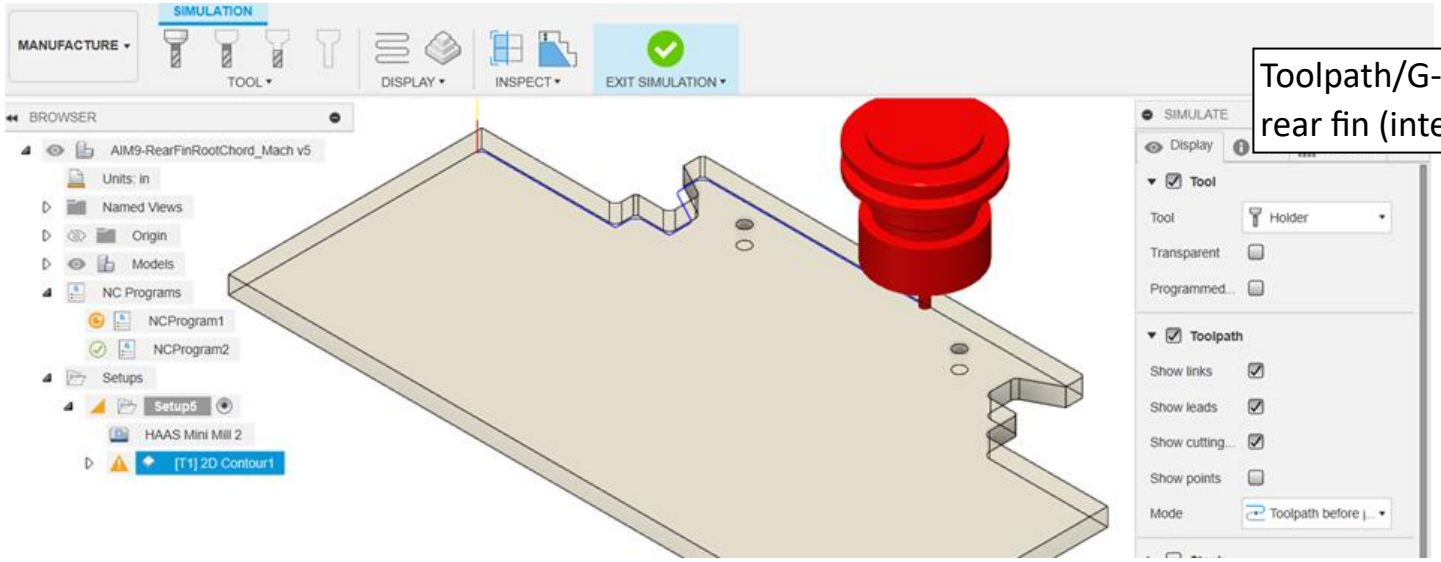
Fusion Manufacture workspace for toolpath generation



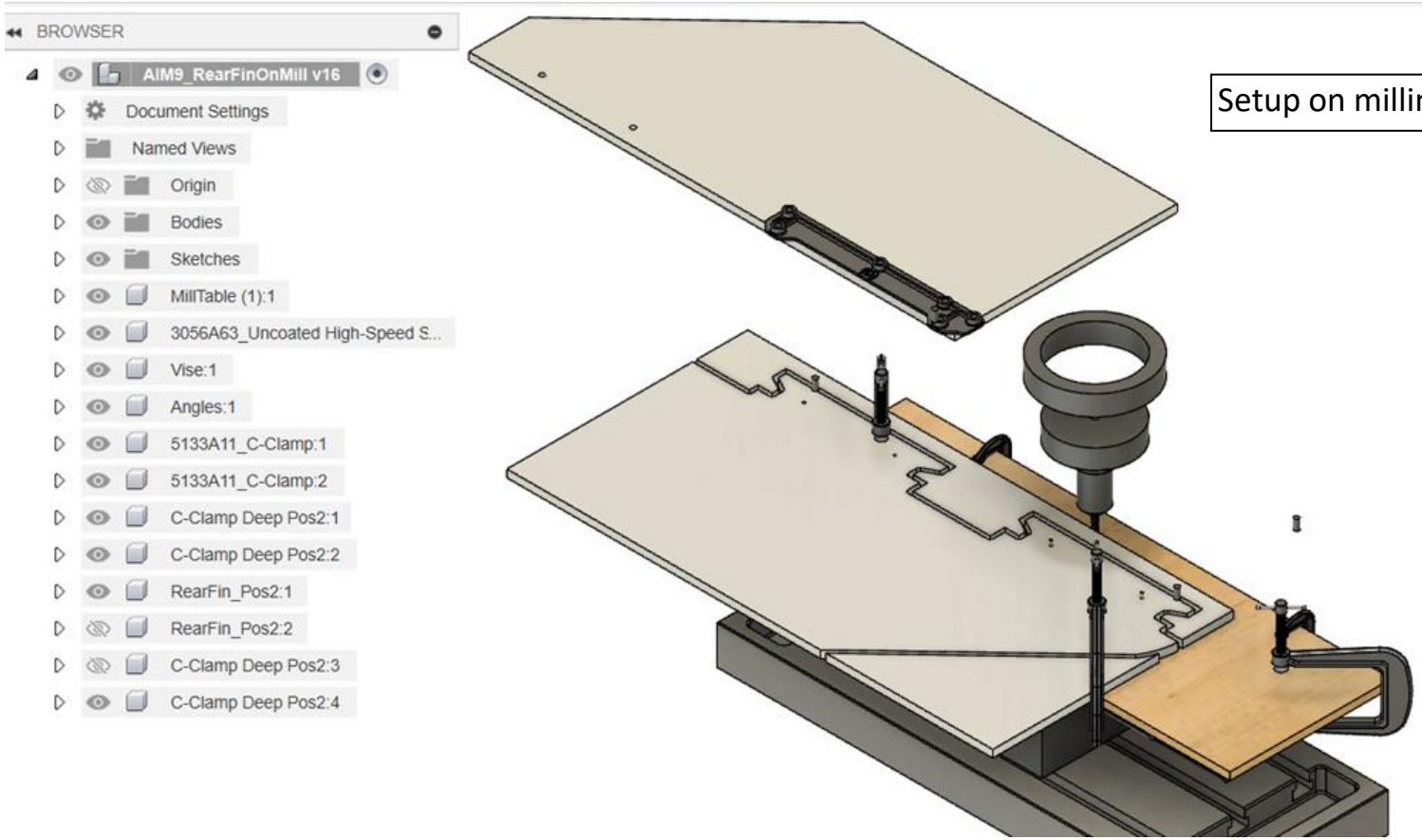
Toolpath/G-code generation for forward fin control forward mounting plate



Toolpath/G-code generation for forward fin control plate

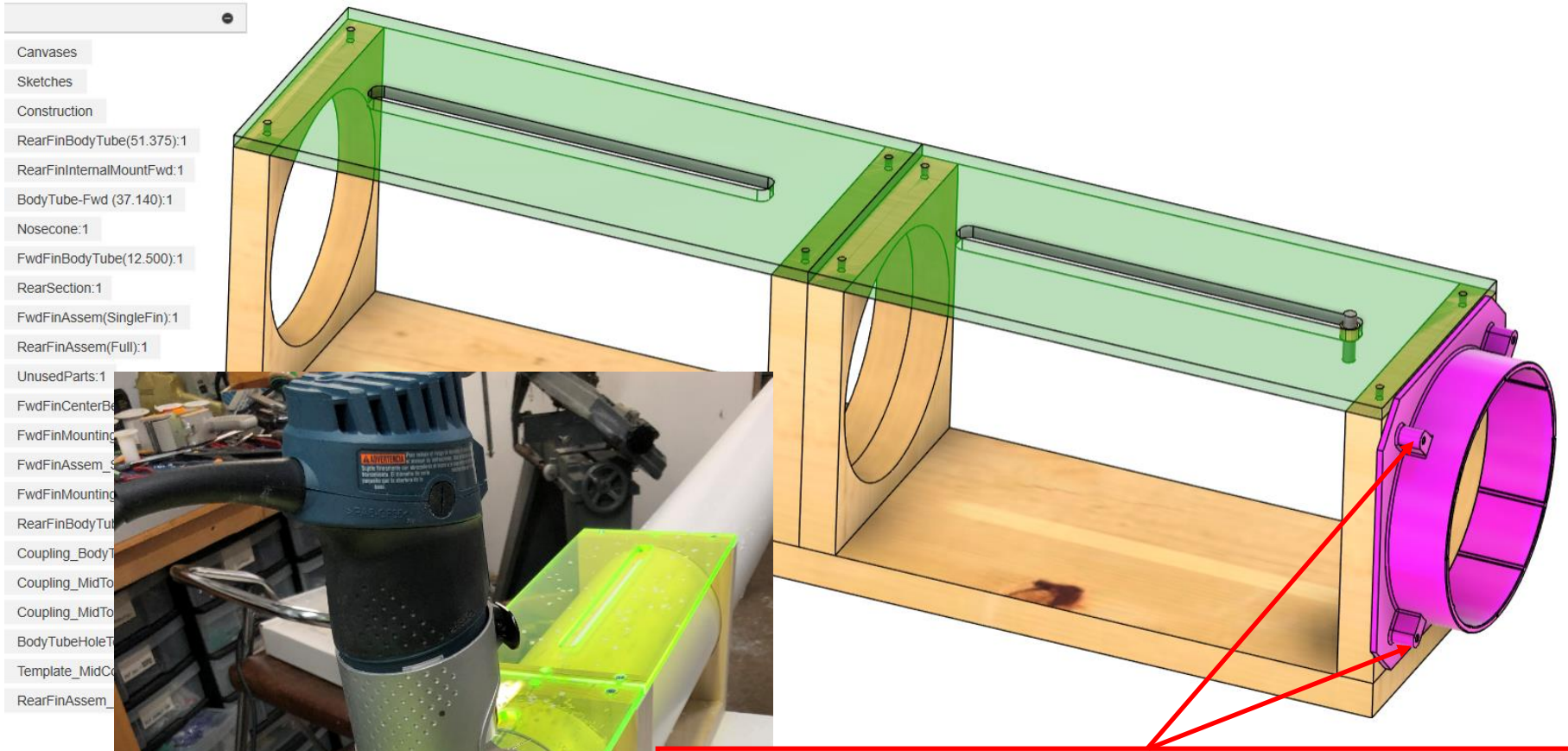


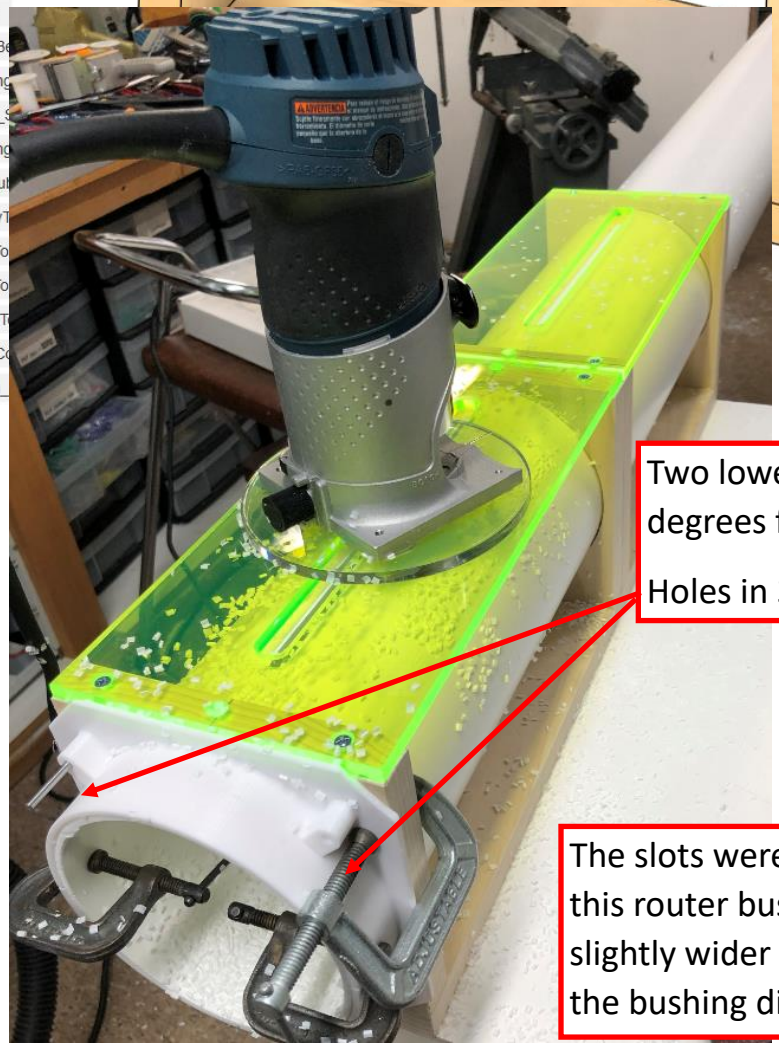
Toolpath/G-code generation for rear fin (internal attachment)



Setup on milling machine

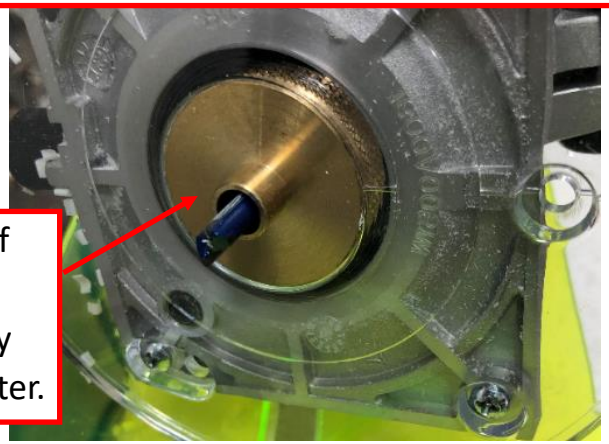
Fusion design and use of jig for body tube slots





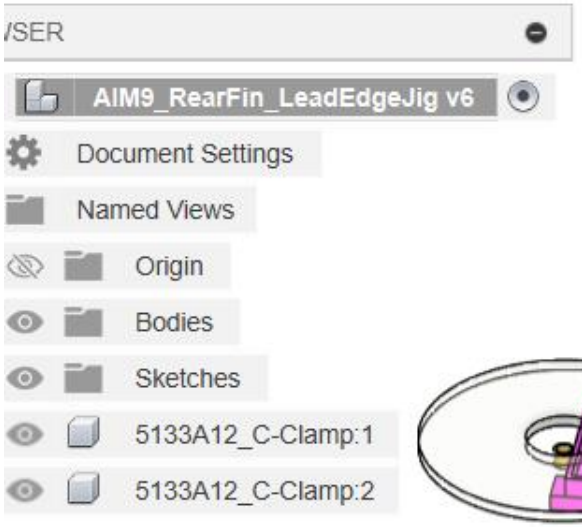
Two lower C-clamps are not removed when rotating rocket body tube 90 degrees for routing additional slots.

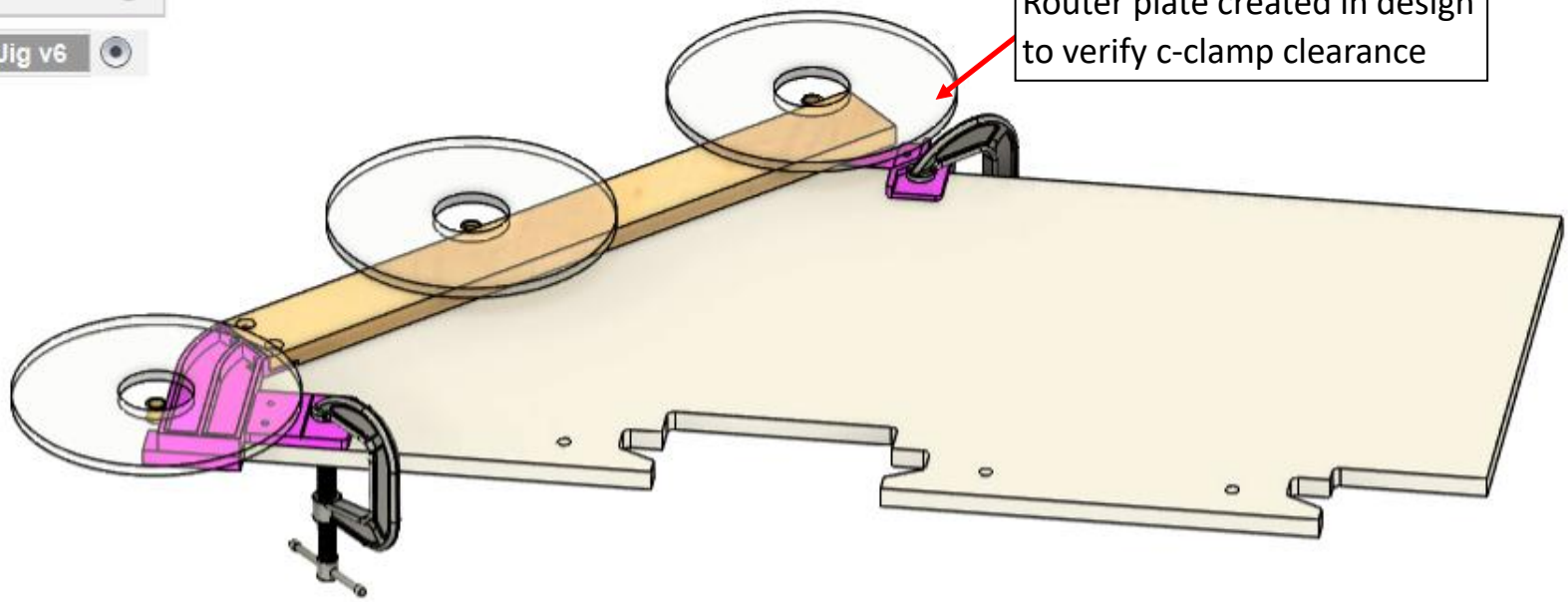
Holes in 3D printed holder allow locking pin to maintain 90 degree positions.

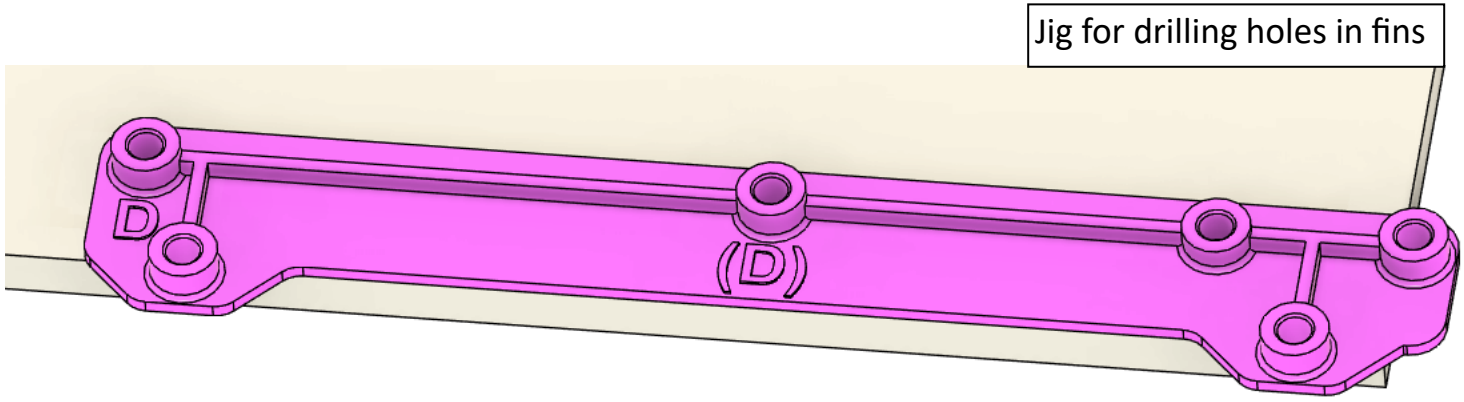


The slots were designed for the use of this router bushing. They must be slightly wider than the desired hole by the bushing diameter – the bit diameter.

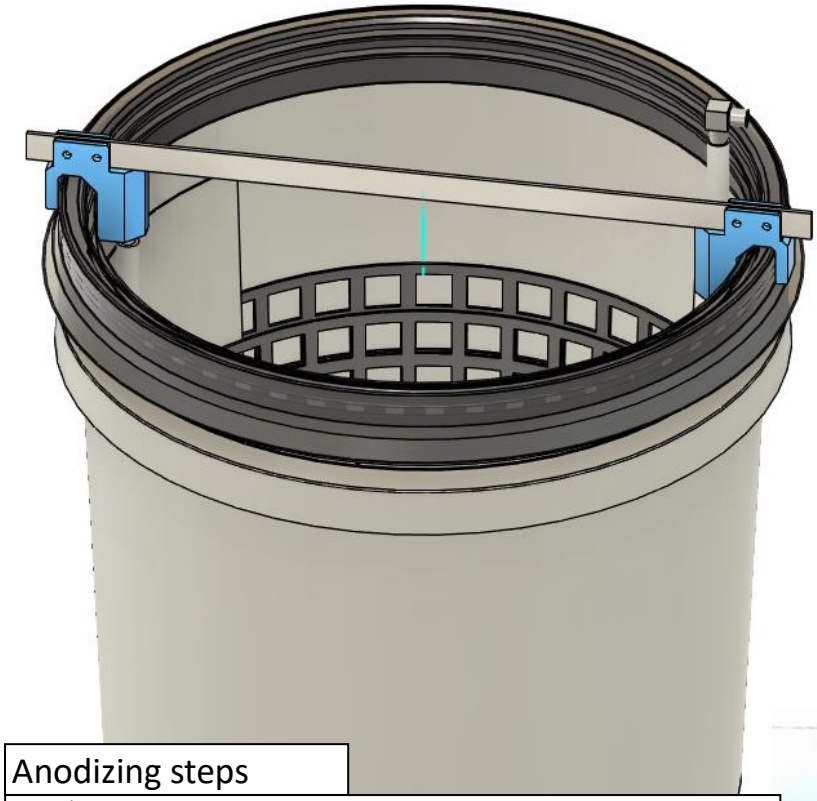
Fusion design of jigs for rear fin



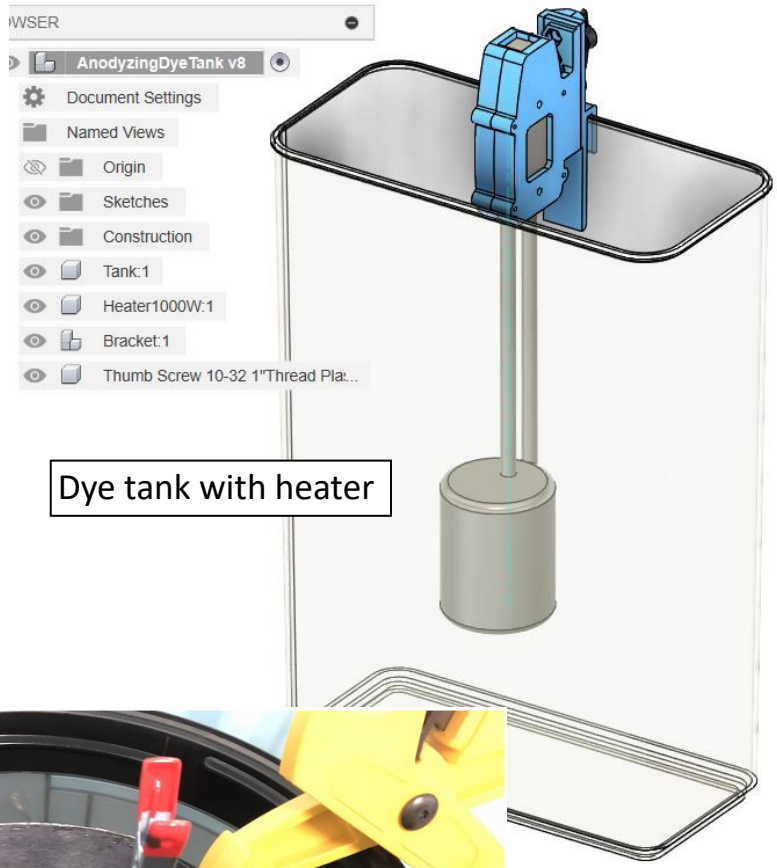




Fusion design of anodizing tanks



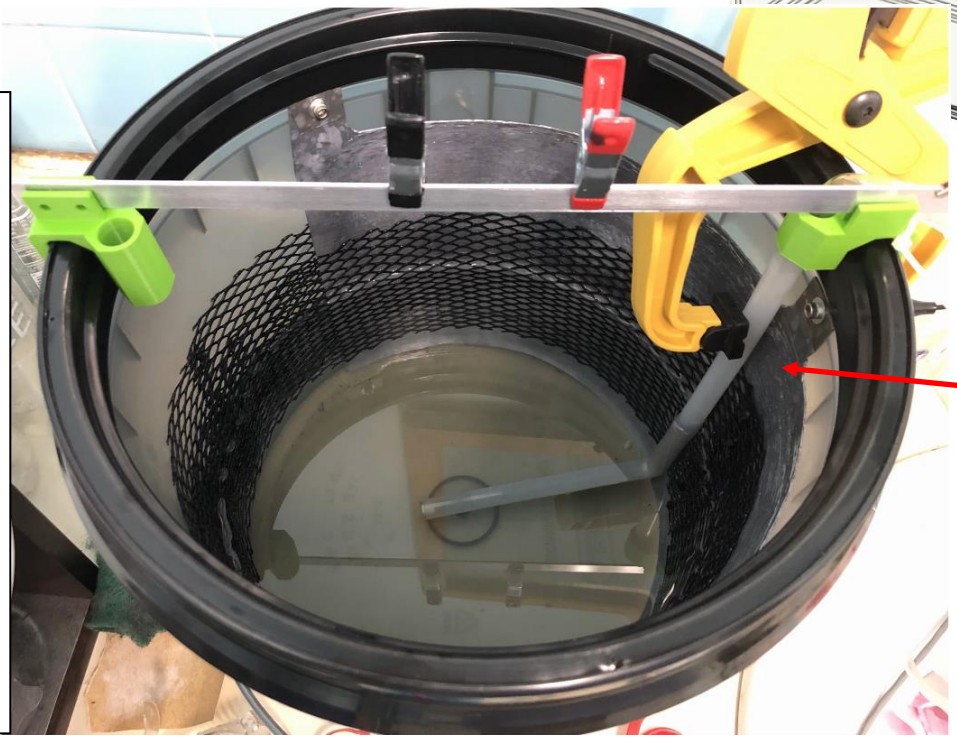
Anode bar



Dye tank with heater

Anodizing steps

-clean/degrease (using Simply Green)
-ensure Ti/Al attached wires are proper length for hanging
-attach Ti/Al wires (bend out bottom hook if needed, if using Al sand connecting area)
-spray (distilled H2O)
-soak in NaOH (ex: 2 mins, optional, skip if using de-oxidizer) (33g NaOH to 1L H2O)
-soak in de-oxidizer (ex: 1-3 mins, optional, for Ai 2024)
-spray down (distilled H2O)
-soak (distilled H2O)
-ensure power supply set for 20V and 0.050A
-clean top hang bar if needed
-hang in bath and ensure parts are not touching
-set start of current ramp (ex: 100mA)
-start heating dye (~15 min before needed)
-remove parts and spray down (distilled H2O)
-soak in NaHCO3 solution (ex: 5 min) (40g NaHCO3 (baking soda) to 1L H2O)
-remove parts and spray down (distilled H2O)
-soak parts in dye (ex: 10 min)
-remove parts and spray down (distilled H2O)
-boil parts (ex: 30 min, optional use of nickel acetate)
-let parts dry



Lead cathode

Pivoting missile stand