HTBYRRRF

Using questionably sound engineering practices and spamming computer-controlled machine tools for fun and ~~profit~~ robots

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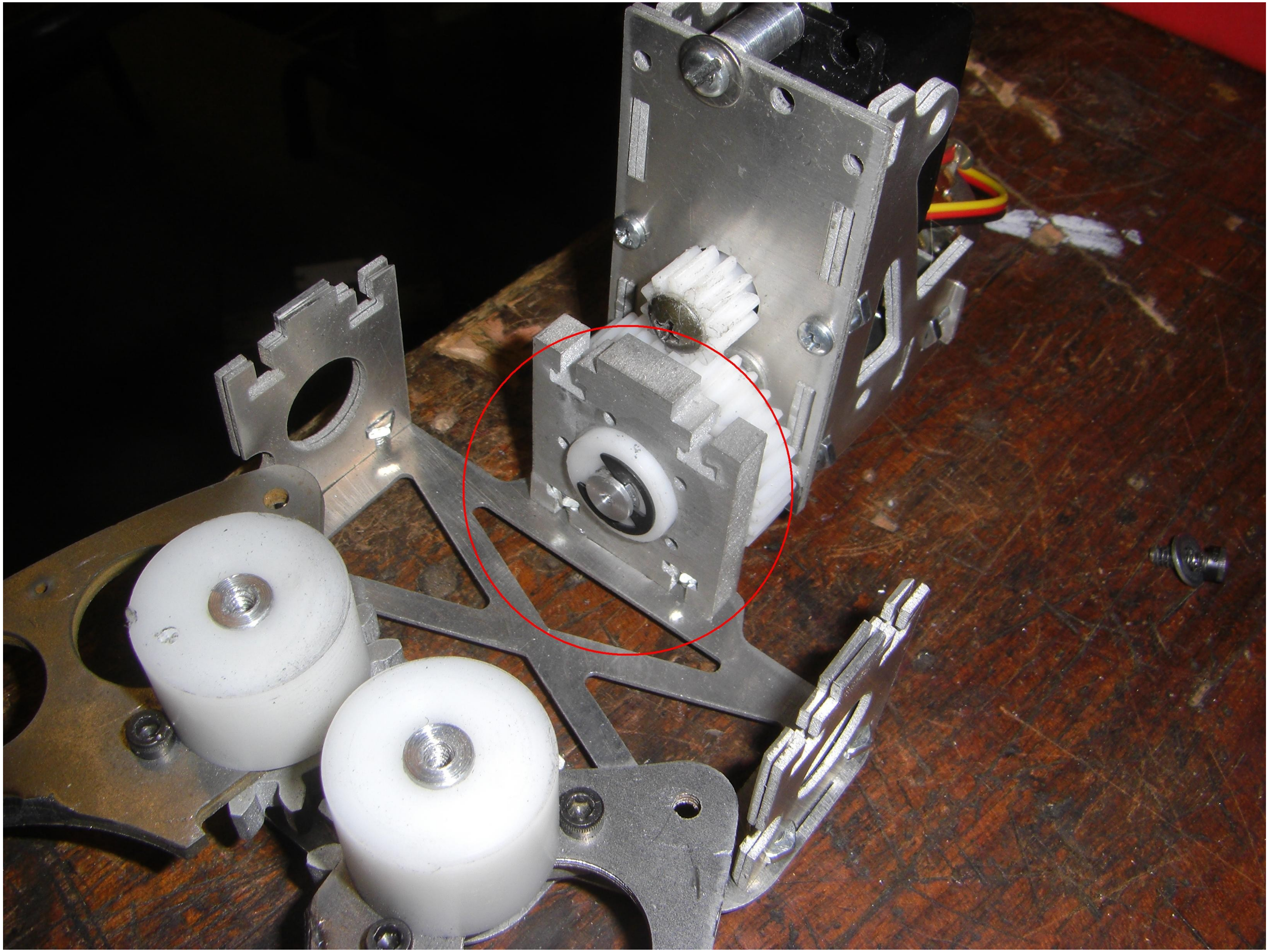
Contents

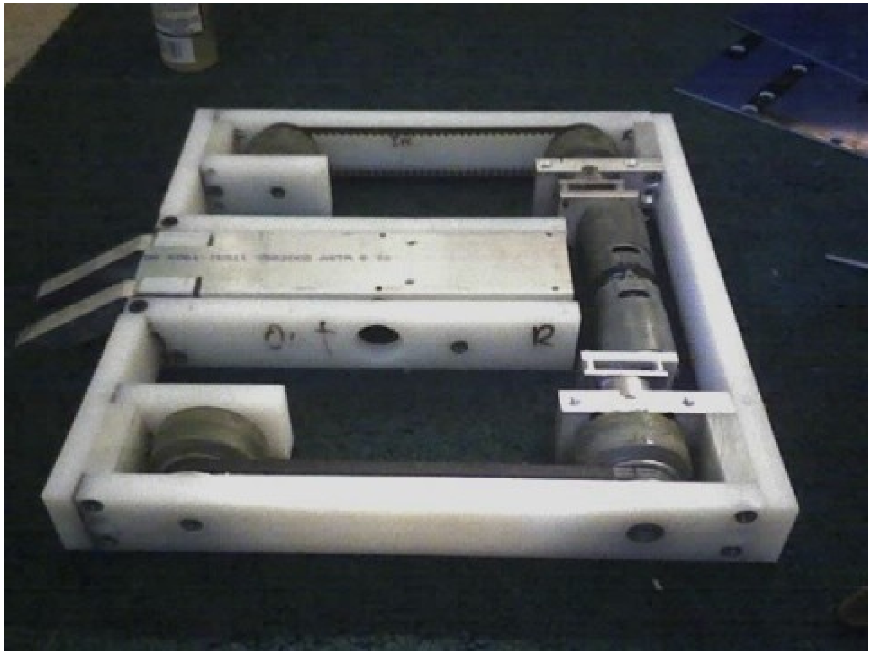
Modularity and Part Interfaces

- Build process tends to be more efficient if one assembly does not depend on another
  - “Oops, forgot to install 1 nut, so I need to take the entire robot apart”
  - “THIS ENTIRE ROBOT SUCKS AND I NEED TO SPEND ALL OF SPRING BREAK REMAKING IT”
- Establish a common mounting interface for major robot subassemblies
  - Mounting blocks with a bolt pattern?
  - Specifically shaped slots or protrusions in the robot frame?
- “Modular Mounting Surface”: Any constraining feature(s) which fully secure one subassembly to another, **that require(s) no modification to either, and is reversible in process.**

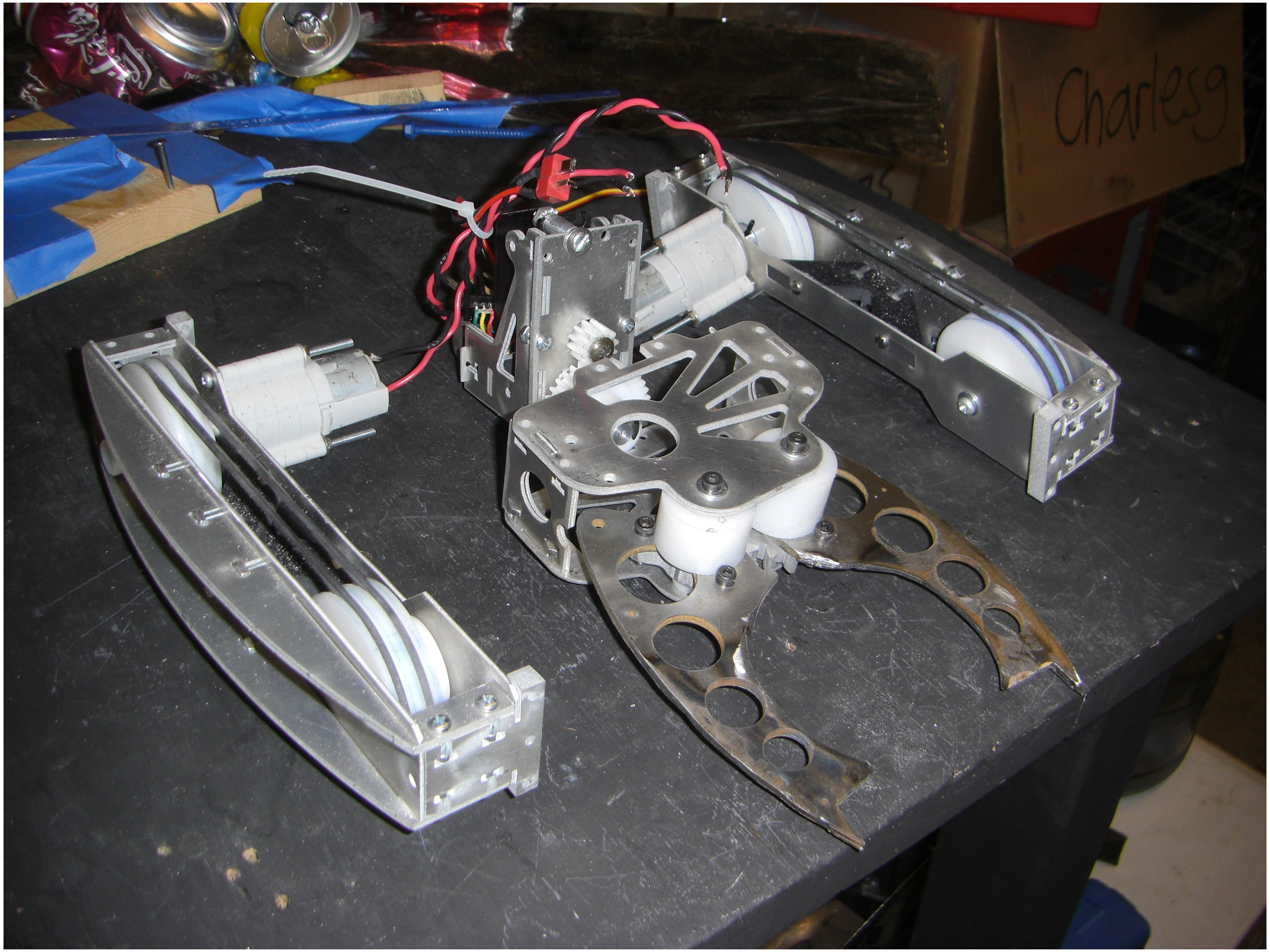


The five hole pattern allowed me to change manipulator designs if the claw ended up not working.

Corner Blocks



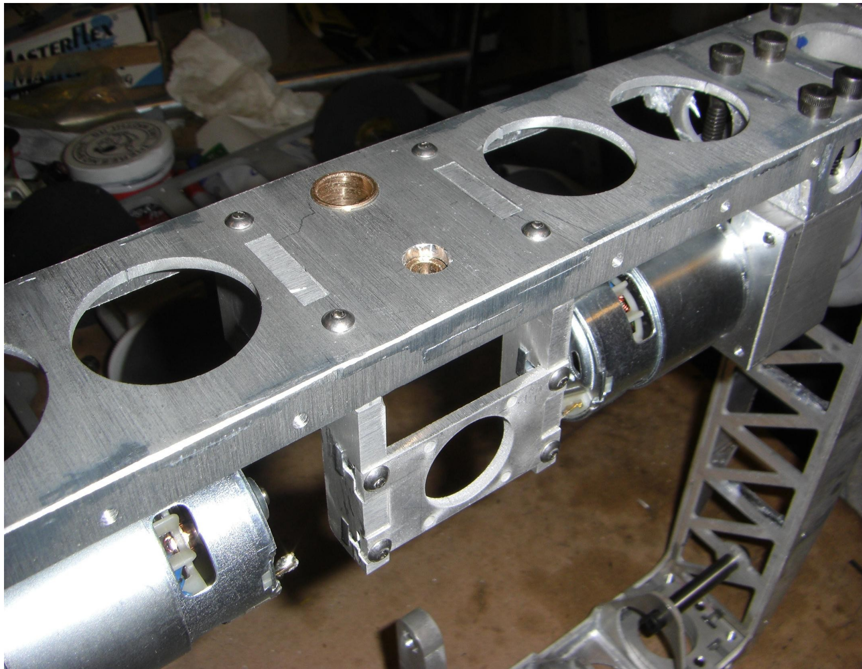
Could swap out to a new drivetrain design if needed – just by untightening corner screws.
More on this later.

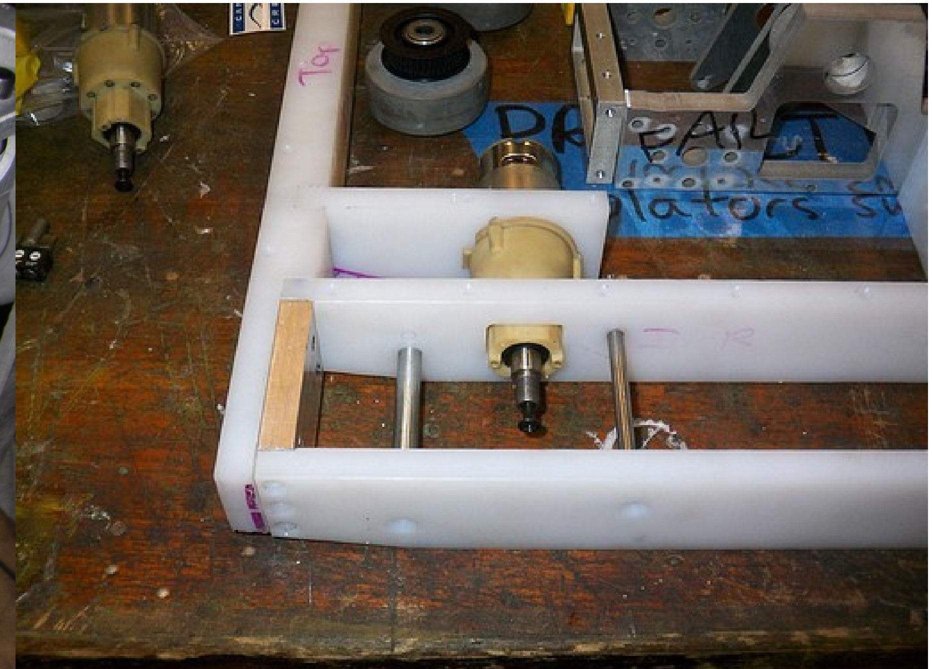


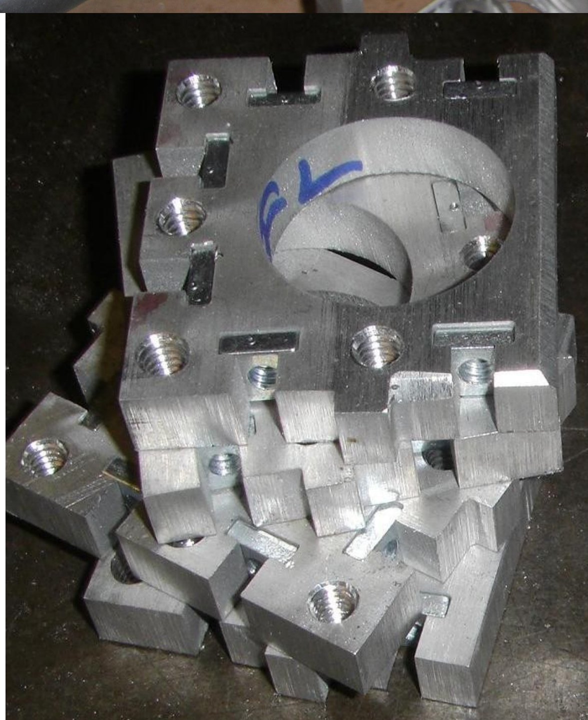
Modularity: If you pile a bunch of assemblies together and it *STILL LOOKS LIKE A ROBOT*!
(the *Pretend-o-bot* stage of construction)

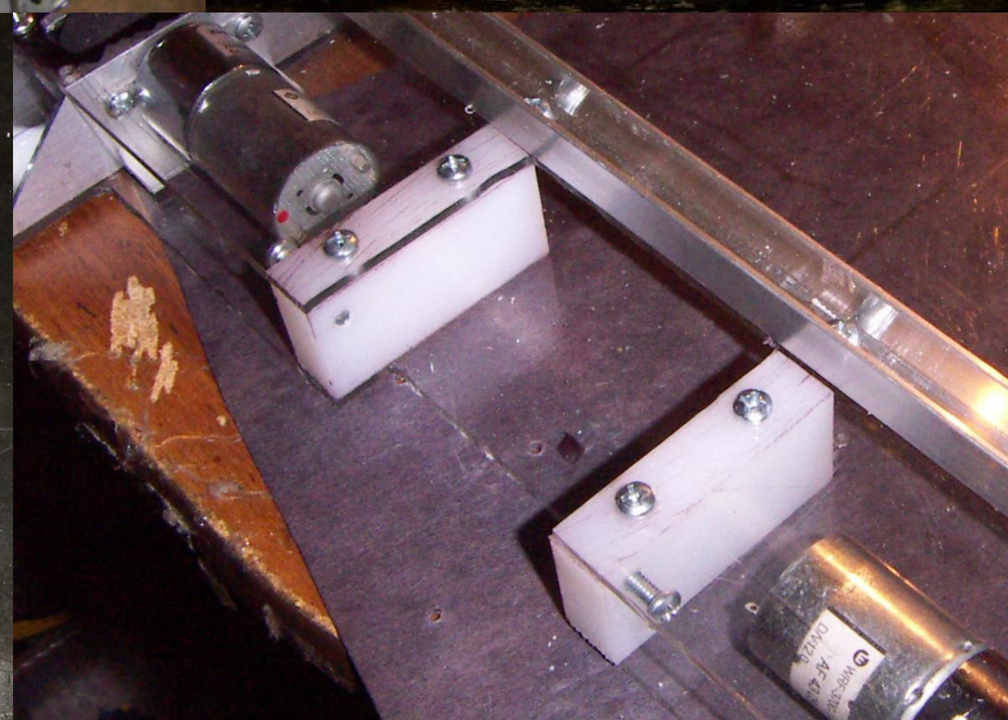
Alternatively, if there is a 1:1 mapping between robot function and robot subassemblies.

More examples









The Fun Part

- a.k.a Maximizing robot functionality, strength, and effectiveness without resorting to machined billet titanium
- Three of my favorite build methods, historical and present
  - *Plate-and-standoff*
  - *T-nuts*
  - *Slot-and-tab*

What a solid billet frame might look like ->

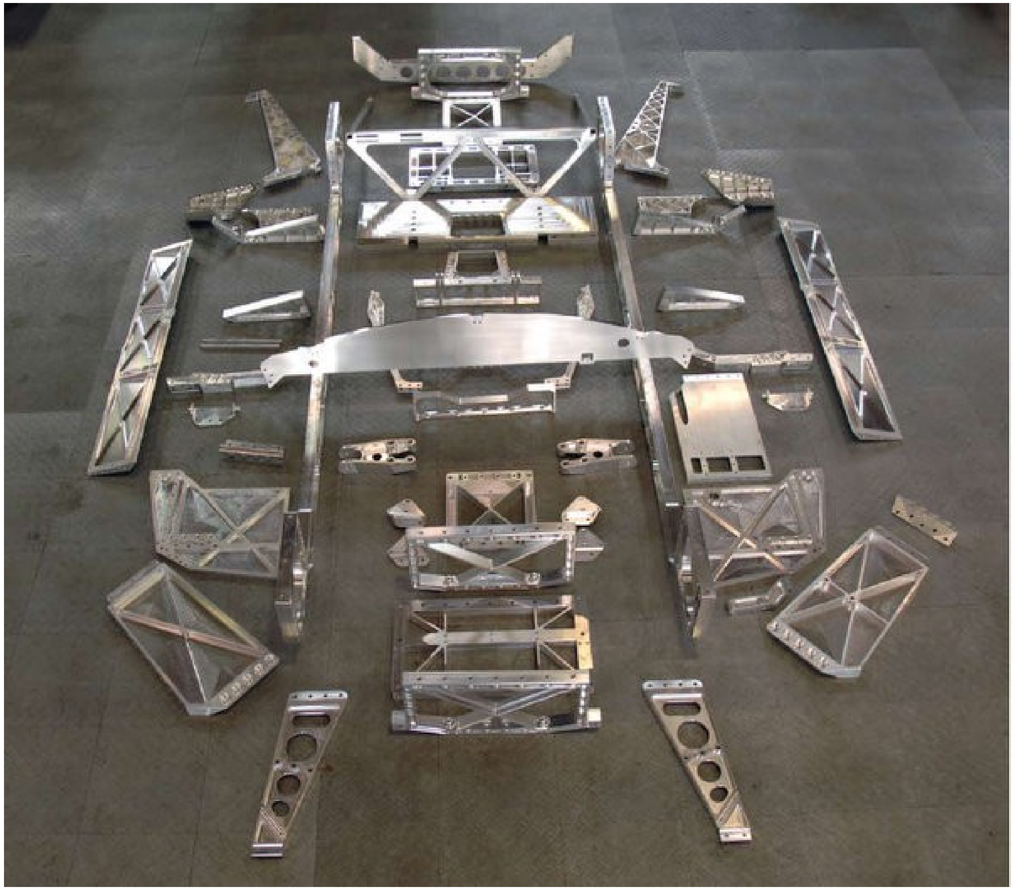
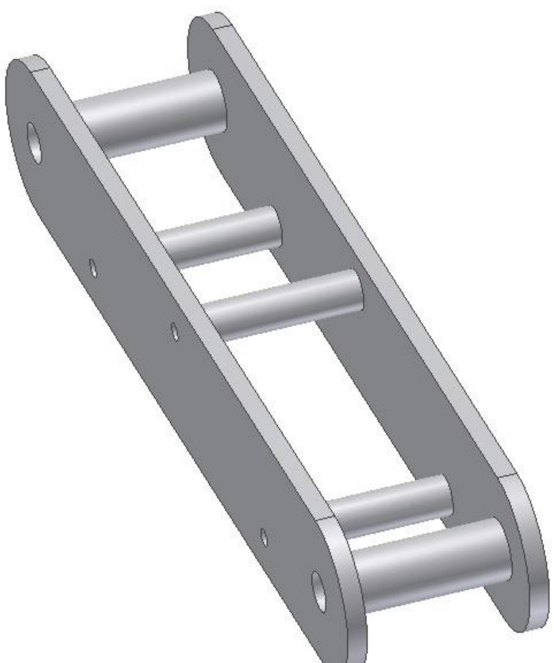
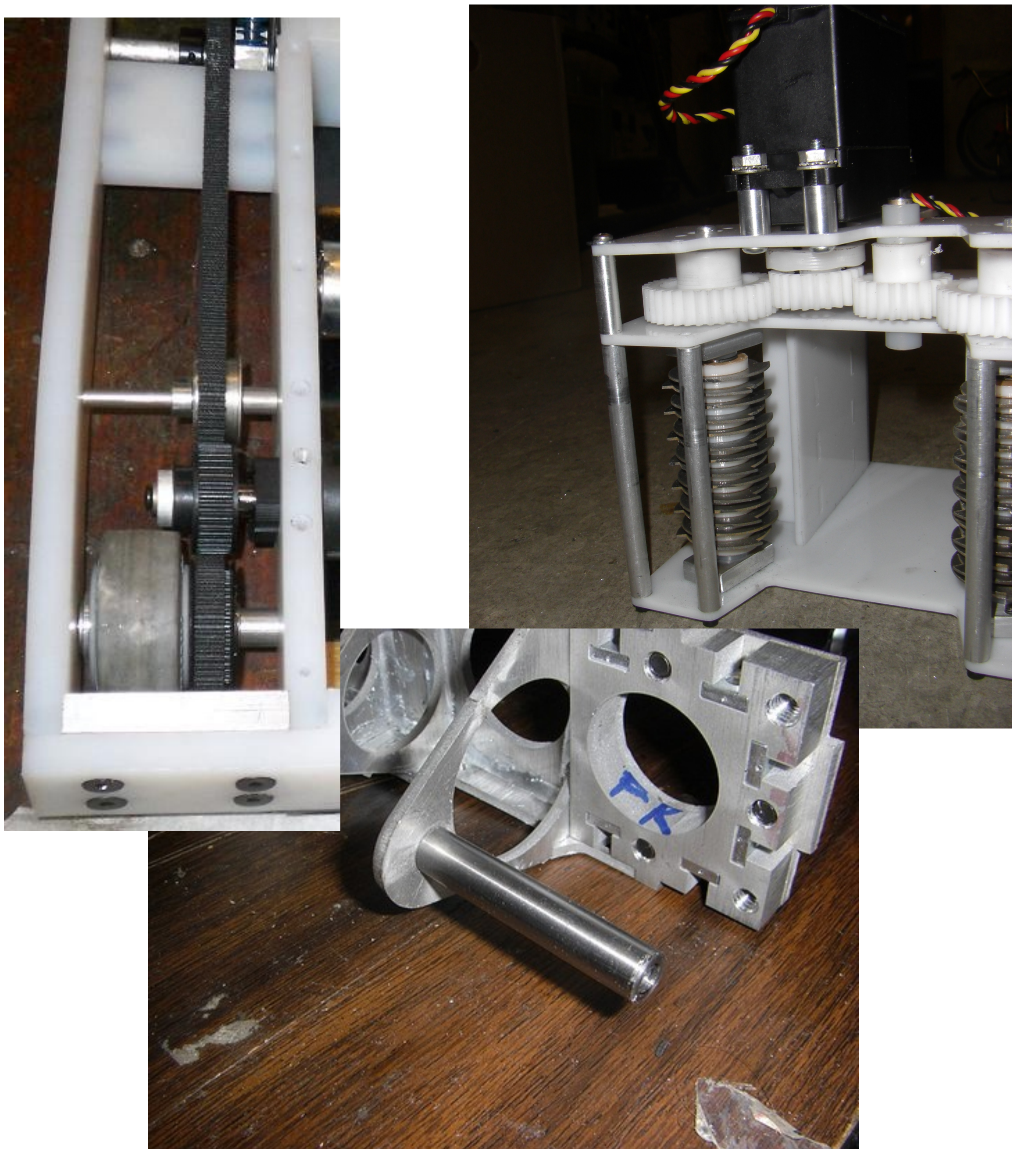


Plate and Standoff



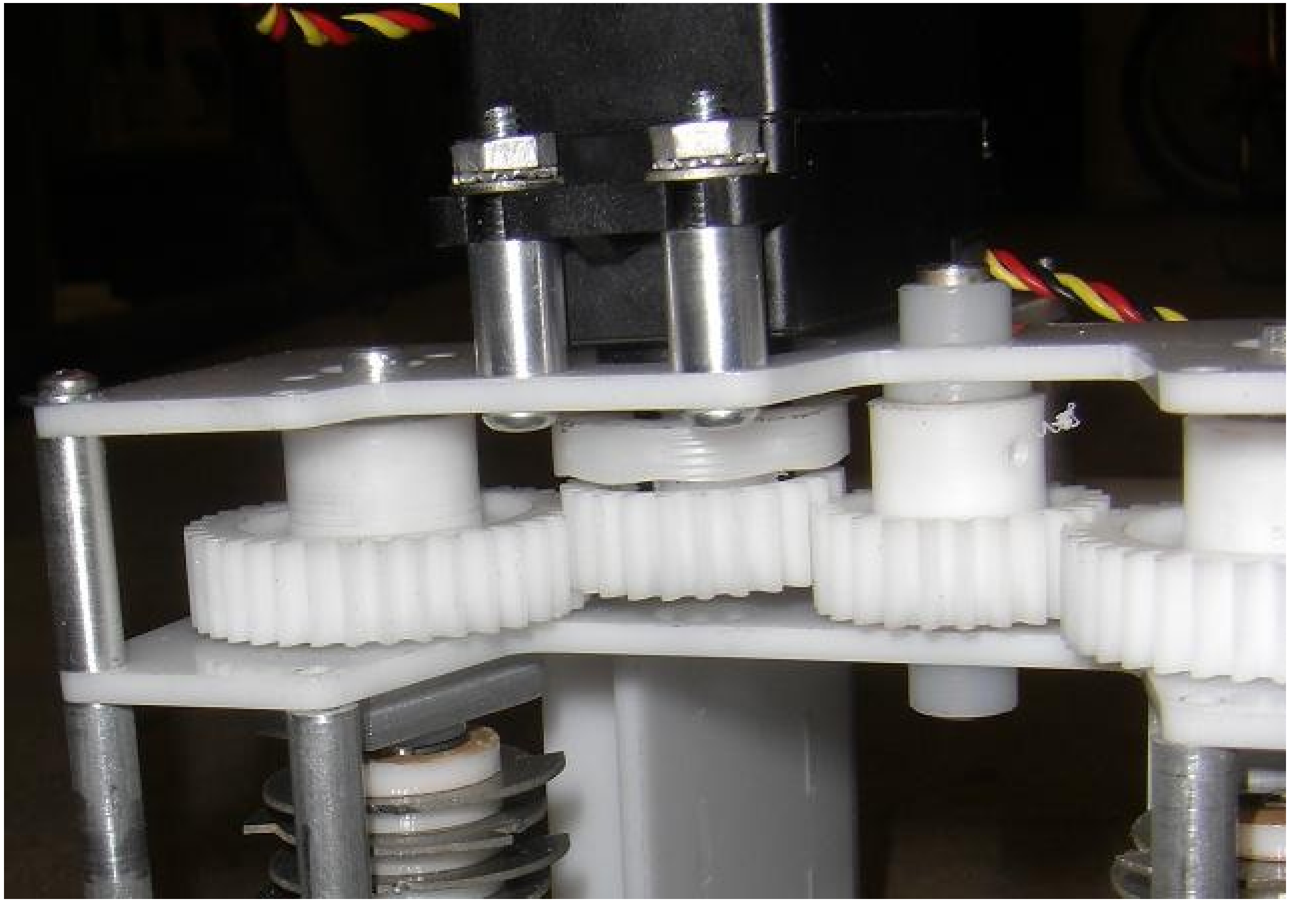
- Nonrotating, internally threaded *standoffs* are held between structural plates
- Standoffs act as screw mounting points for both sides. One side is usually tightened and considered “permanent”.
- Build a whole robot on the shear, punch, and brake, minus the...
- Standoffs, which come off fast on the lathe

Benefits of P&S Construction



- When tightened, there is a known distance between the plates.
    - Parts that go within can *only* be too wide. Easy to fix!
- Transforms bending forces to tension and compression, allowing for very stiff structures
- Captures and supports a rotating (pin) joint on both sides, such as wheels.
- Easy assembly and disassembly
- Allows direct use of the sheet aluminum in structural applications
- Easy to make *modular*

Easy-Bake Gearboxen

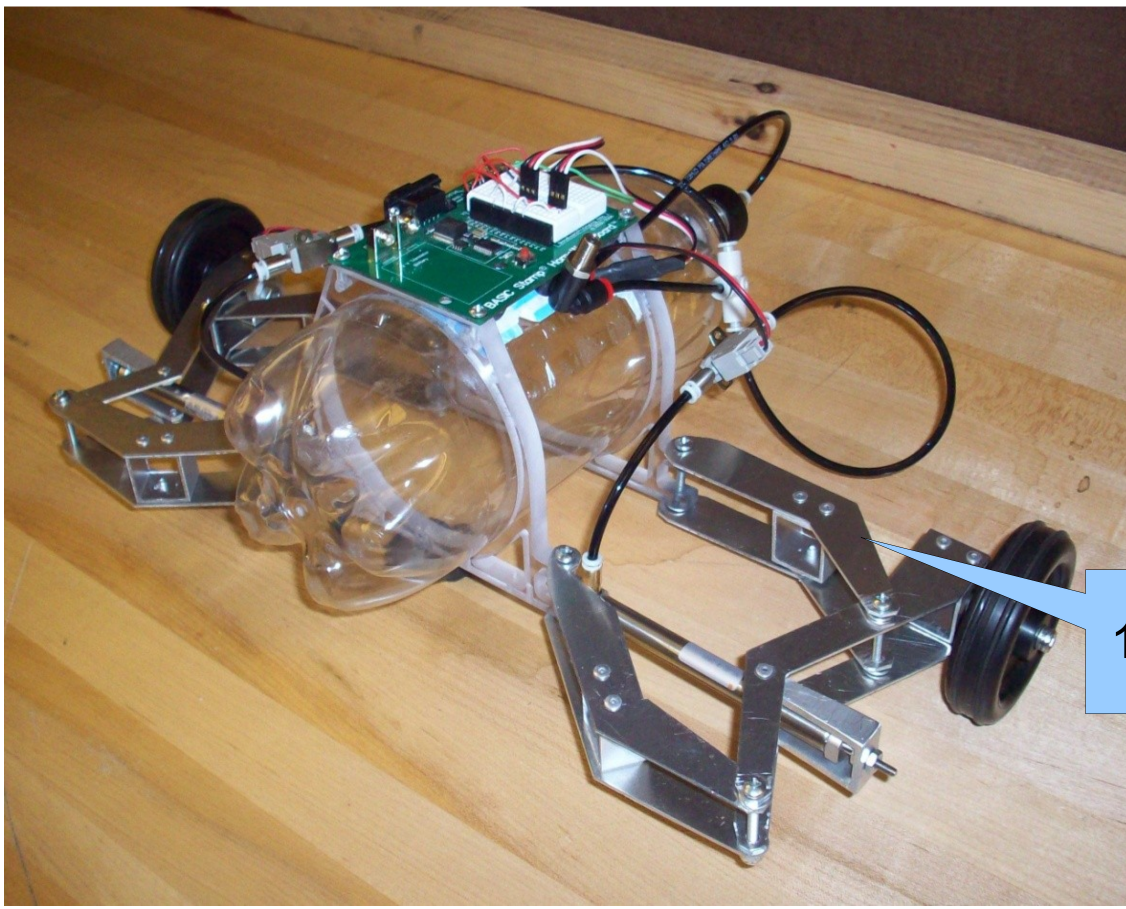


Capture gears between the standoff plates.

They can be either on live shafts (supported by bearings) or ride on stationary standoffs.

Your gearbox will not fail by gears bending away from eachother!

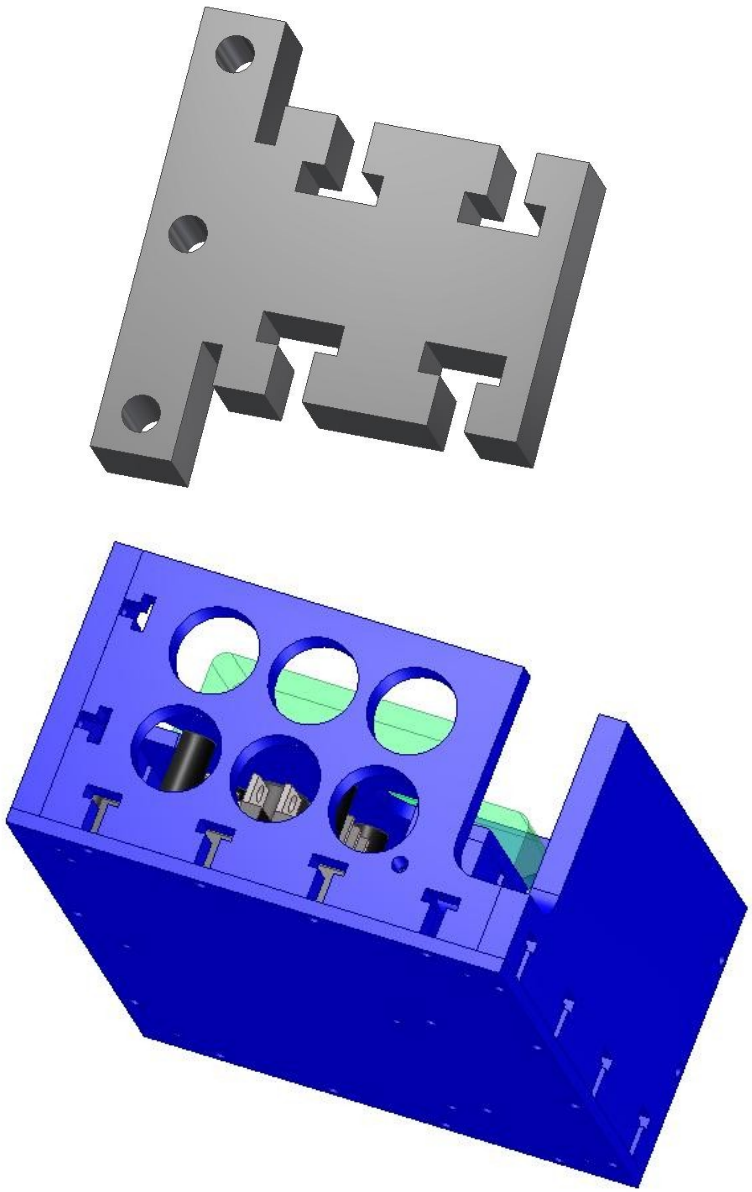
Plate and Box-Extrusion



- In lieu of discrete standoffs, cut off small sections of box extrusion
- Good for structural use and areas where no pin joints are located
- Drill and tap through the side

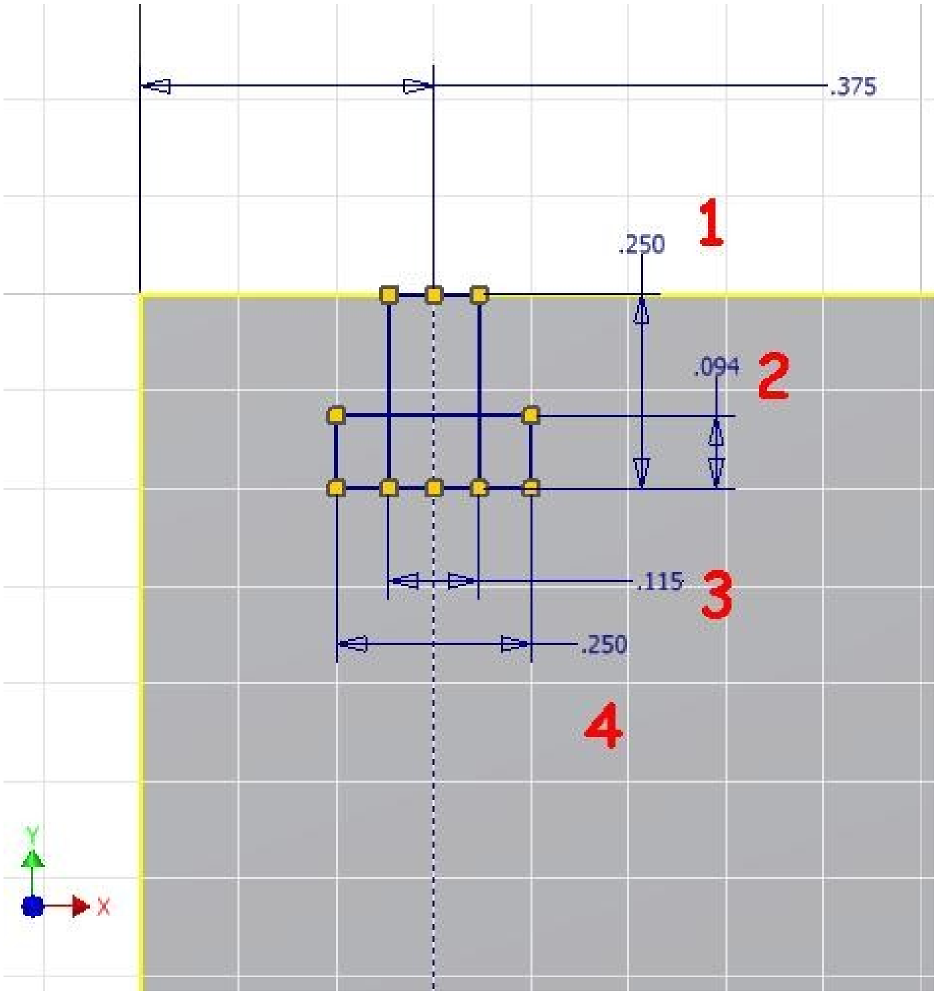
1” square tubing acting as a broad standoff

T-nuts!



- Use stock hardware captured in slots in material as makeshift threaded holes
- Replaces side-tapping (drilling into a piece of material aligned with its L or W dimension)
- Enables “Puzzlebotting”
- More freeform than P&S
- Not as strong due to focused stress
- Requires LASER or waterjet cutting

A Typical T-nut



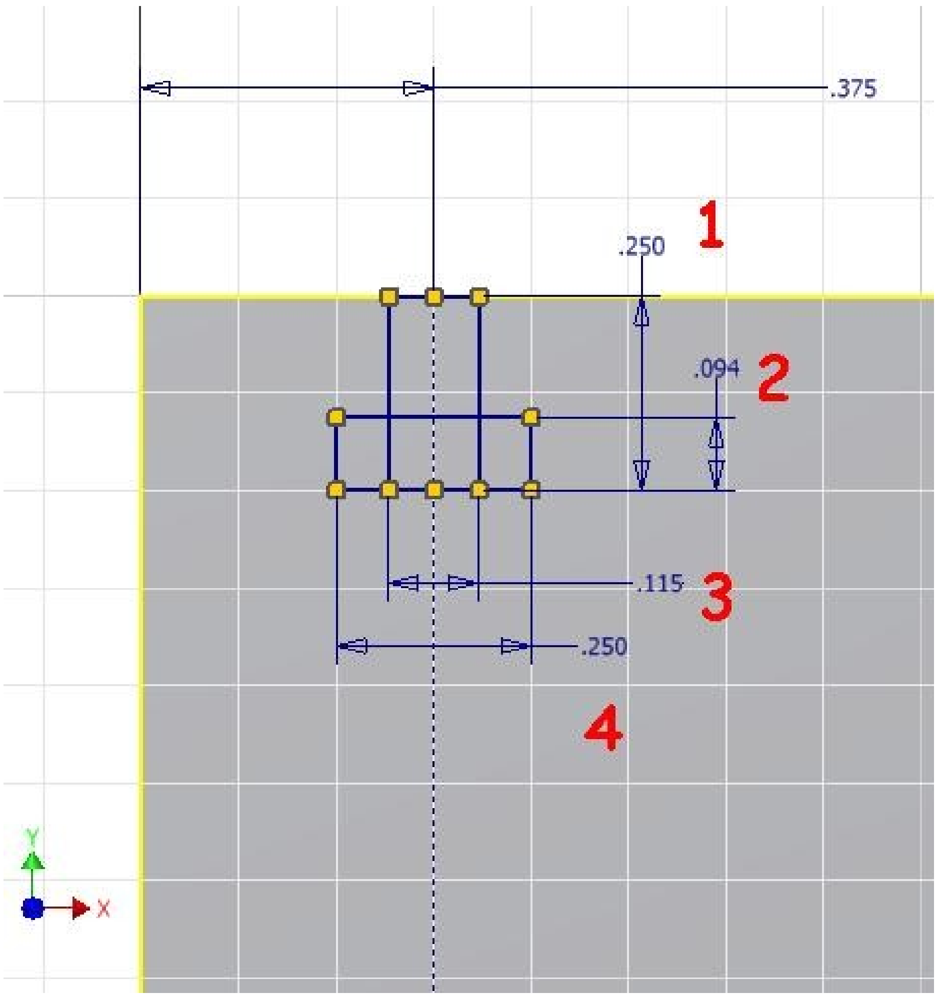
1. **Slot depth**. This affects the length of your hardware.

   Must account for the thickness of the material to be fastened (T) when designing D1. Try to make (T+D1) = a common screw length, or else you will be stuck grinding down hardware.

2. **Nut thickness**. Self-explanatory

   Typical nut thicknesses:
   #4-40: 3/32” (0.09375”)
   #6-32: 7/64” (0.109375”)
   #10-32: 1/8” (0.125”)

A Typical T-nut



3. Screw Clearance Width.

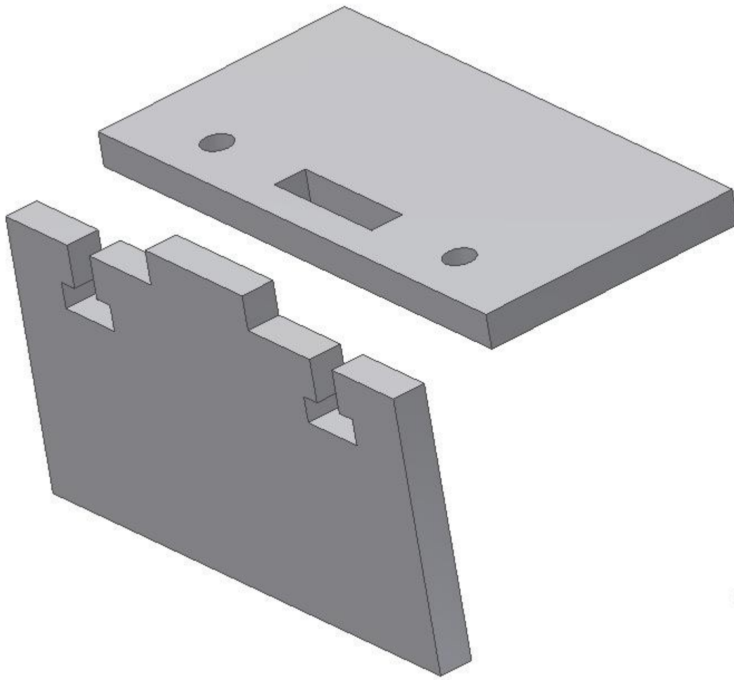
The screw must pass through the slot unimpeded, so this is typically a “close fit” clearance hole.

Typical clearance for #4-40 is 0.115” and #6-32 is 0.140”.

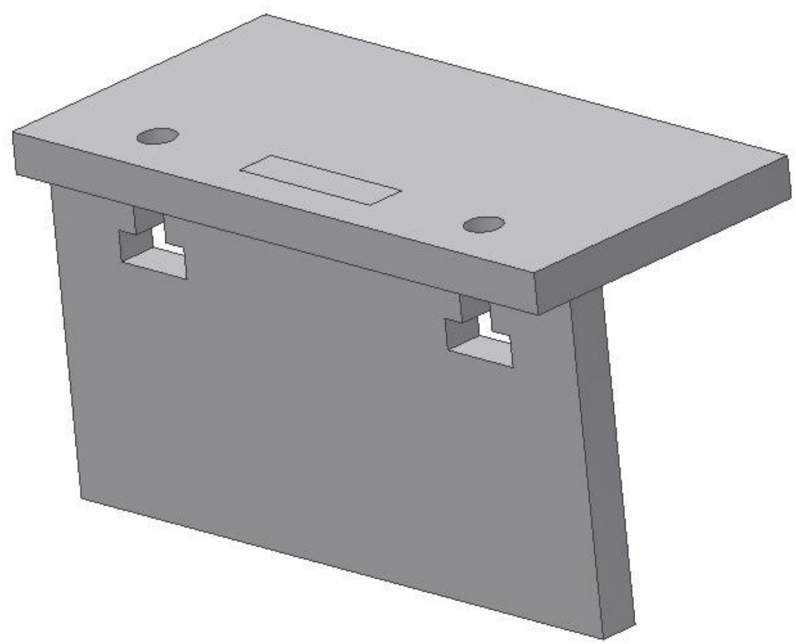
4. Nut Width. Equal to the width between flats of a hex nut.

Typical values:
#4-40: 0.25” (1/4”)
#6-32: 0.3125” (5/16”)
#8-32: 0.34375” (11/32”)
#10-32: 0.375” (3/8”)

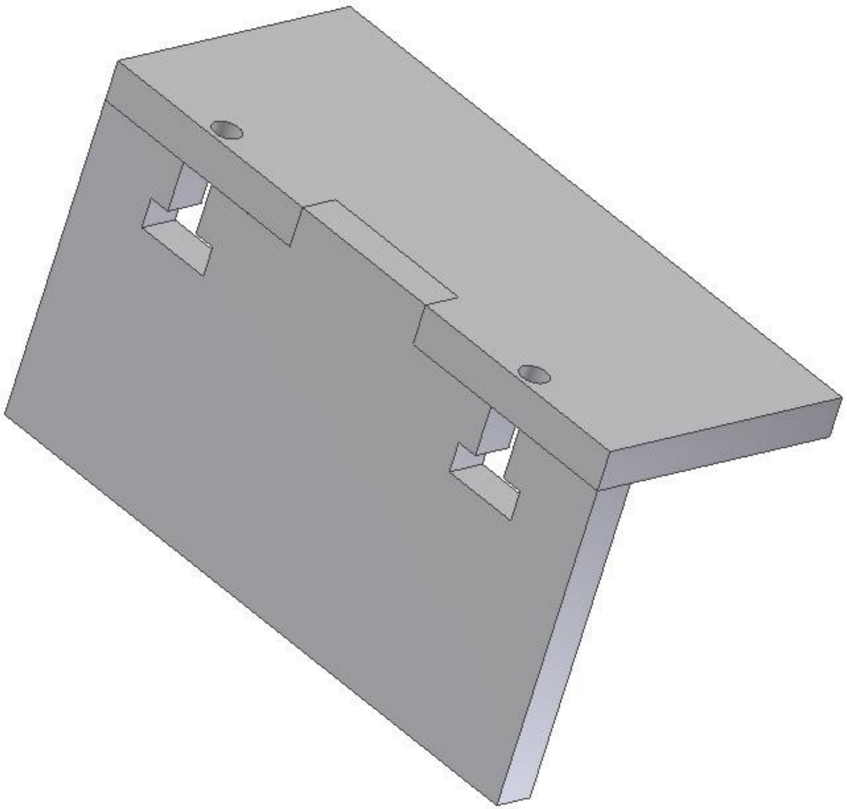
T-nuts and Constraint



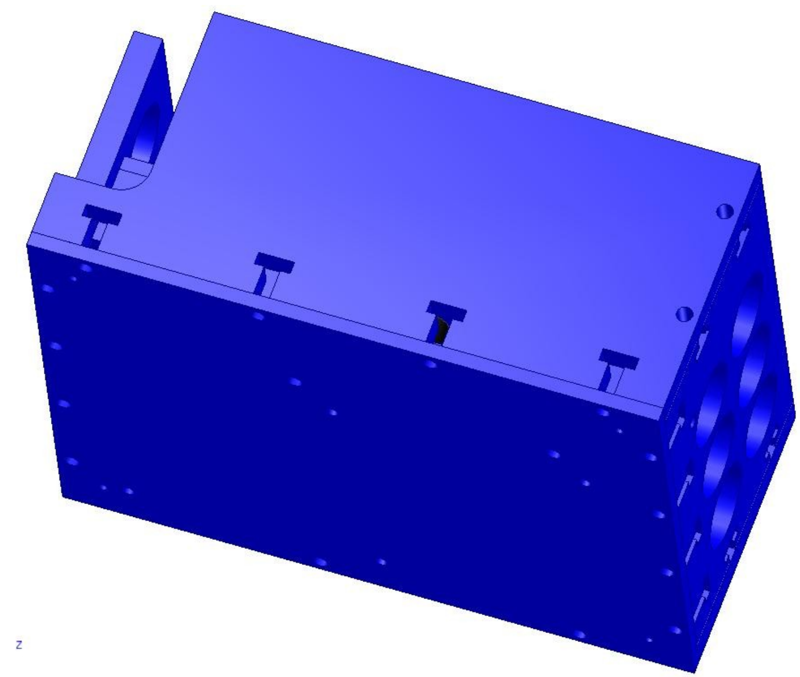
- “Blind” T-nuts fully embed one plate into another using a mating slot and tab
- Fully constraining
  - Material itself locates X and Y, T-nut locates Z

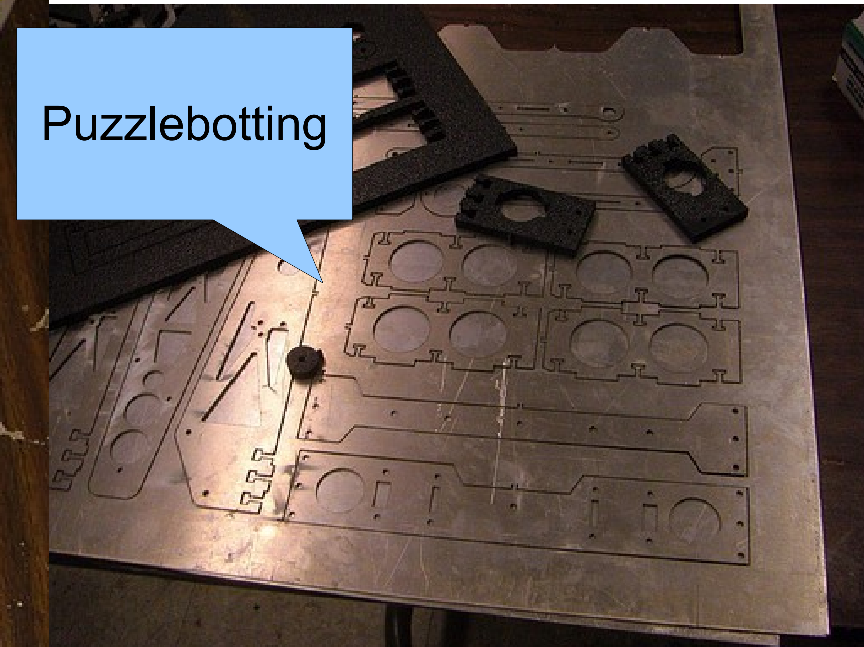


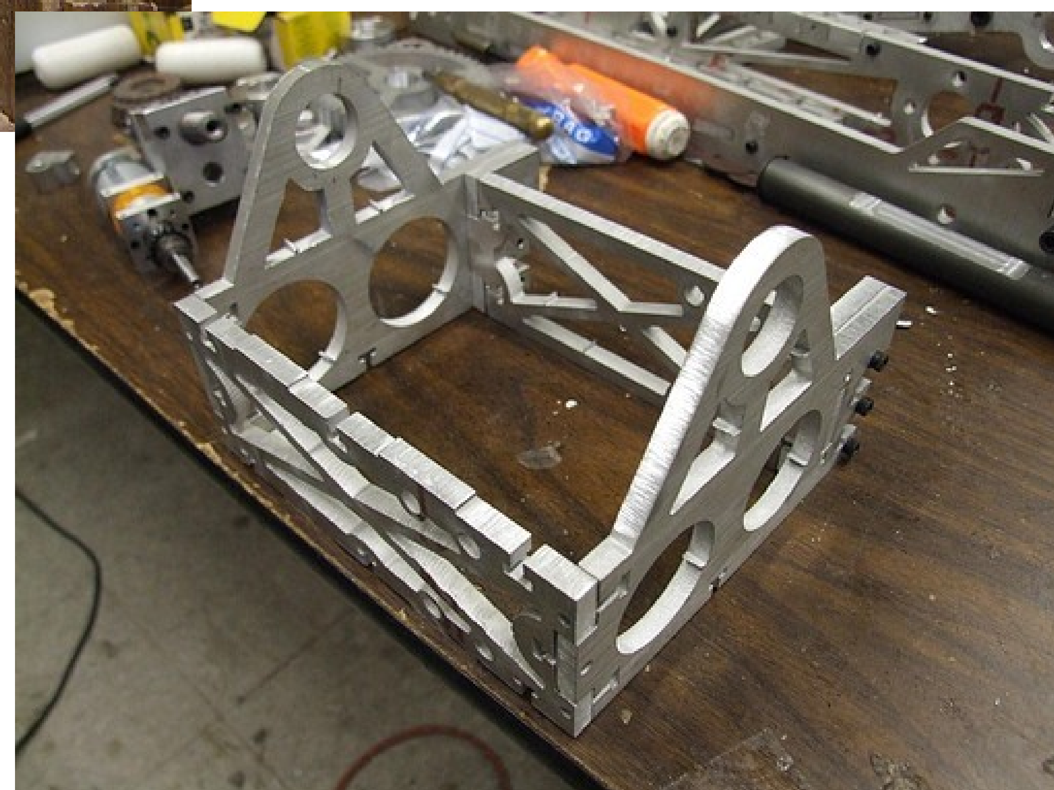
T-nuts and Constraint



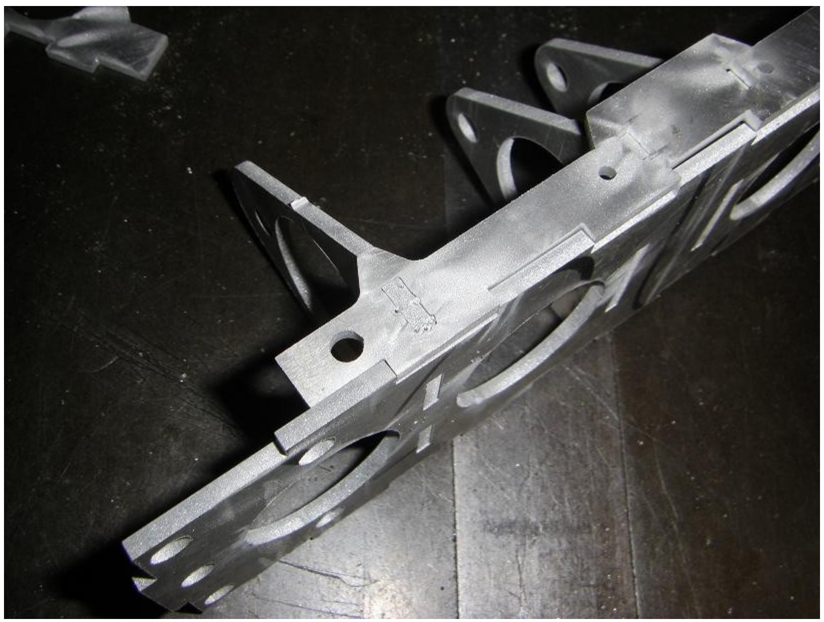
- A nonconstraining or “Edge” T-nut has at least 1 DOF which is only held by friction
- Suboptimal because of the potential for slippage
- Also poor bending strength
- May or may not have mating tabs



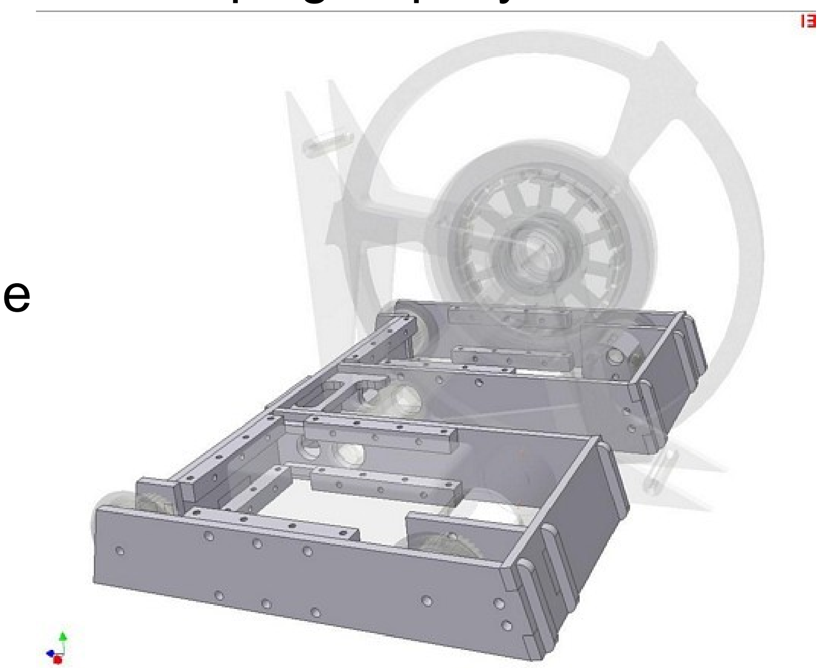

Puzzlebotting



Slot and Tab

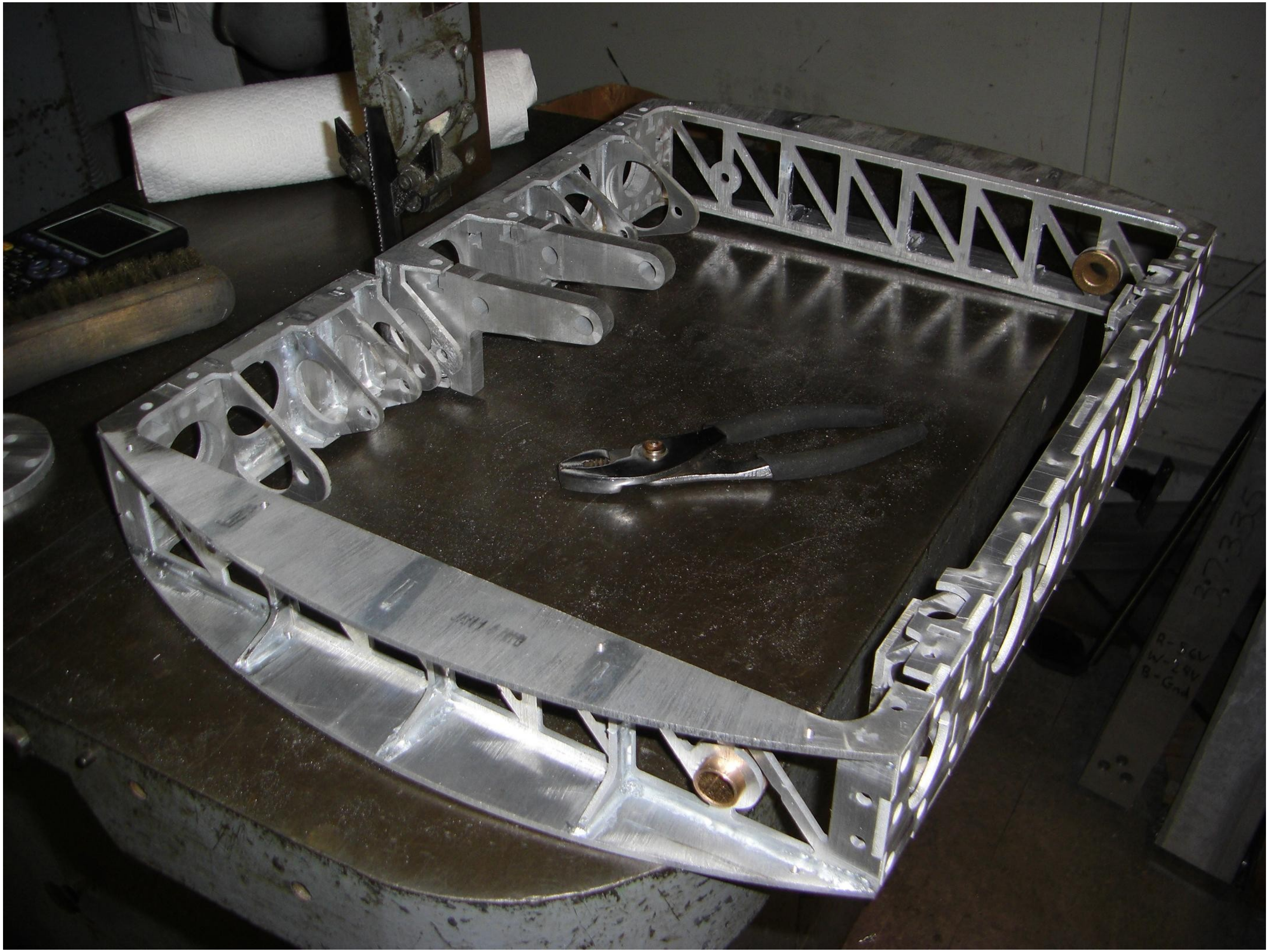


- Only uses mating slots and tabs in the individual structural elements for **alignment**.
- Another method is used to fasten them together
- Welding, brazing, soldering
- Crimping? Epoxy?



- Individual S&T assemblies tend to be 1-piece (unibody) because of the permanent joinery.

Slot and Tab



Four S&T assemblies: Left, right, front, and back.

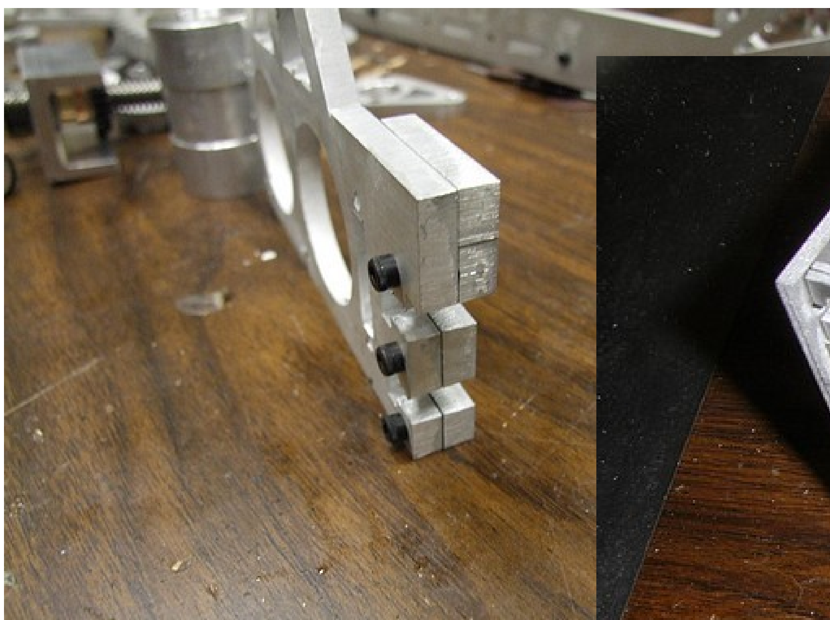
Joined at the corners with screws and corner blocks!

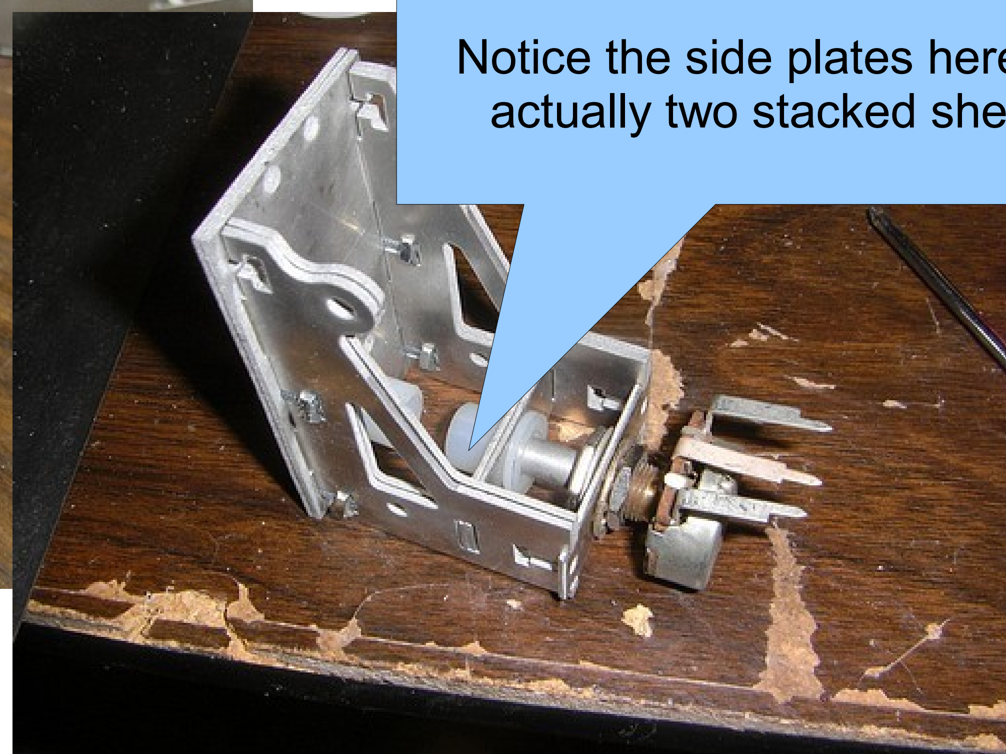
Random Tips and Tricks

- Any slot and tab fit is sensitive to machining tolerances
  - Design your slots slightly over, tabs slightly undersize
  - “Slightly” → About .002 per .100 of material thickness
  - May need some fine filing work afterwards
    - But still better than carving your piece out manually.
- Waterjet tolerances: Generally 0.002 or better
  - “Edge draft” is an issue on thicker materials, such as 1/4” aluminum
- LASER tolerances: 0.006 or better.
  - LASER cutter cuts “on the line” - all holes will be slightly bigger, outer dimensions slightly smaller... actually better for S&T in conjunction with T-nuts

Random Tips and Tricks

- 1/4” ABS, 3/8” Plywood are both acceptable for T-nutting
  - The ABS works REALLY well for T-nutting
- 1/16” aluminum will require 'thickness buffering'

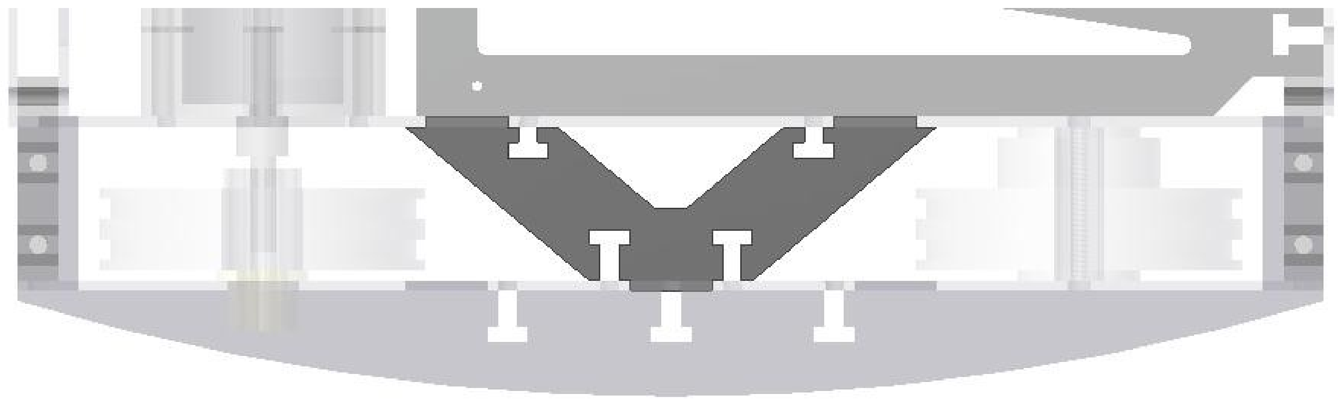




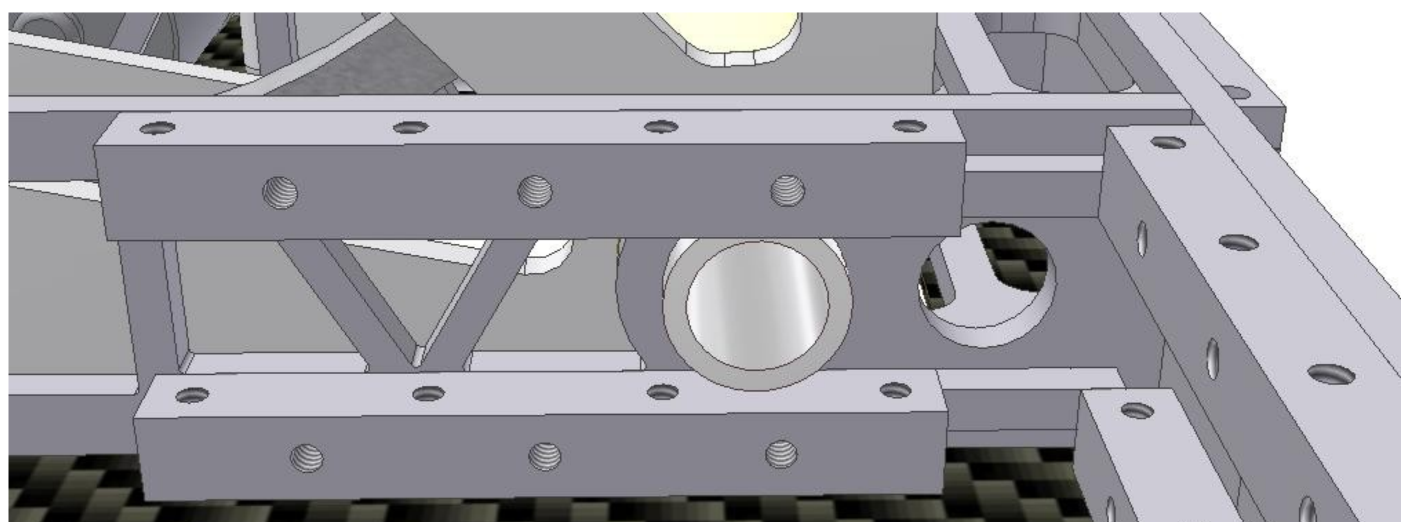
Notice the side plates here are actually two stacked sheets

Random Tips and Tricks

- Combining S&T, T-nuts, and Standoffs into one
  - The Meta-standoff

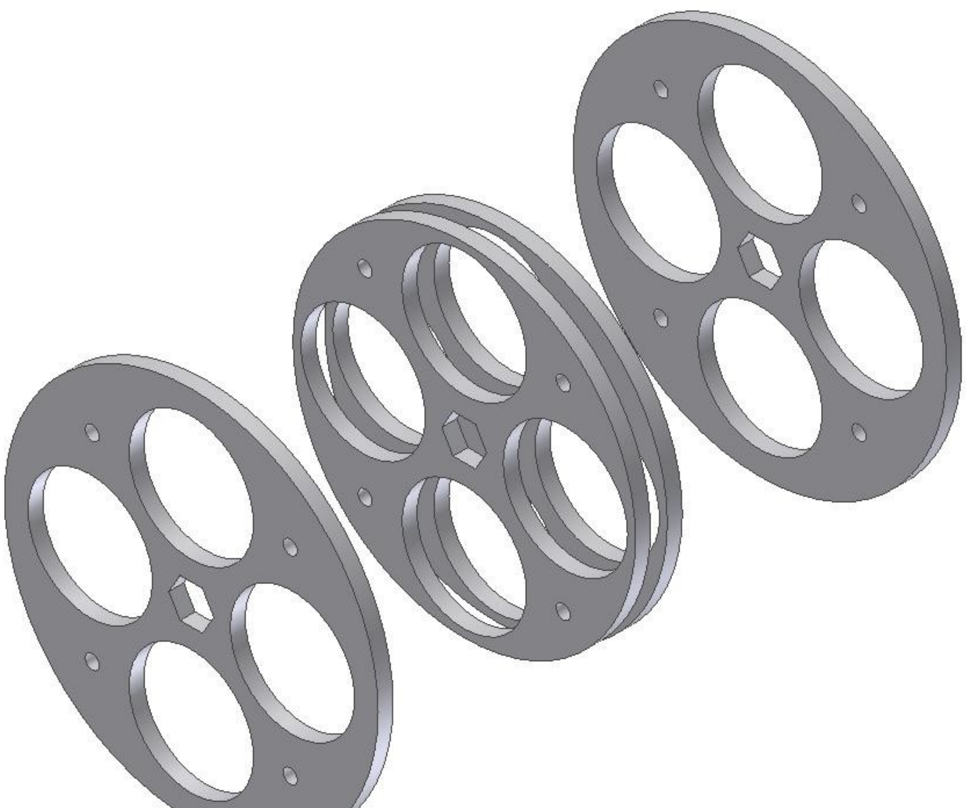


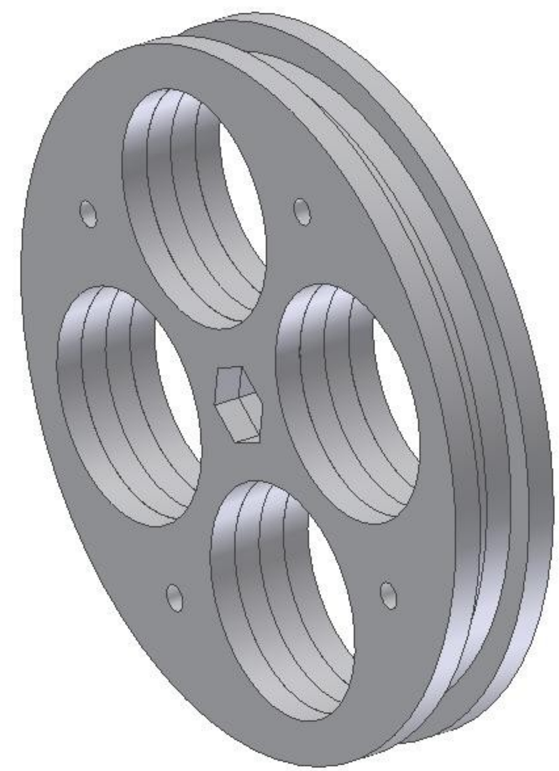
  - The Über-nut



Make a custom wheel or pulley

- Three plates: Two outer flanges, one (or more) slightly smaller middle.
  - Can put custom face and bore features, e.g. hex bore, holes for mounting LEDs, spinning hubcaps





Bottom line

- Trade off manual fab time for design time early
- ...but don't wait too long