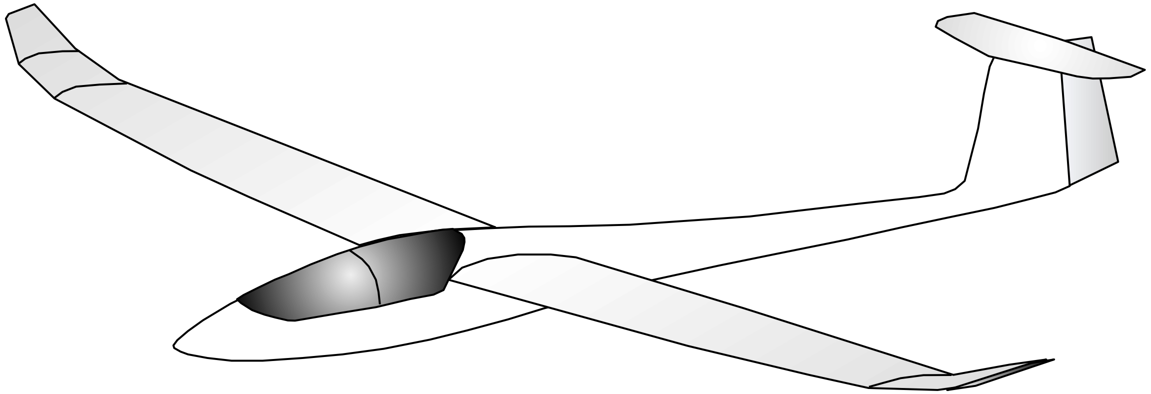
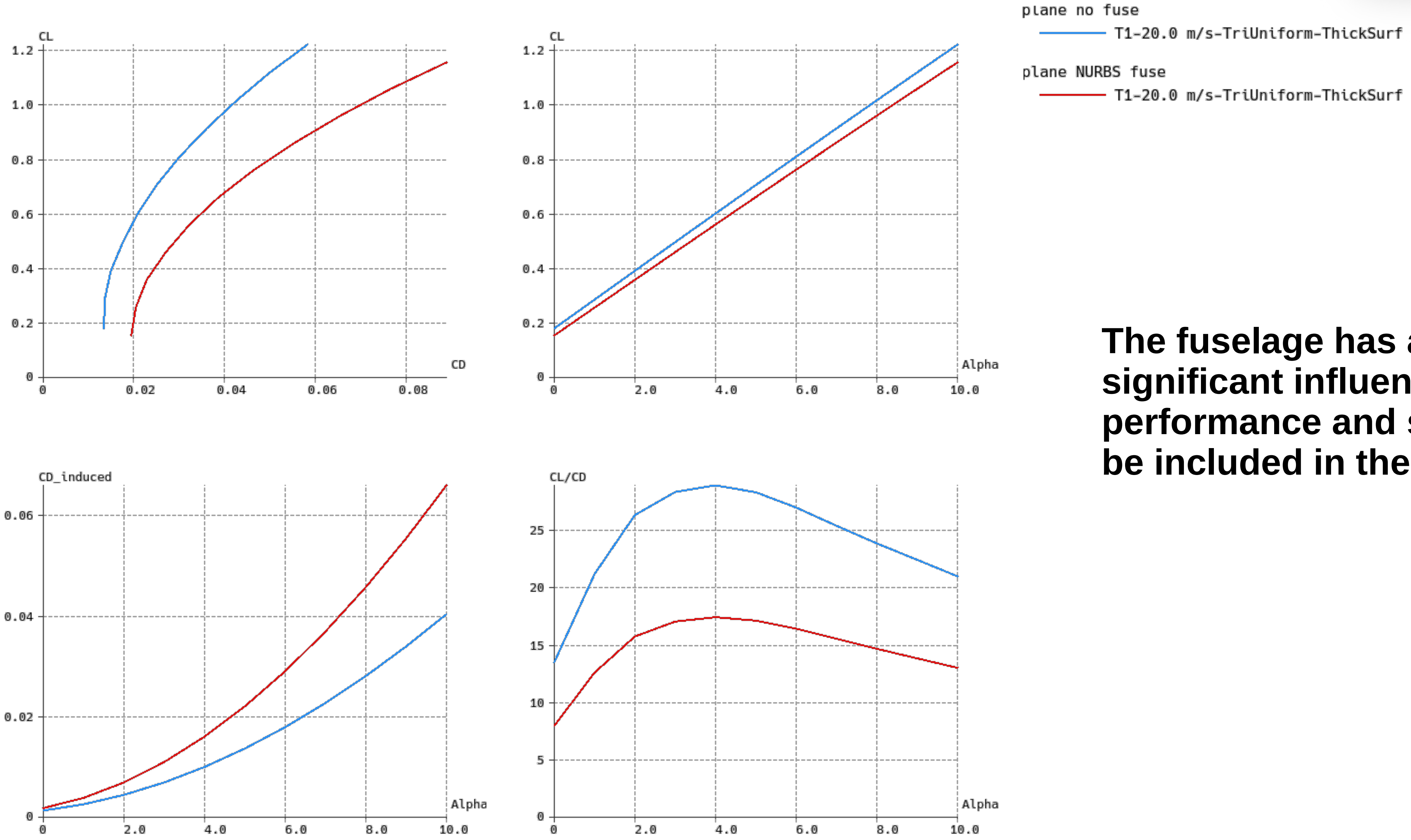


Analysis of planes with fuselages

Fuselage influence



The fuselage has a significant influence on performance and should be included in the analysis

Cautionary note

- The inclusion of the fuselages in the analyses is not a click-run process.
- It requires careful construction of the geometries and of the surface mesh.
- A critical analysis of the results should always be performed.

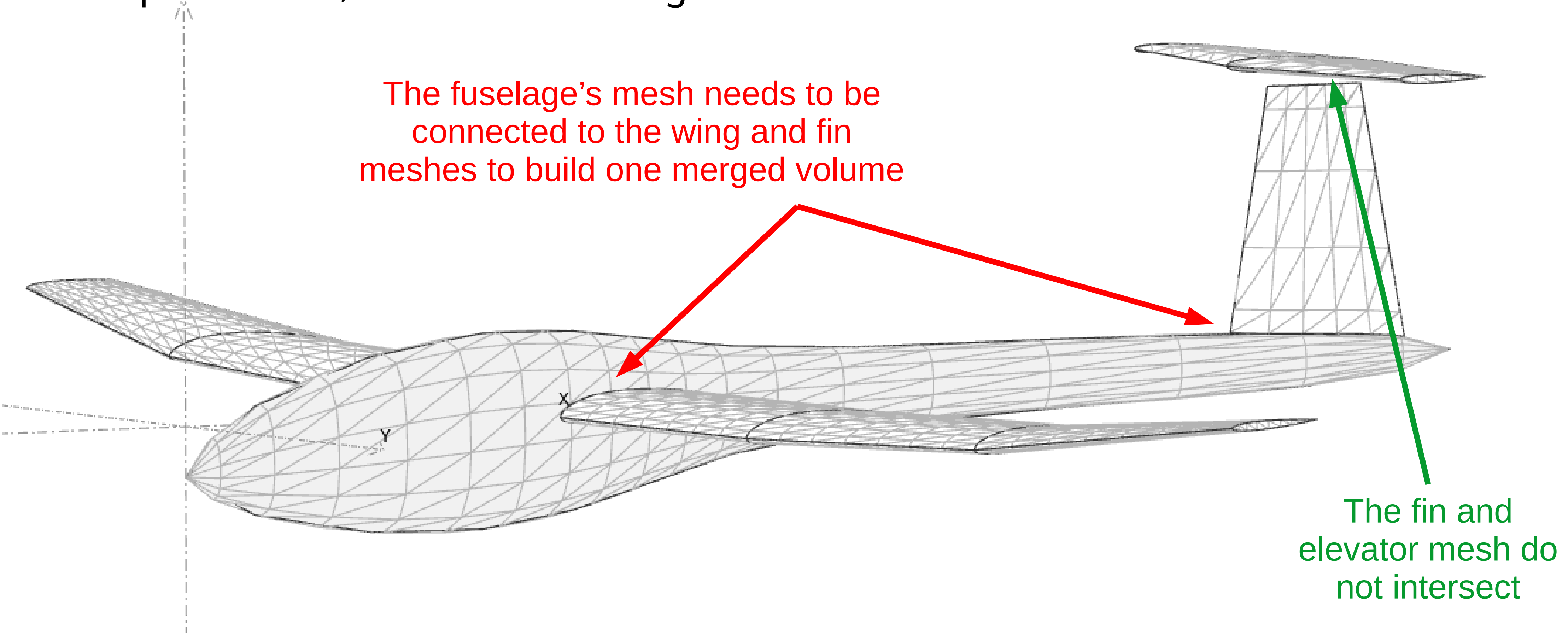
Content

- Part I: Preliminary considerations
- Part II: Quad face type fuselage
- Part III: NURBS type fuselage
- Part IV: STL type fuselage
- Part V: STEP type fuselage

Geometry and surfaces

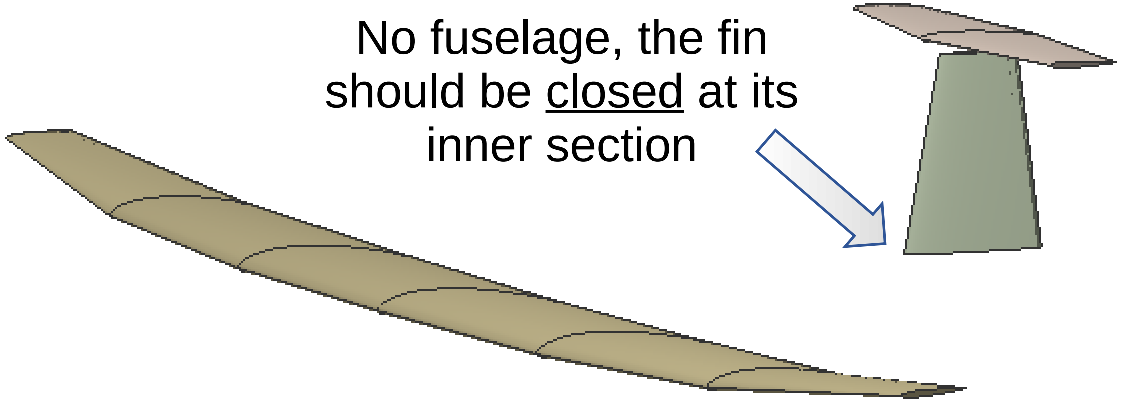
Close the volumes

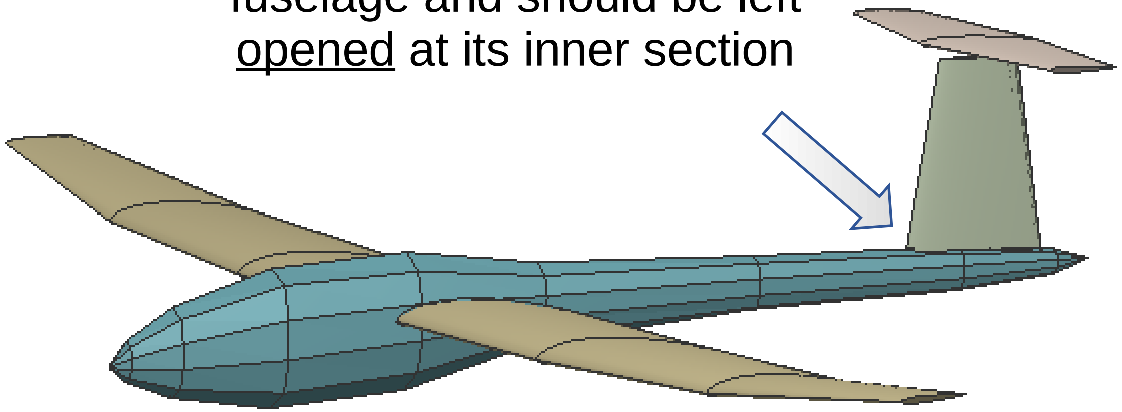
- All panel methods require that the union of mesh elements define one or multiple closed, non-intersecting volumes.



Close the volumes

- The OpenCascade API requires that the wings must form closed SOLIDs to cut the fuselage shell → close the wing T.E.
- In the case of half-wings, such as the fin, check carefully if the inner section needs to be closed or not





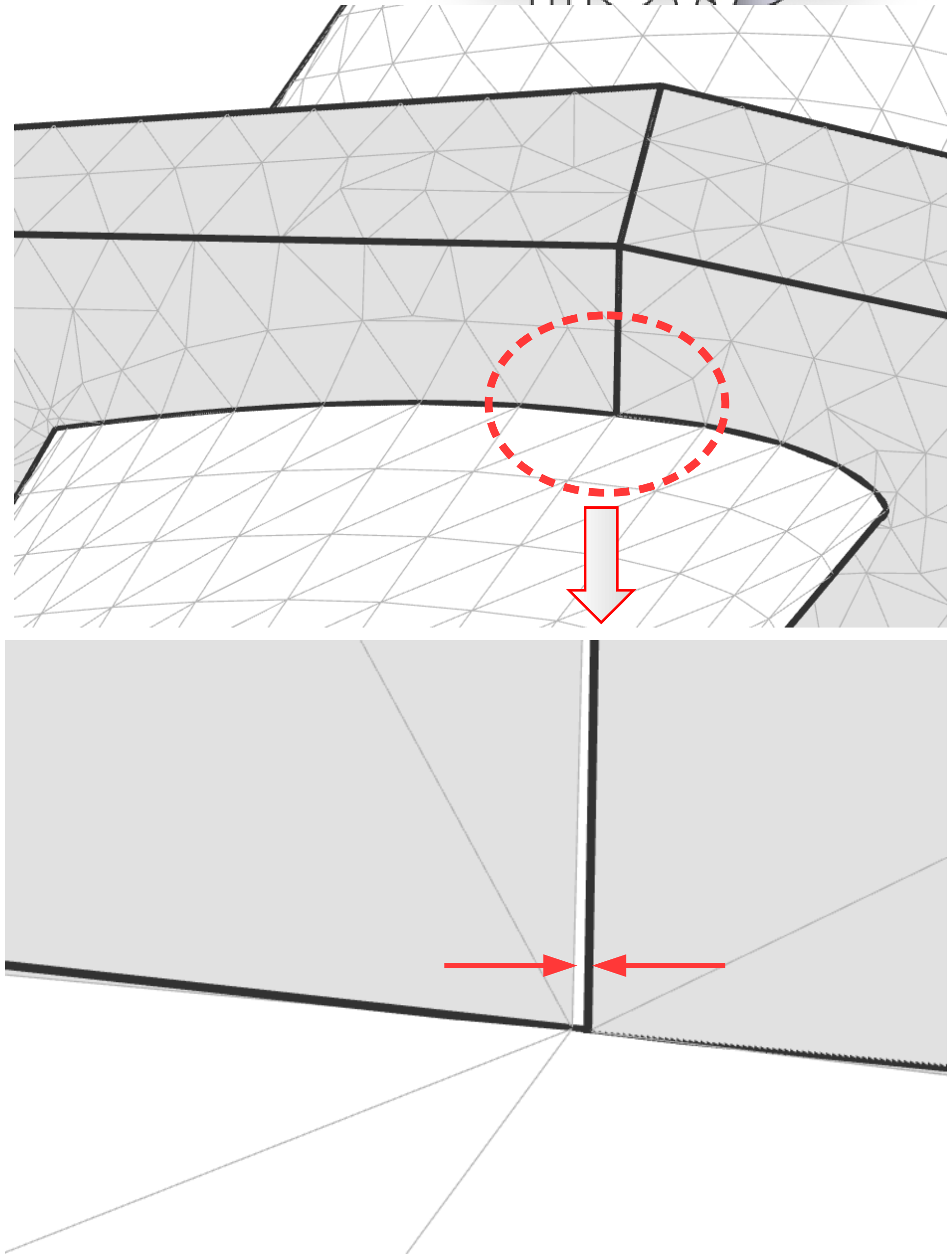
Triangle mesh

The mesher

- The triangle mesh is built by a custom advancing front type mesher
- It expects the geometry to be defined as a union of faces, defined by closed contours, and without free edges
- It will perform well in the vast majority of cases
- It may fail or diverge in the case of small edges

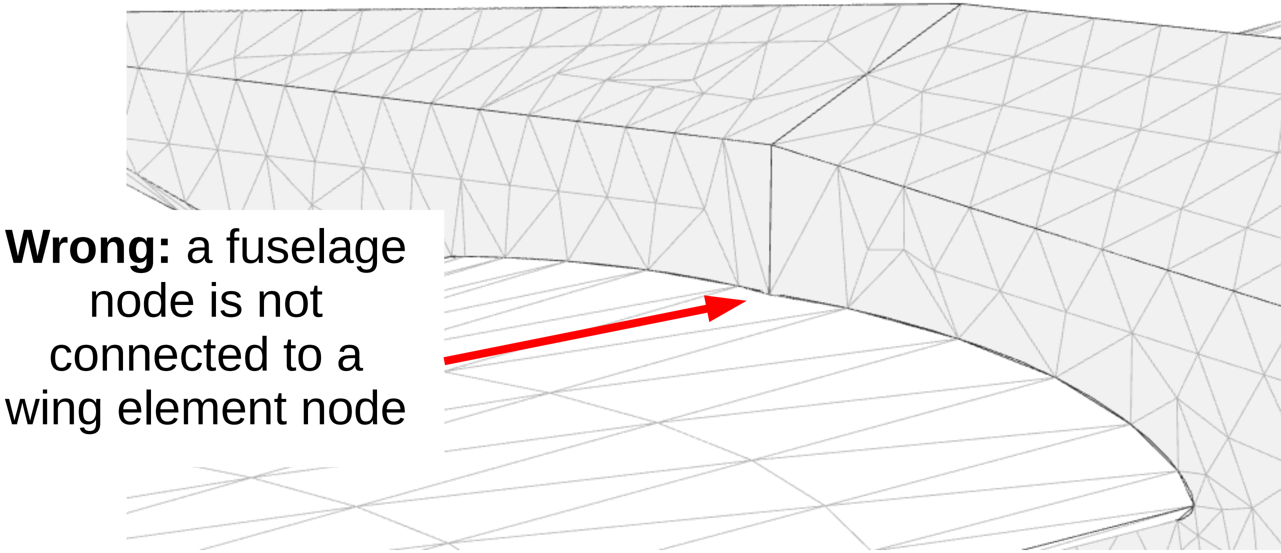
➡ Simplify and clean the geometry before importing it into flow5

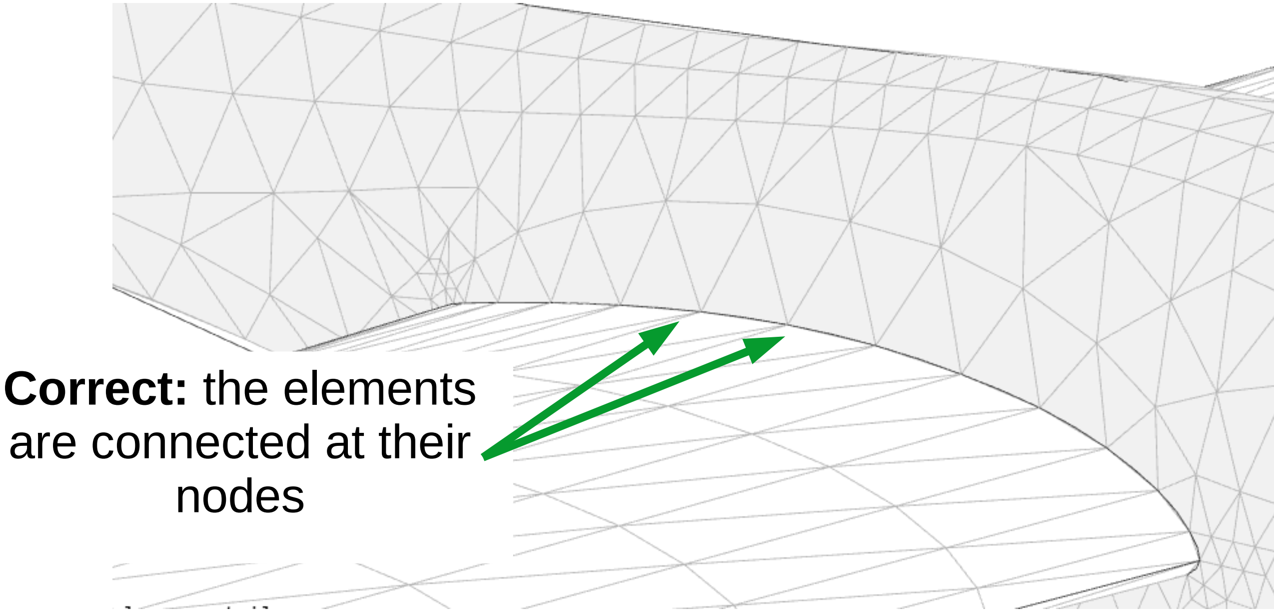
➡ Watch out for small edges which may be created at the intersection of fuselage edges and wing panels



Triangle connections

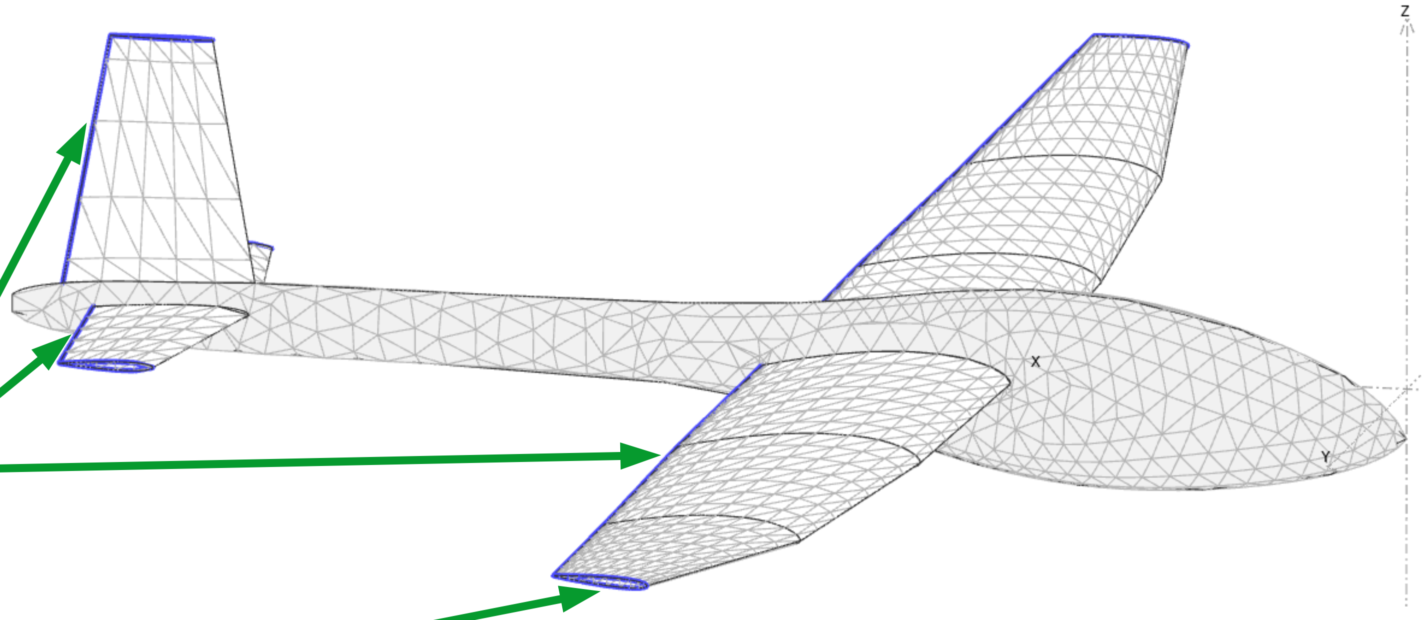
- To avoid numerical issues, triangle elements should be connected at their nodes
- Not strictly necessary, but will improve the quality of the results
- Done automatically for quad meshes
- Done automatically for wing and fuselage triangular meshes
- Manual correction may be required wheif an edge of the fuselage geometry cuts the wing root section





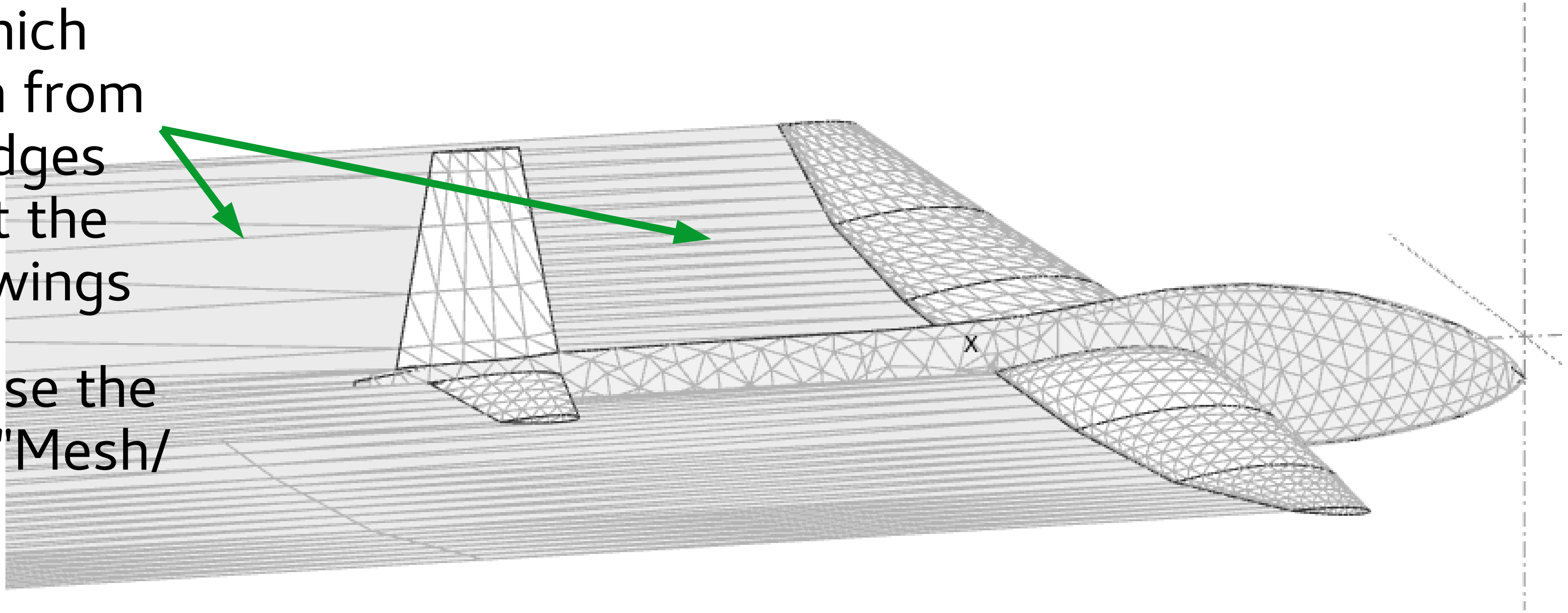
Checking triangle connections

- Connect the triangles
  - Can be done manually using the menu option
  - Done automatically when running the analysis
- Display the free edges; the only free edges should be:
  - the wing trailing edges; the upper surface is not connected to the lower surface to create a vortex and to apply the Kutta condition
  - The side surfaces of the wings



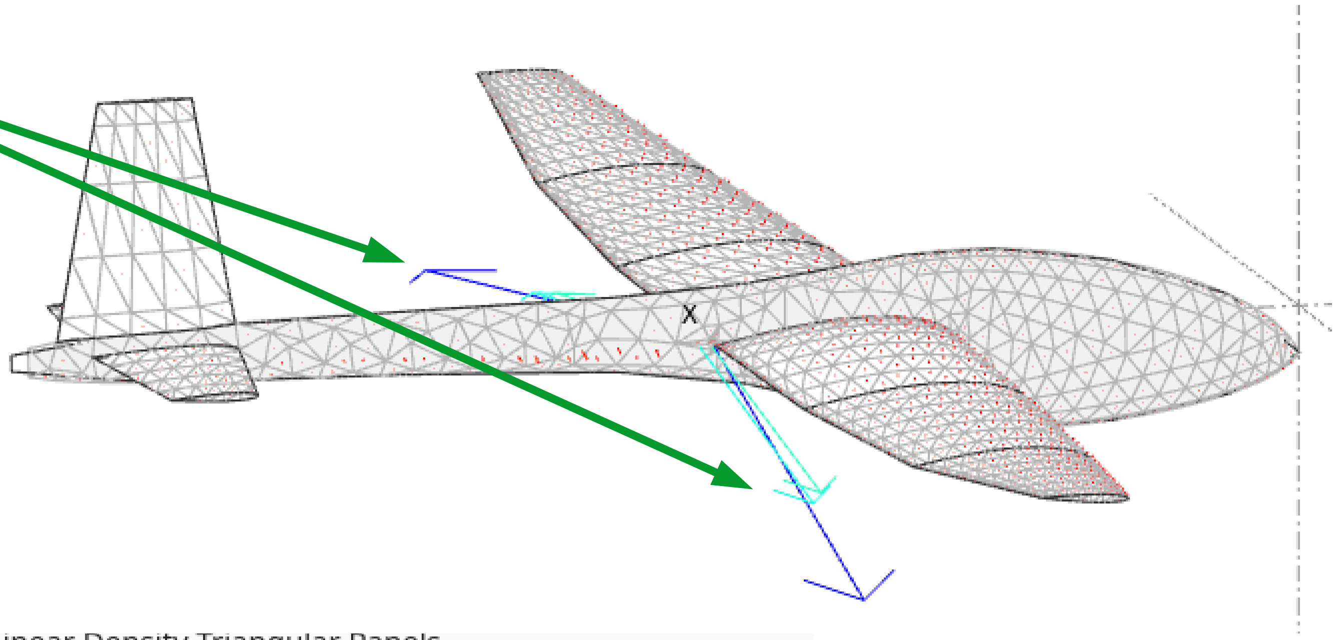
Wake panels

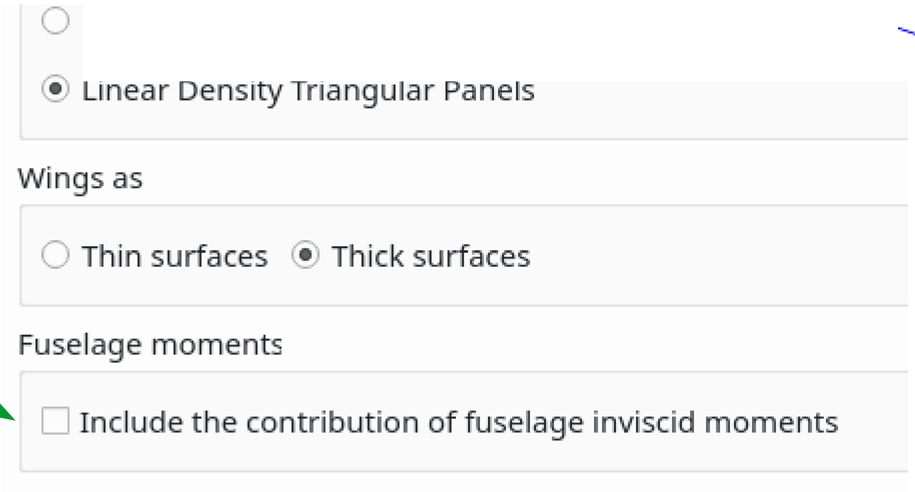
- The wake panels which extend downstream from the wings trailing edges should not intersect the fuselage nor other wings
- Select a polar and use the context menu item "Mesh/ Show wake panels"



Interactions between wake and fuselage panels

- The numerical interactions between wake and fuselage panels lead to unrealistic pressure coefficients which mess up the calculation of moments
- Recommendation: disable the inclusion of the fuselage's contribution in the evaluation of moments.



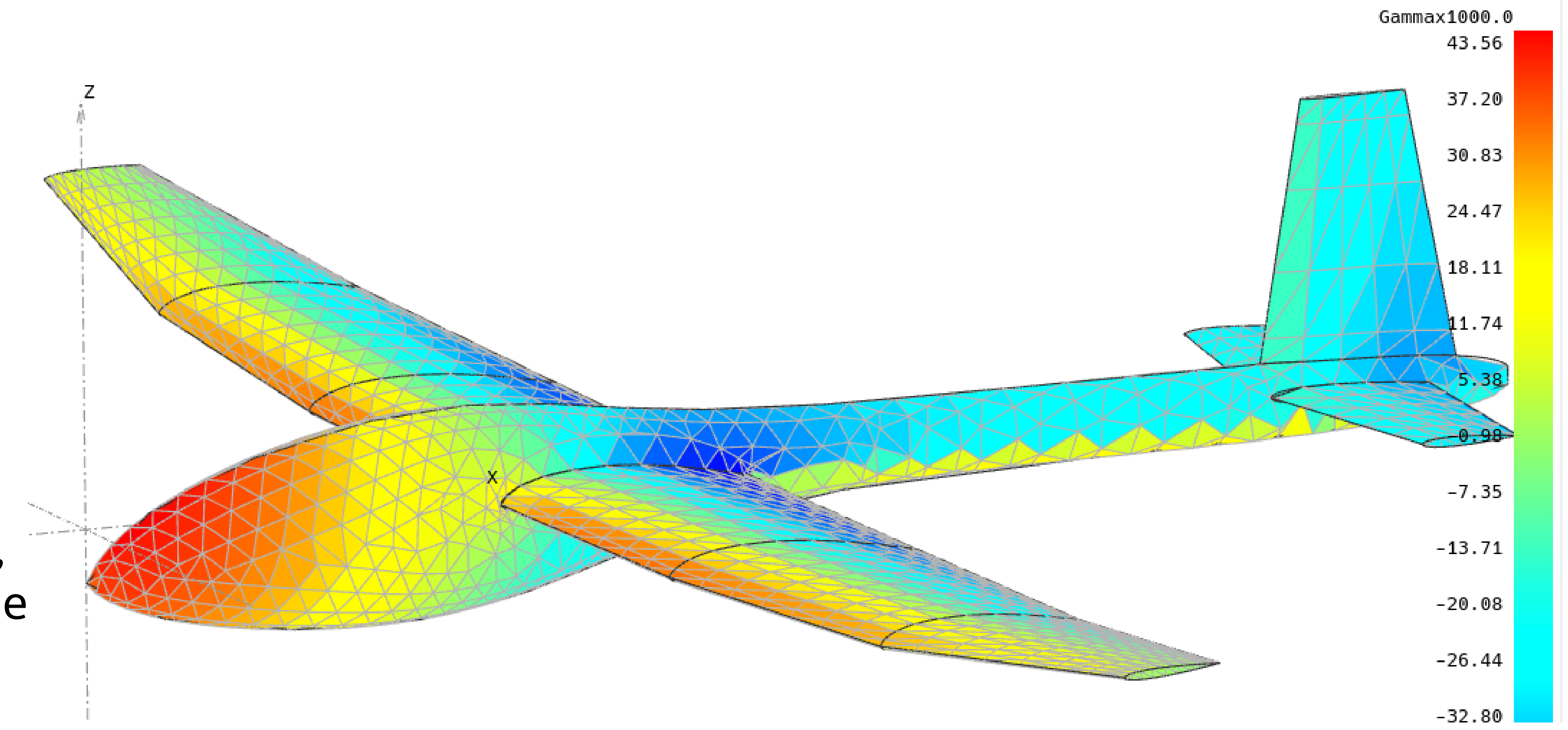


Doublet densities and pressure coefficients

Doublet densities

A panel analysis solves the linear system for the doublet densities on the panels. All other results are deduced from the doublet densities.

- A smooth distribution of the doublet densities is a good indicator of the quality of the analysis and of its results
- If the color scale indicates that there are local numerical issues, then the triangle mesh should be improved

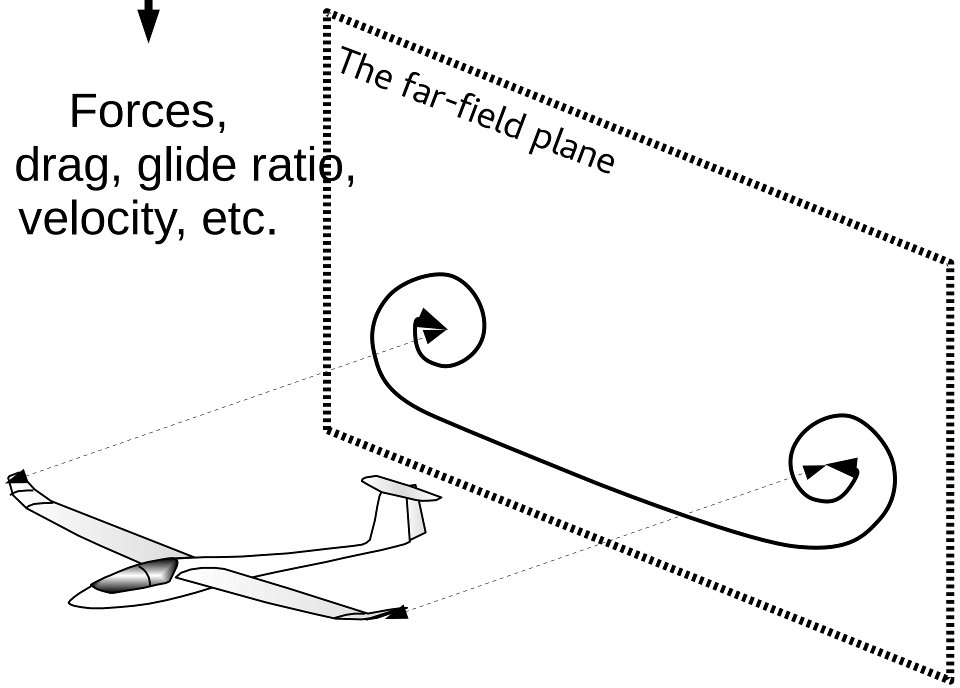


Doublet densities

A panel analysis solves the linear system for the doublet densities on the panels. All other results are deduced from the doublet densities.

"Off-body" results calculated downstream in the far-field plane

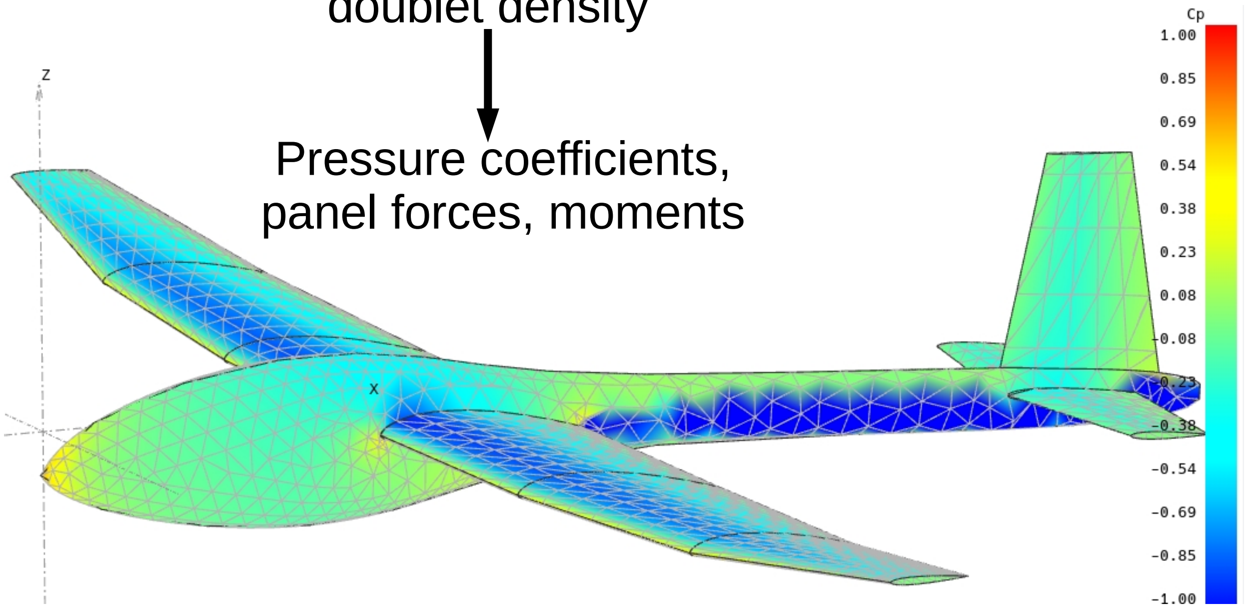
Forces,
lift, drag, glide ratio,
velocity, etc.



"On-body" results calculated on the surfaces

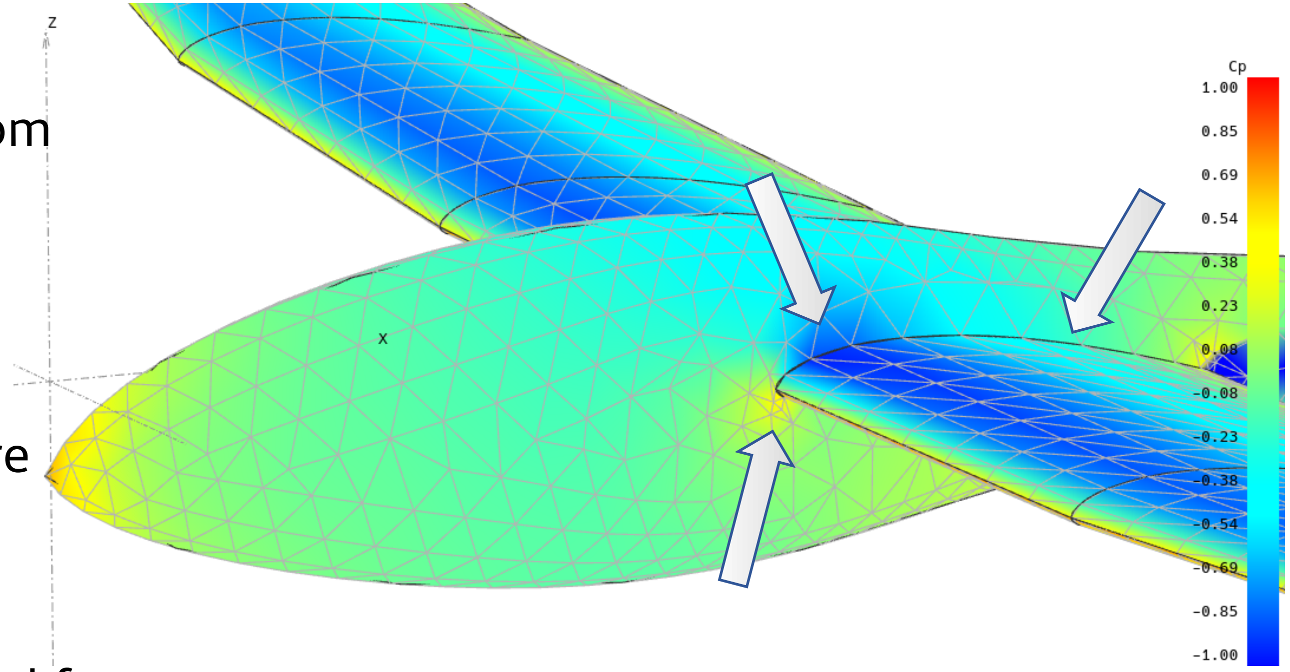
Surface gradient of the doublet density

Pressure coefficients, panel forces, moments



Pressure coefficients - Cp

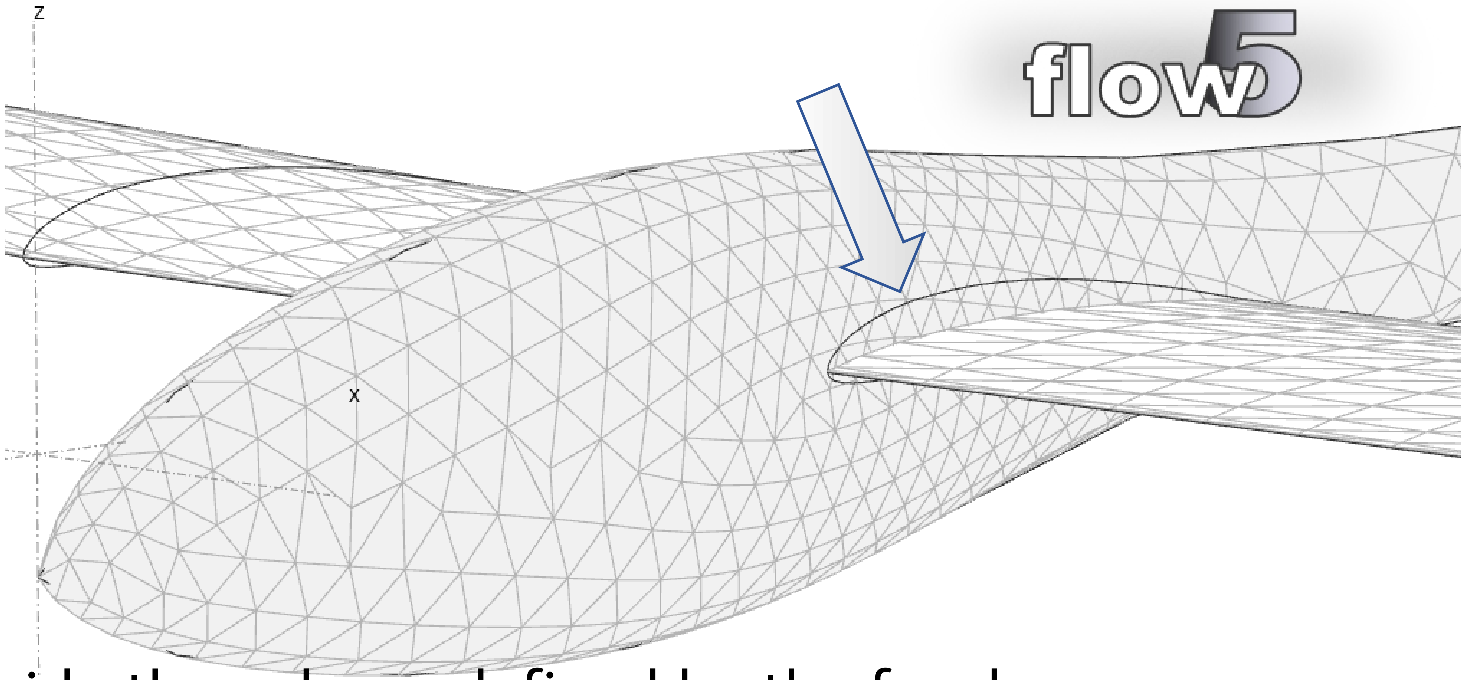
- The pressure coefficients (Cp) are calculated from the surface gradient of the doublet densities.
- This requires that the elements be connected at their nodes
- The calculation is tricky when adjacent panels are not in the same plane such as at the junction of wings and fuselages



- It only impacts the moments which are calculated from pressure forces acting on the panels.
- It does not impact the lift and drag calculated in the far-field plane
- Potential to improve the precision of the Cp coefficients in the linear case
  → to be evaluated in the β-phase

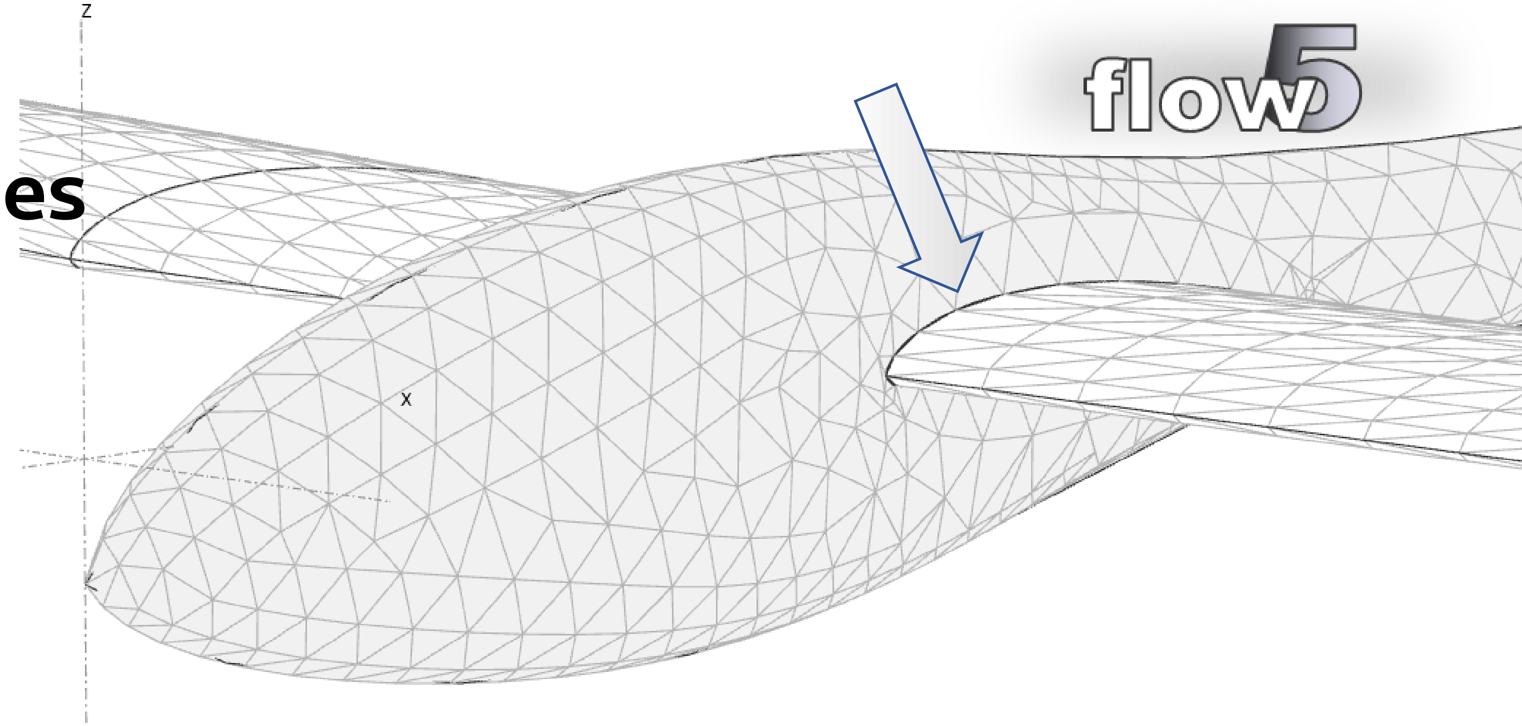
Design options

Wings as thin surfaces



- **Rules**
  - Wings must not extend inside the volume defined by the fuselage
- **flow5 enforces this rule**
- **Notes**
  - Numerical issues may occur where the wing joins the fuselage
- **Recommendation**
  - Not the preferred method

Wings as thick surfaces



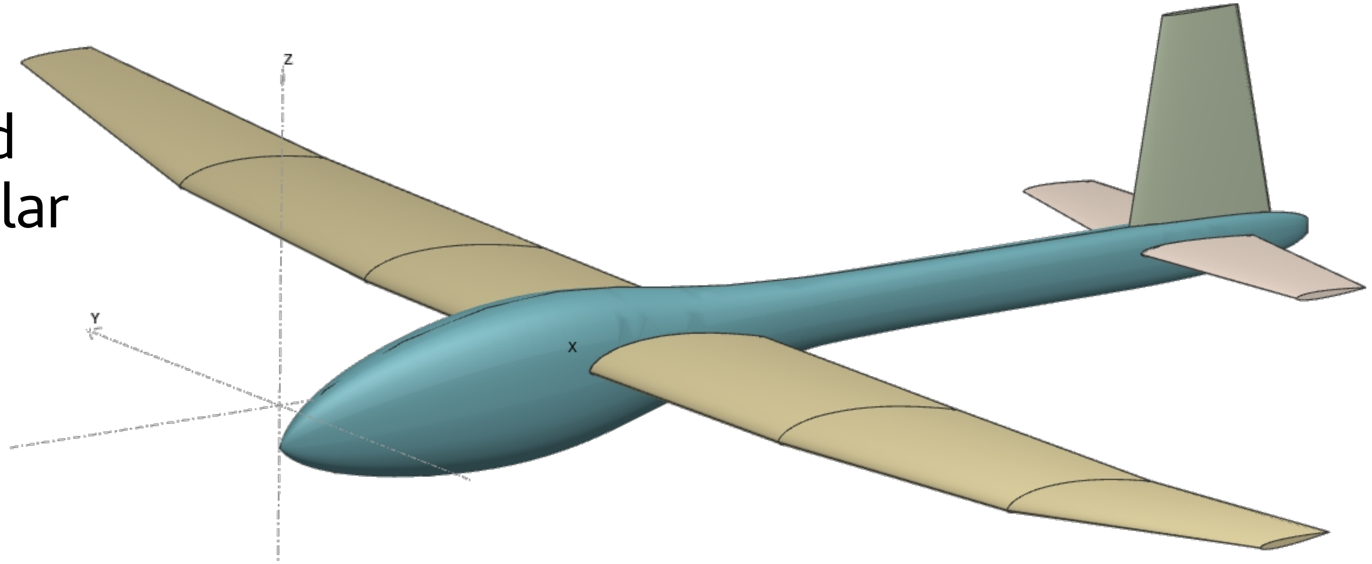
- **Rules**
  - The analysis must use the quad or triangle panel methods – not the VLM
  - The connection of fuselage and wing mesh elements is only implemented for the triangle panel methods
- **Points to watch**
  - Quality of the triangle elements at the junction of wing and fuselage
  - Connections of wing and fuselage triangles

Fuselage drag

- Fuselages do not shed wakes, and therefore do not create induced drag or lift.
- Fuselages generate friction drag; two friction drag models are implemented in flow5 :
  - The Karman-Schoenherr model
  - The Prandlt-Schlichting model
  - Additional drag models may be implemented in the future.

Recommendations

Recommendations



- The current robust, recommended method is to use the thick triangular panel method, with linear doublet densities.
- Simplify and clean the fuselage geometry before importing it into flow5; more specifically, be sure to remove all small edges.
- To reduce the mesh size, define the fuselage with flat faces.

flow5