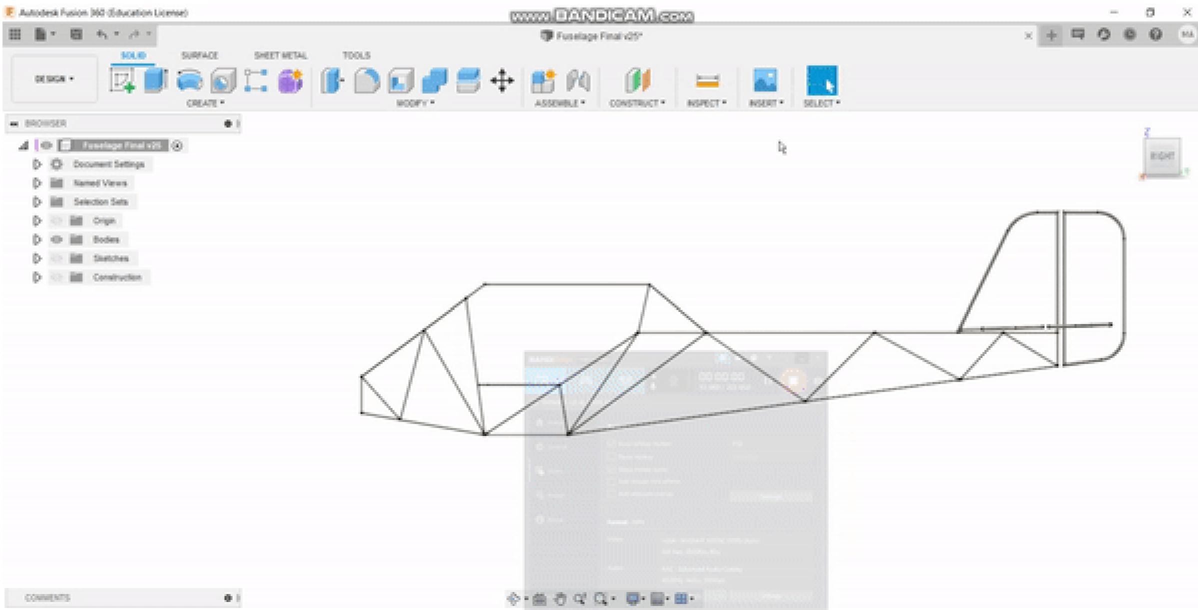
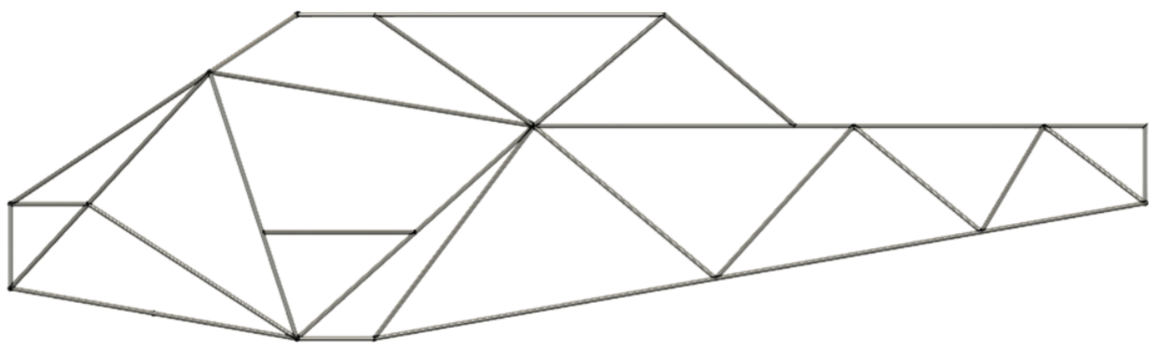
Updates To Fuselage Design

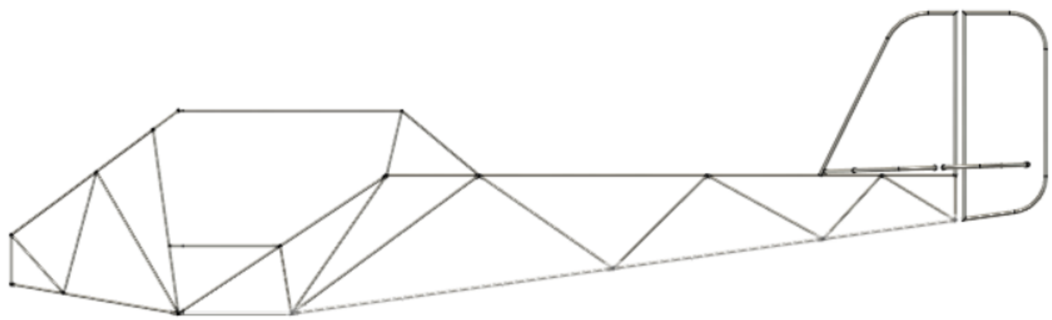


The design team has just gotten a couple of new members, and we've been hitting the grind in terms of the fuselage! These are some updates from our [last iterations in November.]

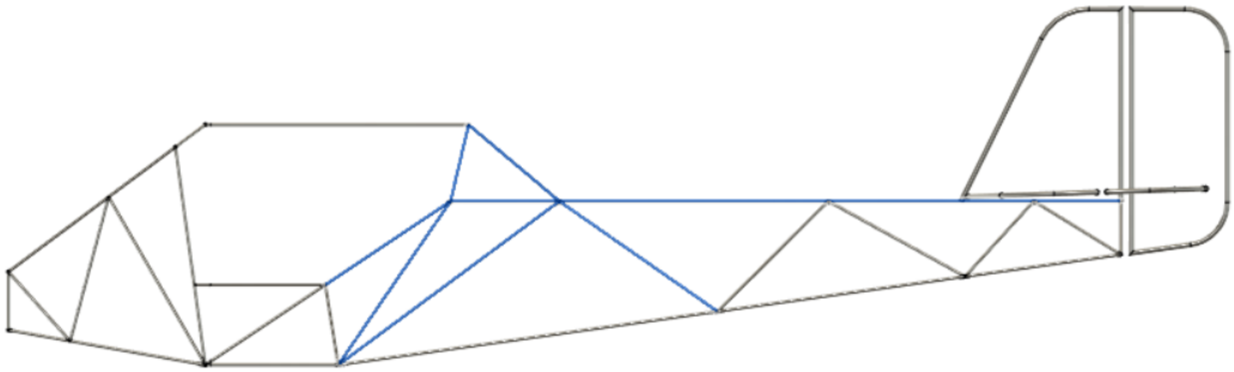
Changes:

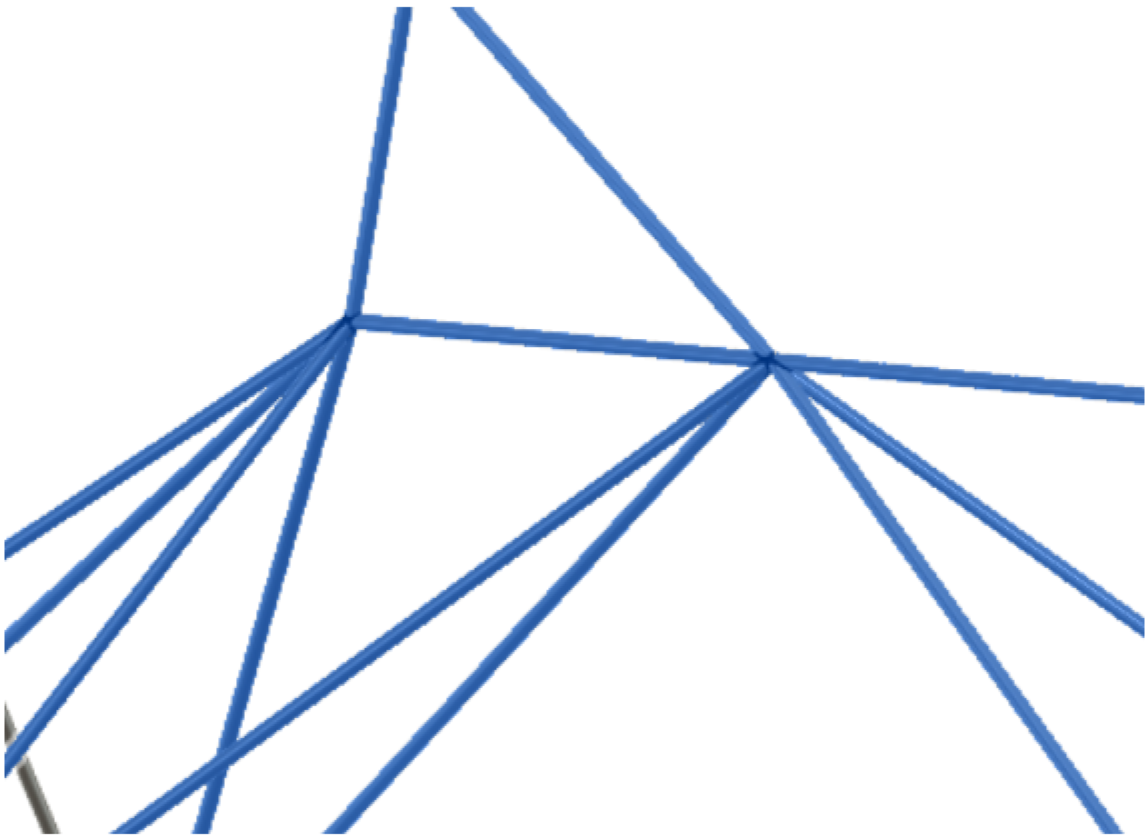
Tail + Sizing: Our XFLR5 simulations dictate that the tail needed to farther out to have dynamic stability. We also added the tail to the design, which has the same sizing as our previous models. We found it very difficult to constrain curves in a 3D sketch, so we had to create inclined construction planes in the fusion model to draw our elevator and horizontal stabilizer on.





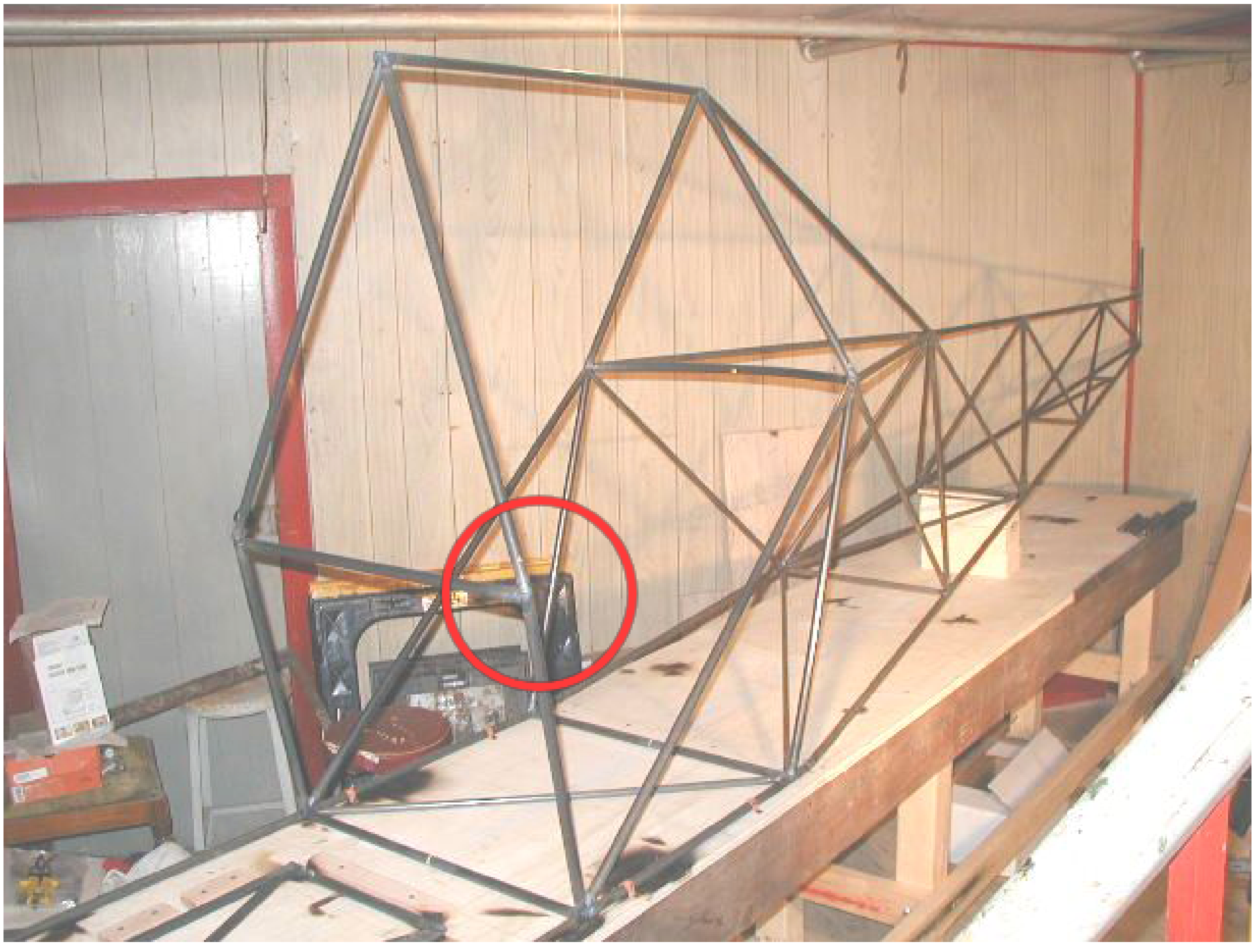
Beam Cluster: Extending the empennage also solved our large cluster, as it created more space for the cabin and upper longeron beams to connect. We initially were concerned about the weldability of so many beams joining together:





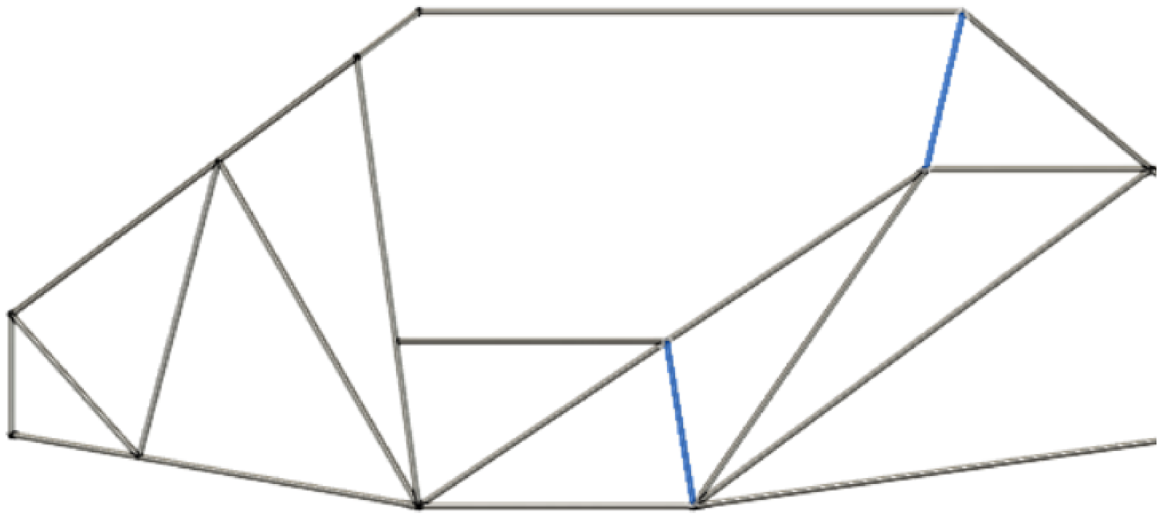
However, life-long ultralight builder Bob Mackey advised us to keep the joints together since it makes forces transfer better. His welding experience has proven to him that almost any cluster of beams can be welded together, so the only restriction on joints would be that the angles between beams must be larger than 25 degrees.

The Legal Eagle actually uses small strips of steel to close off strangely welded joints, which we're using as a last resort when inevitably our welds are not perfect. They use it to make u for imperfections in coping, or spaces between welds. Below is a picture of their welded frame, with a circle over just an example of

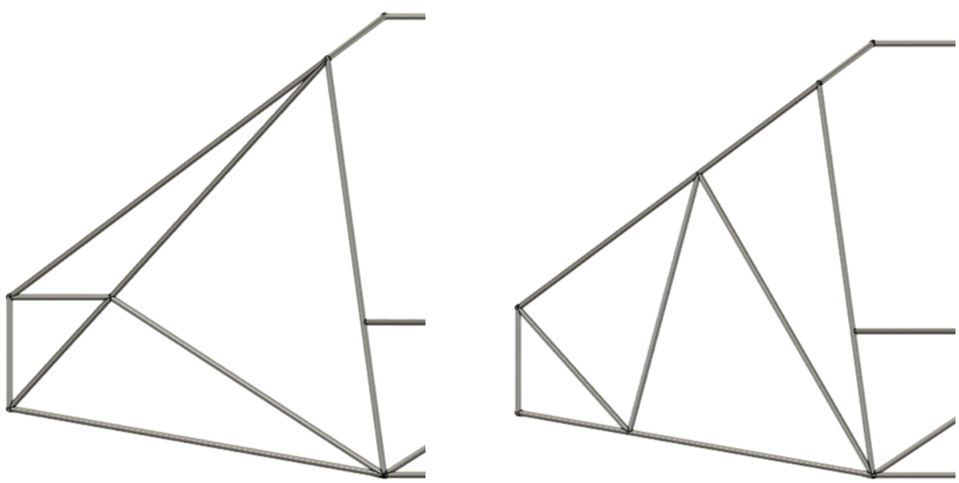


The red section shows one of the Legal Eagle's welds that were filled in with reinforcing scrap steel.

Cabin Beams: With the new empennage length, we had more options on cabin beam positions. We decided to have the front and back cabin beams still join at the end of the empennage, but the validity of this position will need to be assessed with simulations. Bob also pointed out that a couple of our beams needed reinforcement, so we added beams for support, as highlighted in blue below.



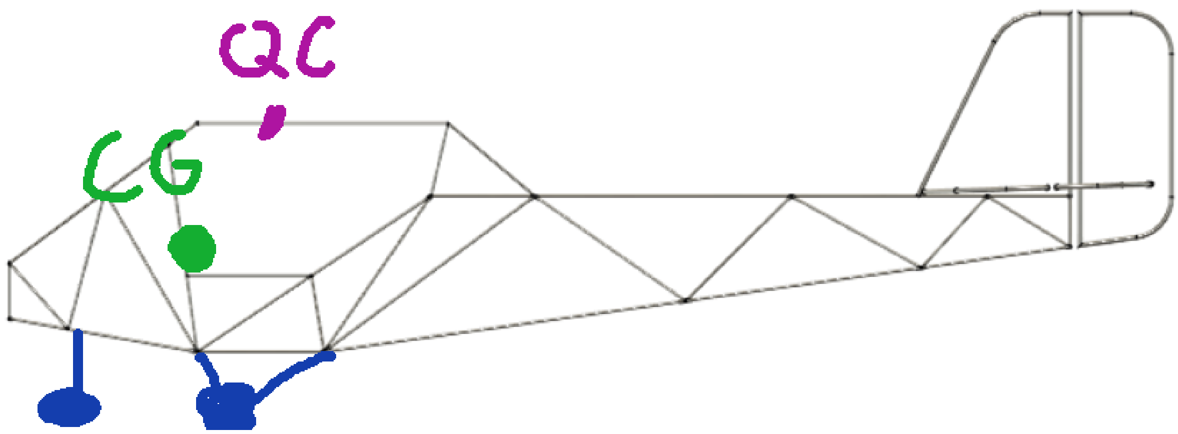
Nose beams: We originally had the beams going across the nose, which created some near-right angles. Perpendicular beams are inherently bad at mitigating forces, so we believe a zig-zag design in the nose would be stronger than the previous design.



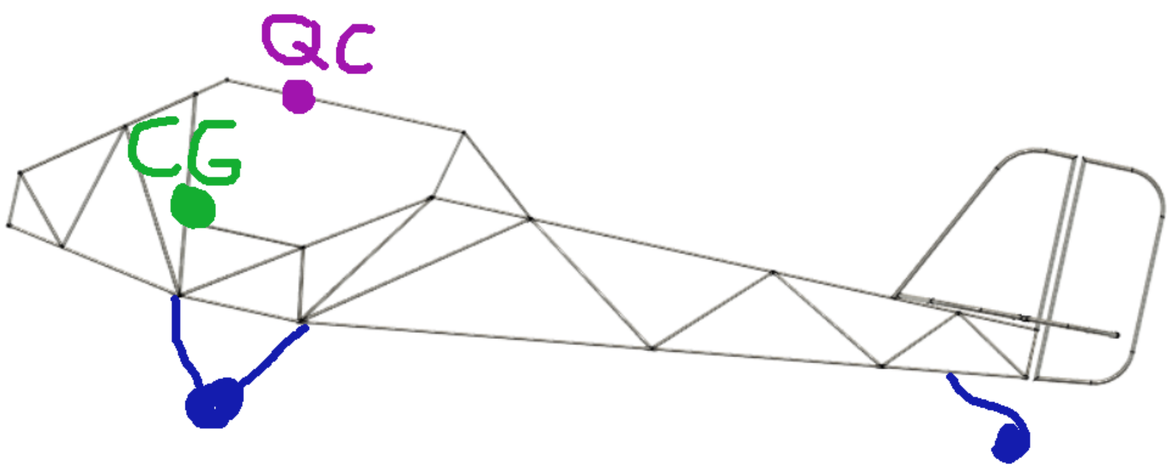
Old → New

Pilot viewing area: We've decided to stop worrying about the square-shaped pilot view because other ultralights have used it successfully. Our simulations will tell us if our nose shapes successfully mitigate forces, so we'll deliberate further then.

Landing gear positioning: We have yet to make a decision, but we did get great advice from Bob on what to take into consideration.



Trike Configuration



Taildragger Configuration

Where
Blue: landing gear wheels
CG: center of gravity
QC: Quarter Chord/ Mean Aerodynamic center of lift. This is purely for reference.

As these *super professional* drawings depict, the center of gravity would be in front of the landing gear in a taildragger, making it unstable on the ground. To fix this problem during takeoff, the pilot seat will need to be adjustable enough to slide the CG back. The larger issue here is during landing the brakes will be activated, so we're worried it would create a moment large enough to tip the plane over the front.

Simulations will need to be run to find the maximum braking power we can have before the moment is too large, to properly deliberate the two options. The main advantage of the taildragger (and the reason it's still on the table) is it's advantageous on runways not made of pavement, which most ultralights take off from.

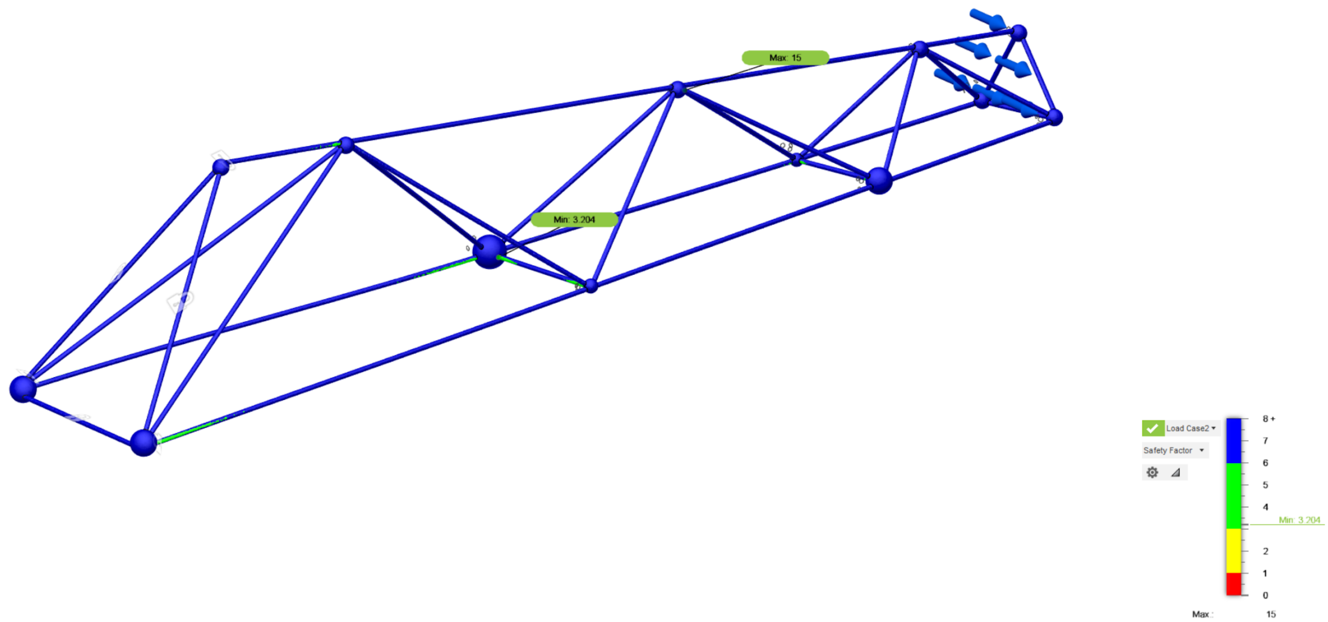
Simulation Results

Tail:
We have two current designs for the tail structure. One of them uses diagonal beams on the underside, while the other uses horizontal beams instead. To conclusively decide between the two, we utilized simulations with identical constraints and loads.

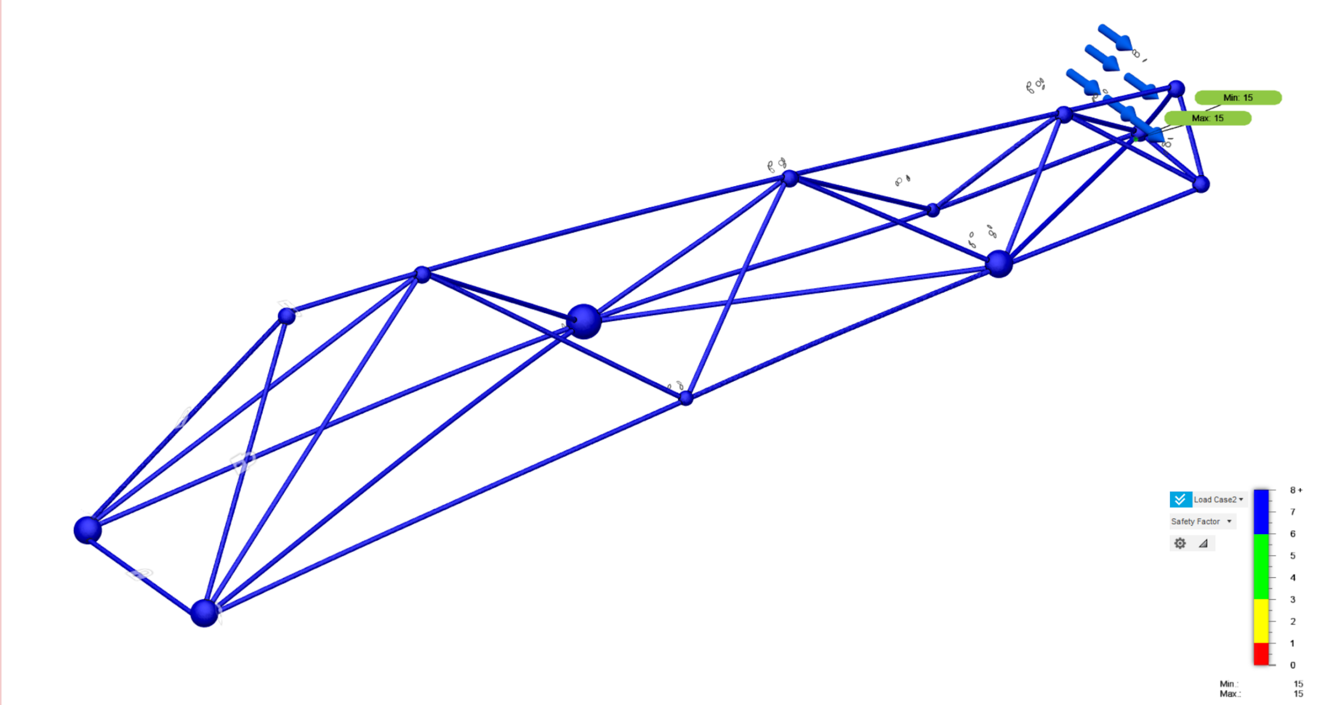
Each tail was set up so only the tail is being tested. This way we can only compare the tails, not any other geometries. This also massively simplifies the meshing process as there is much less to mesh. The tails were subjected to identical load cases: in load case one, 80 pounds of force were applied downwards at the end of the tail; in load case two and three, 60 pounds of force were applied to the left and right.

Results:
The results for the downward load cases were spectacular. Both of the tails performed very well, but this also meant that this could not be used to decide which tail was suitable for our needs.

More useful data was received from the sideways forces simulations (Shown below). The diagonal tail performed much better with a minimum safety factor of 7, while the horizontal tail had a minimum safety factor of 3.204. While this may be seen as immediately conclusive, the weight must be accounted for.



Above: Horizontal Beam Underside Tail



Above: Diagonal Beam Underside Tail

Bodies (1)	
Area	24.8351 ft^2
Density	490.0595 lbmass / ft^3
Mass	17.8054 lbmass
Volume	0.0363 ft^3
Physical Material	Steel AISI 4130 259 QT
Appearance	Steel - Satin

Horizontal Tail Beams

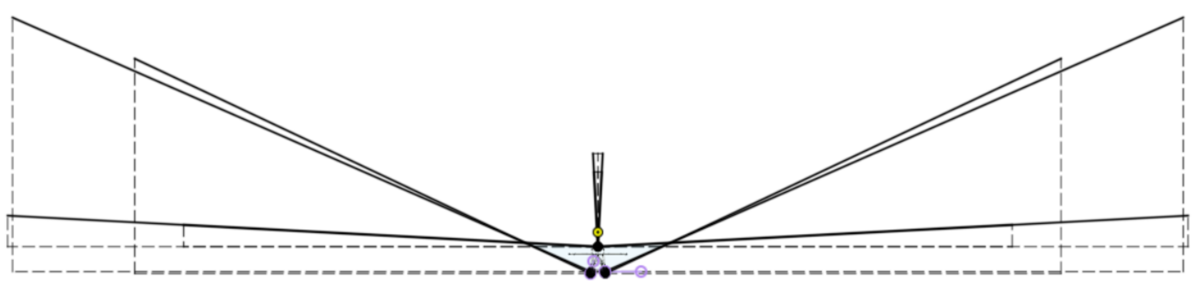
Bodies (1)	
Area	28.0121 ft^2
Density	490.0595 lbmass / ft^3
Mass	20.0957 lbmass
Volume	0.041 ft^3
Physical Material	Steel AISI 4130 259 QT
Appearance	Steel - Satin

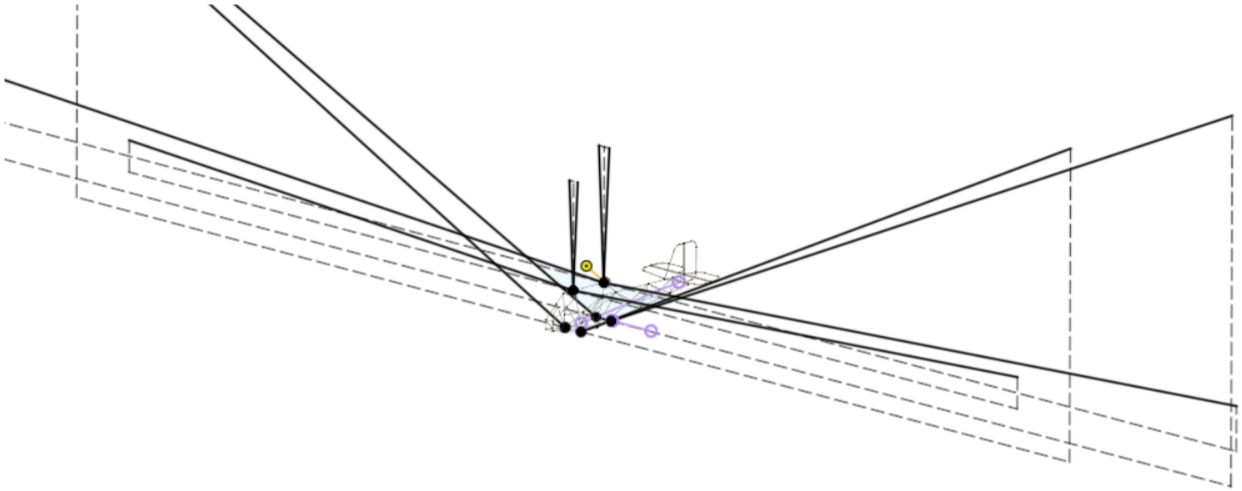
Diagonal Tail Beams

For now, we've decided to go with the Horizontal Tail Beams because it is two pounds lighter. A safety factor of 3 is already insanely more than we need, since that means it can take 3 times the amount of force we calculated to be acting on the empennage. When we finish simulations with the forces of the wing, we'll know for certain and update the blog accordingly.

Future Simulations:

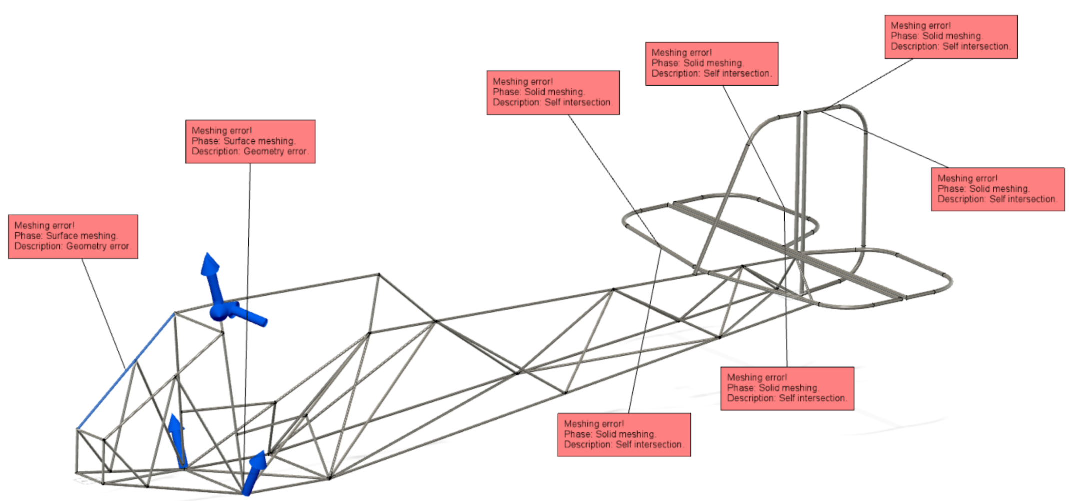
Forces:
We are currently running simulations on the fuselage to see what changes are needed. So far we have modeled the forces as lines on our design, the length of each line corresponding to the amount of force.

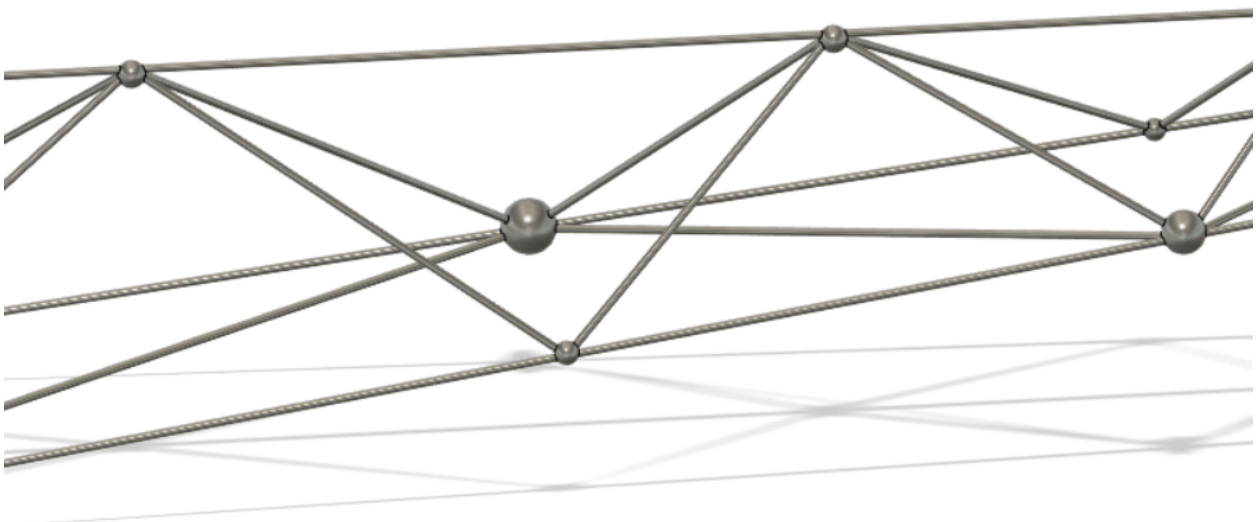




Note: these are just from the force of the wing acting on the fuselage.

Joint Problems:
We encountered some difficulties while attempting to simulate the fuselage, mainly errors with meshing and long solving times. Fusion's pipe tool has difficulty handling complex joints, so in some of our simulations, we chose to replace the joints with spheres to avoid meshing errors.

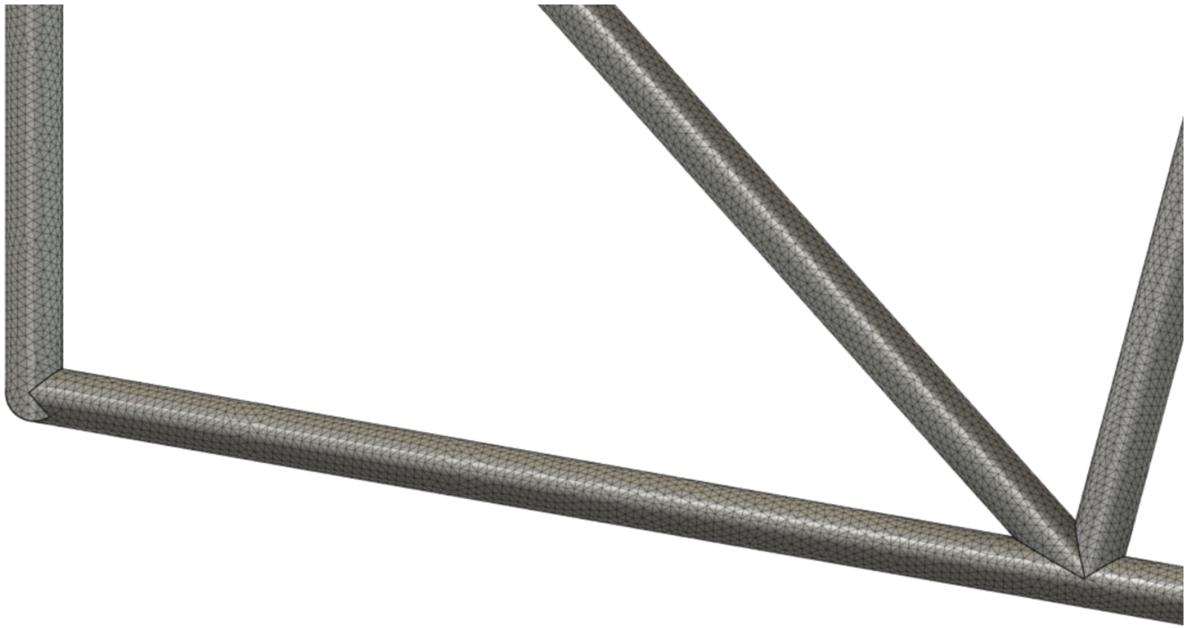




Note: this was actually done on a separate simulation and we were able to do the full fuselage without this sphere-joint method.

Because the strength of our joints will be highly dependent on our ability to weld, we are currently not too concerned with testing joints. In the future, we intend to run stress tests on physical joints.

Mesh:
Most ultralights use 0.035 inch tubing as it is very light, and we were able to find this size of tubing at our local metal shop. However, the thin tube walls forced us to use a 0.1 inch mesh which increased meshing time to close to half an hour for the whole fuselage. Without this small mesh, we would get “self-intersection” errors from Fusion, but as an added bonus smaller meshes create more accurate results.

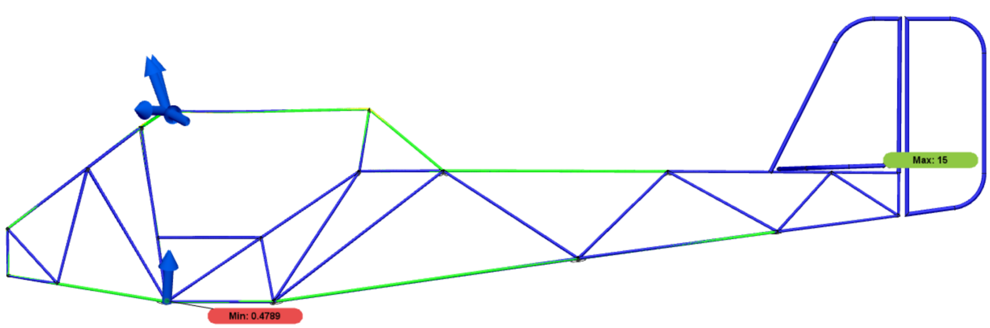


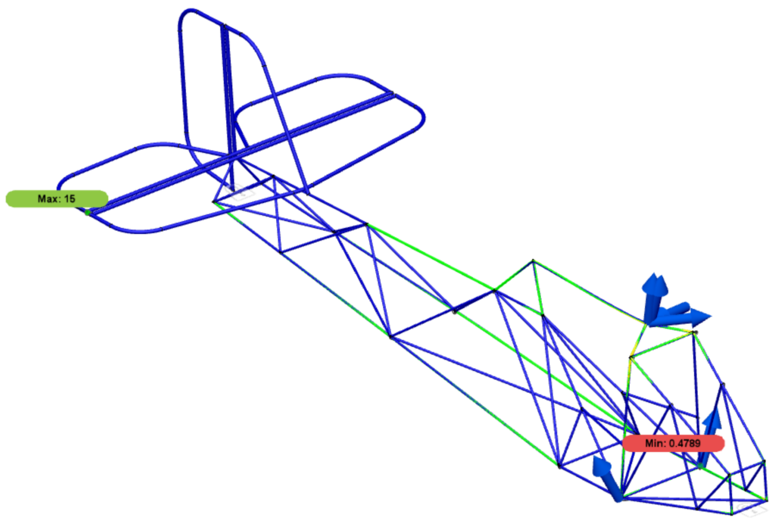
This is what our 0.1 in mesh looks like.

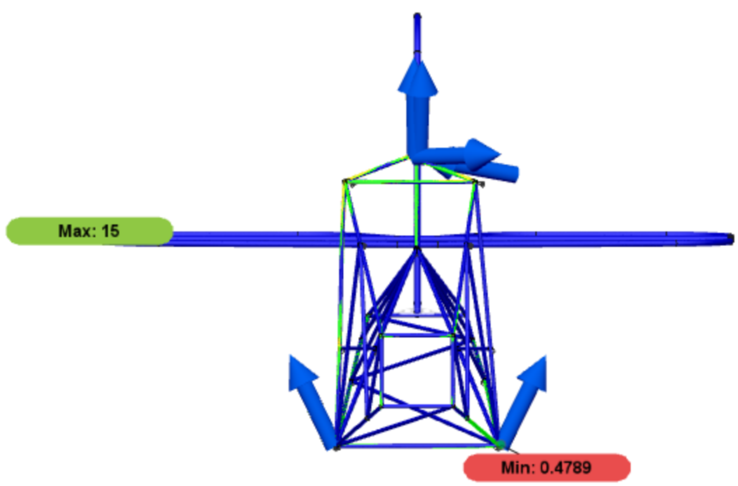
Matt created a Fusion 360 simulation tutorial, for those interested.

Results:
Simulating the whole fuselage with all forces has not been successful so far; either our computers crash or the simulation refuses to solve. We are currently troubleshooting, but have been able to solve simulations with a small number of forces.

We started by simulating the forces due to lift, compression of the spar, and tension from the strut in the aft connection to the fuselage. Blues and greens indicate a higher safety factor; reds and oranges a lower one. The top bar of the cabin is taking a large amount of stress, so in the future, we will experiment with changing the size of the pipes.







The bottom strut forces are about 800 lbf, the compression is around 700, and the upwards forces are only at 100 lbf, since most is turned into tension and compression.

We will continue troubleshooting, and keep this blog updated with our solutions.

Future Steps:

Forces: There's a lot to learn about our fuselage, and most pressing is how the wing forces affect the structure of our fuselage. We already know the upper longeron needs to be thicker, but it will also dictate the placement of our cabin beams.

Nose configuration: we assume the triangles will be stronger than our previous design, but this needs to be validated by simulations.

Pilot placement: Our plane currently fits the [standard pilot], but to get a better feel for control system spacing, we will be constructing the cabin area out of cardboard. We did this back in August on a previous version:

Weld Joint Strength: As mentioned before, the simulation tests the perfect weld, not our own. We will need to test some of the majorly stressed joints by creating physical prototypes and loading them to our desired magnitudes.

We hope this helps and happy engineering!
For any questions/comments/concerns please email general@flightclubaerospace.com