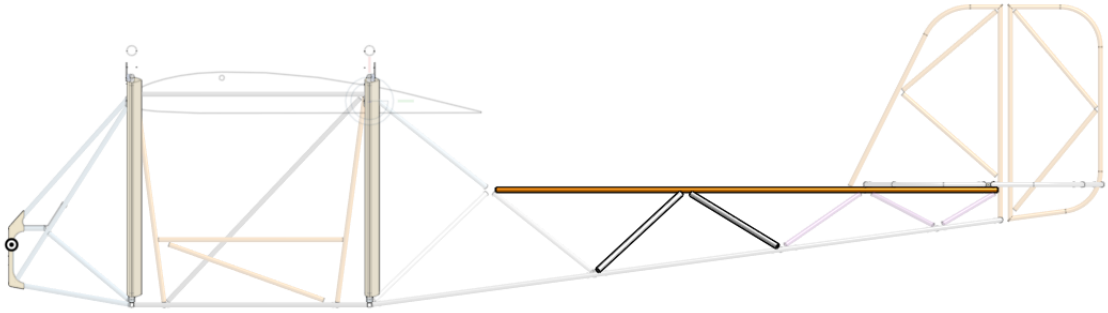
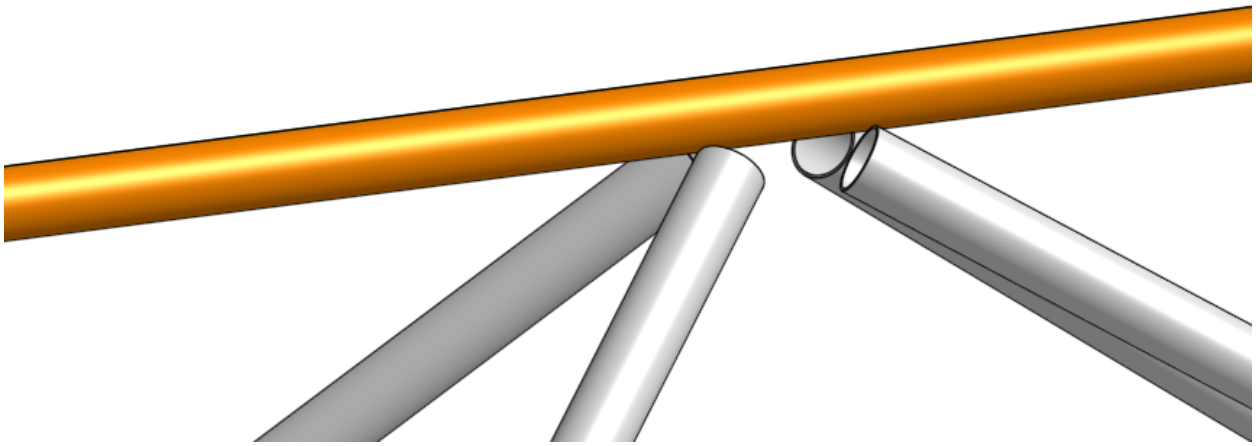
Welded vs Gusseted Truss Frame

Ever since the beginning of our fuselage design process, the question of whether to use a welded or gusseted truss frame has always been a topic of avid debate within Flight Club. Each solution poses significant benefits as well as shortcomings. This blog post aims to shed some light on why we ultimately chose to go for a welded 4130 Chromoly steel frame, the most common solution for ultralight airplanes.

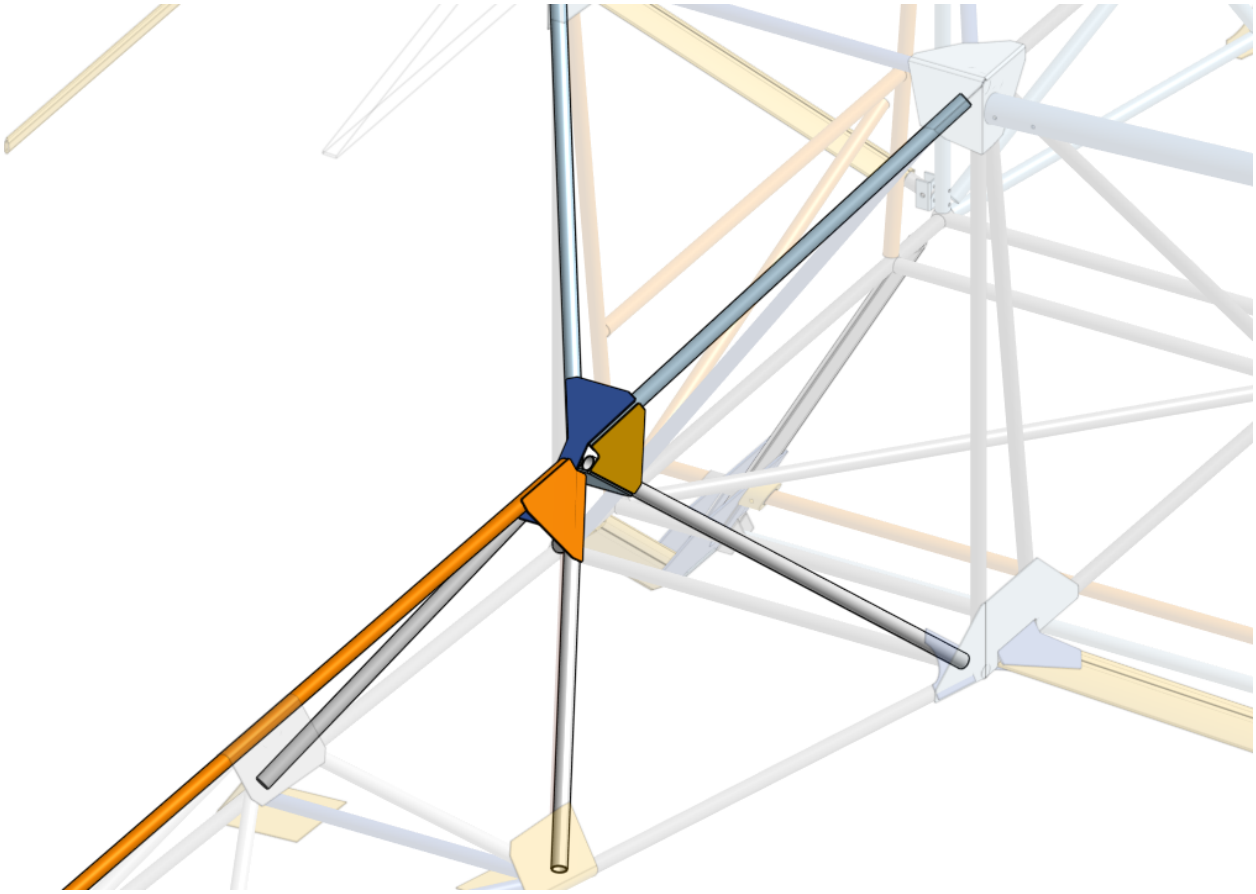
The Truss Frame

The decision to weld or gusset is rooted in finding solutions to manufacturing the many complex joint clusters in our truss frame. We originally opted for the gusseted aluminum truss frame since there seemed to be a demand for an ultralight that didn't require welding.



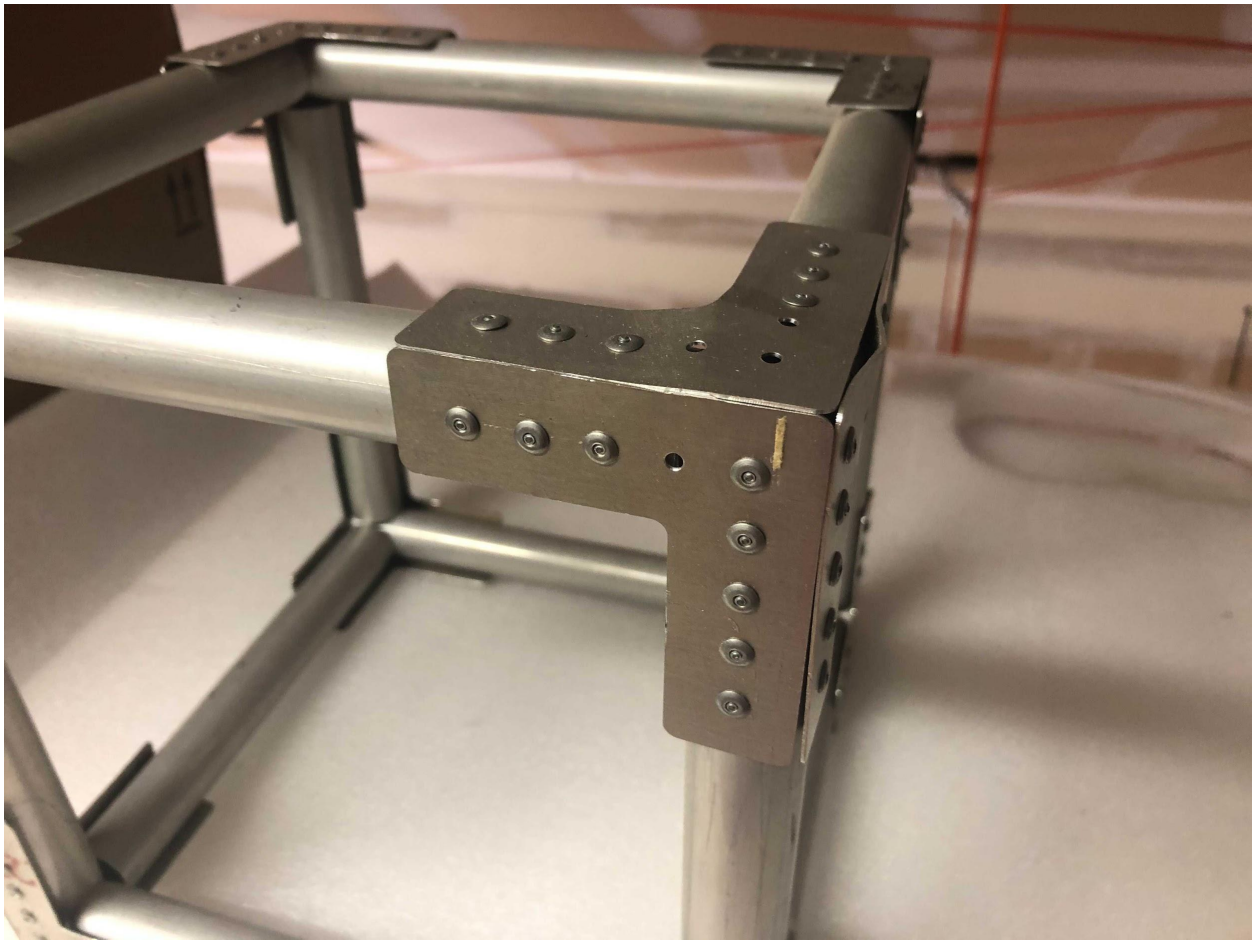


Fuselage redesign #1 empennage cluster



Fuselage redesign #1 “big boi cluster” & gussets

We were able to find solutions to every gusset problem but when it came time to build a test cube, we realized how difficult and time-consuming it is to measure, mark, drill, deburr, and rivet each hole within the required tolerances.

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The picture above displays the precision needed to line up the tubes, and our wonderful Ollie proving the box's strength.

Although the box was capable and seemed like a viable option to build our truss out of, the process was extremely extensive considering all the tube joints were perpendicular. That's when we started seriously considering welding our truss frame. Here's a quick comparison of the pros and cons we're balancing of each method:

6061-T6 Aluminum Frame:
Primary beam dimensions: 1" OD x 0.035" wall thickness

This is our alloy of choice if we were to go with Aluminum for a couple of reasons:

- The 6xxx series is the primary aluminum used for structural applications
- 6061 is abundant, making it much cheaper and easier to acquire than any other alloy.
    - There are stronger alloys such as the 2024 T3, but we would have to order off Aircraft Spruce and would cost around 3x more per foot.
- T6 heat treatment offers the highest strength with a 6061 alloy

Advantages	Disadvantages
- Easier to make major modifications once constructed - Higher column buckling strength (almost 2x that of the 4130).	- Rivets only offer 75% of the strength of welded joints - Some clusters required very complex gusset solutions which would be difficult to manufacture and assemble in practicality. - Cherry and CherryMax rivets are extremely expensive. We would end up spending $1.5-2k just in rivets. - Requires (extremely) tight tolerances during manufacturing

4130 Chromoly Steel Welded Frame

Primary beam dimensions: 5/8" OD x 0.035" wall thickness.

- It can be easily found at any local metal shop, making it much cheaper than any other steel that would need to be bought off Aircraft spruce
- There is no stronger alloy out there that is sold as tubing

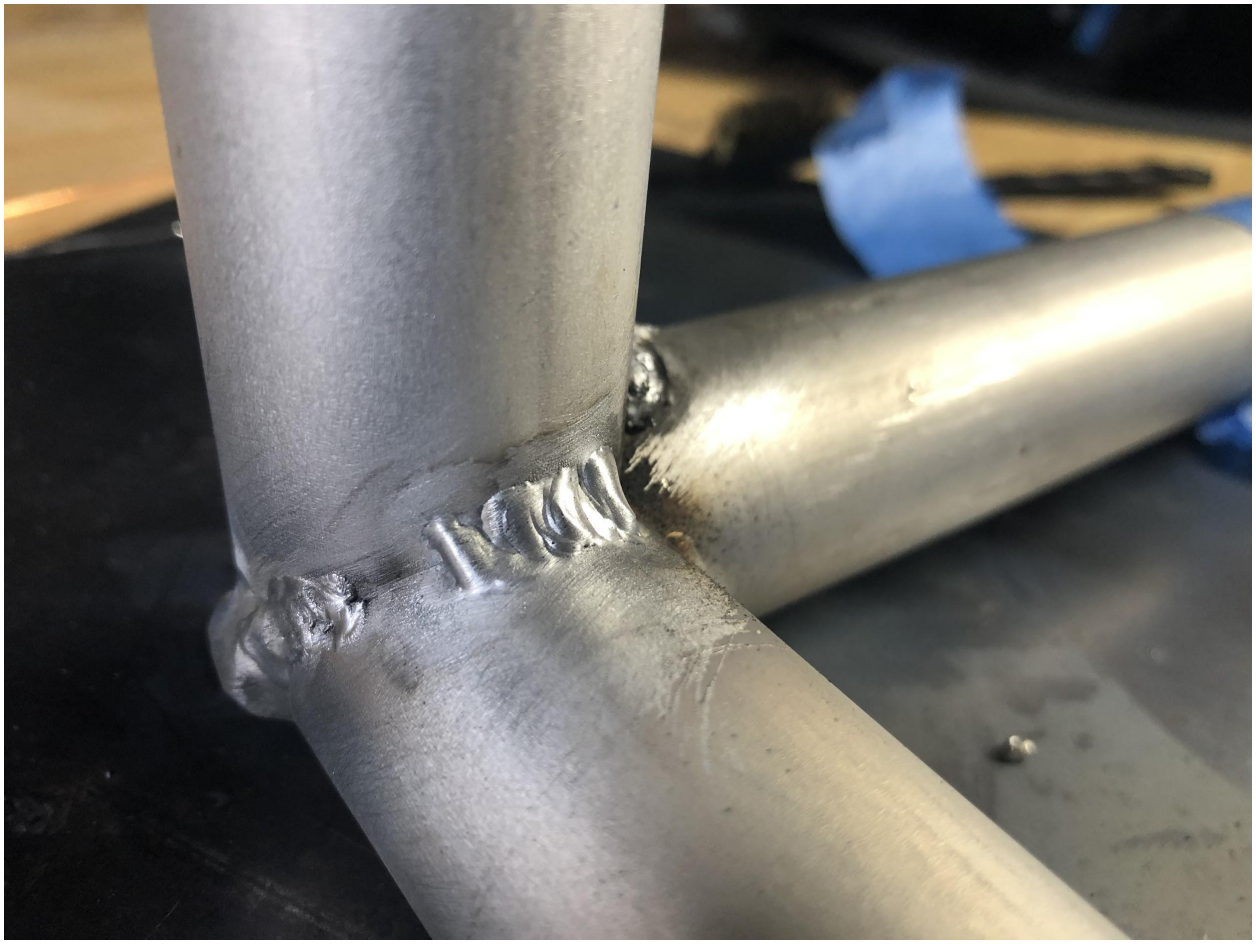
- NOTE: generally, you don't need to specify the heat treatment of steel because there is only one type per alloy
- All other steel Ultralights use this alloy

Advantages	Disadvantages
- Quick and easy(er) manufacturing process - Majority of other ultralight choose this method → more resources & better documentation - Easier to make quick fixes and reinforcements.	- Would need to cope our beams - Redesign the truss to accommodate the weaker compressive strength of the smaller OD tubing - Likely heavier due to the lower compressive strength. - Requires a welder - We'd still use aluminum for non-structural body panels, etc. When steel and aluminum touch, there is a possibility of galvanic corrosion

Some of our members have welding experience so we decided to make some practice joints to compare its difficulty to gusseting. Shout out to Jody (WeldMonger) for all his great welding resources!

Welding 6061 T6 Aluminum

We initially considered welding our fuselage out of 6061 T6 aluminum due to its higher compressive strength:



AC TIG welding thin-walled aluminum tubing is extremely difficult and General Airplane Aviation Textbook discourages the use of welded aluminum as a structural component of any part of the airplane. Some of the issues we had to deal with when AC TIG welding included:

- High thermal conductivity quickly dissipated heat throughout the part making the pool difficult to manage and limiting us to 1” beads before the part became too hot to touch even through welding gloves.
- Getting sufficient weld penetration while avoiding blow through
- The “T6” refers to the aluminum’s heat treatment process. TIG welding effectively removes that heat treatment so it’s critical to move as quickly as possible to minimize the heat affected zone.
- A thick gas lens made it difficult to get our #17 torch into tight clusters
- Welding aluminum is like babysitting a petulant child that never does what you want them to do.

Welding 4130 Chromoly Steel

Welding the 4130 was incomparably easier than welding the aluminum. You still need to minimize the heat affected area and manage blow through but it’s generally really cooperative.

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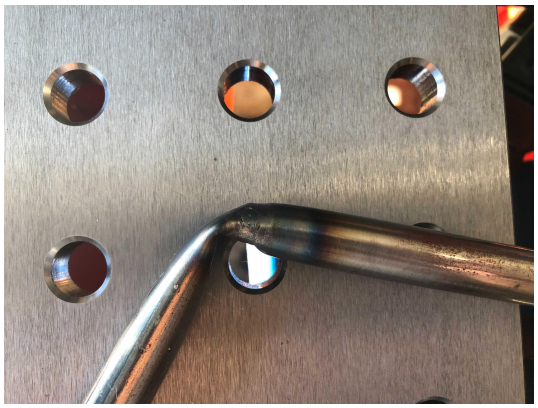


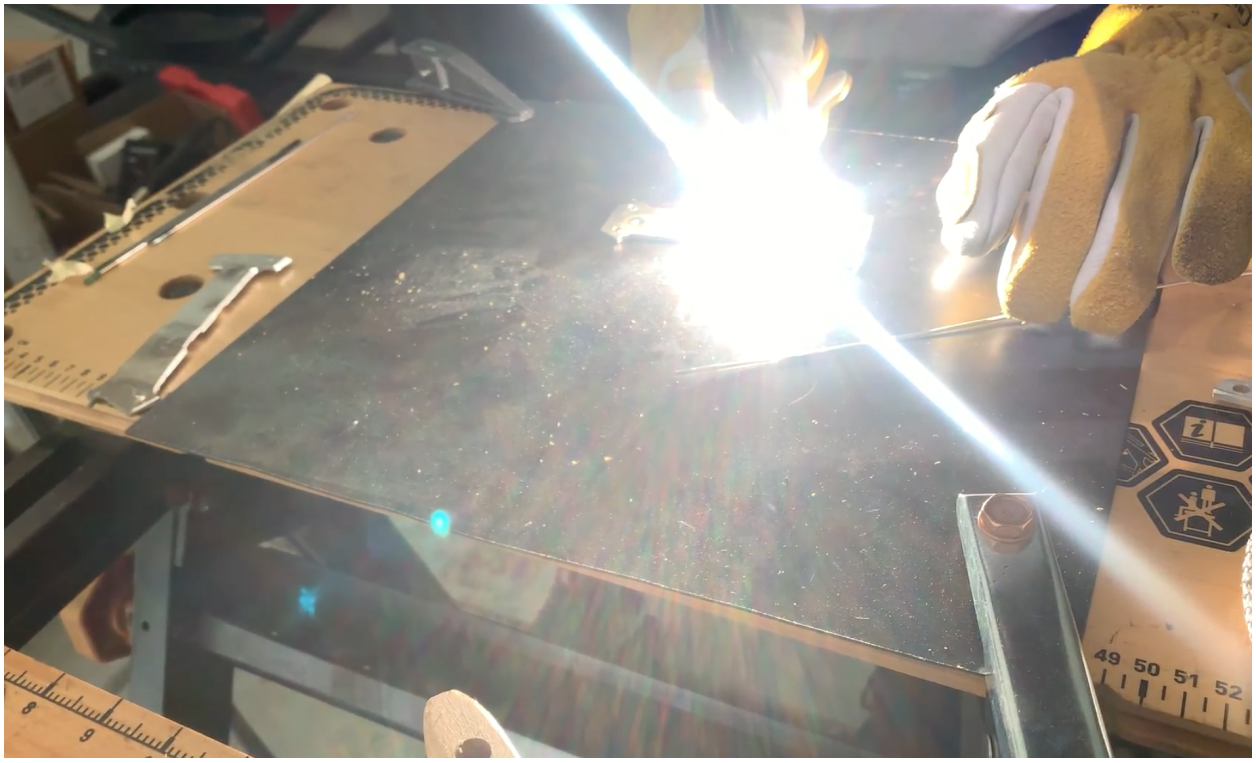

The photos above depict a simple butt weld that we bent to confirm the tube collapsed adjacent to the weld. This proves that the weld itself was strong and would not be the cause for failure.

Steel was incredibly easier to learn, and threw any consideration of Aluminum welding out the door. Our joints were cleaner, stronger, and were quicker to make. With enough practice, we were confident we could build our fuselage out of welded 4130 Chromoly steel.

Decision

Although our team was founded to create a plane that can be reproduced with no prior background, we decided that for our first iteration we needed to feel comfortable in the design. One of the 7 deadly sins of aircraft design is too much innovation, so we decided that once we know the steel can fly, we can later create an aluminum gusseted fuselage.

We decided to buy a Vulcan ProTig 205 AC/DC Welder as well, so our team can practice for the final product.



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