MEMOIRE DE FIN D'ETUDES

Département de GENIE MECANIQUE

THEME

Study of the Mesh Influence on the 3D Flow Around a Tourist Aircraft

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Presentation Outline

- Introduction and Objectives.
- Different Meshing Methods.
- Simulation results.
- Conclusion.

Introduction and Objectives

Introduction

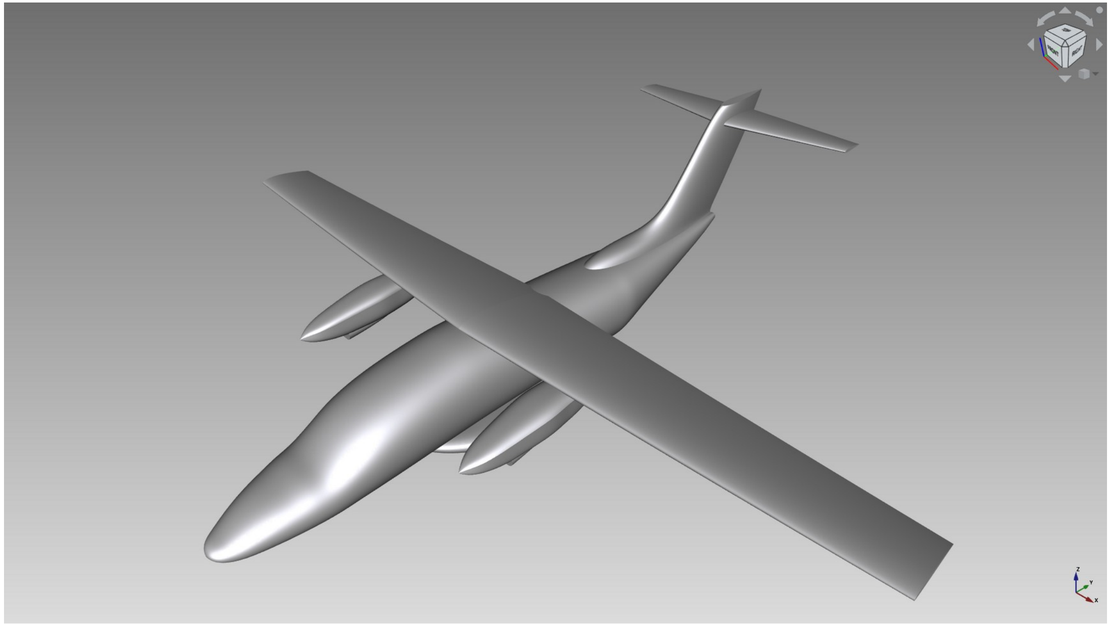
- Over the past two decades, computational fluid dynamics (CFD), which involves numerical simulation of fluid flows, has experienced significant growth across various fields, particularly in the aerospace industry. Nowadays, it is extensively used in the aeronautical industry from the pre-project phase to production to assess the aerodynamic performance of aircraft. Simultaneously, the computational power of computers has increased, enabling CFD simulations to solve the averaged Navier-Stokes equations (RANS) within an acceptable timeframe for industrial purposes. However, the geometric complexity of the simulated configurations has also increased, incorporating the relative motion of bodies, such as propellers on airplanes or rotors on helicopter fuselages, and incorporating intricate geometric details.

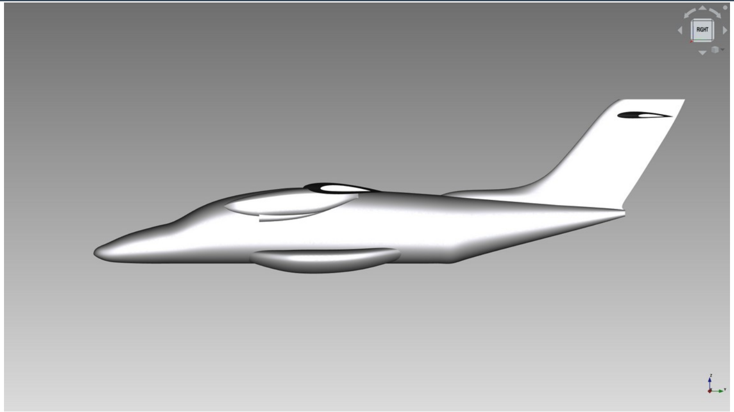
Objectives

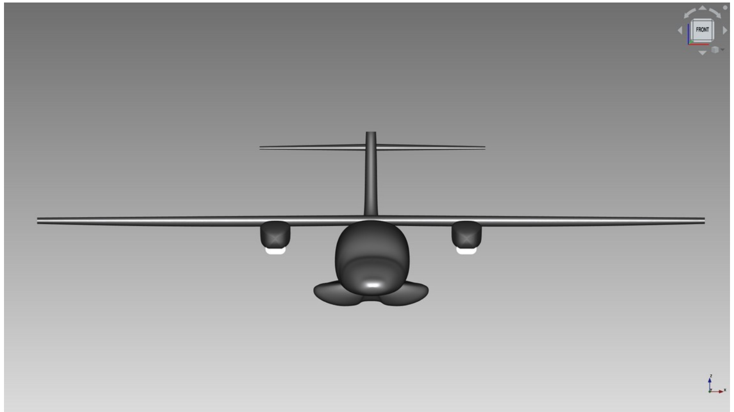
Our goal in this work is to study the impact of the mesh on the flow characteristics is to use the free "*OpenSource*" software available to solve an aerodynamic problem involving air flow analysis around a tourist plane known as the Outback EV-55. During the flight of this study, we chose to use different software tools. *FreeCAD* has been selected for 3D design, *cfMesh* for network generation, *openFOAM* as a store that uses the limited size method, and *ParaView* as a visualization tool to analyse the obtained results.

Different Meshing Methods

- *EV-55 Aircraft design*

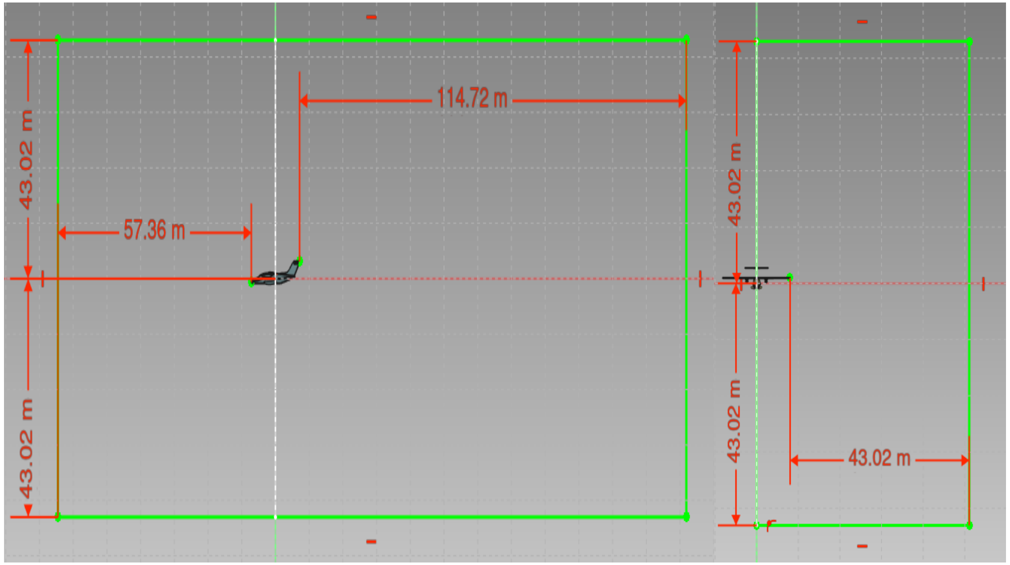


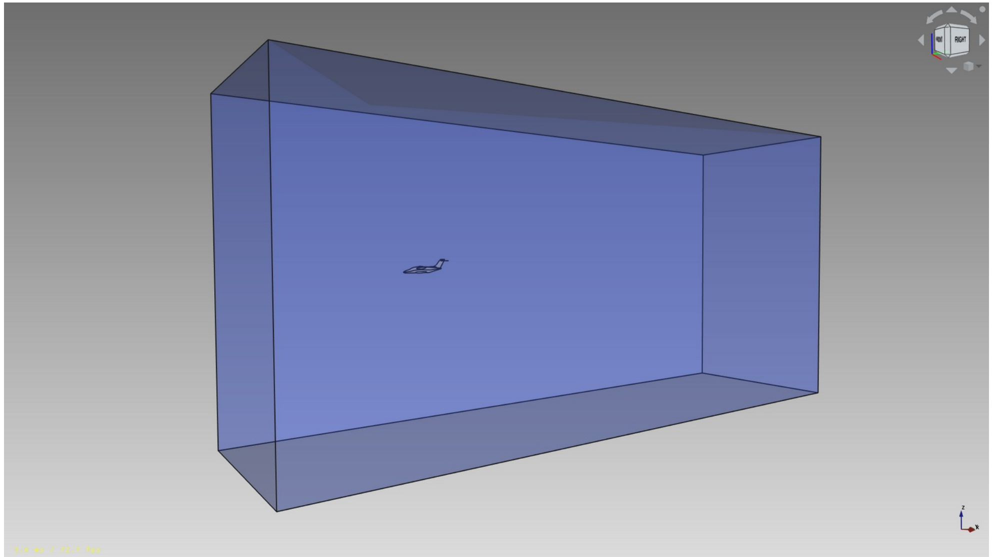




Different Meshing Methods

Computational domain

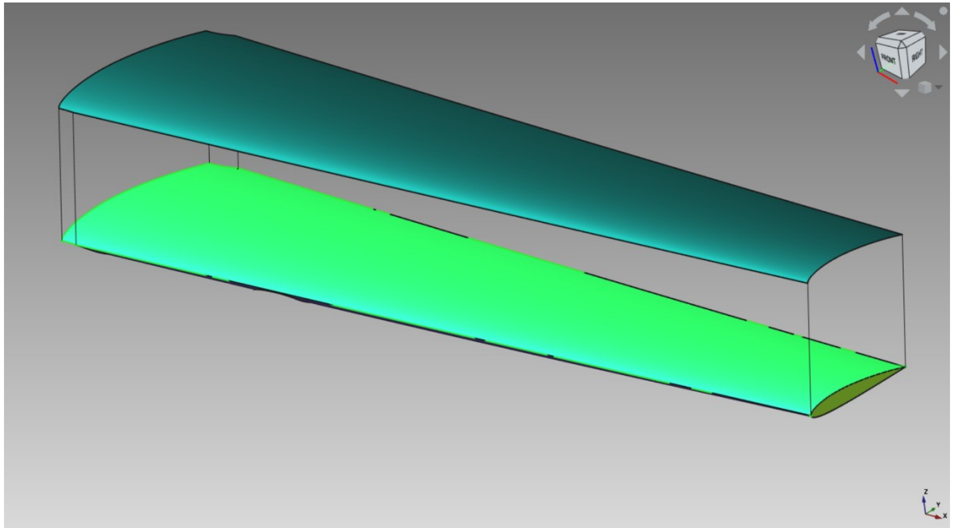


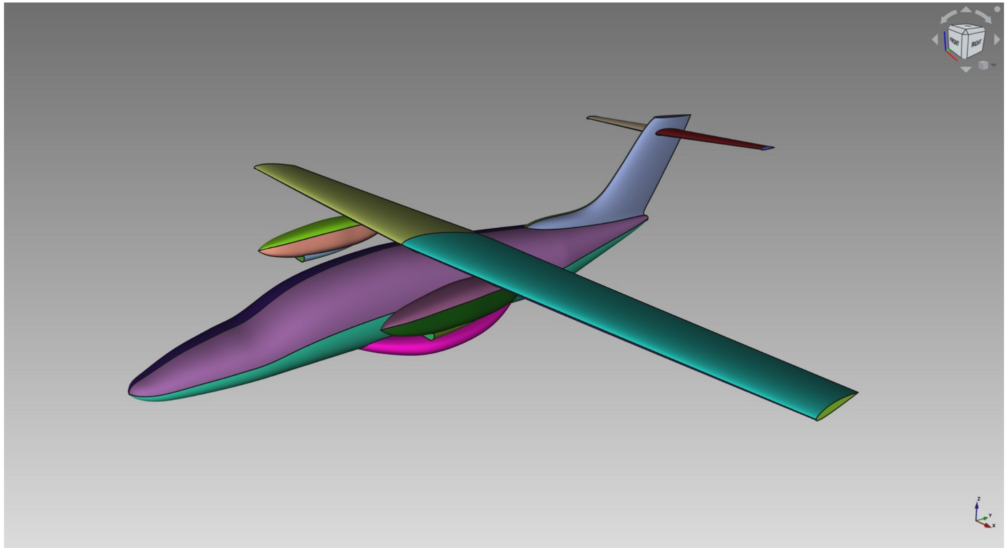


Different Meshing Methods

Method 1

It is an advantage in the workbench *Draft*. In this way, we divide flight surfaces by pressing the downgrade button and fixing a surface from the surfaces and pressing the *Trimex* feature you extrude the surface and we choose the direction of the extrusion following the geometry.



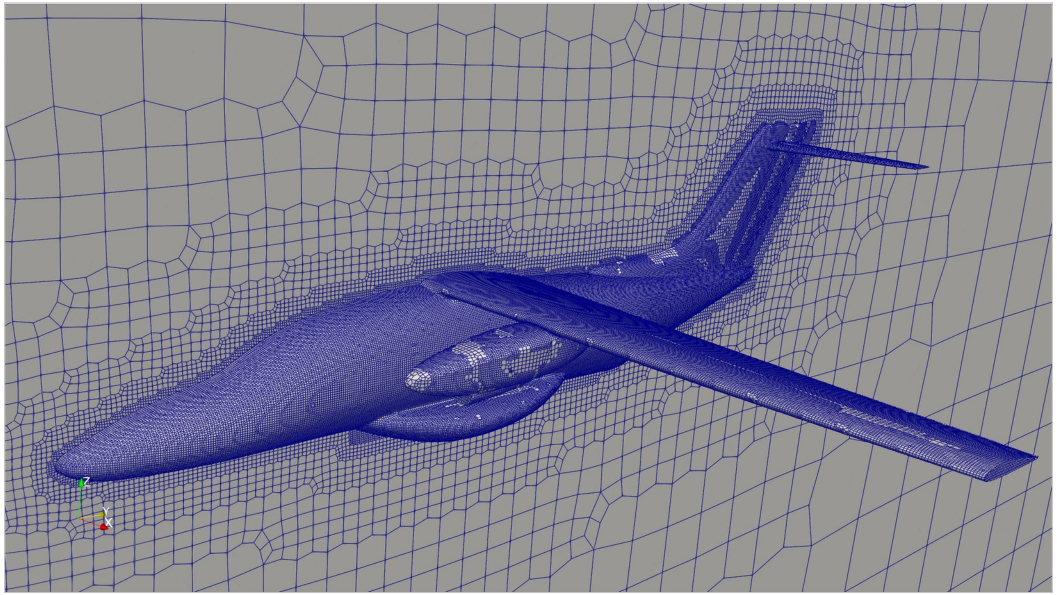


Different Meshing Methods

Method 1

We do this step on the entire surface of an airplane that requires a lot of effort, time and concentration When we finish, we combine all the surfaces and get an aircraft-shaped template. Extrusion thickness = 50 mm.

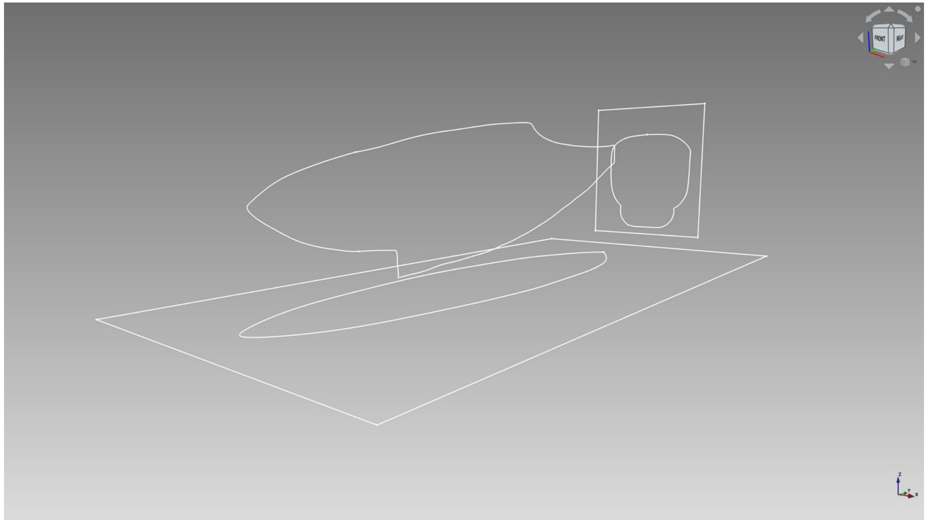
Mesher	Cartesian
Base Element Size	3 m
Trimex	0.020
Boundary Layer number (surface)	20
Mesh time	1 min 47s
Disk size	435 MB
Total number of nodes	**2 766 302**

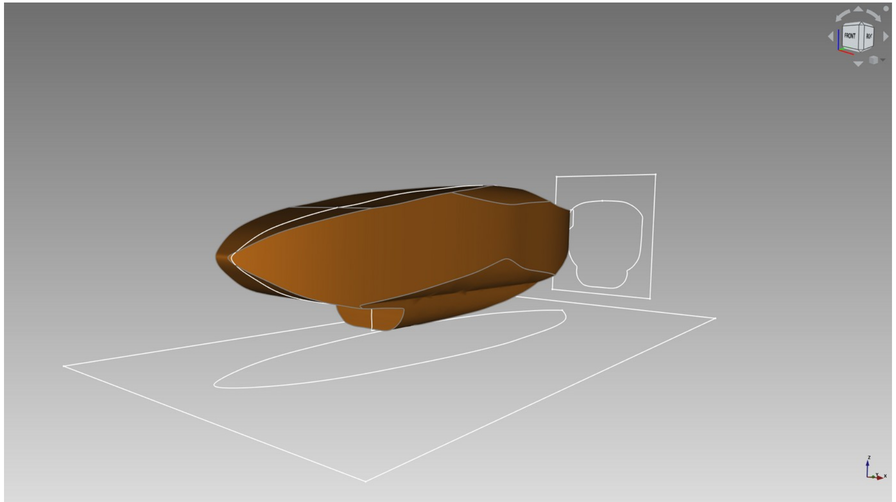


Different Meshing Methods

Method 2

In this method, we create volume around the fuselage, the tail and the engine, the front and rear parts of the aircraft, the landing gear, and the wing.

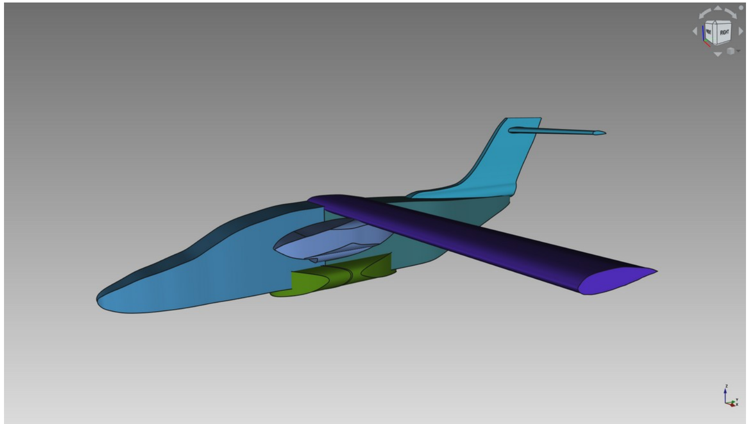


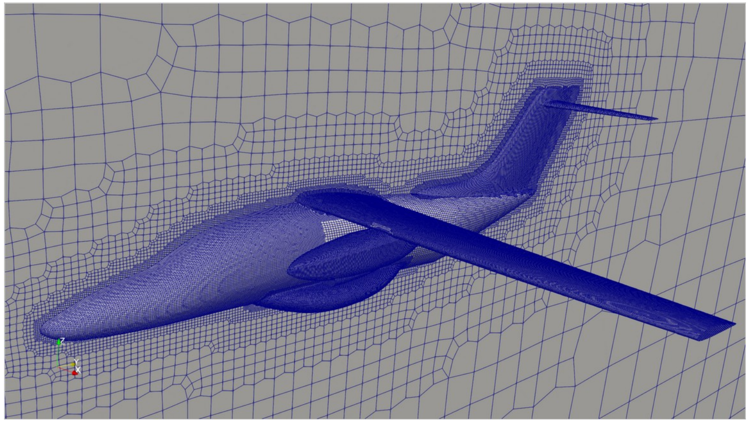


Different Meshing Methods

- ***Method 2***

Mesher		Cartesian
Base Element Size		2 m
scale	Wing + engine + box landing	0.015
	fuselage face + tail	0.020
	fuselage behind	0.040
Boundary Layer number (surface)		20
Mesh time		09 min 49s
Disk size		593 MB
Total number of nodes		**6 747 625**



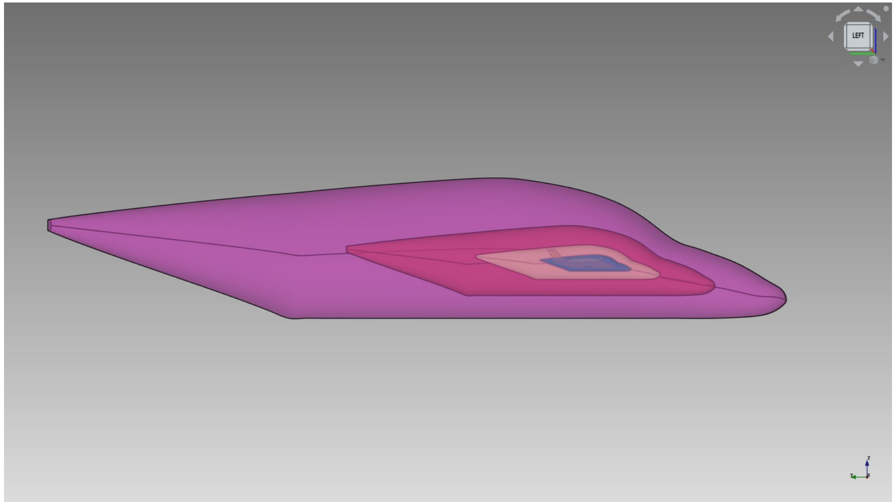


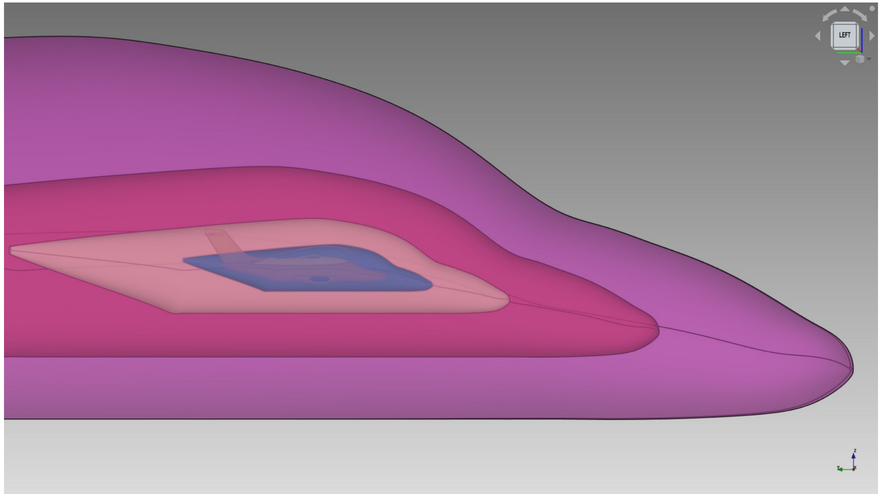
Different Meshing Methods

Method 3

We create four copies of an air plane body while increasing the size of each one.

- Scale 0 (1;1.5 ;1.5)
- Scale 1 (1 ;3 ;2.5)
- Scale 2 (1 ;5 ;4)
- Scale 3 (1 ;10;6)

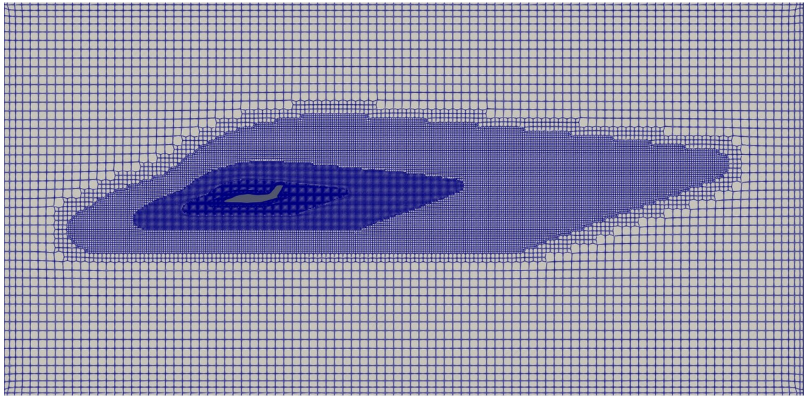


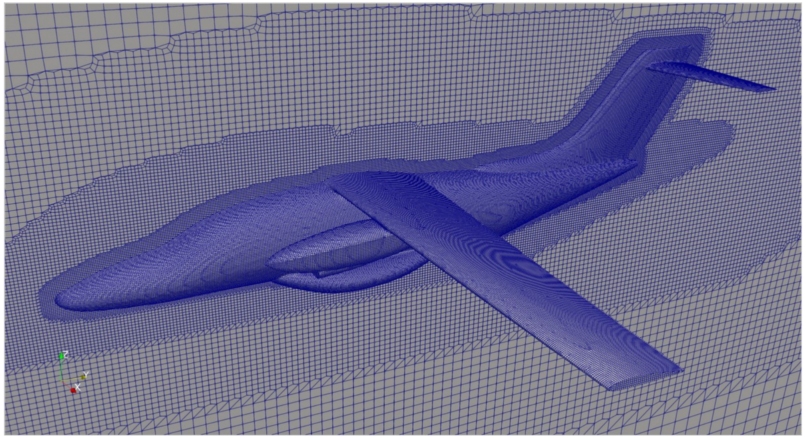


Different Meshing Methods

Method 3

Mesher		Cartesian
Base Element Size		2 m
Surface refinement airplane		0.020
scale	Scale0 / Scale wing	0.050
	Scale1	0.100
	Scale2	0.200
	Scale3	0.300
Boundary Layer number (surface)		20
Mesh time		03 min 20s
Disk size		656 MB
Total number of nodes		**4 673 620**



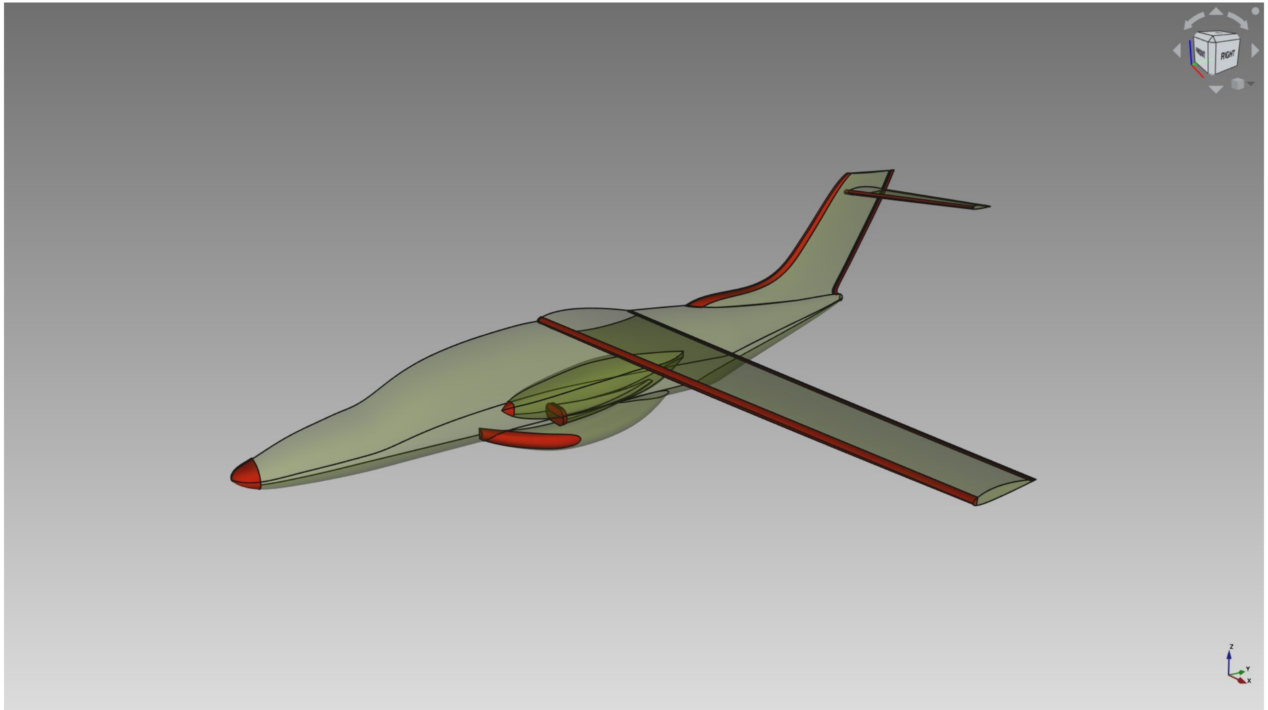


Different Meshing Methods

Method 4

In this method, we cut out parts of an air plane, the front of an air plane, the engine, the air intake, the front and rear of the wing, and the tail.

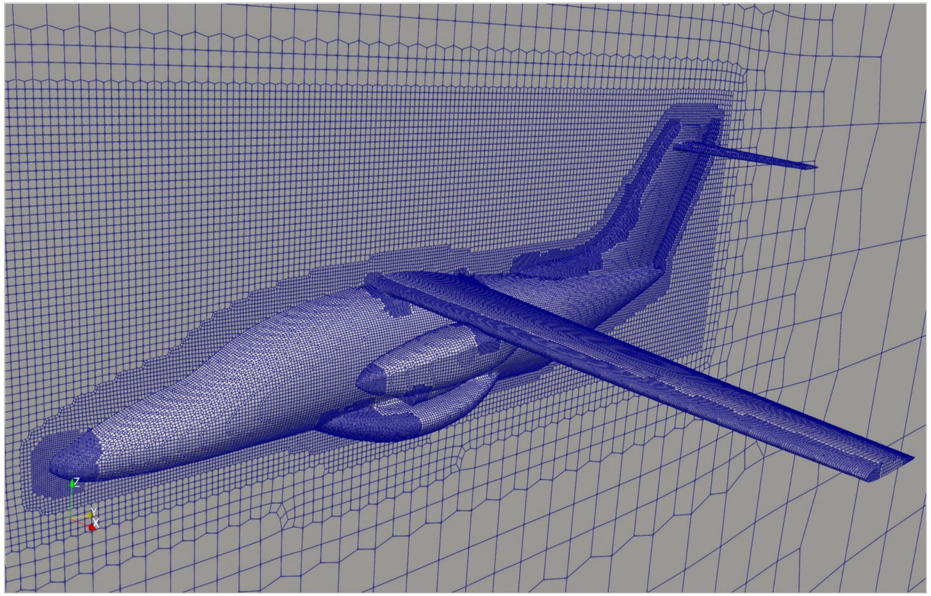
- Lay a plane in a cube and sand it low to organize the grid because sanding in large chunks warps the grid around the plane.



Different Meshing Methods

Method 4

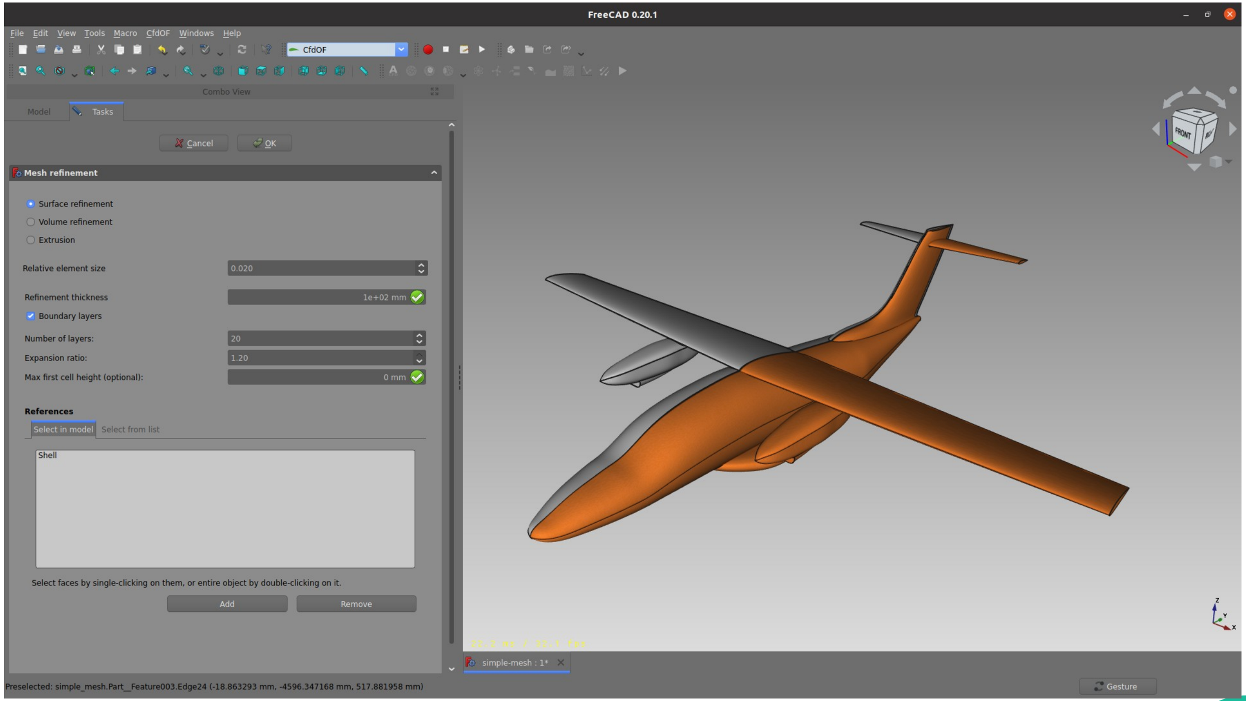
Mesher		Cartesian
Base Element Size		3 m
Surface refinement		0.020
Refinement thickness		100 mm
Volume	box	0.100
	The back of the wing	0.005
	other parts	0.010
Boundary Layer number (surface)		20
Mesh time		6 min 47s
Disk size		467 MB
Total number of nodes		**5 222 639**



Different Meshing Methods

Method 5

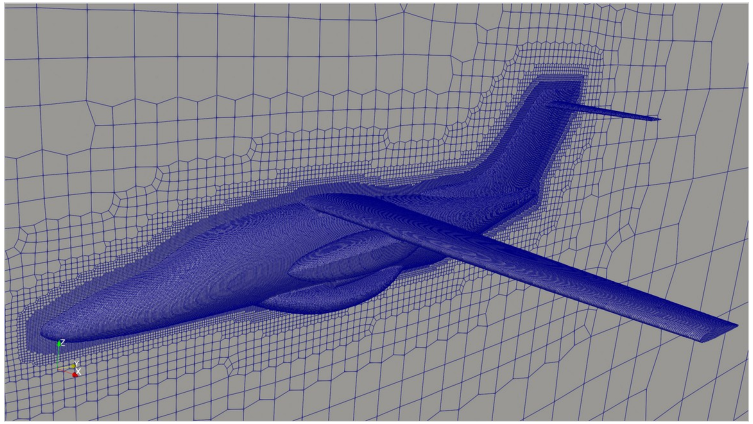
We select half of the surface of the plane and polish it well with a thickness of 100 mm.

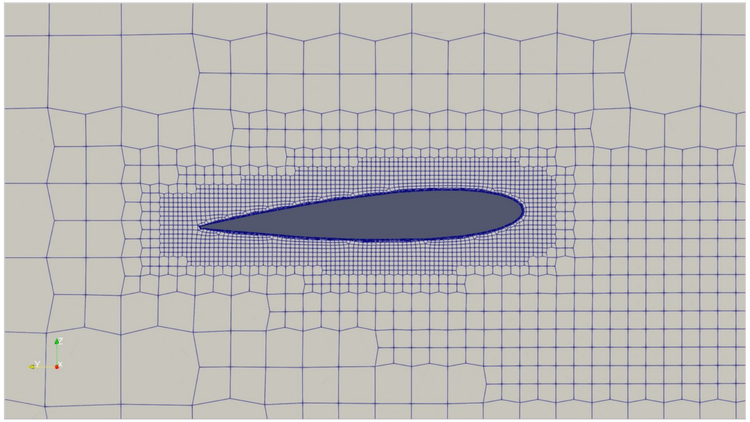


Different Meshing Methods

Method 5

Mesher	Cartesian
Base Element Size	3 m
Surface refinement	0.020
refinement thickness	100 mm
Boundary Layer number (surface)	20
Mesh time	0.40 min
Disk size	216 MB
Total number of nodes	**1 369 246**

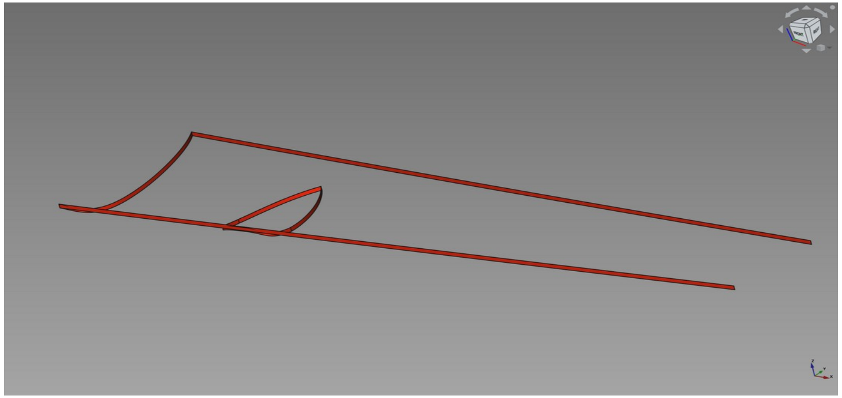


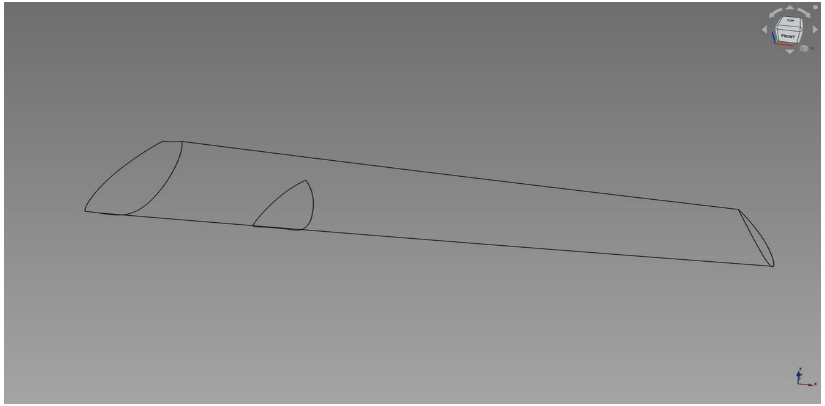


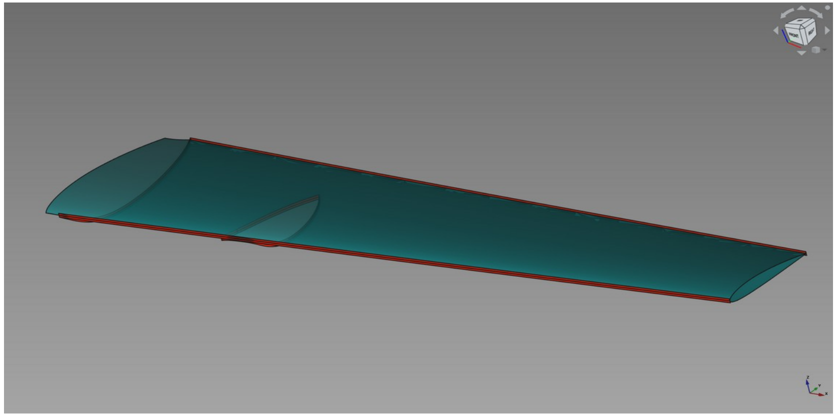
Different Meshing Methods

Method 6

We create strips around the edges of a plane with a width of 50 mm by converting the edges of a plane into wires and extruding them.



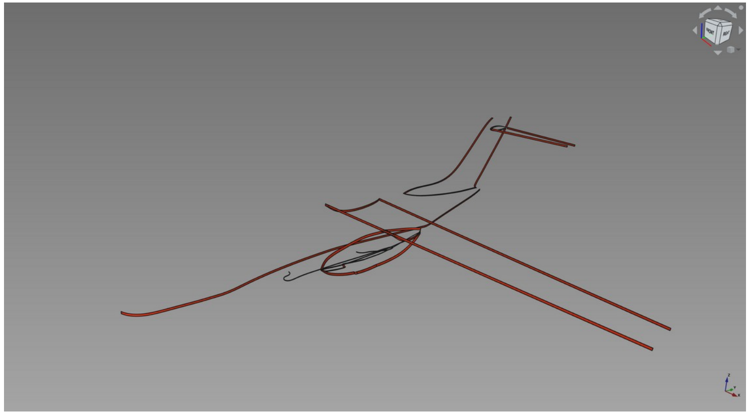


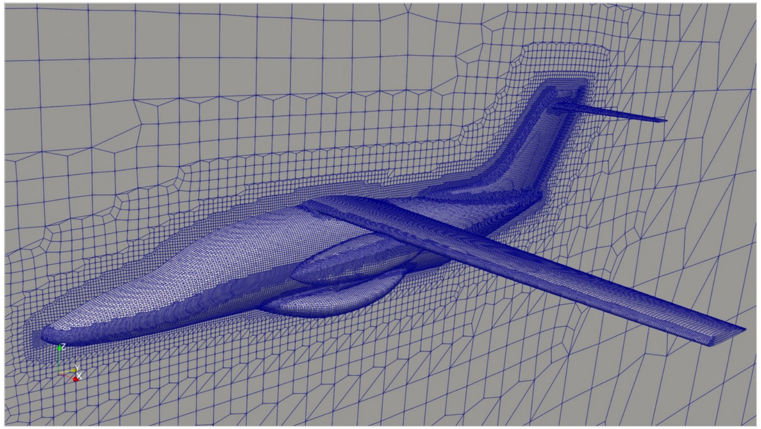


Different Meshing Methods

Method 6

Mesher		Cartesian
Base Element Size		3 m
Surface refinement		0.030
Refinement thickness		10 mm
Strips Surface refinement	All strips	0.010
	Strips wing	0.005
Boundary Layer number (surface)		20
Mesh time		1 min 49s
Disk size		410 MB
Total number of nodes		**2 409 878**

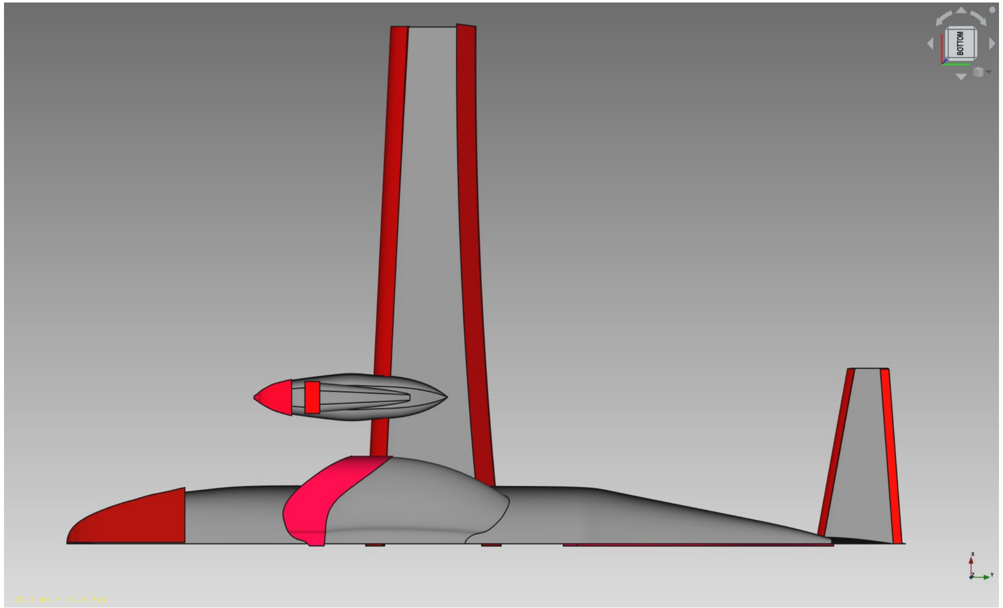


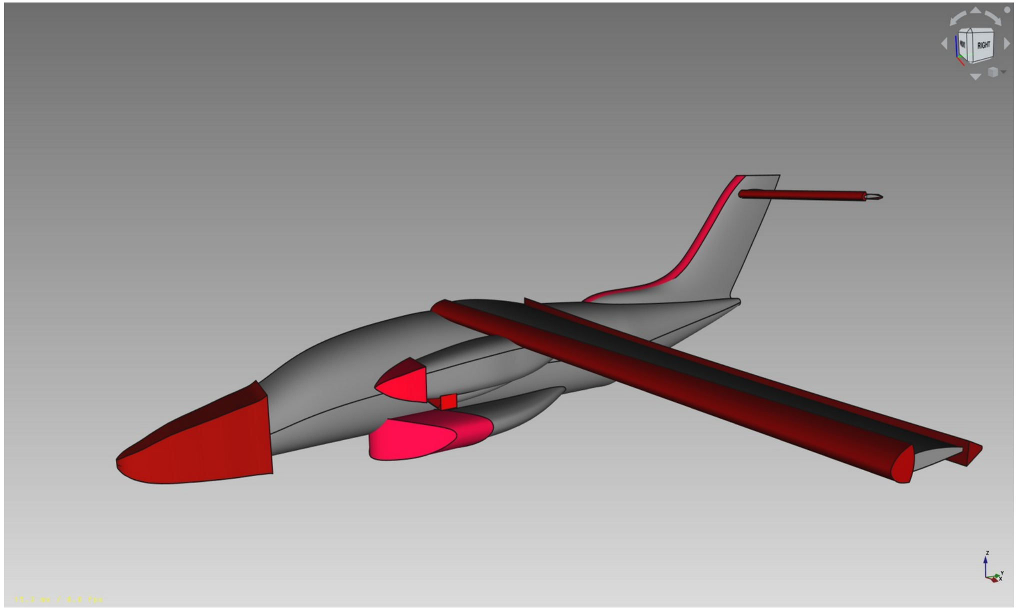


Different Meshing Methods

Method 7

We focus on the active parts of a plane by creating a volume slightly larger than the part we want to refine.

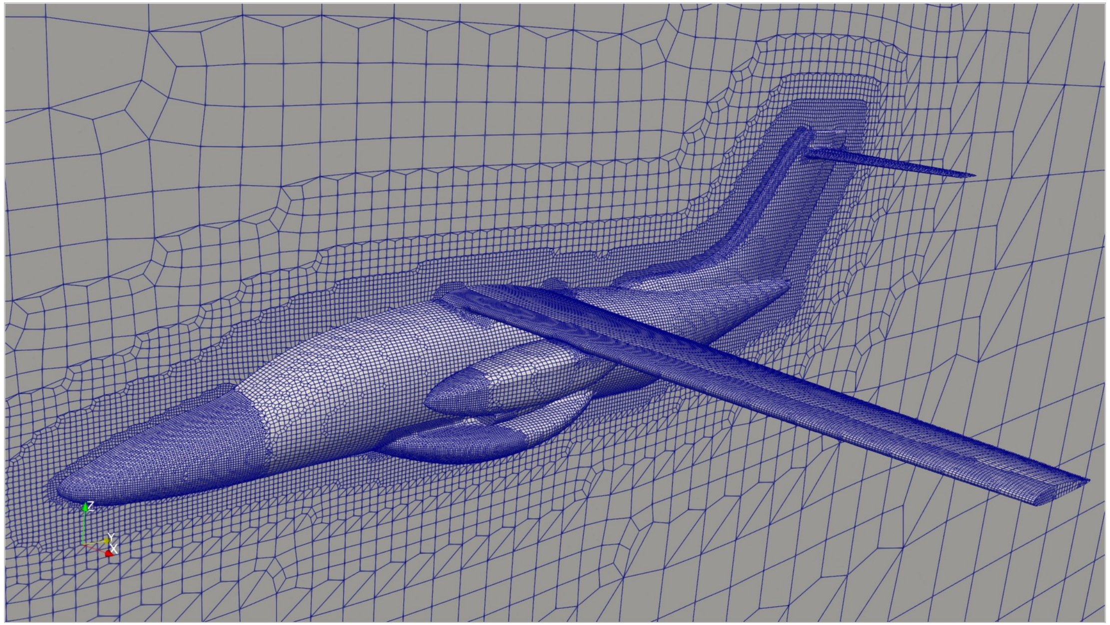




Different Meshing Methods

Method 7

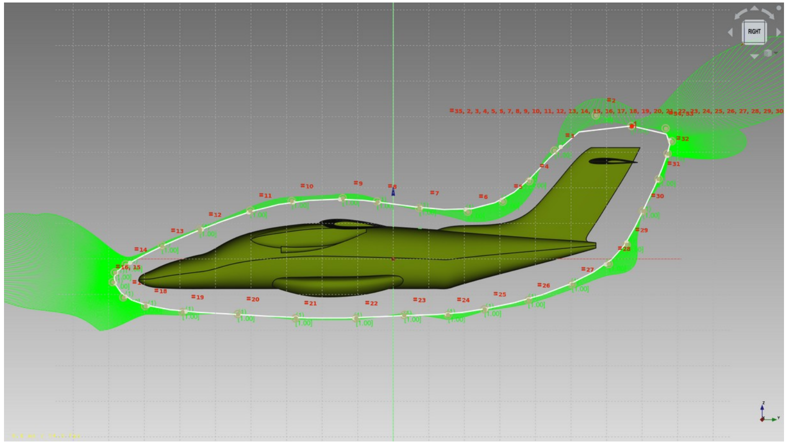
Mesher	Cartesian
Base Element Size	3 m
Surface refinement airplane	0.050
Volume refinement	0.020
Boundary Layer number (surface)	20
Mesh time [min]	5 min
Disk size	240 MB
Total number of nodes	**1 500 000**

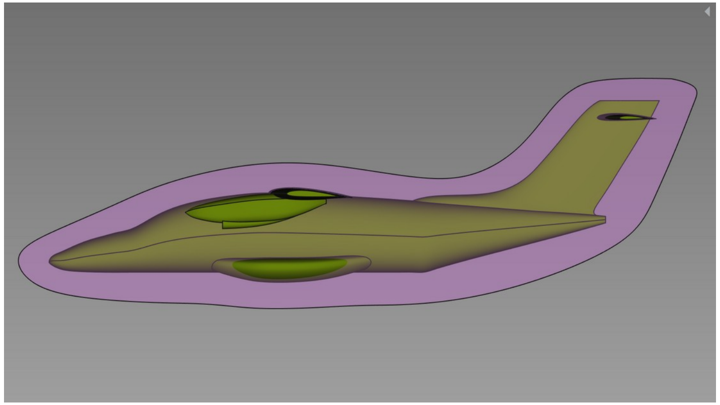


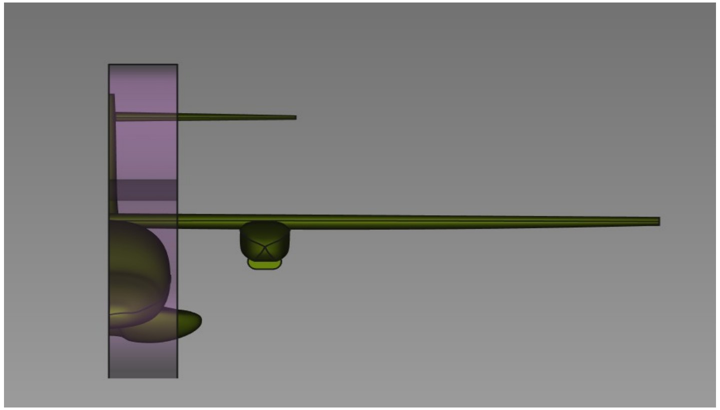
Different Meshing Methods

Method 8

We create a sketch around the body of an air plane and extrude it to get the volume around an air plane.



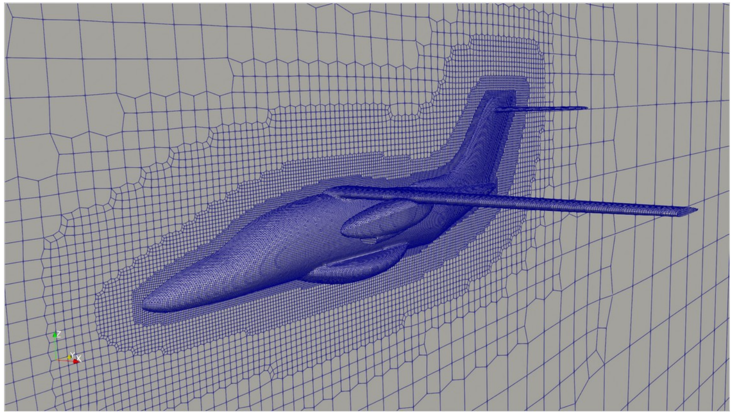


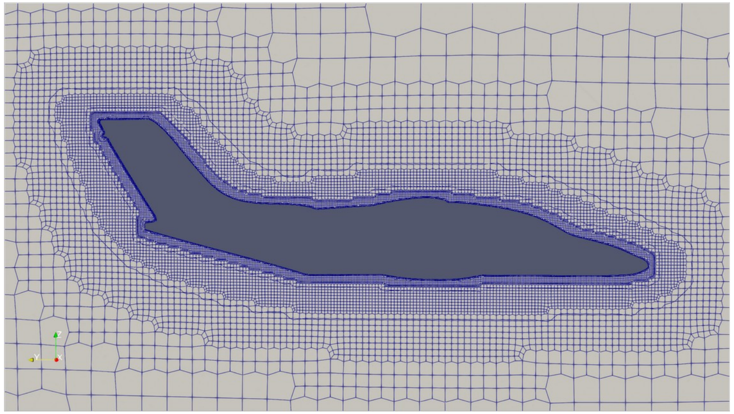


Different Meshing Methods

Method 8

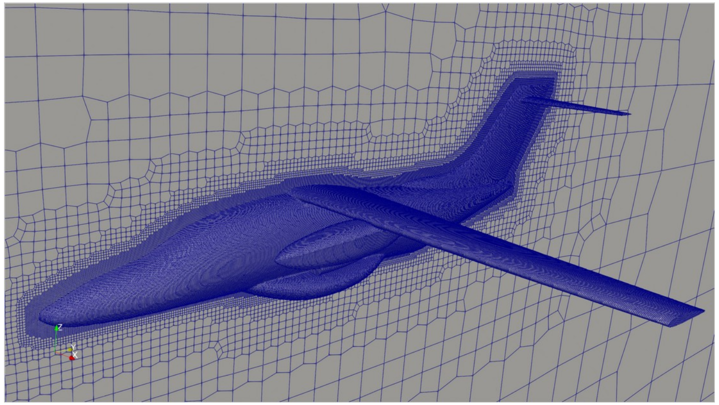
Mesher		Cartesian
Base Element Size		2.6 m
Surface	Surface refinement airplane	0.020
	Refinement thickniss airplane	10 mm
Volume	Volume refinement	0.040
	Surface refinement	0.080
Refinement thickniss form		500 mm
Boundary Layer number (surface)		14
Mesh time		0.35 min
Disk size		230 MB
Total number of nodes		**1 471 379**



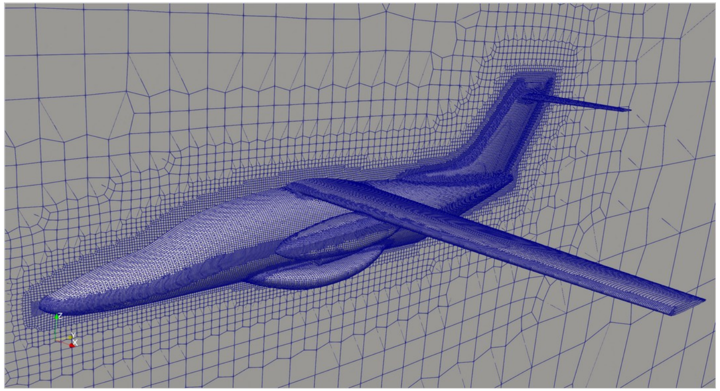


Selected Meshes

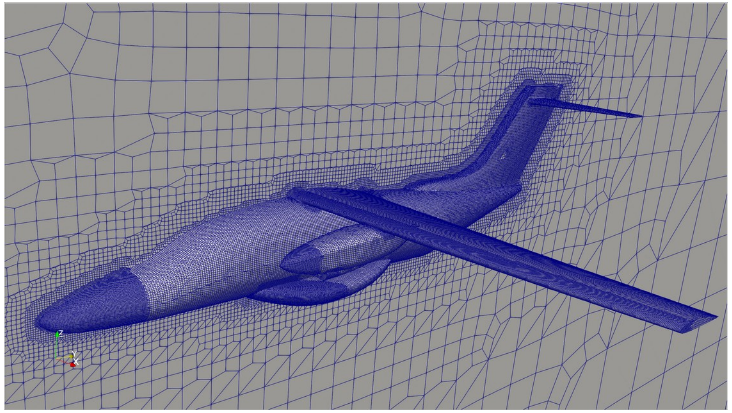
Method 5



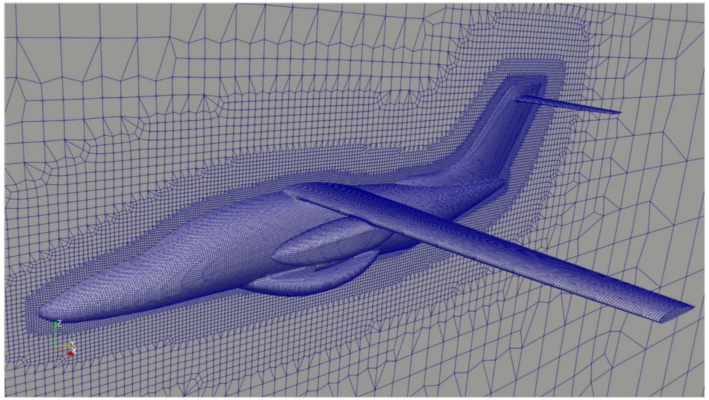
Method 6



Method 7



Method 8



Coparison of the Selected Meshes

At this stage four ways have been selected to continue with the next stages:

Method 5, Method 6, Method 7 and Method 8 are renamed to Case1, Case2, Case3 and Case4.

	Case 1	***Case 2***	***Case 3***	***Case 4***
Mesh time	40 s	1 min 49s	4 min 8s	35 s
Disk size [MB]	216	410	361	230
Total number of nodes	1 369 246	2 409 878	2 303 751	1 471 379
badCells	285	295	200	70
checkMesh	Failed	ok	Failed	Failed

Simulation Results

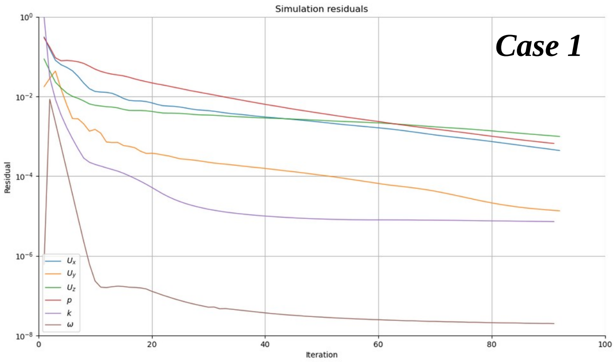
Means of Calculations

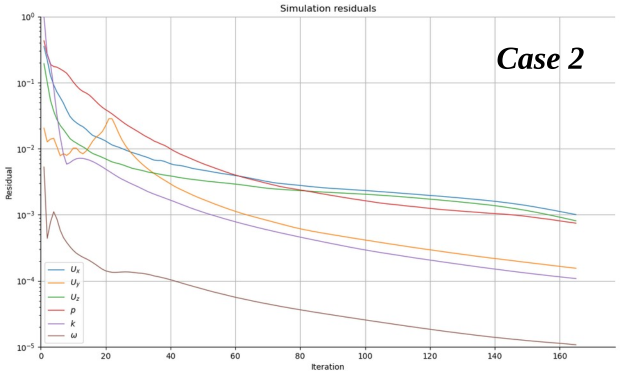
*We used a low-cost computer compared to those used in aerodynamics, We used **i5-9300H** Intel® CoreTM CPU at **2.40 GHz**, **8** processors with **4 cores** and **16 GB RAM**, Nvida GTX 1650 with 4 GB.*

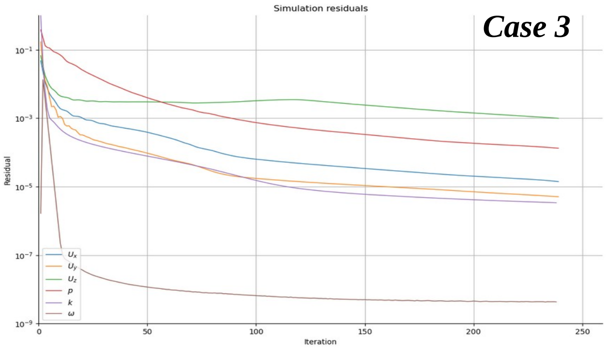
	Case 1	*Case 2*	*Case 3*	*Case 4*
Calculation Time	38 min	32 min 33 s	49 min 30 s	25 min 24 s

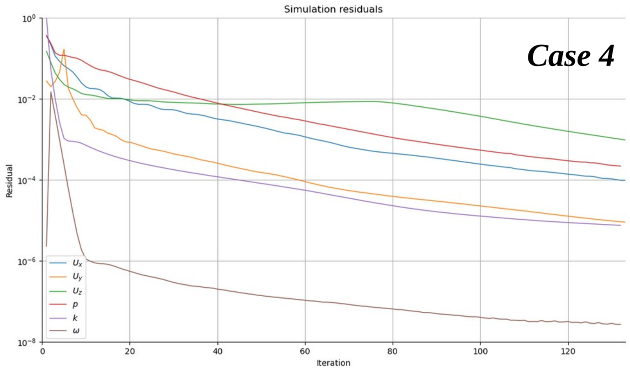
Simulation Results

Simulation Residuals



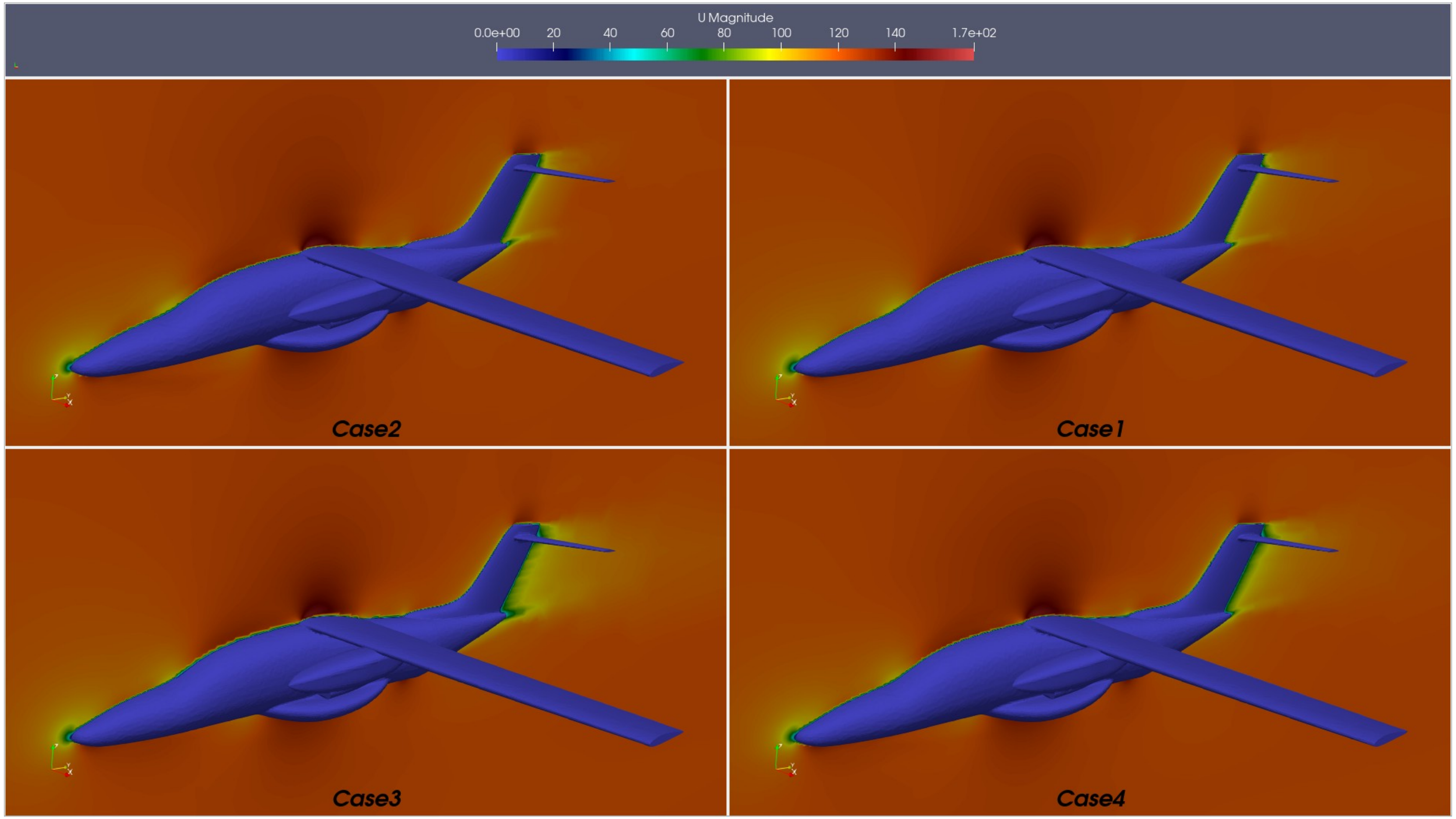






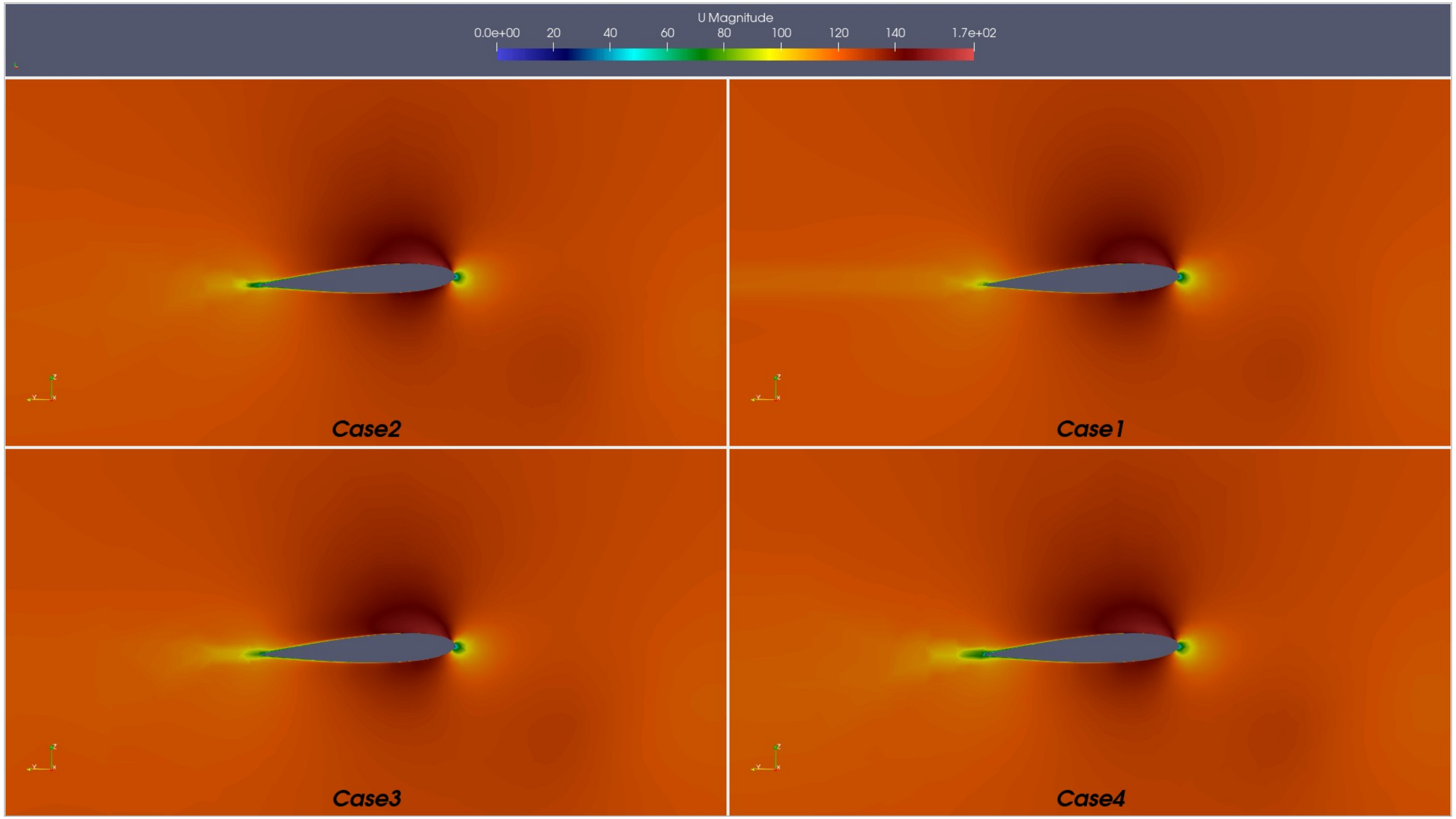
Simulation Results

Velocity distribution around the aircraft 3D view



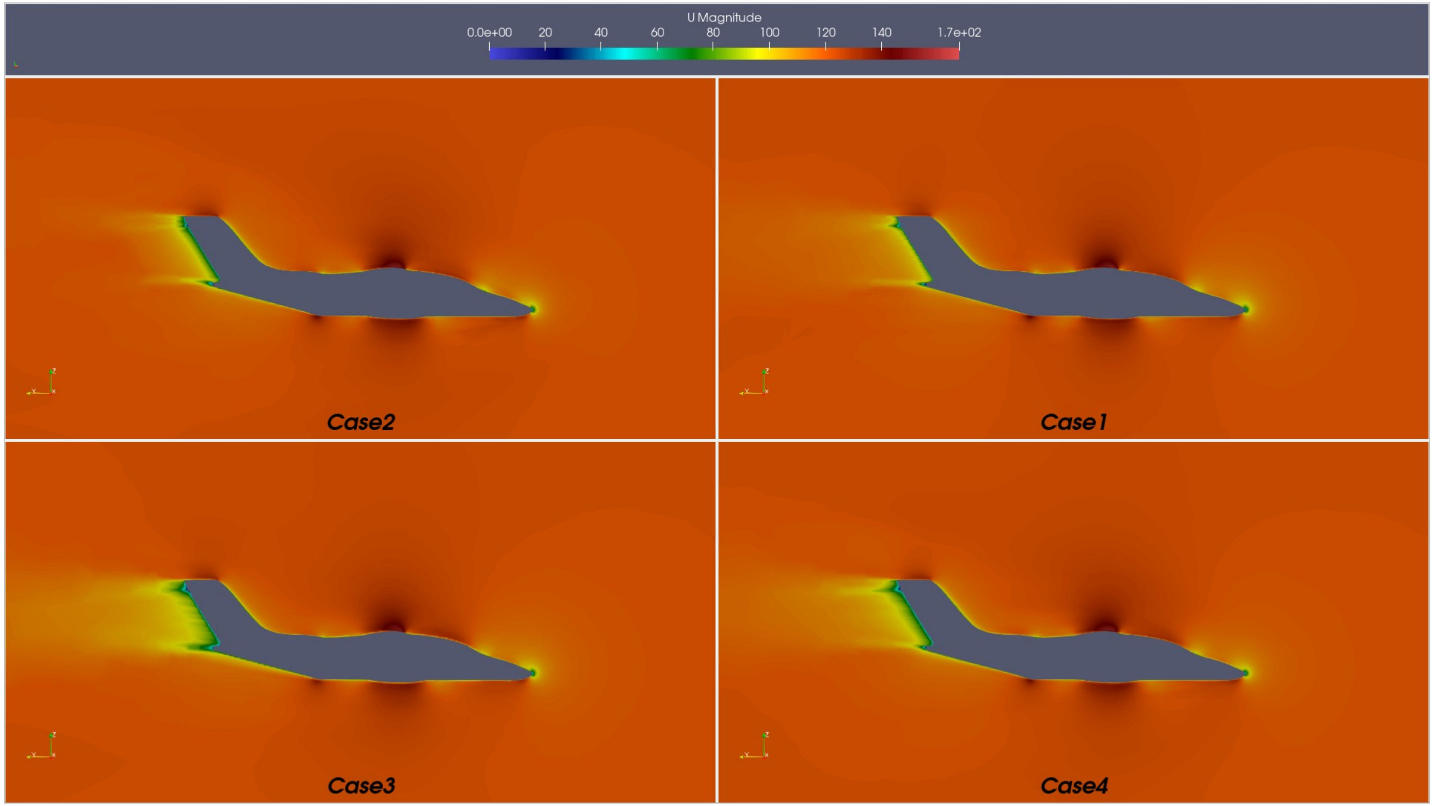
Simulation Results

Velocity distribution around the wing at X = 3 m



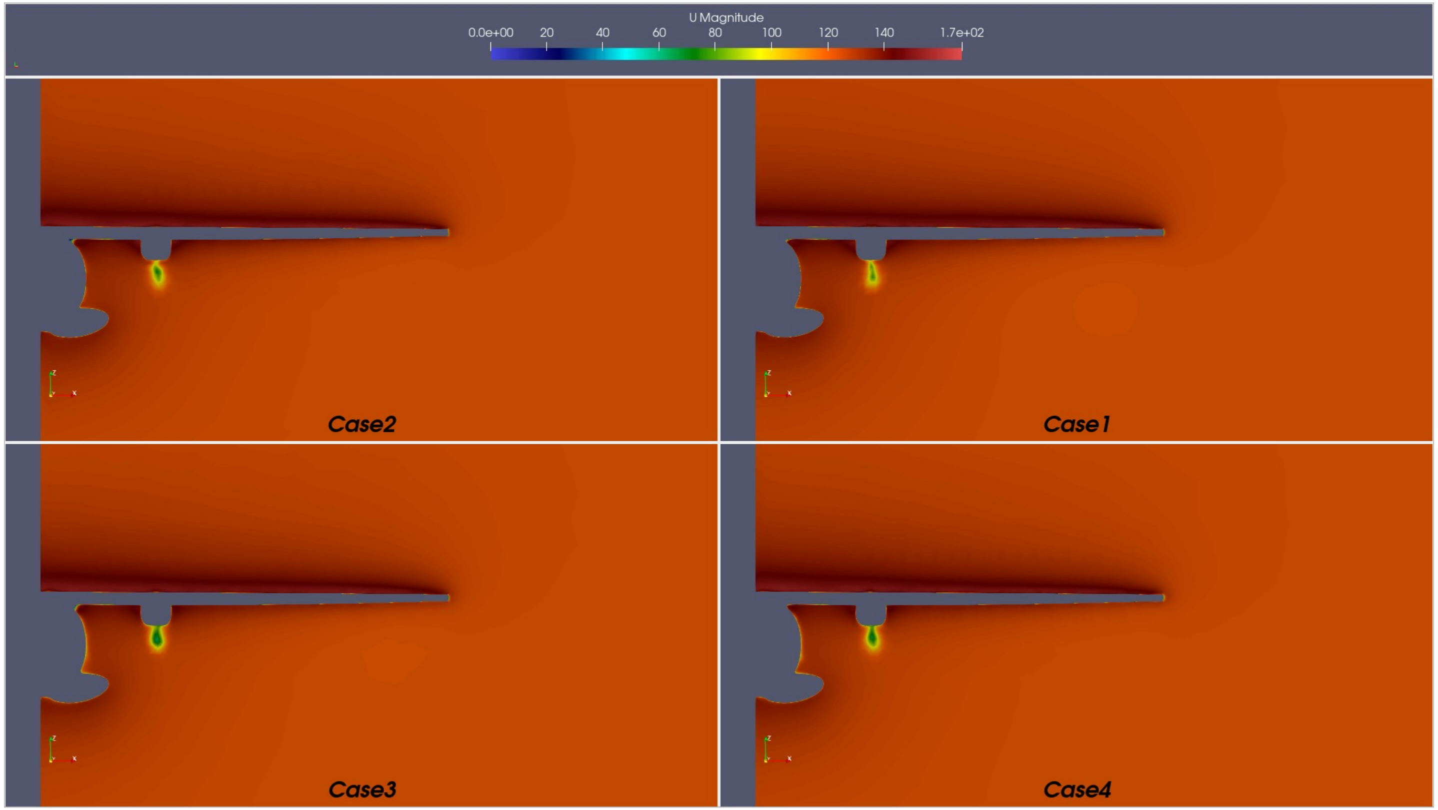
Simulation Results

Velocity distribution around the aircraft at X = 0.001 m



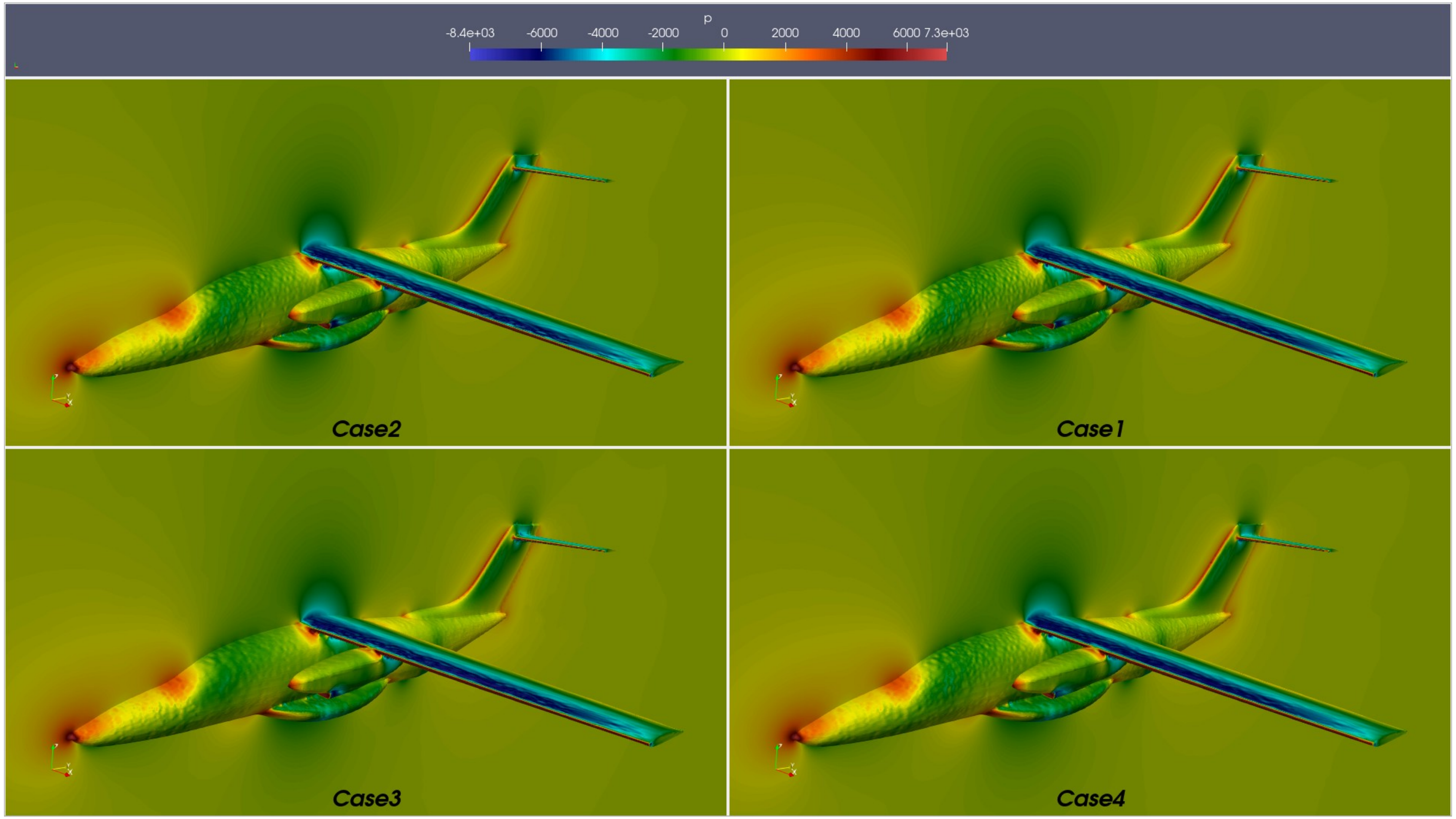
Simulation Results

Velocity distribution around the aircraft at Y = -1.5 m



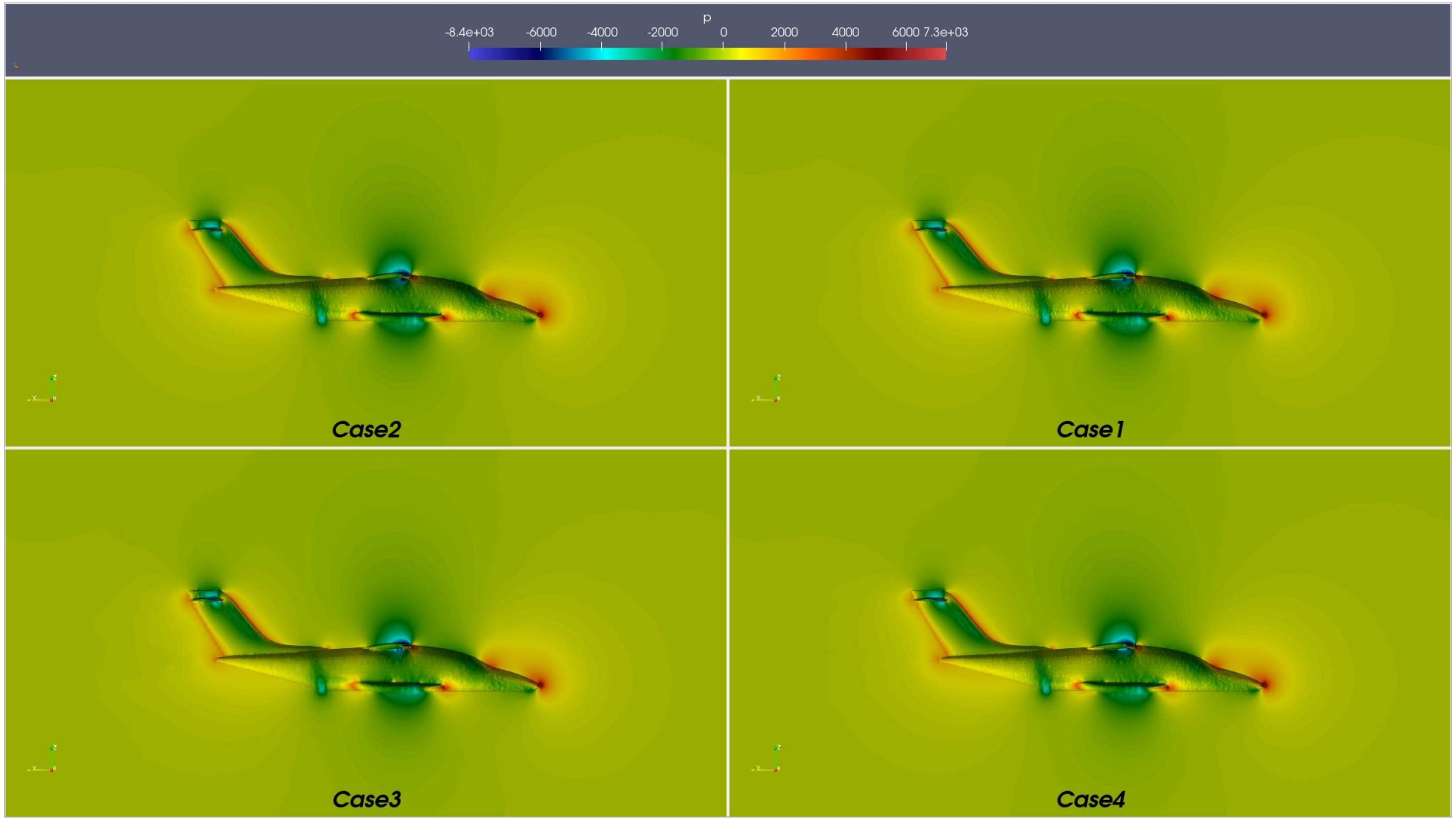
Simulation Results

Pressure distribution 3D view



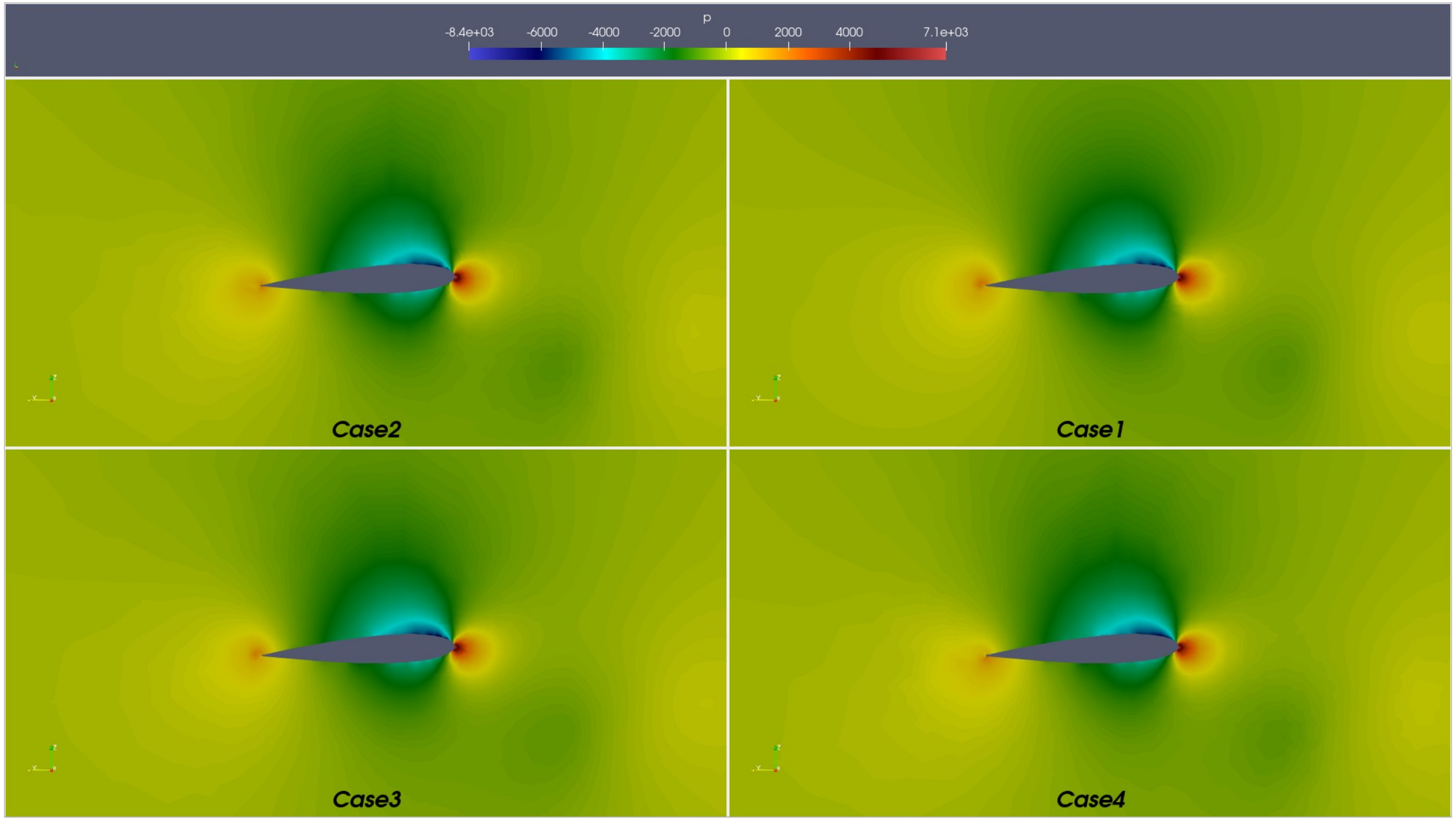
Simulation Results

Pressure distribution around the aircraft at X = 0.001 m



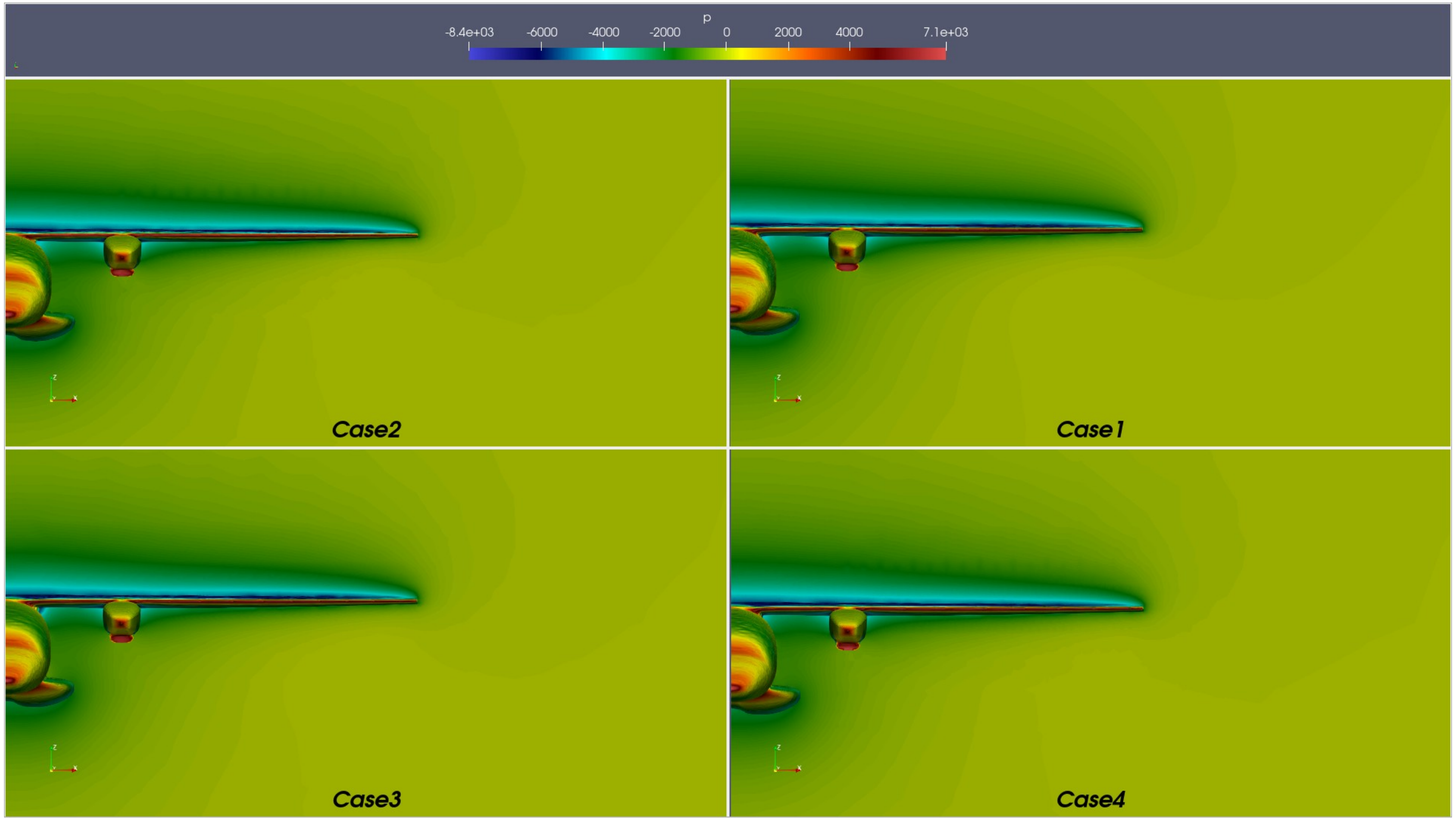
Simulation Results

Pressure distribution around the wing at X = 3 m



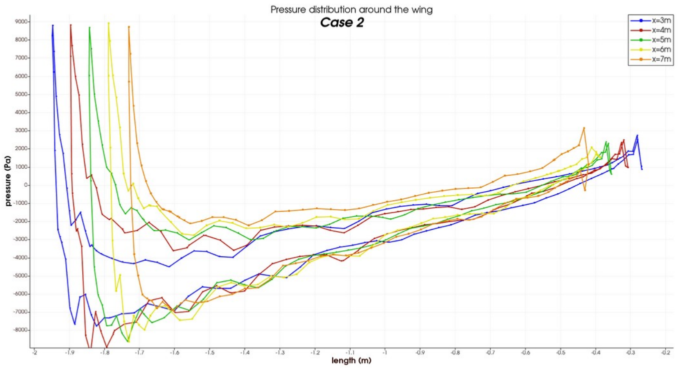
Simulation Results

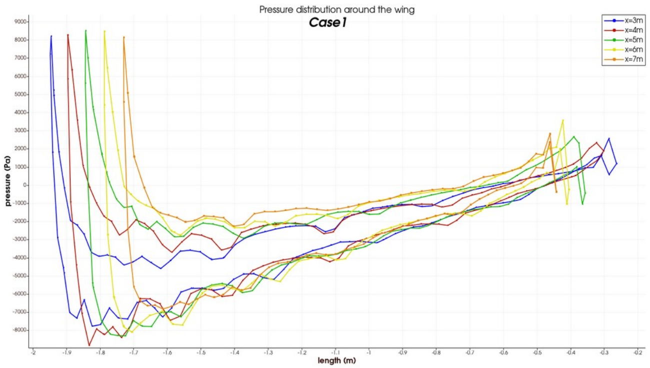
Pressure distribution around the aircraft at Y = -1.5 m

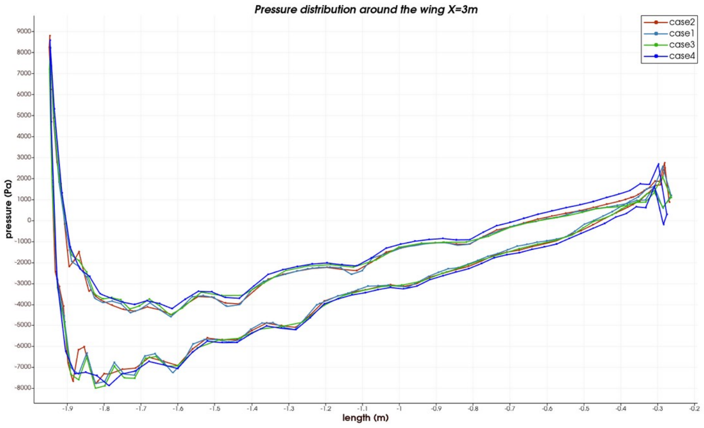


Simulation Results

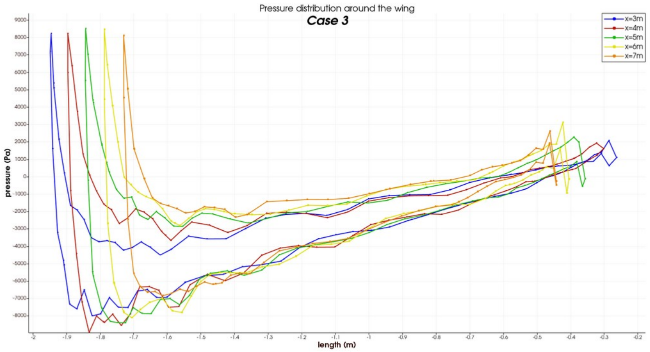
Pressure distribution at different locations : X = 3, 4, 5, 6 and 7 m .

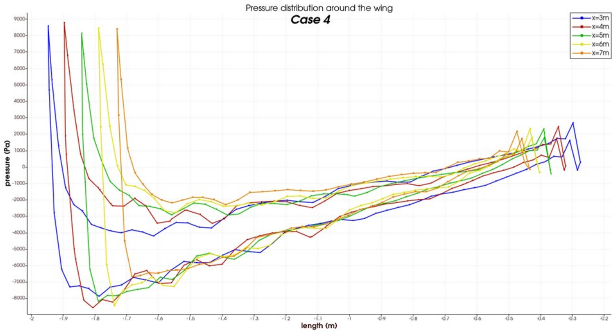






Pressure distribution for the four cases at X = 3 m.

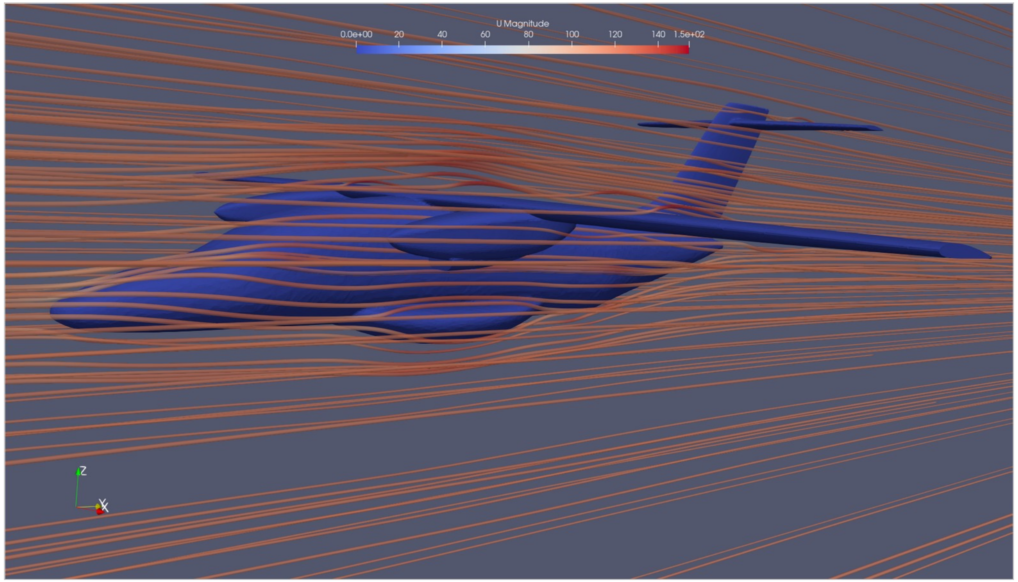




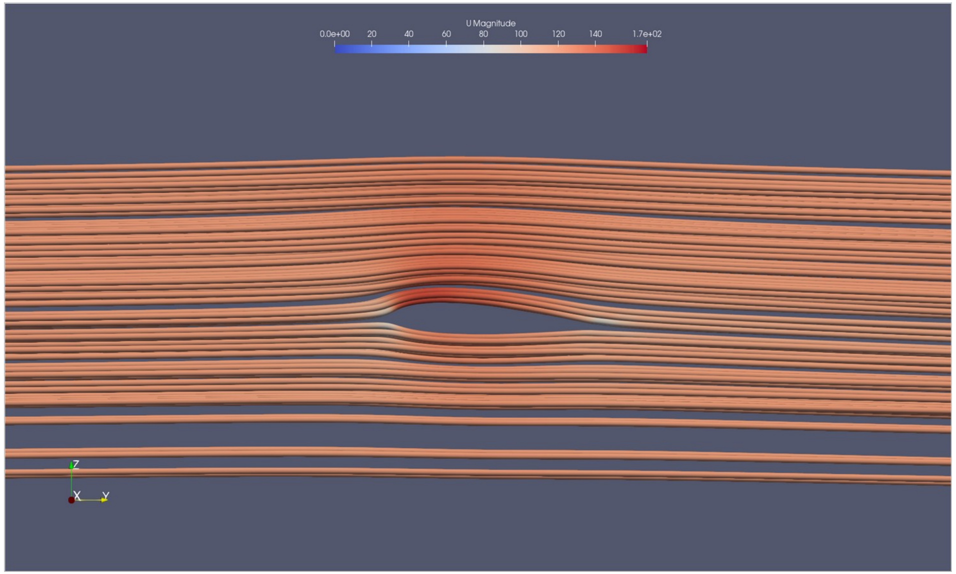
Simulation Results

Streamlines

Illustrate the streamlines around the EV-55 aircraft (x=0.27; y=-23.5; z=0.75).



The streamlines around the wing are shown along the x axis (x=8.1; y=-23.5; z=0.95).



Simulation Results

Aerodynamic forces:

The results of calculating the Lift and Drag forces and their treatment are shown in the following table:

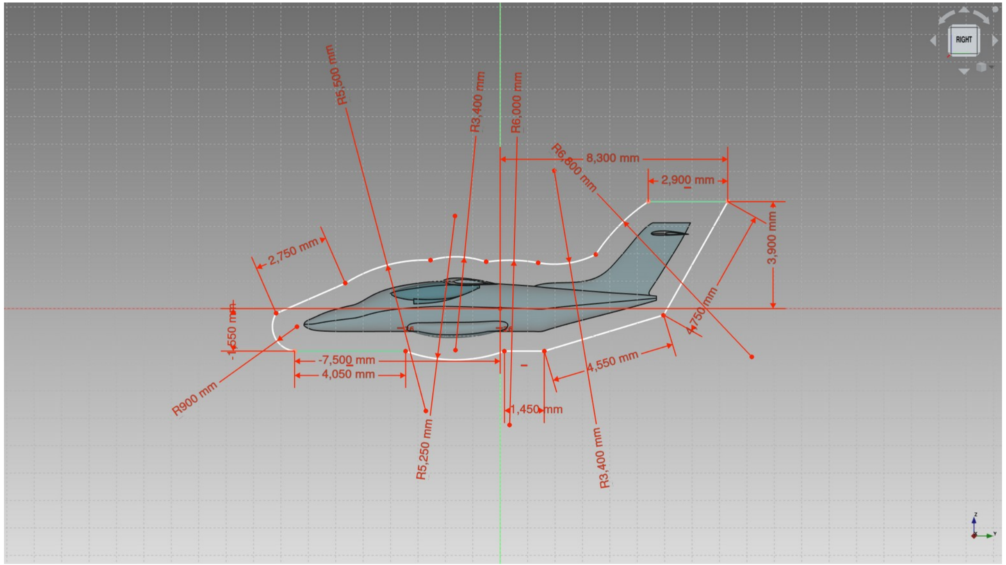
	Area [m²]	*Lift [N]*	*Drag [N]*	C_L	C_D
Case1	141.096	59378.5	6603.24	0.047	0.0053
Case2	141.504	58480.3	5922.82	0.046	0.0047
Case3	140.326	62206.2	7206.19	0.050	0.0058
Case4	140.604	60307.6	8344.68	0.048	0.0067

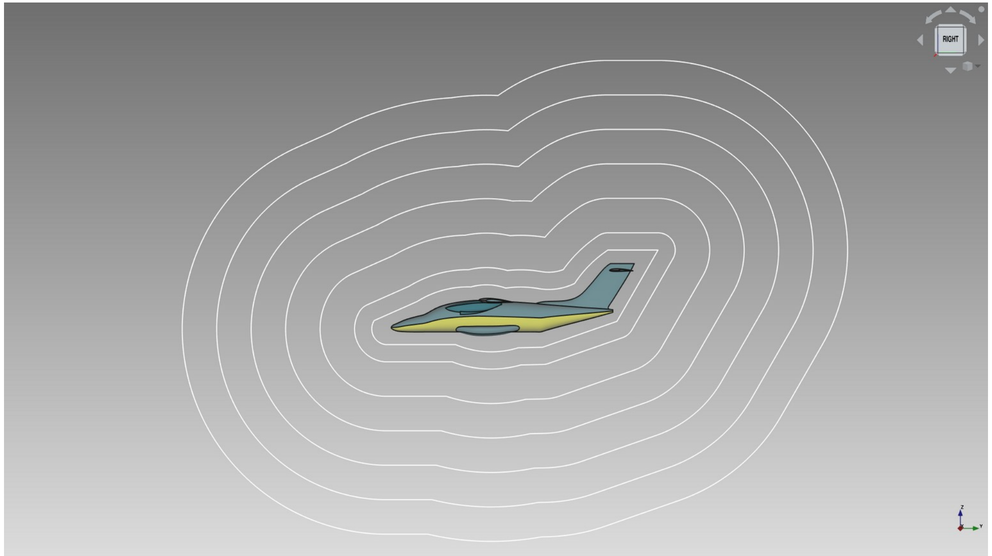
Conclusion

During this experiment, we understood the difficulty and importance of numerical simulation stages and their significant role in technological advancement. The aircraft design phase is challenging, complex, and crucial. However, the meshing phase cannot be neglected, as it plays a vital role in the simulation process. The most challenging stage we encountered was adapting the mesh and attempting to develop a method to improve it to suit our complex engineering and limited computer resources. It took us a considerable amount of time and experimentation. A good mesh provides better and more realistic results within a reasonable analysis time.

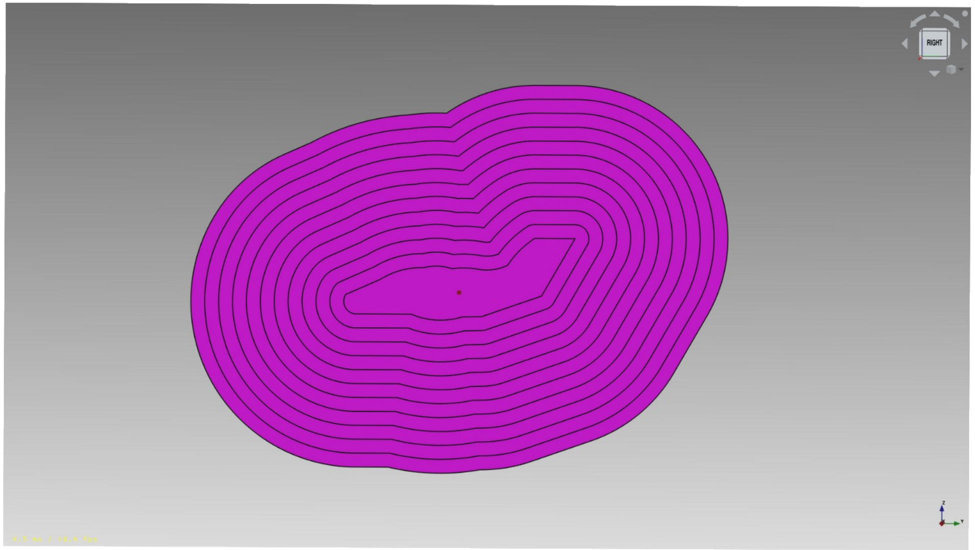
Annexes

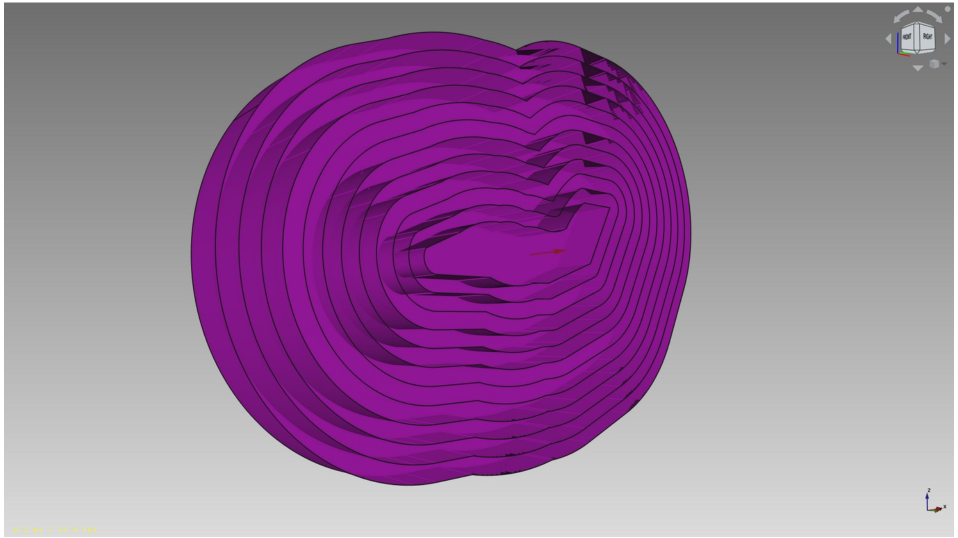
offset





Annexes





Annexes