

21KT007069

4th AIAA CFD High-Lift Prediction Workshop

KHI's Grid Information

Unstructured Grid: "*Cflow*"

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Aerospace Business Division
Aerospace Systems Company
Kawasaki Heavy Industries, Ltd. (KHI)**

April 22, 2021

 **Kawasaki**
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General Information on Grid Generator

- KHI's Grid Generator "**Cflow**"
- Available Data Format
- Contact Information

Information on Generated CRM-HL Grid

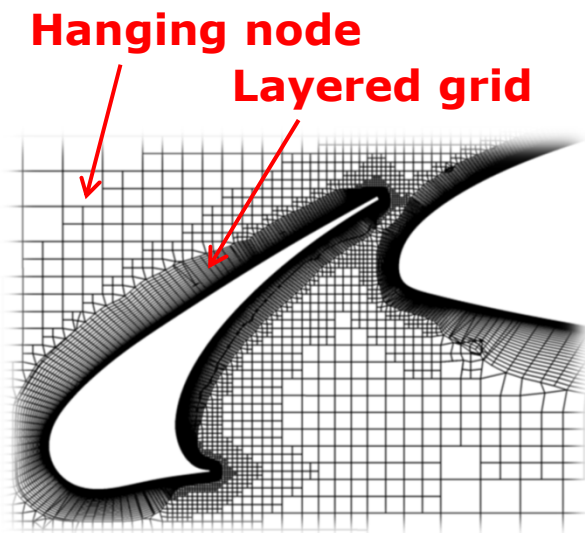
- Grid Information
- Geometry Modifications
- Comparisons with other grids (Pointwise, ANSA)

Cflow (in-house CFD tool)

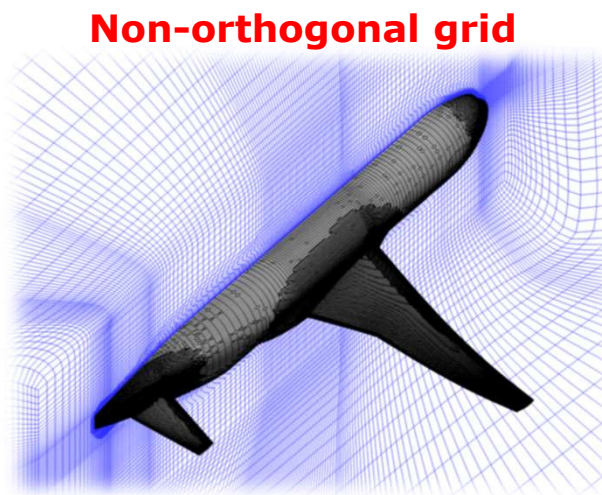
- **KHI** originally developed "**Cflow**" (not our product)

$$\text{Cflow} = \boxed{\text{Grid Generator}} + \boxed{\text{Flow Solver}}$$

- Cflow has the function of an **automatic grid generator** using an **Adaptive Mesh Refinement (AMR)** method
- Sample grid photos used in other workshops:



HLPW

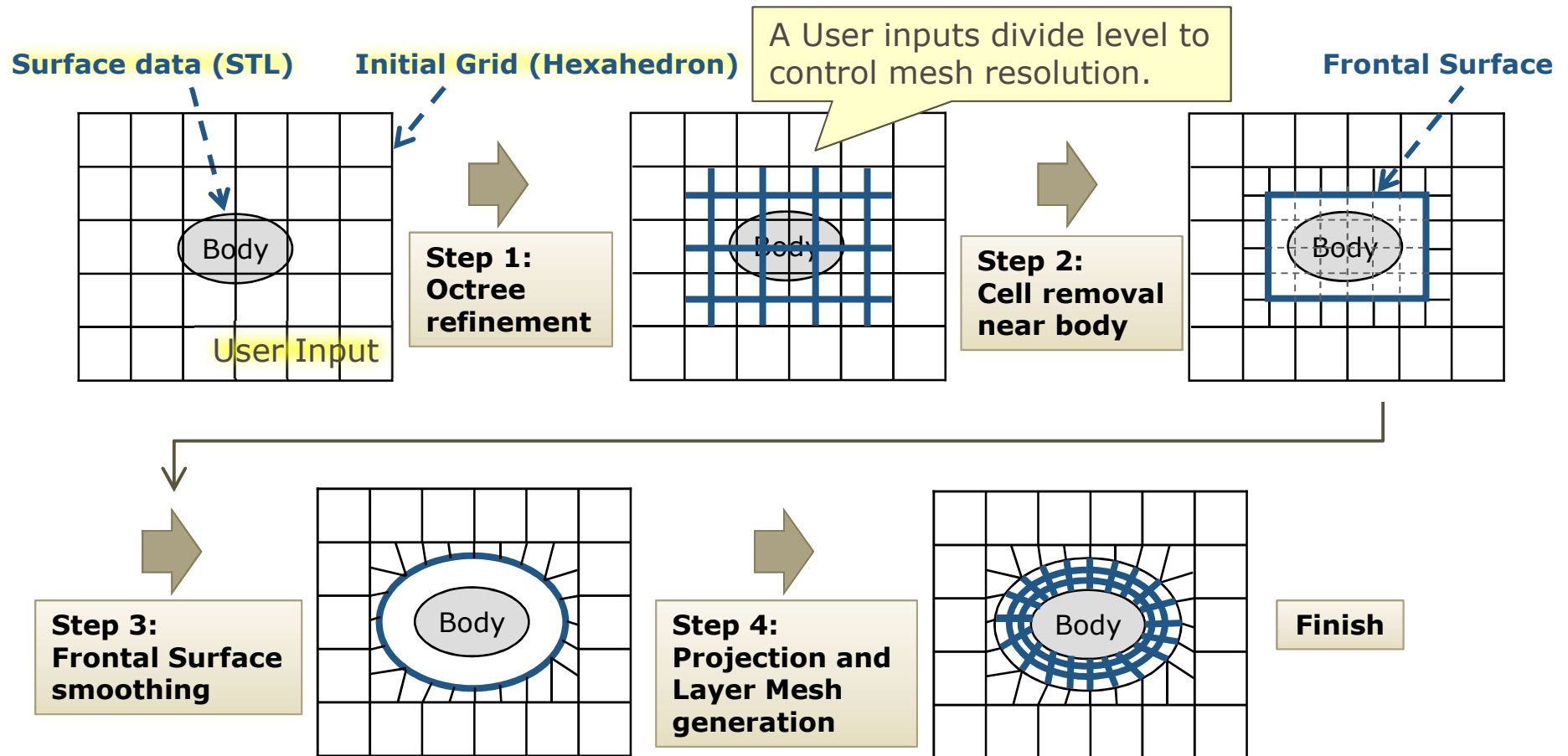


DPW



BANC

Grid Generation Procedure in *Cflow*



Cflow automatically generates body-fitted layered grids on no-slip walls to resolve boundary layers and hexahedral grids in the other regions. Surface grid is also automatically generated after the projection in Step 4.

Available Data Format

Cflow can provide the following data formats:

- **CGNS (for visualization with “Paraview”)**
- **PLT (for visualization with “Tecplot”)**
- **UNS (for visualization with “Fieldview”)**

* Cflow is not our product; other formats are not supported.

* Cflow grid has hanging nodes; other solvers may not be able to handle it.

* The main objective of sharing our grid is to allow other participants to see its details and use it as a reference when creating their own grid. We would be grateful if you could provide useful feedback for improving our grid and our grid generator.

Contact Information

- Yosuke Ueno (ueno_yosuke@khi.co.jp)
- Hidemasa Yasuda (yasuda_hidemasa@khi.co.jp)

Latest Reference Papers on **Cflow** details

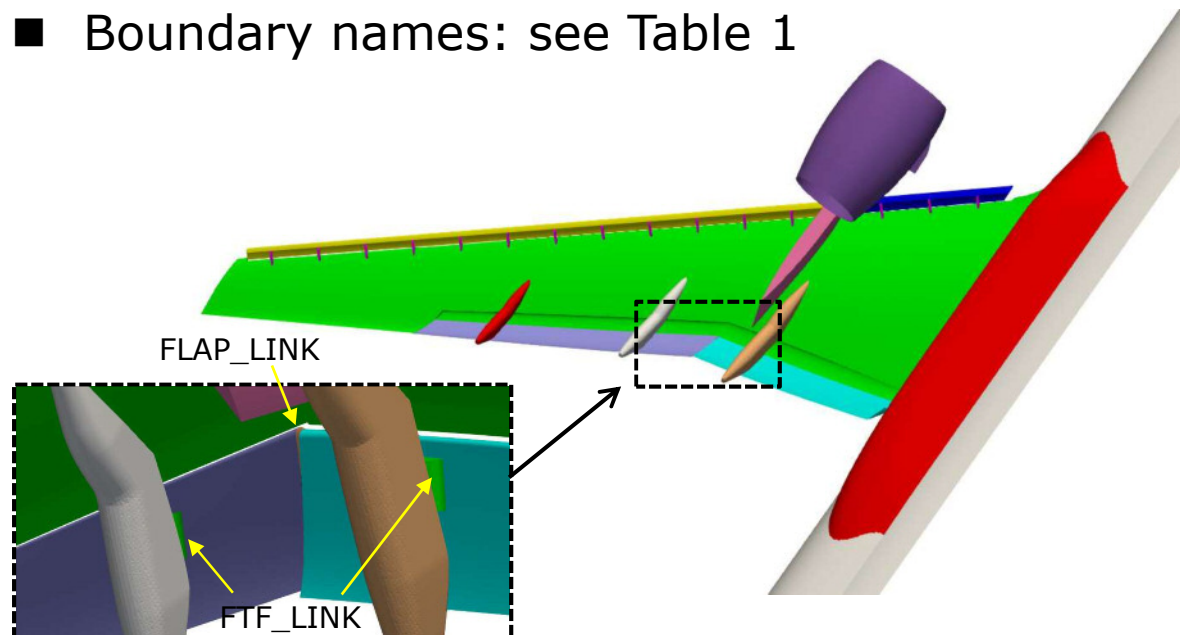
1. Ueno, Y. and Ochi, A., "**Airframe Noise Prediction Using Navier-Stokes Code with Cartesian and Boundary-fitted Layer Meshes**," 25th AIAA/CEAS Aeroacoustics Conference, (AIAA 2019-2553). <https://doi.org/10.2514/6.2019-2553>
2. Yasushi Ito, Mitsuhiro Murayama, Atsushi Hashimoto, Takashi Ishida, Kazuomi Yamamoto, Takashi Aoyama, Kentaro Tanaka, Kenji Hayashi, Keiji Ueshima, Taku Nagata, Yosuke Ueno and Akio Ochi, "**TAS Code, FaSTAR and Cflow Results for the Sixth Drag Prediction Workshop**," *Journal of Aircraft*, Vol. 55, No. 4, pp. 1433-1457, 2018. <https://doi.org/10.2514/1.C034421>
3. Yasushi Ito, Mitsuhiro Murayama, Yuzuru Yokokawa, Kazuomi Yamamoto, Kentaro Tanaka, Tohru Hirai, Hidemasa Yasuda, Atsushi Tajima and Akio Ochi, "**JAXA's and KHI's Contribution to the Third High Lift Prediction Workshop**," *Journal of Aircraft*, Vol. 56, No. 3, pp. 1080-1098, 2019. <https://doi.org/10.2514/1.C035131>

Generated CRM-HL Grid Information

- Configuration: **nominal flap deflection (40/37)** only (as of Apr. 22nd)
- Target Level: **C** (though cells on trailing edges are smaller)
- Scale, unit: **Full-scale, inch**
- $Y^+ \sim 1$ (minimum cell size=0.00106 inch)
- Total number of cells: **365,745,692**
- Total number of nodes: **367,946,331**
- Total number of surface cells: **9,573,151**
- Boundary names: see Table 1

Table 1. Boundary names / cells

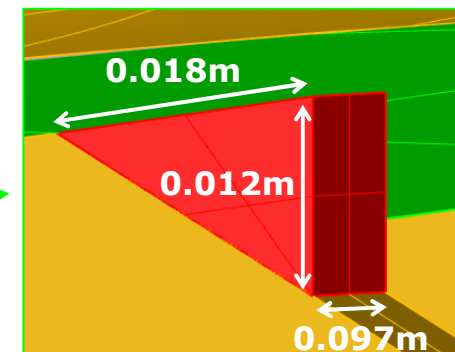
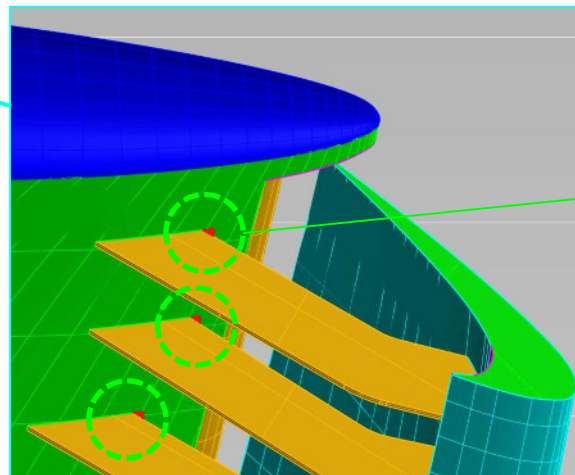
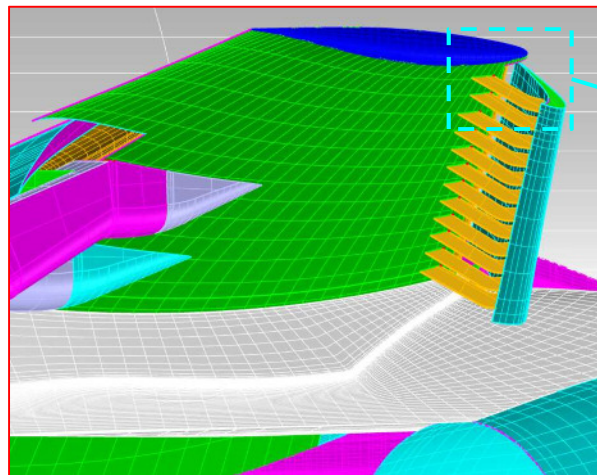
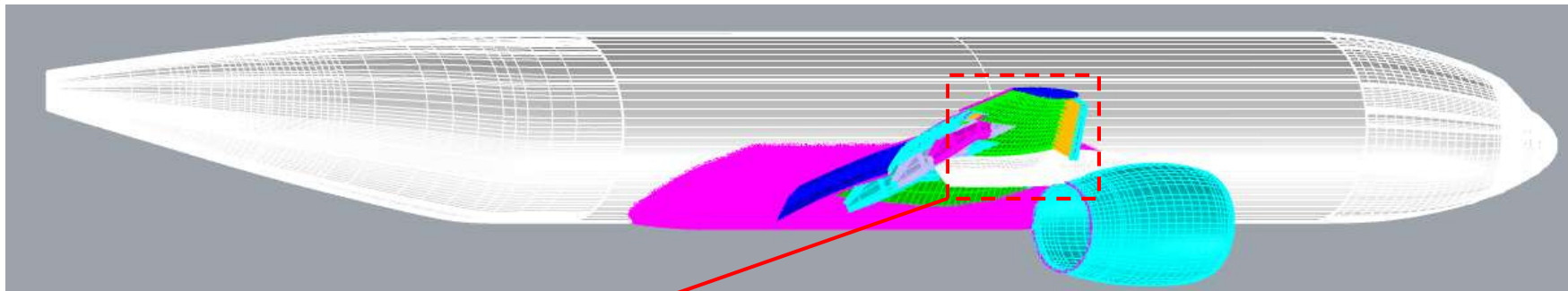
_Free (Farfield)	62,208
_Symmetry (Y=0)	244,211
BODY	185,628
FAIRING	40,695
WING	1,921,277
SLAT_INNER	969,157
SLAT_OUTER	3,060,019
SLAT_LINK (Bracket)	262,186
FLAP_INNER	845,236
FLAP_OUTER	1,359,107
FLAP_LINK	4,360
PYLON	48,998
NACELLE	393,850
FTF_IN	59,300
FTF_MID	37,264
FTF_OUT	43,369
FTF_LINK	36,286



Geometry Modifications

Slat bracket sharp region:

We add **triangular blocks** (shown in red) to fill small gaps.

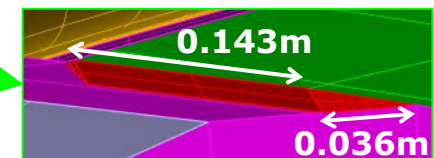
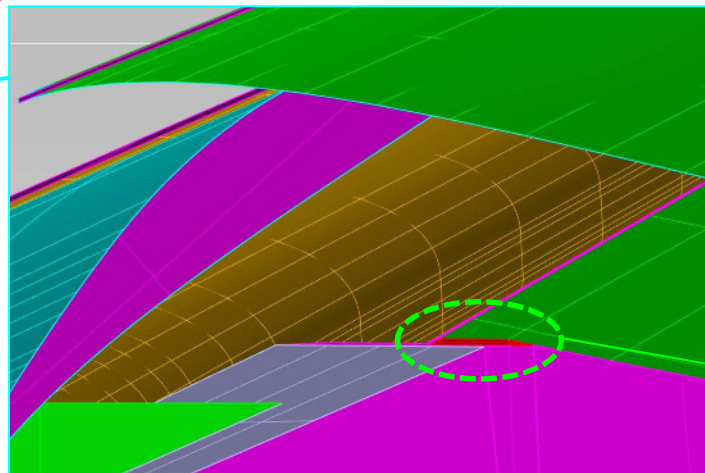
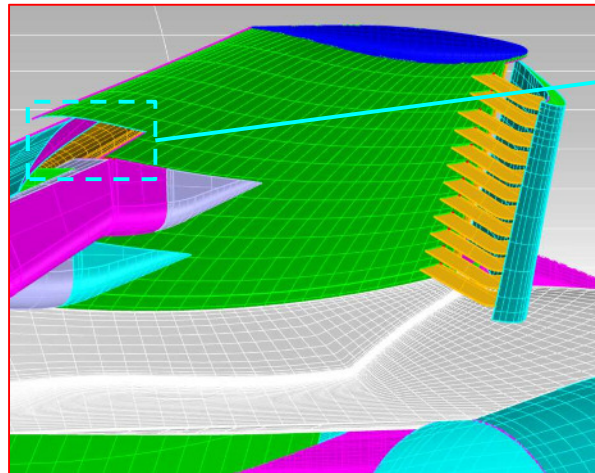
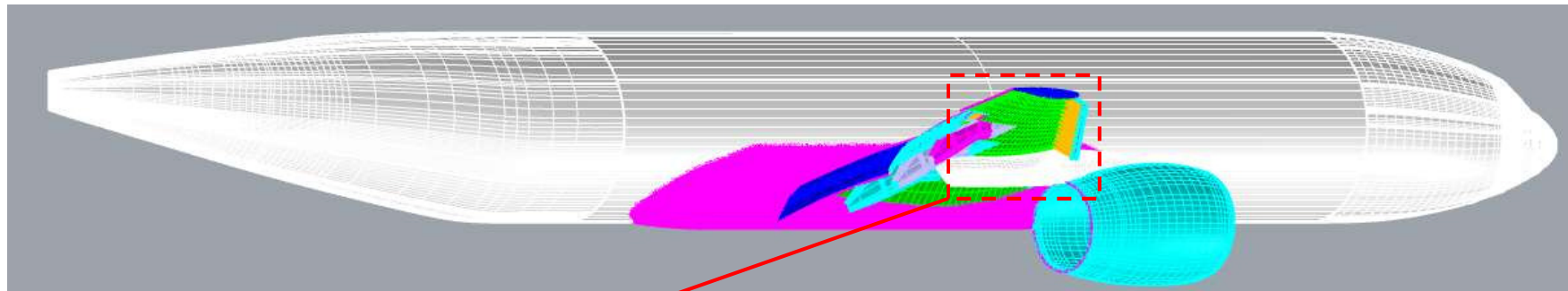


Triangular block

Geometry Modifications

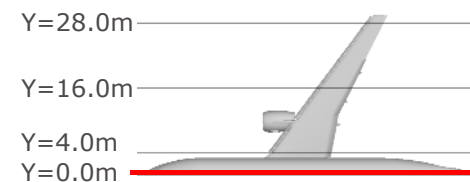
FTF sharp region:

We add **triangular blocks** (shown in red) to fill small gaps.

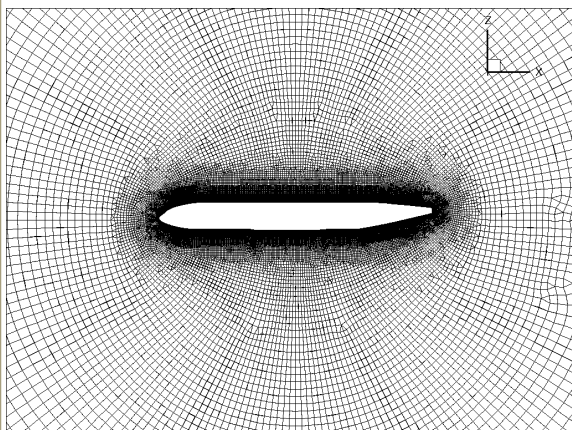


Triangular block

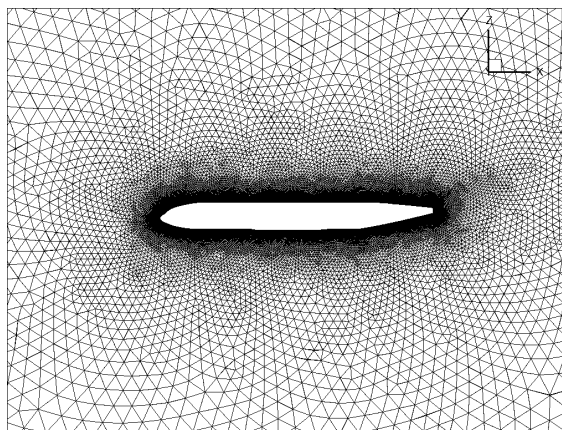
Comparisons with other grids



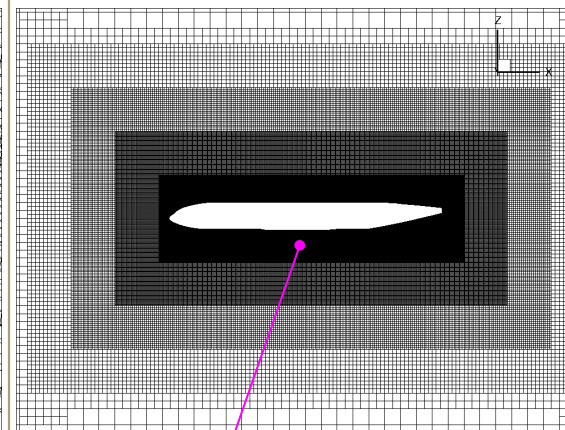
Pointwise
(1.3.C, 142M cells)



ANSA
(101.C, 217M cells)

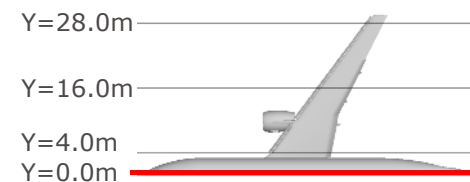


Cflow
(366M cells)

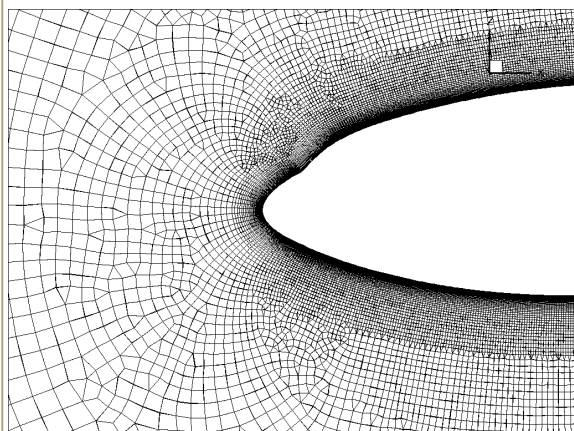


Cell size: 114 mm
(=4.5 inch)

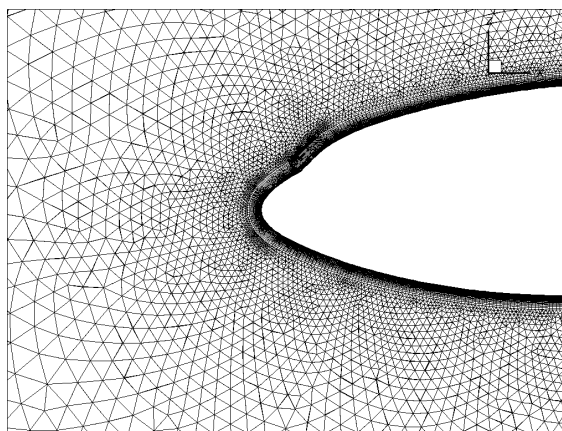
Comparisons with other grids



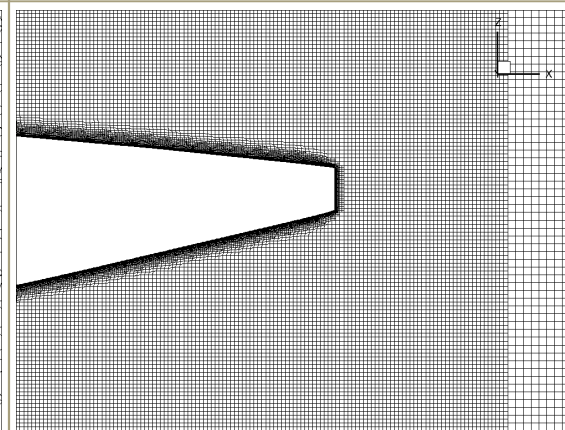
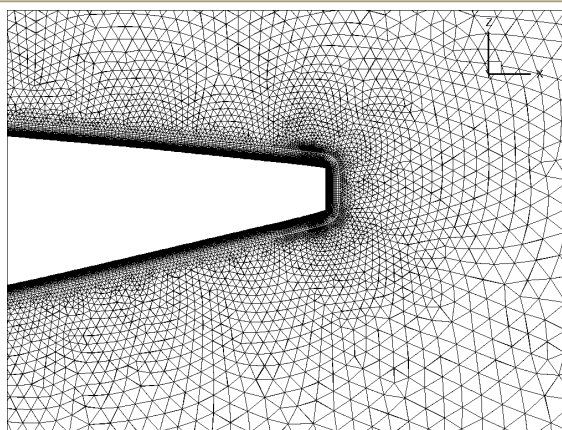
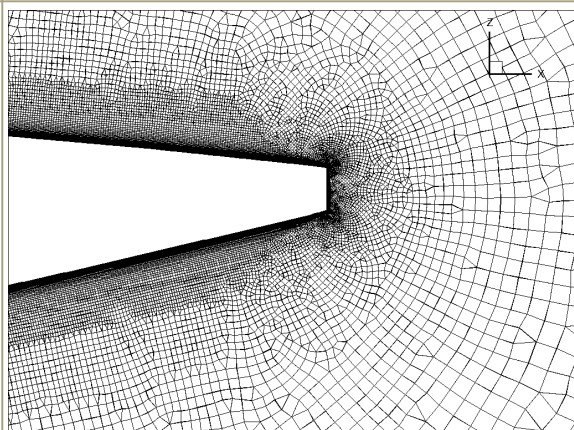
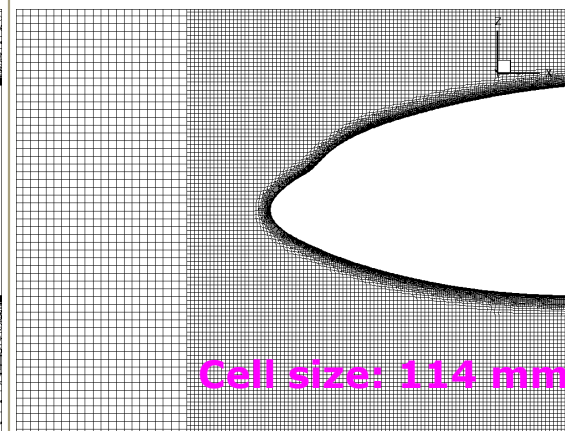
Pointwise
(1.3.C, 142M cells)



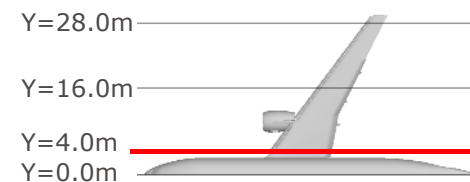
ANSA
(101.C, 217M cells)



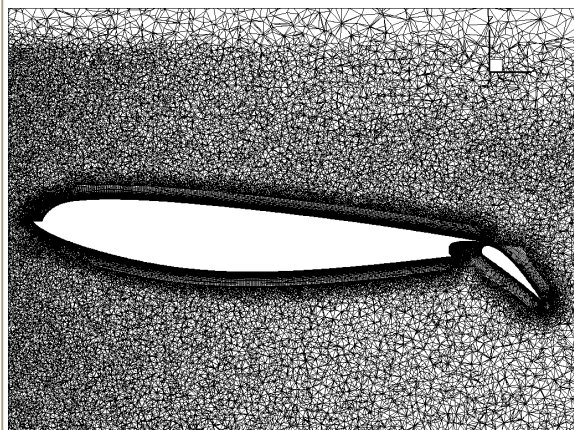
Cflow
(366M cells)



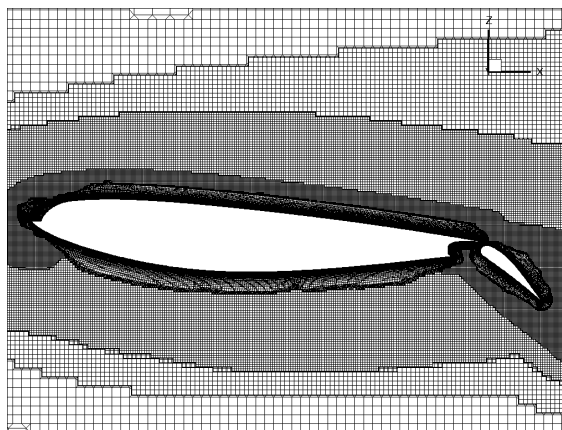
Comparisons with other grids



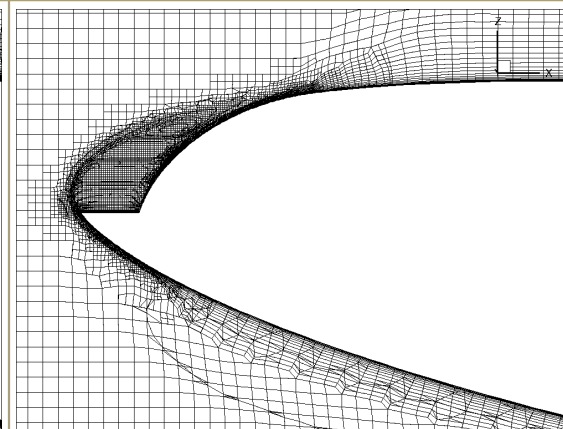
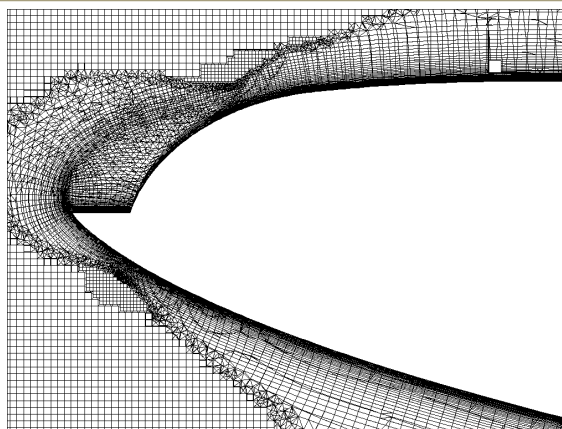
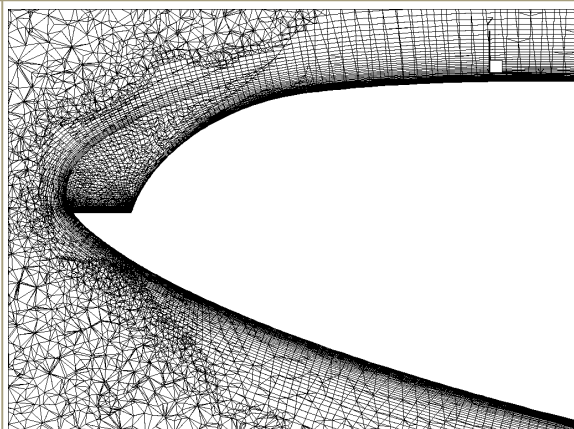
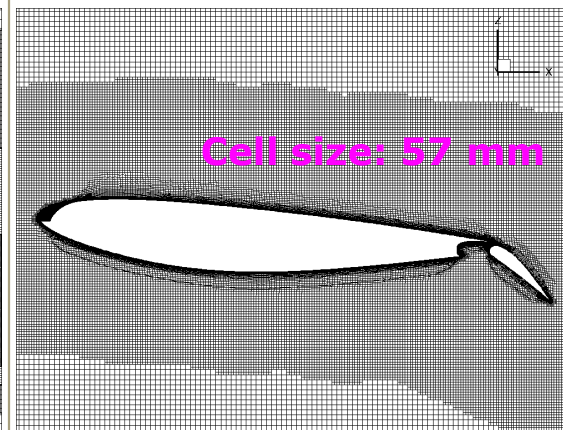
Pointwise
(1.3.C, 142M cells)



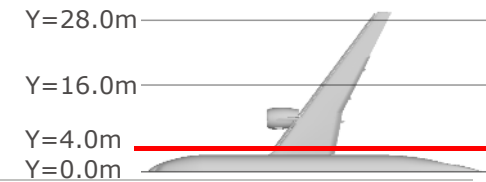
ANSA
(101.C, 217M cells)



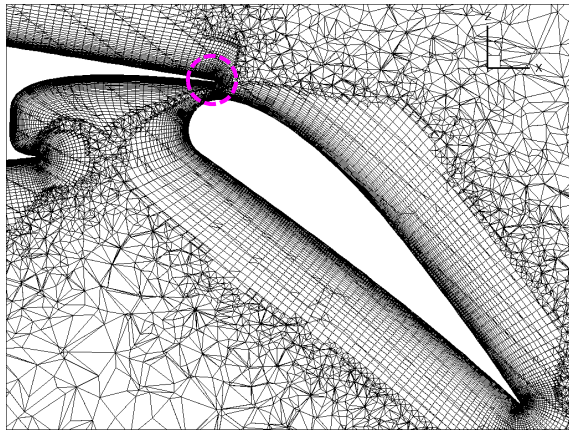
Cflow
(366M cells)



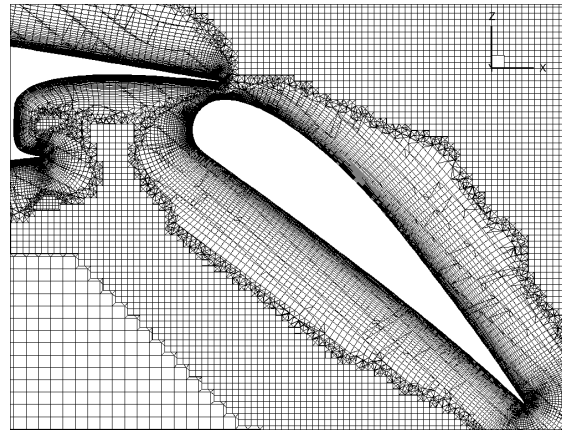
Comparisons with other grids



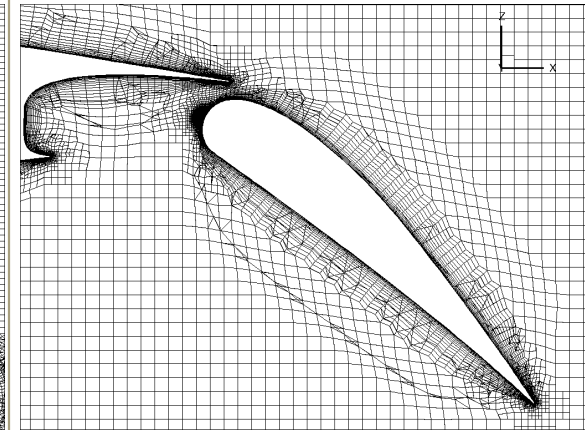
**Pointwise
(1.3.C, 142M cells)**



**ANSA
(101.C, 217M cells)**

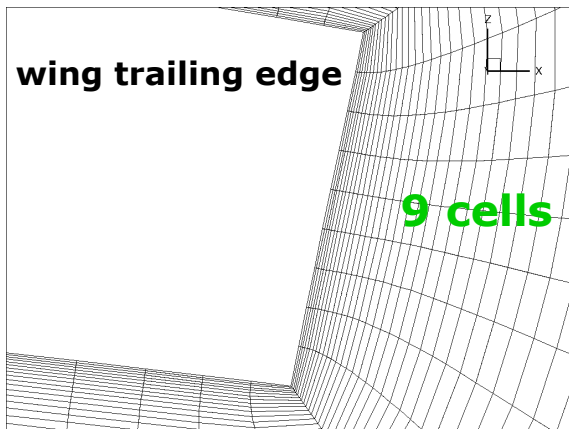


**Cflow
(366M cells)**

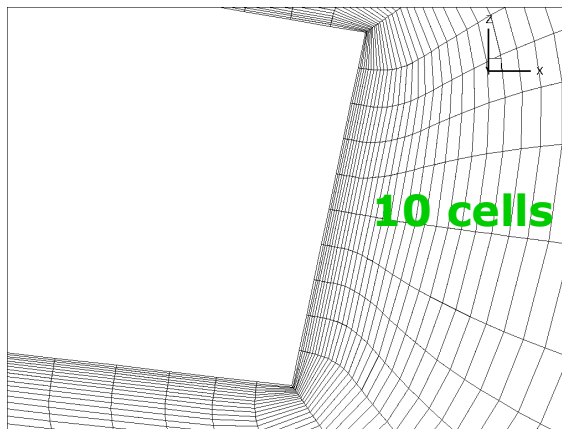


wing trailing edge

9 cells

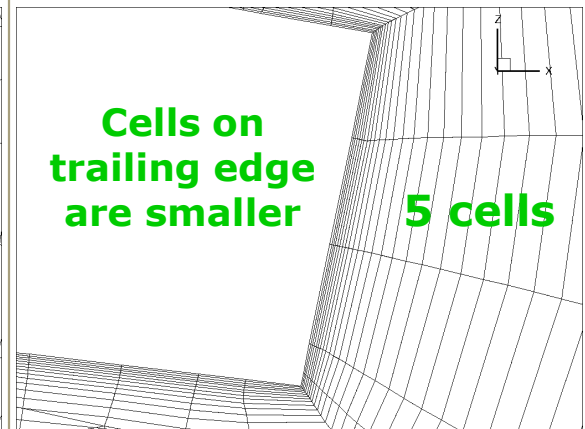


10 cells

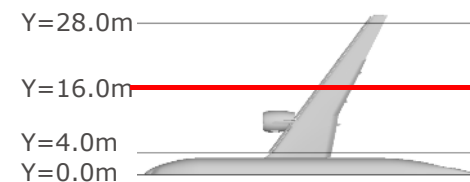


**Cells on
trailing edge
are smaller**

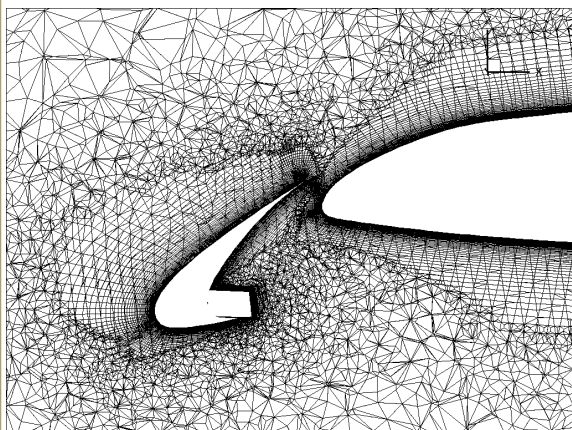
5 cells



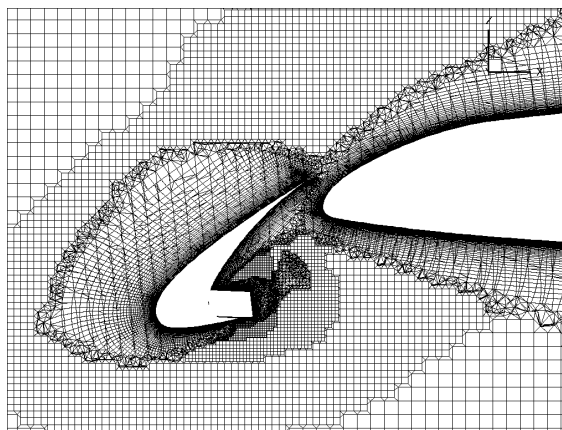
Comparisons with other grids



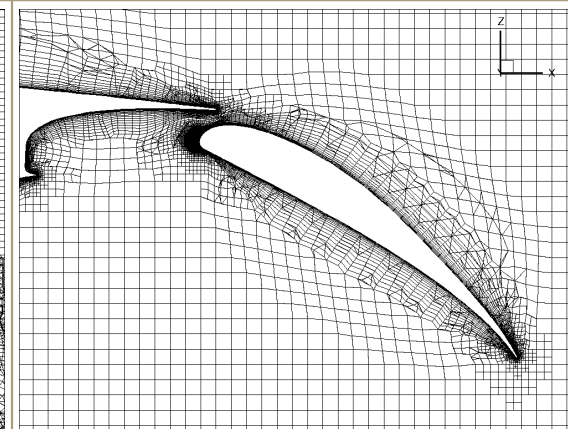
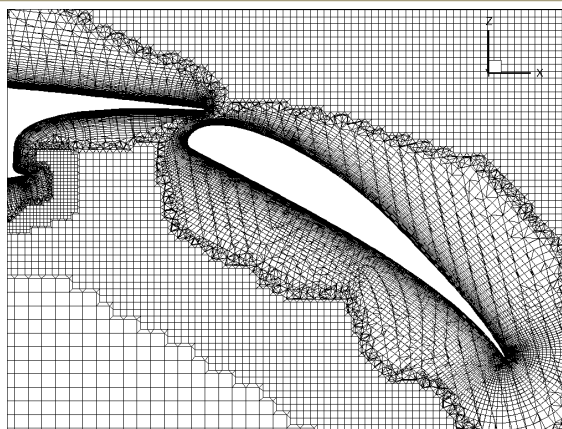
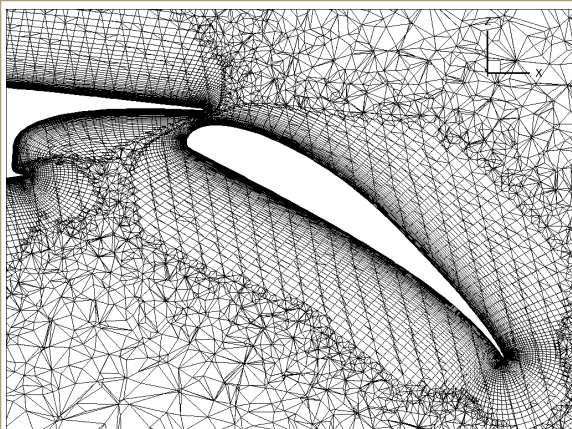
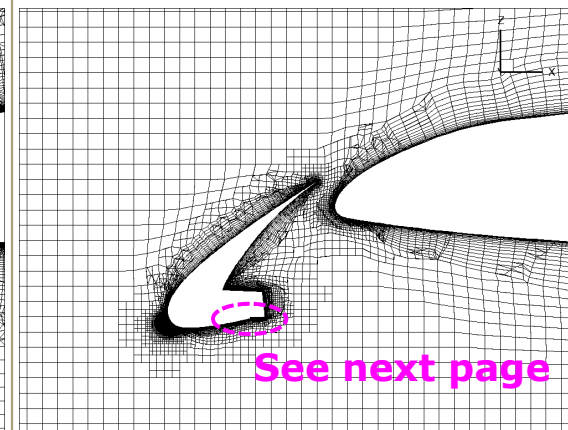
Pointwise
(1.3.C, 142M cells)



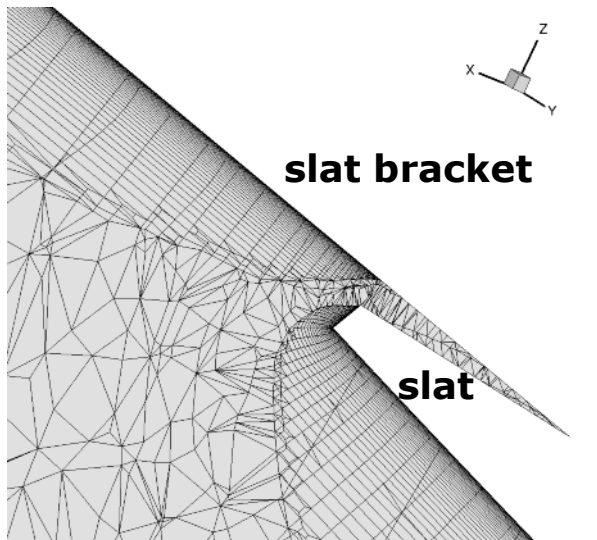
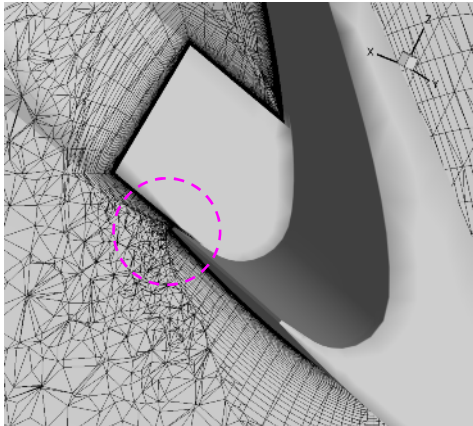
ANSA
(101.C, 217M cells)



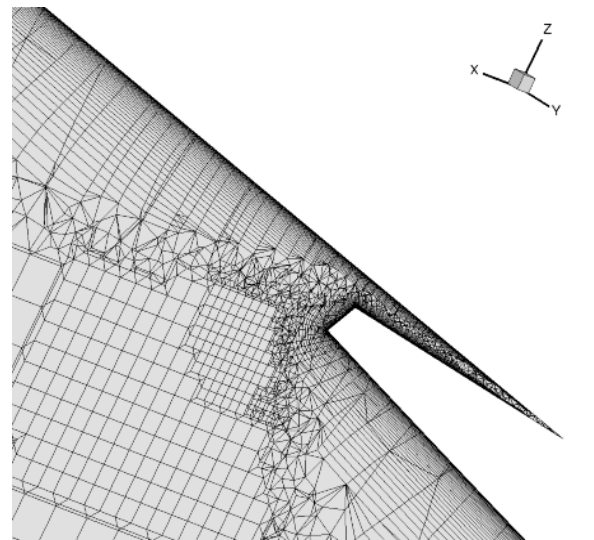
Cflow
(366M cells)



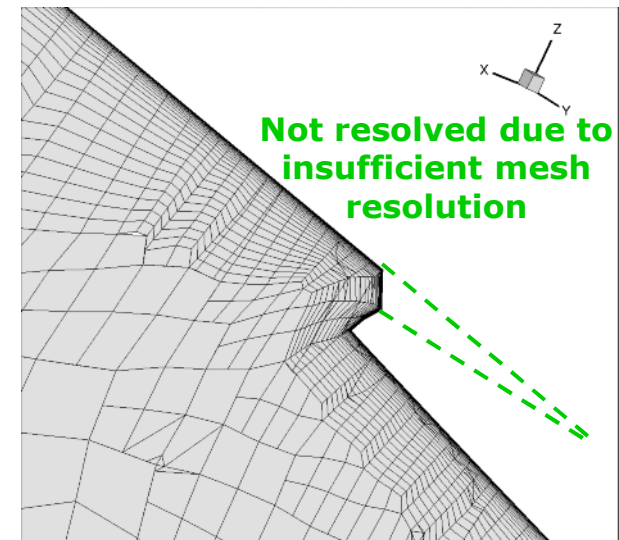
Comparisons with other grids



Pointwise
(1.3.C, 142M cells)

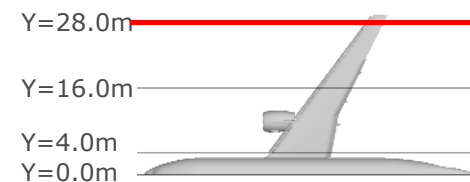


ANSA
(101.C, 217M cells)

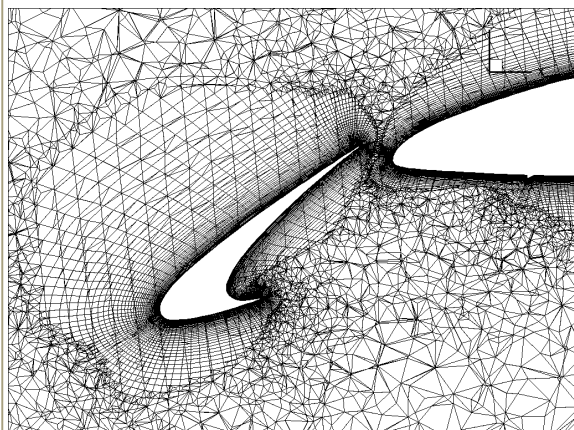


Cflow
(366M cells)

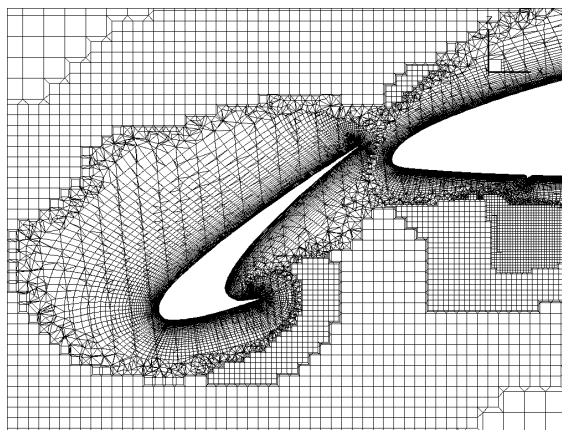
Comparisons with other grids



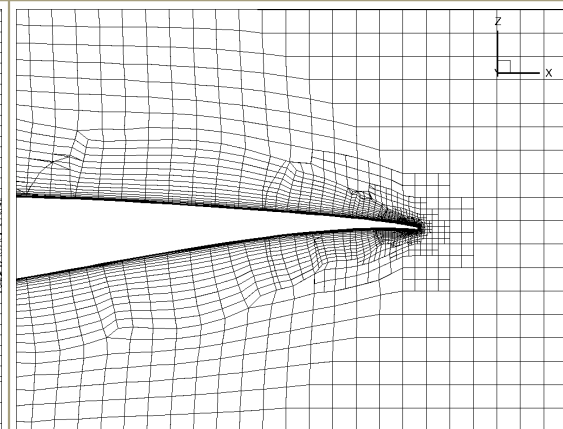
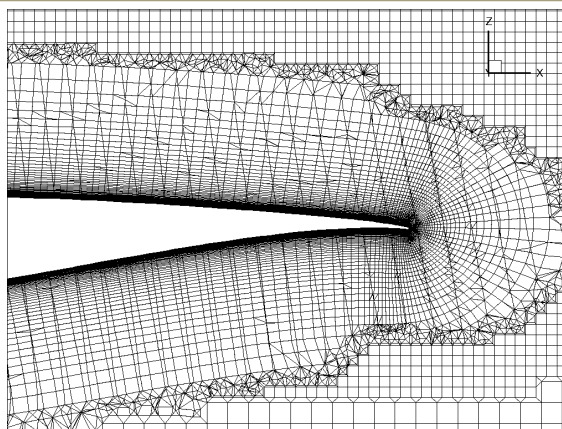
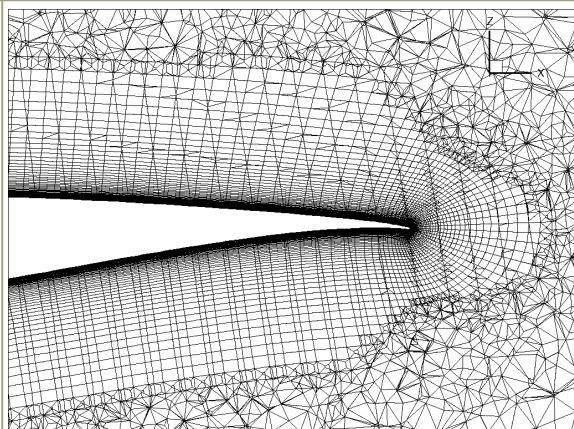
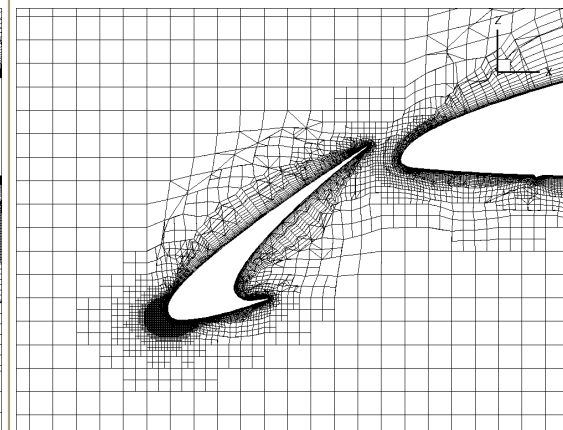
Pointwise
(1.3.C, 142M cells)



ANSA
(101.C, 217M cells)



Cflow
(366M cells)

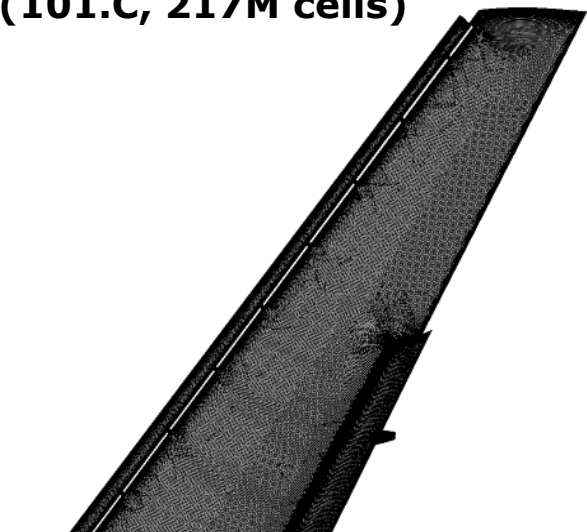


Comparisons with other grids

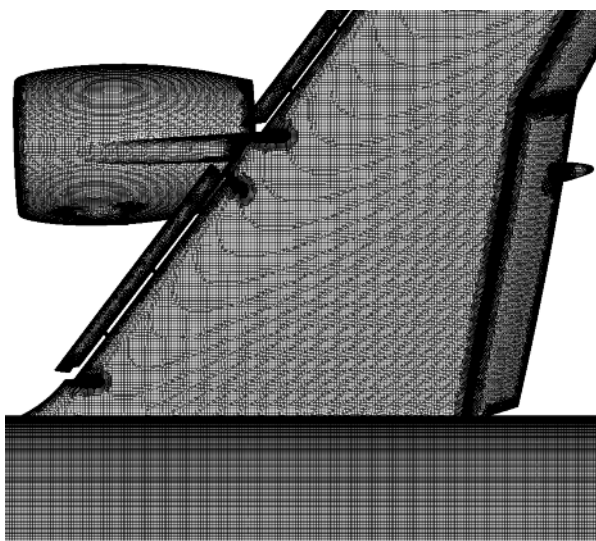
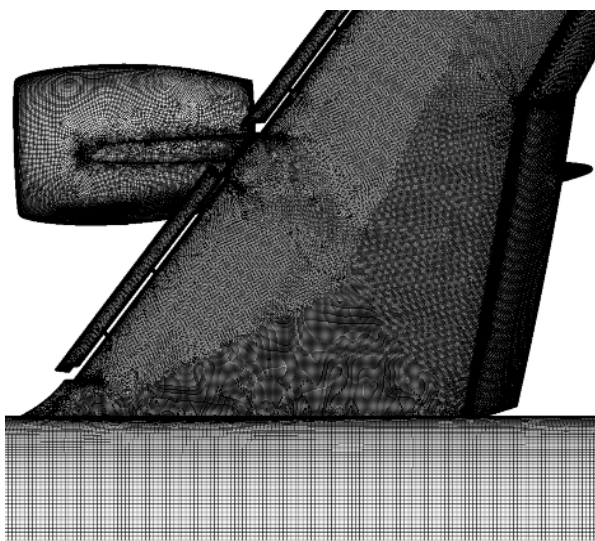
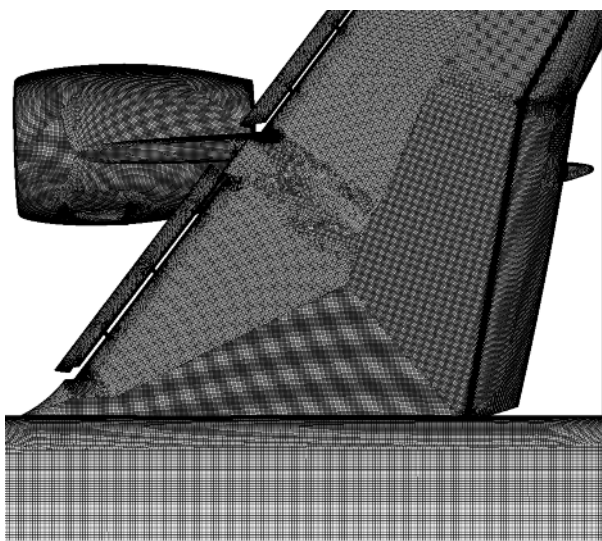
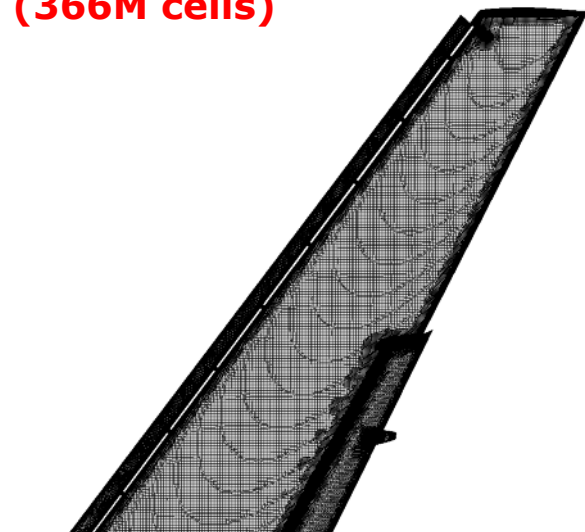
Pointwise
(1.3.C, 142M cells)



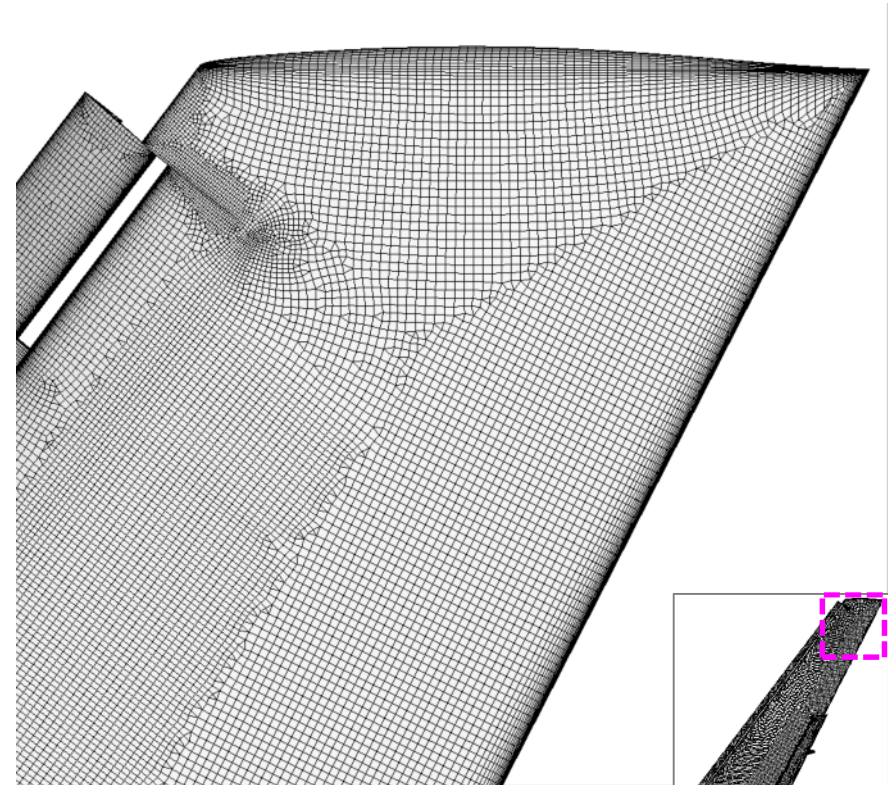
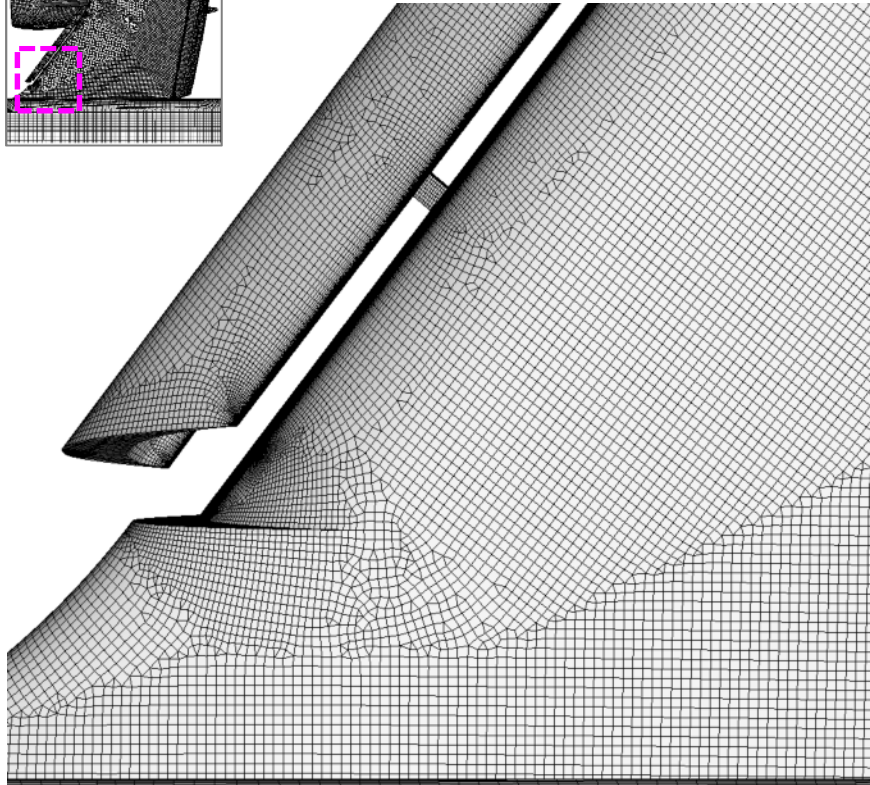
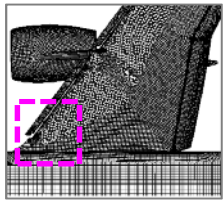
ANSA
(101.C, 217M cells)



Cflow
(366M cells)

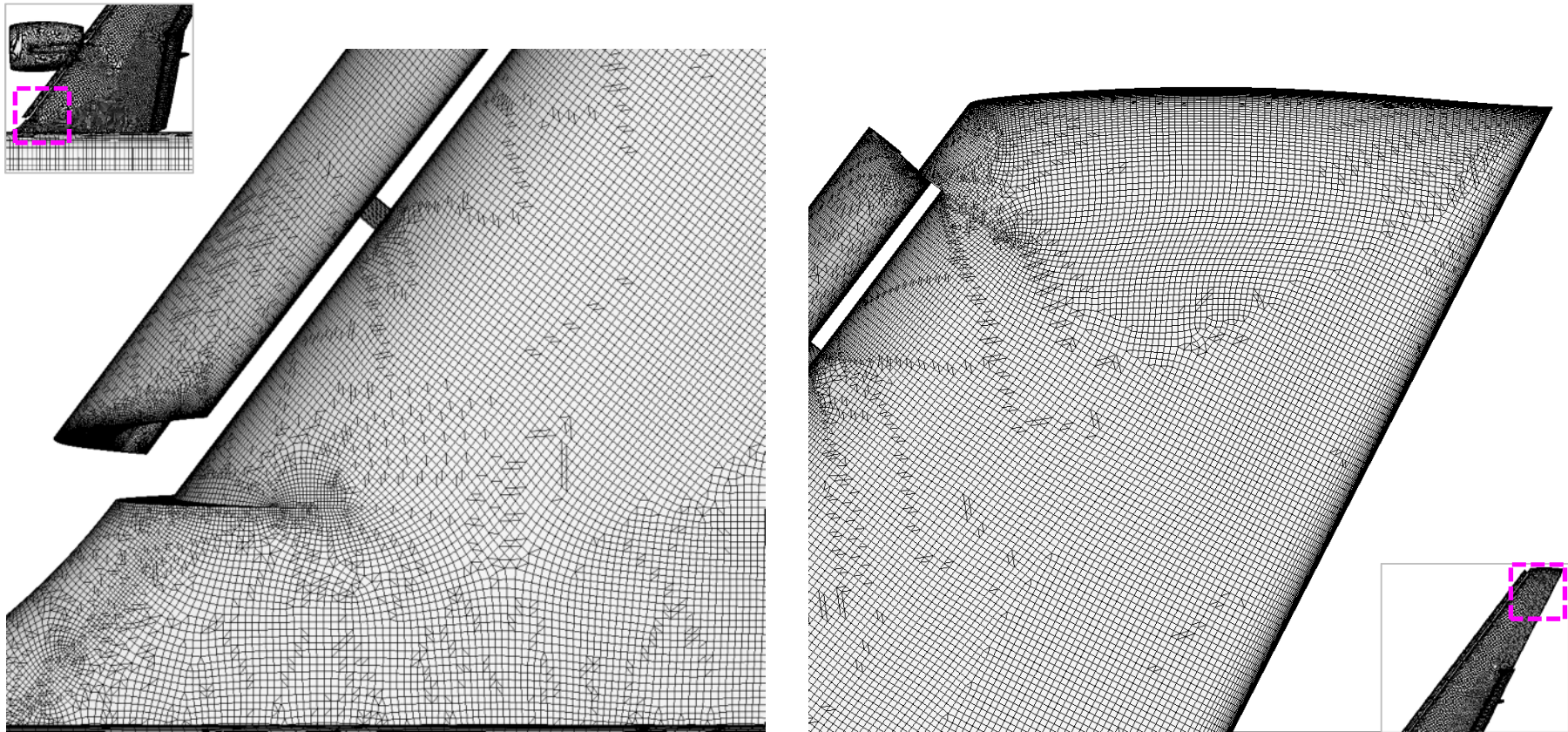


Comparisons with other grids



**Pointwise
(1.3.C, 142M cells)**

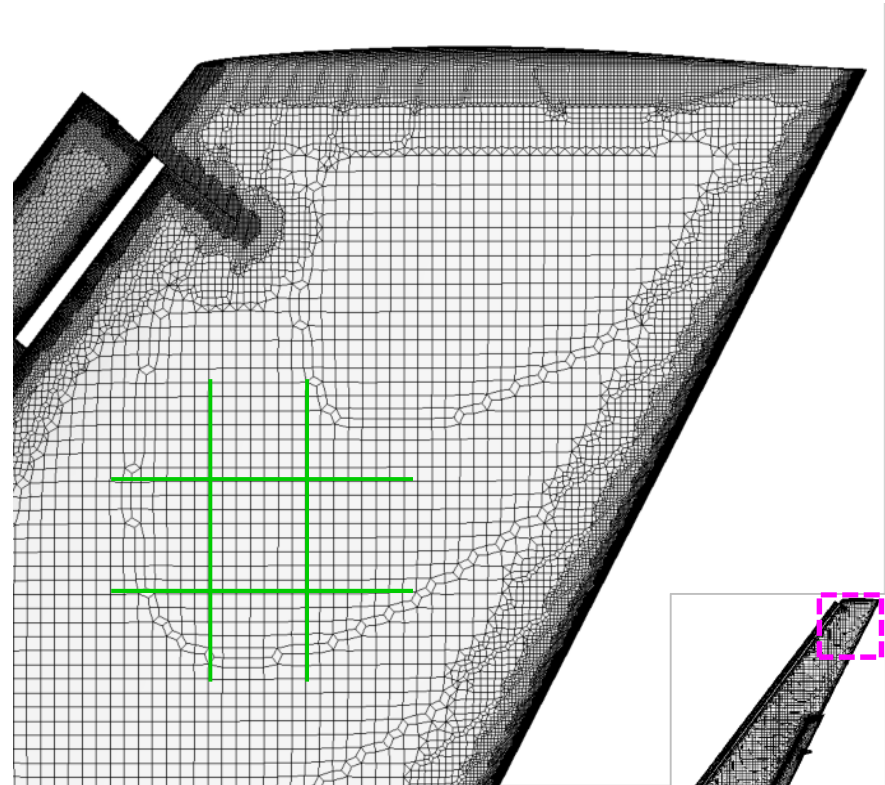
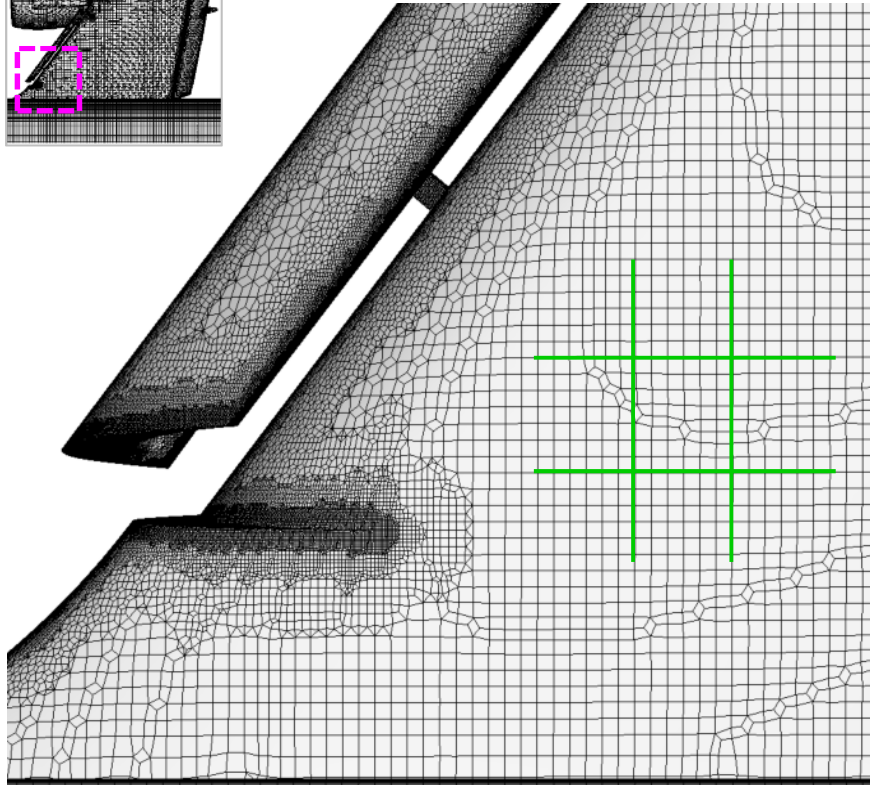
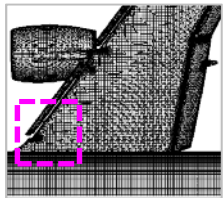
Comparisons with other grids



ANSA
(101.C, 217M cells)

Comparisons with other grids

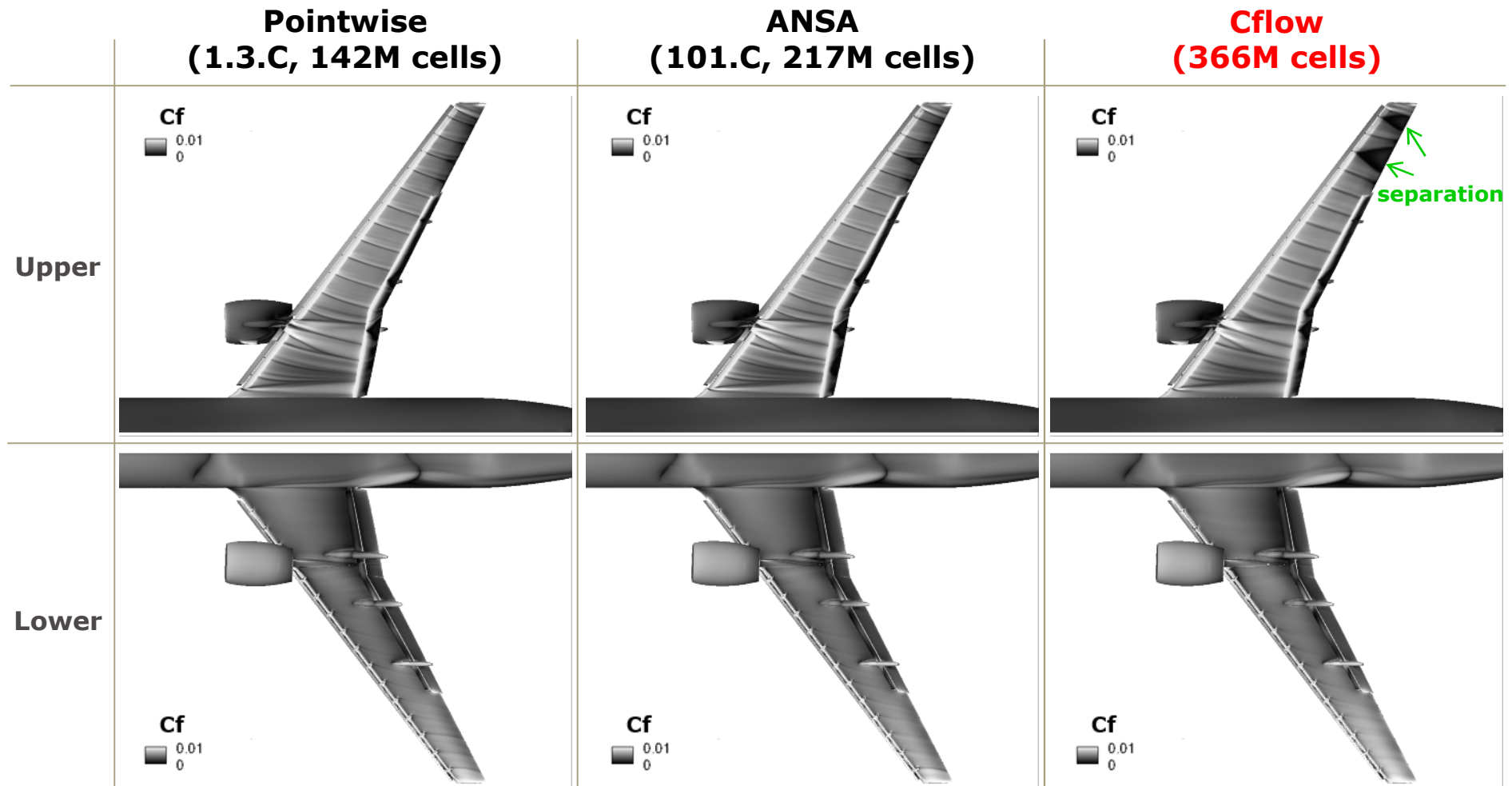
Surface mesh is not parallel/normal
to the leading and trailing edges



Cflow
(366M cells)

Comparisons with other grids

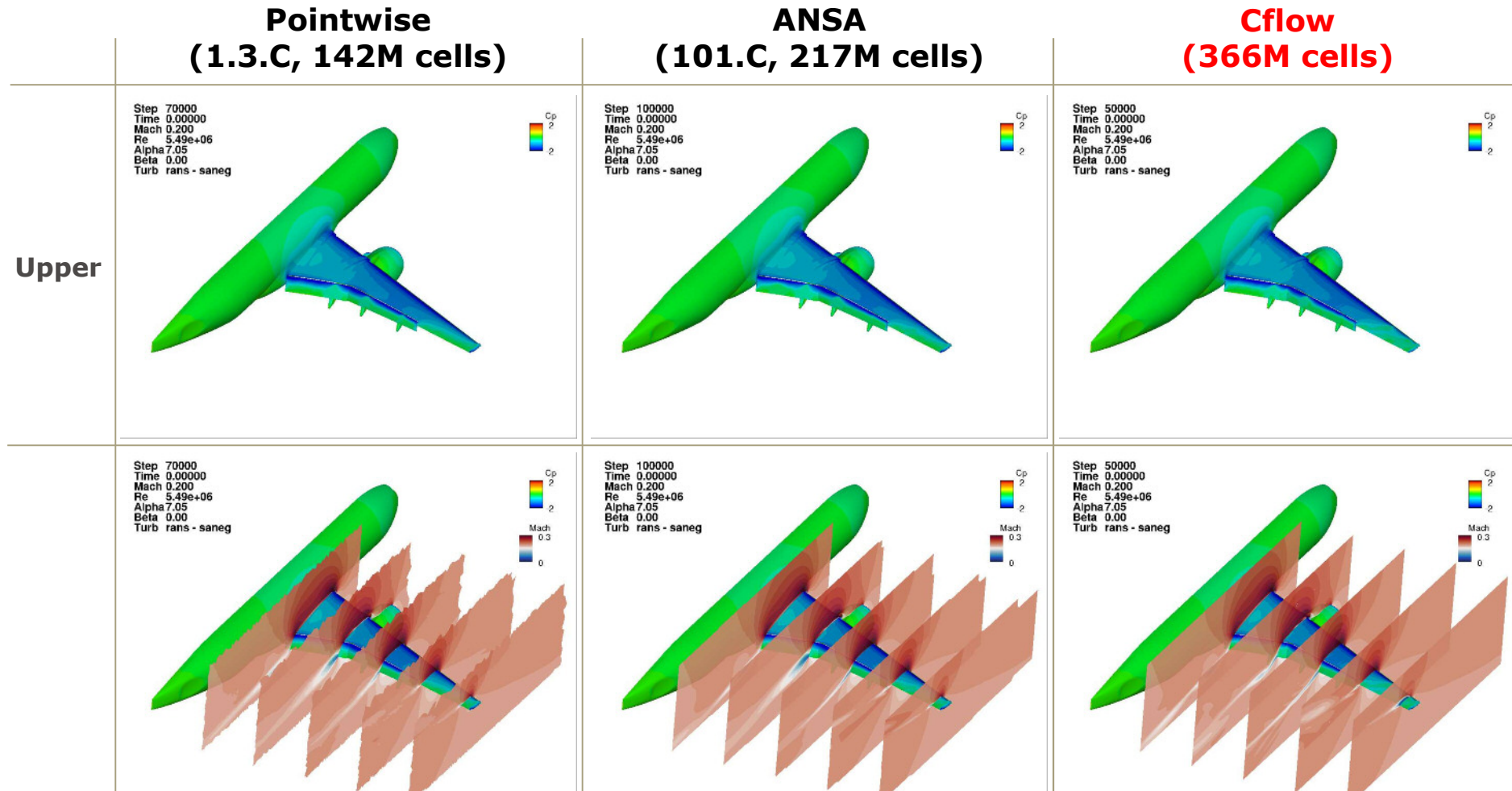
(CFD Results: RANS with SA-neg, AoA=7.05)



Skin friction (Cf)

Comparisons with other grids

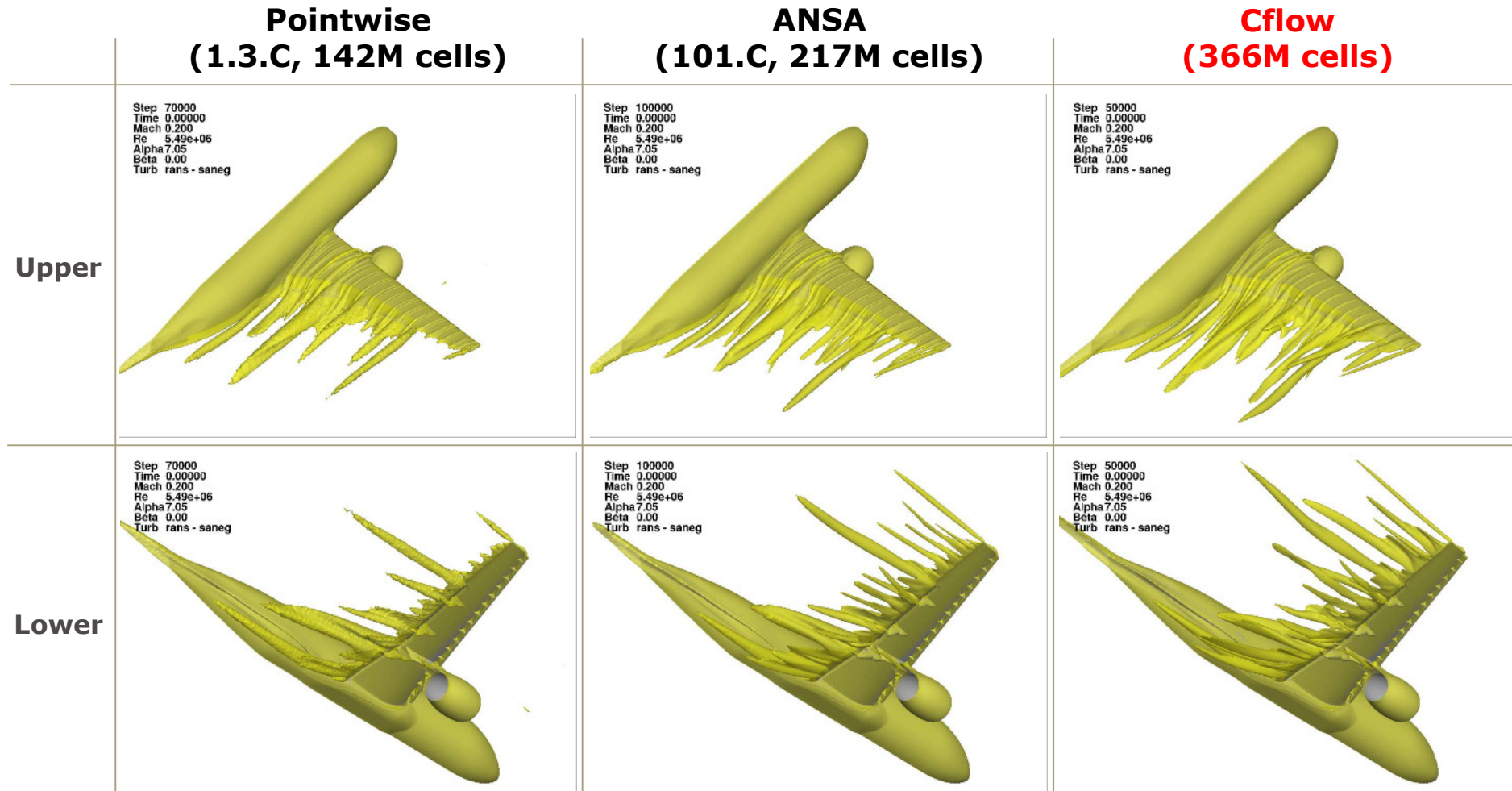
(CFD Results: RANS with SA-neg, AoA=7.05)



Surface pressure and cross-section Mach

Comparisons with other grids

(CFD Results: RANS with SA-neg, AoA=7.05)



Iso-surface of total pressure ($P_{ratio}=0.99$)

Kawasaki, working as one for the good of the planet
“Global Kawasaki”