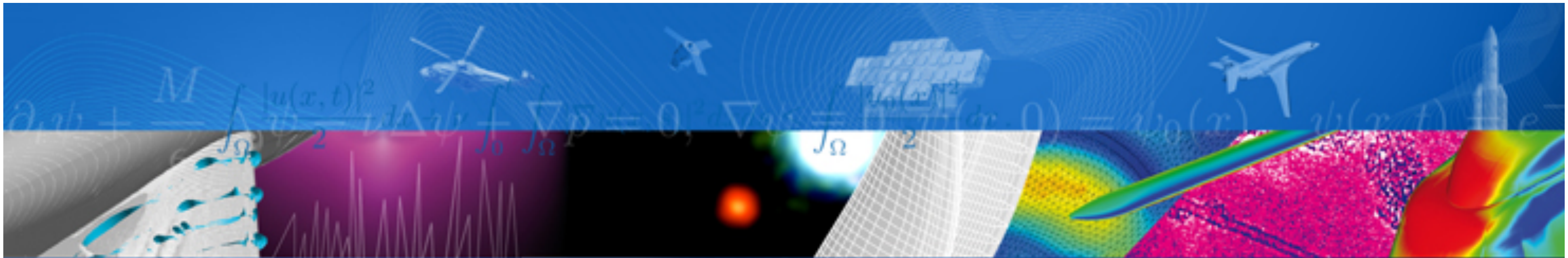

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# 4th Drag Prediction Workshop

## ONERA results

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June 20-21 2009, San Antonio, Texas

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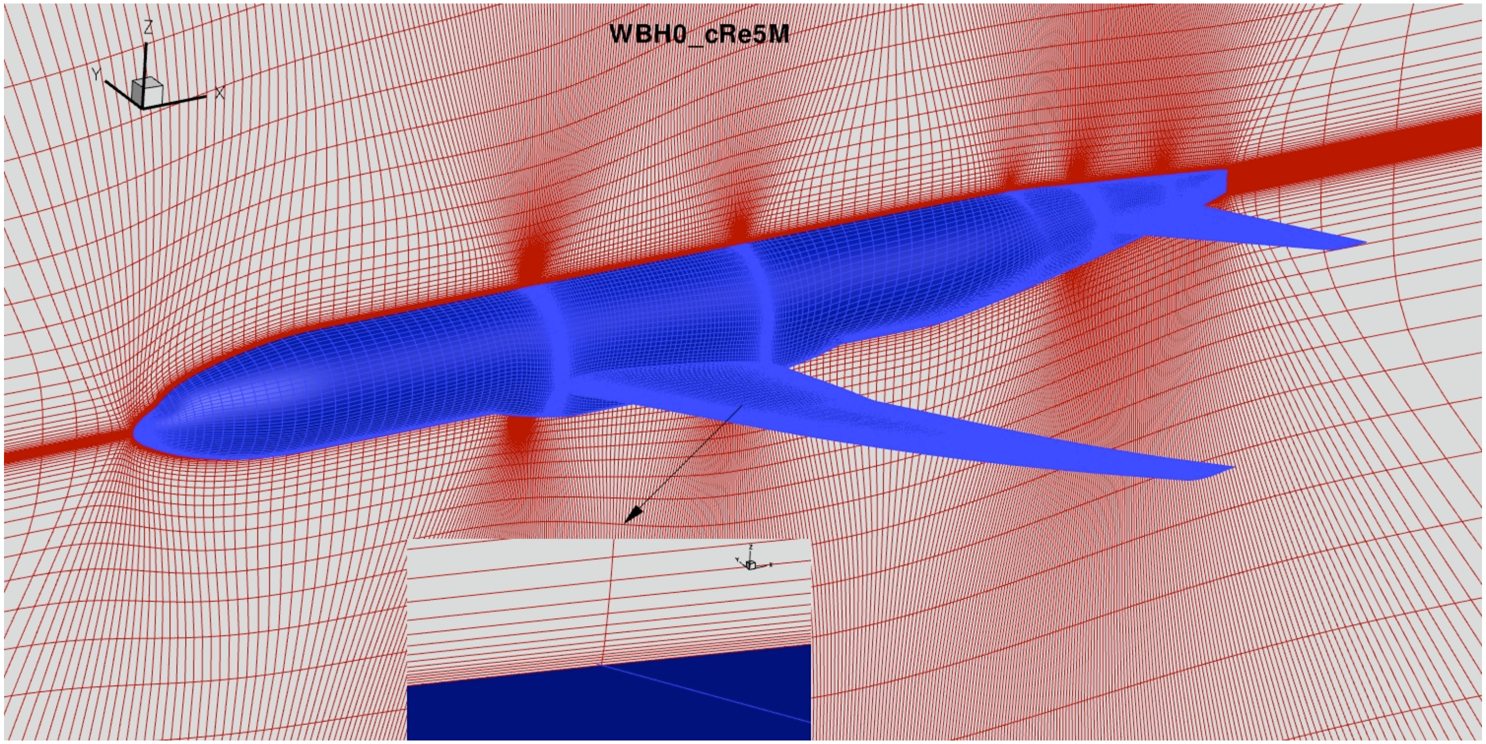
r e t u r n o n i n n o v a t i o n

# MB structured grids provided by Boeing (1/2)

*CRM W/B/H – Coarse grid (4.9 million nodes)*

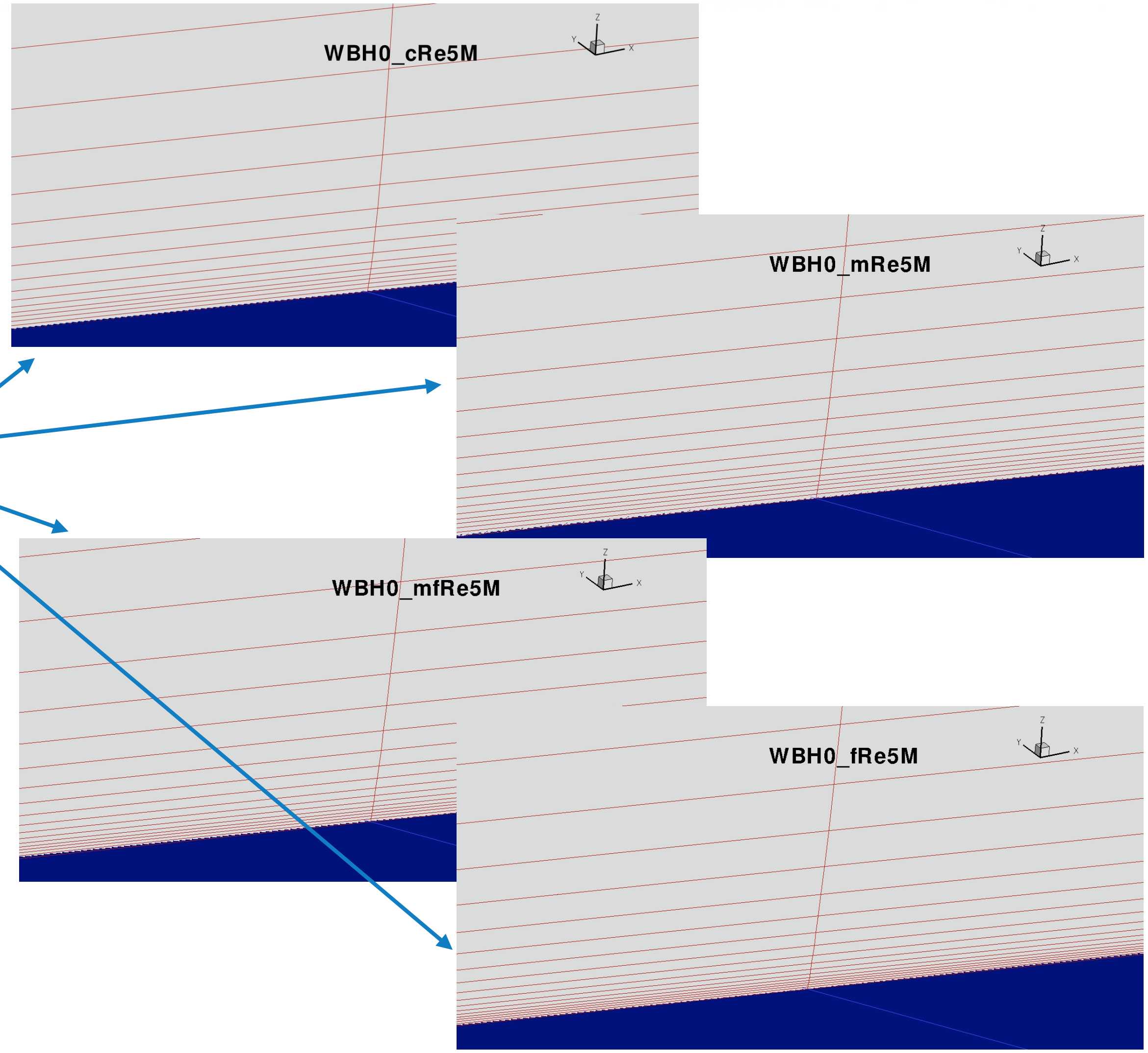



*Skin surface, symmetry plane and slice in the boundary layer on the coarse grid*

# MB structured grids provided by Boeing (2/2)

**Boeing MB structured grids converted from Plot3D to CGNS format**

| | |
|---|---|
| **Coarse grid** | **4.9 M nodes** |
| **Medium grid** | **11.2 M nodes** |
| **Medium-fine grid** | **26.0 M nodes** |
| **Fine grid** | **47.8 M nodes** |




*Boundary layer refinement*

# *elsA* solver

***elsA-structured code***

## ***elsA solver:***

RANS computations

Cell-centered finite volume on structured multi-block meshes

Time integration : Backward-Euler scheme with LU-SSOR relaxation

Spatial discretization : centred Jameson scheme

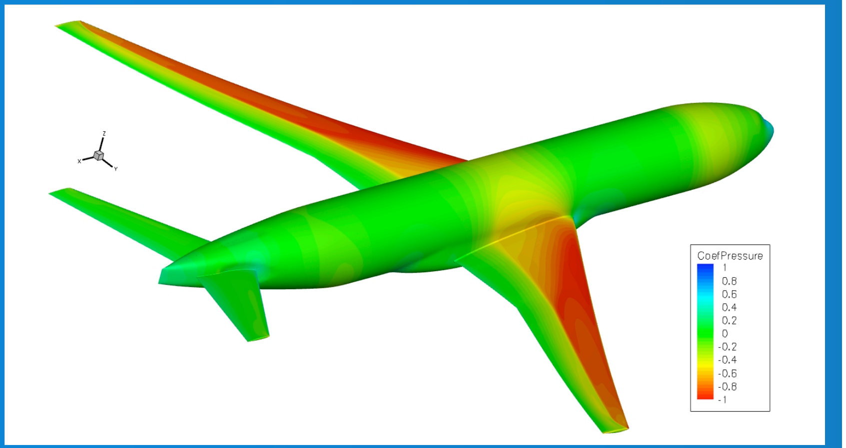
Multigrid technique

Spalart-Allmaras turbulence model

CGNS input and output format

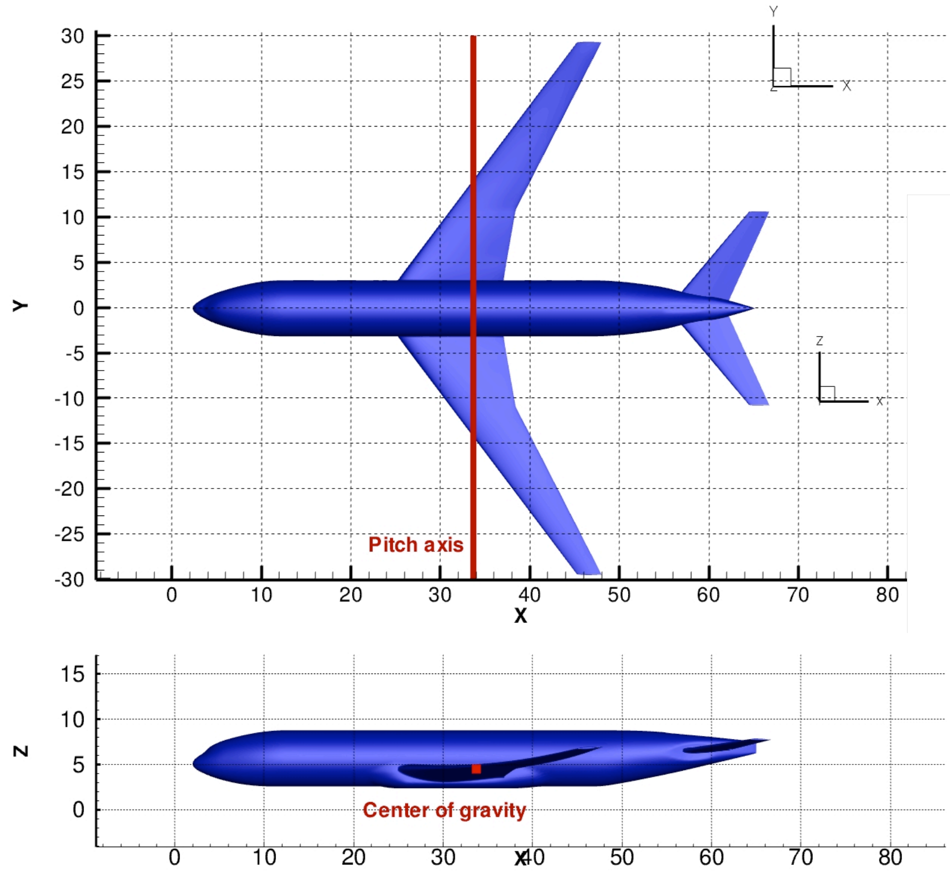
Sequential (NEC-SX8)

Parallel mode (Bull Novascale)

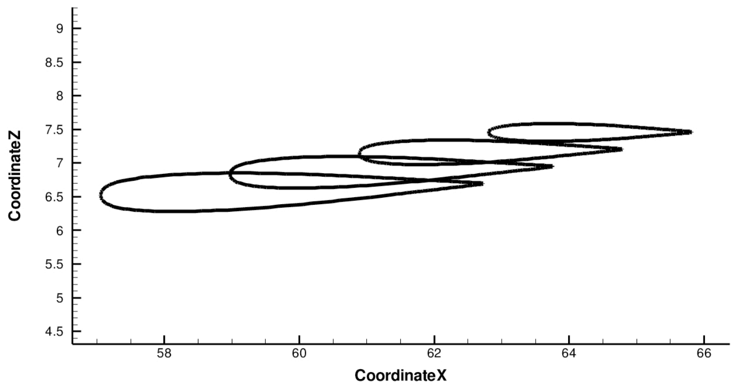


# Reference dimensions (m) and pitch axis – Tail sections

*CRM Wing/Body/Horizontal Tail*



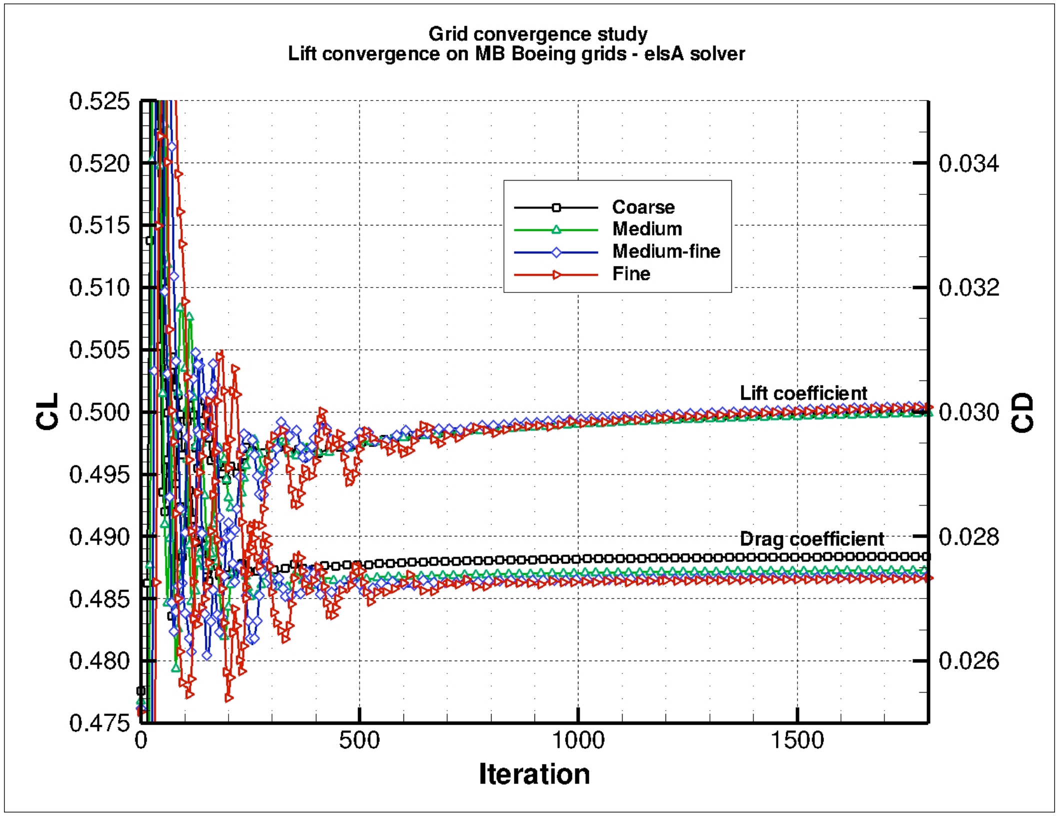

*Skin surface of CRM wing-body configuration*




*Horizontal tail iH=0.0° - 4 spanwise sections*

# Case 1.1: Grid Convergence study

***CRM wing/body/horizontal tail – Coarse , medium, medium-fine and fine grids***



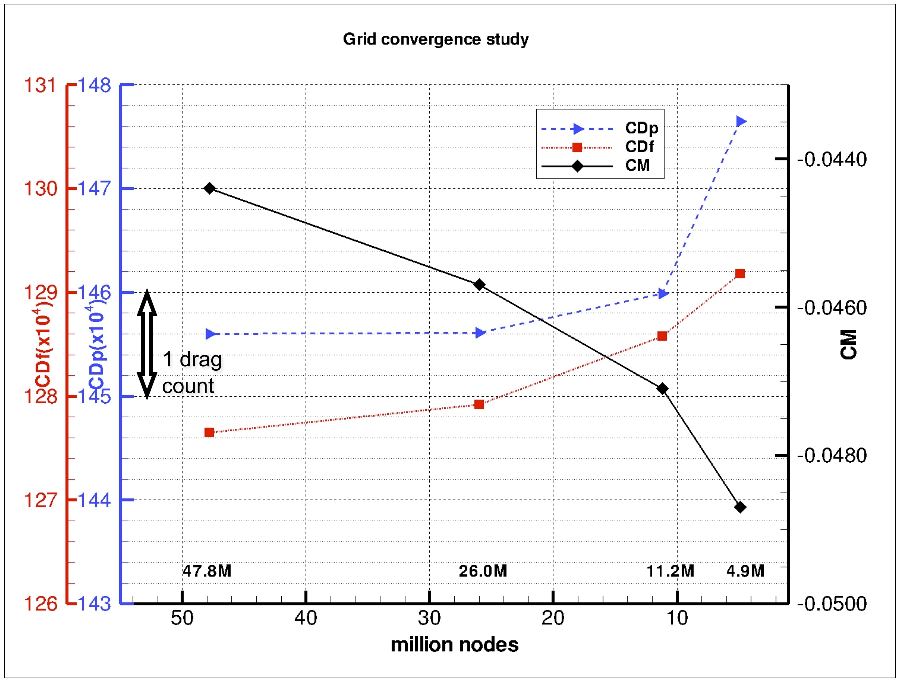

***Influence of grid refinement on lift, drag and pitching-moment prediction***

**Good convergence for the 4 grid refinement levels**

**1800 MG cycles to ensure a high convergence level**

# Case 1.1: Grid Convergence study

*CRM wing/body/horizontal tail – Coarse , medium, medium-fine and fine grids*




*Influence of grid refinement on lift, drag and pitching-moment prediction*

| CRM Tail ($i_H = 0.0°$) | $\alpha$ | $CL$ | $CD_p$ | $CD_f$ | $CD_{nf}$ | $Cm_y$ |
|---|---|---|---|---|---|---|
| **Coarse grid** | 2.35 | 0.5000 | 147.65 | 129.18 | 276.83 | -0.0487 |
| **Medium grid** | 2.34 | 0.4999 | 145.99 | 128.58 | 274.57 | -0.0471 |
| **Medium fine grid** | 2.35 | 0.5005 | 145.61 | 127.92 | 273.53 | -0.0457 |
| **Fine grid** | 2.36 | 0.5004 | 145.60 | 127.65 | 273.25 | -0.0444 |

**CD Total** within 3.5 drag counts through the grid convergence process

**CD Pressure**: reduction of 2 drag counts with grid refinement

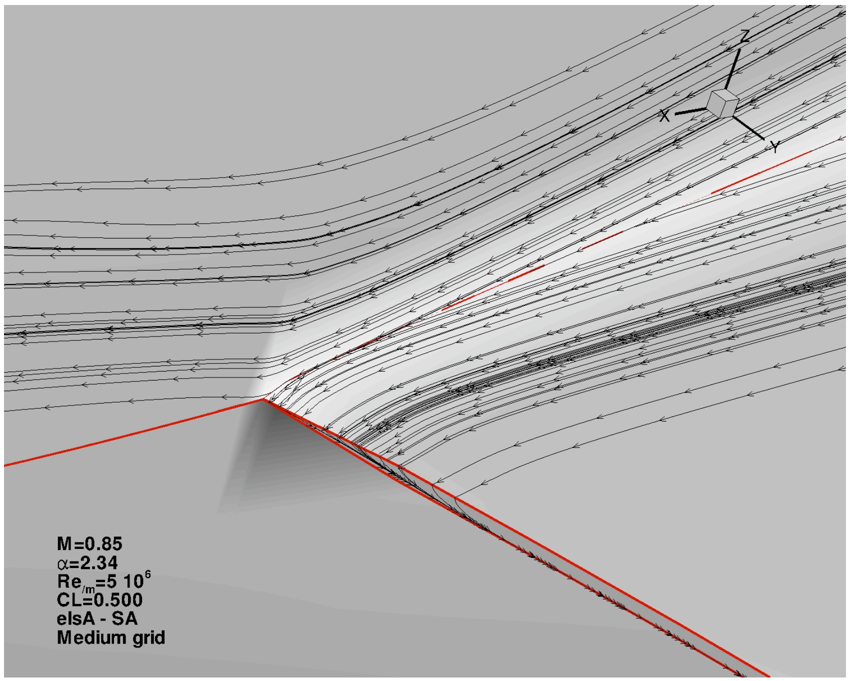
**CD Friction**: 1.5 drag counts variation with refinement

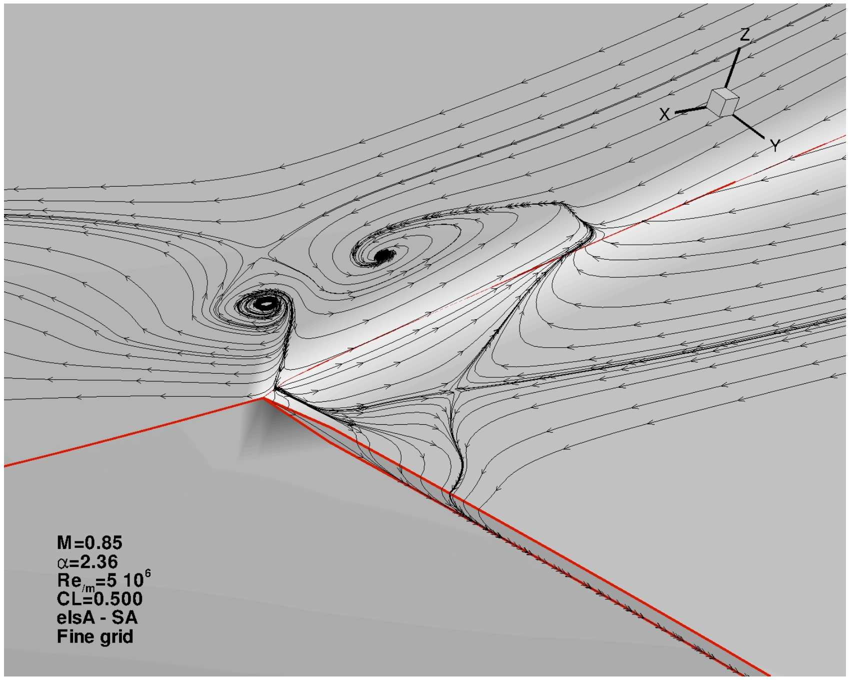
**Pitching-moment** is more sensitive than drag to the grid refinement

Variation from -0.0487 on the coarse grid to -0.0444 on the fine grid

# Case 1.1: Flow separation study

***CRM wing/body/horizontal tail – M=0.85 CL=0.50 $Re_{/c}$=5 $10^6$***



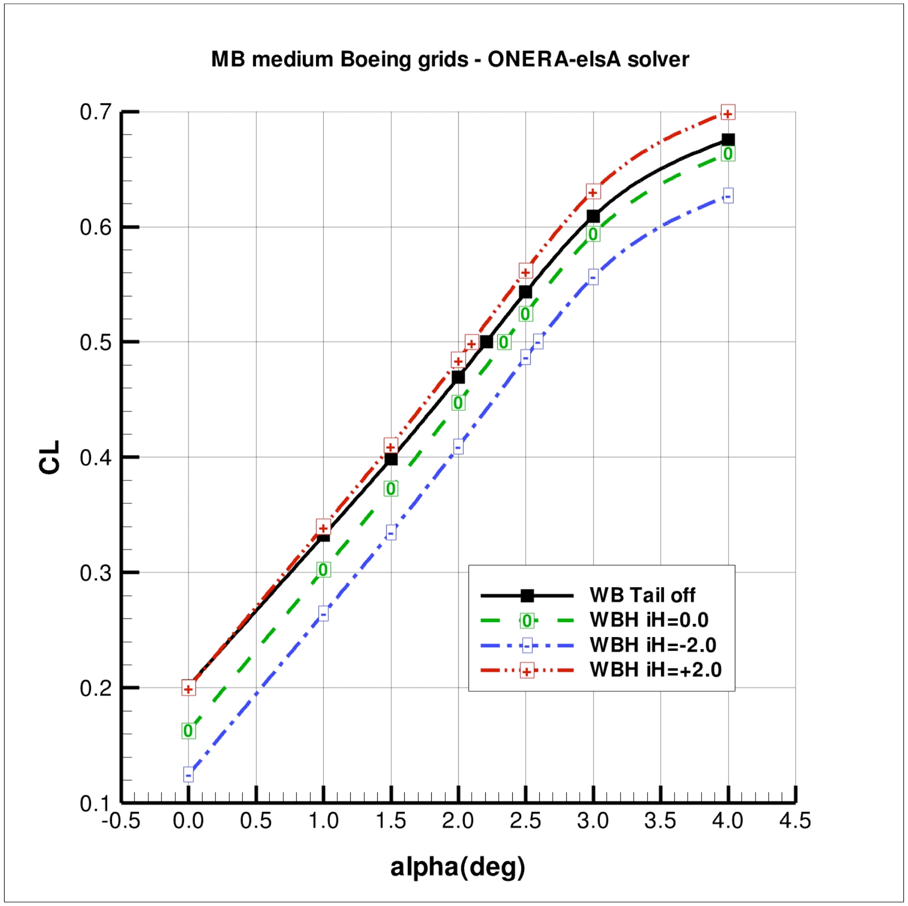



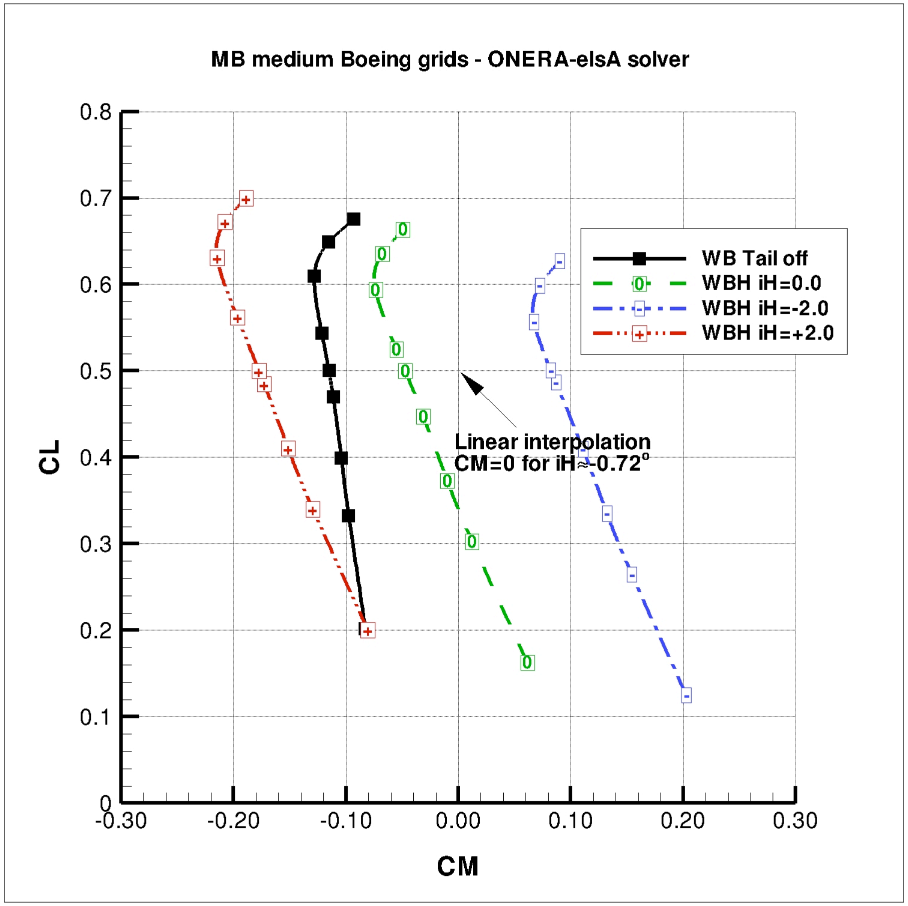

**No flow separation captured with the Spalart-Allmaras turbulence model on the medium (11.2 M nodes) nor on the medium fine grid (26.0 M nodes)**

**Small flow separation with the Spalart-Allmaras turbulence model on the fine grid (47.8 M nodes)**

# Case 1.2: Downwash study

***Lift polar and pitching-moment predictions***

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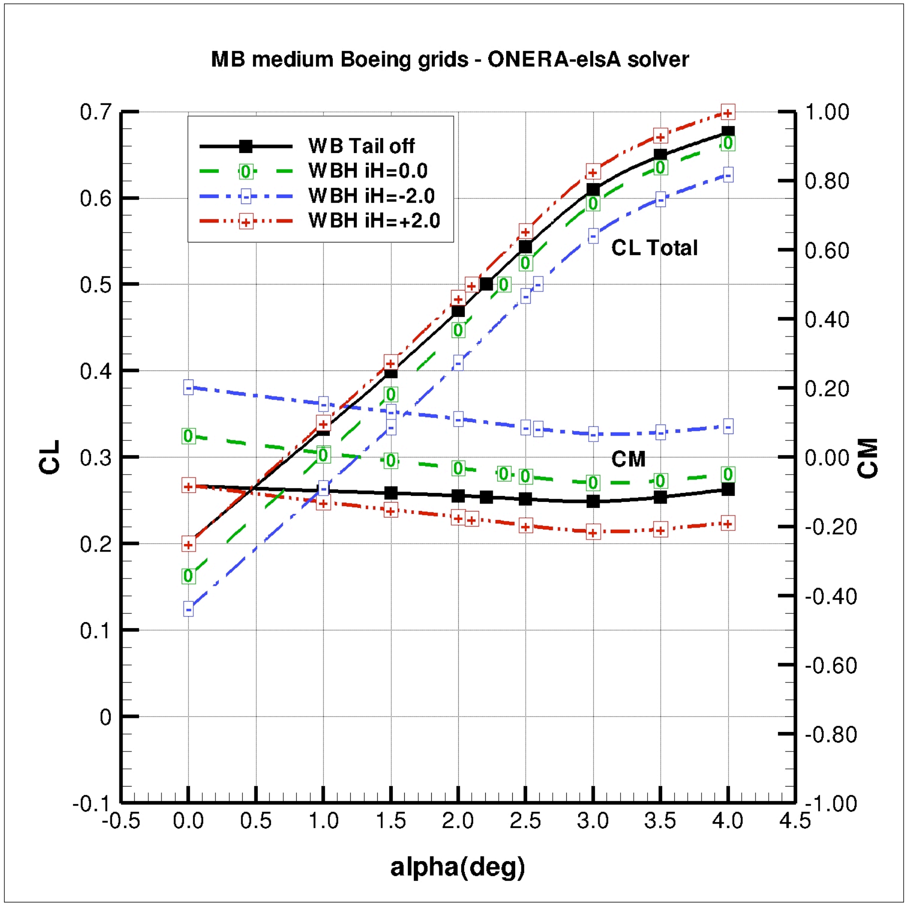
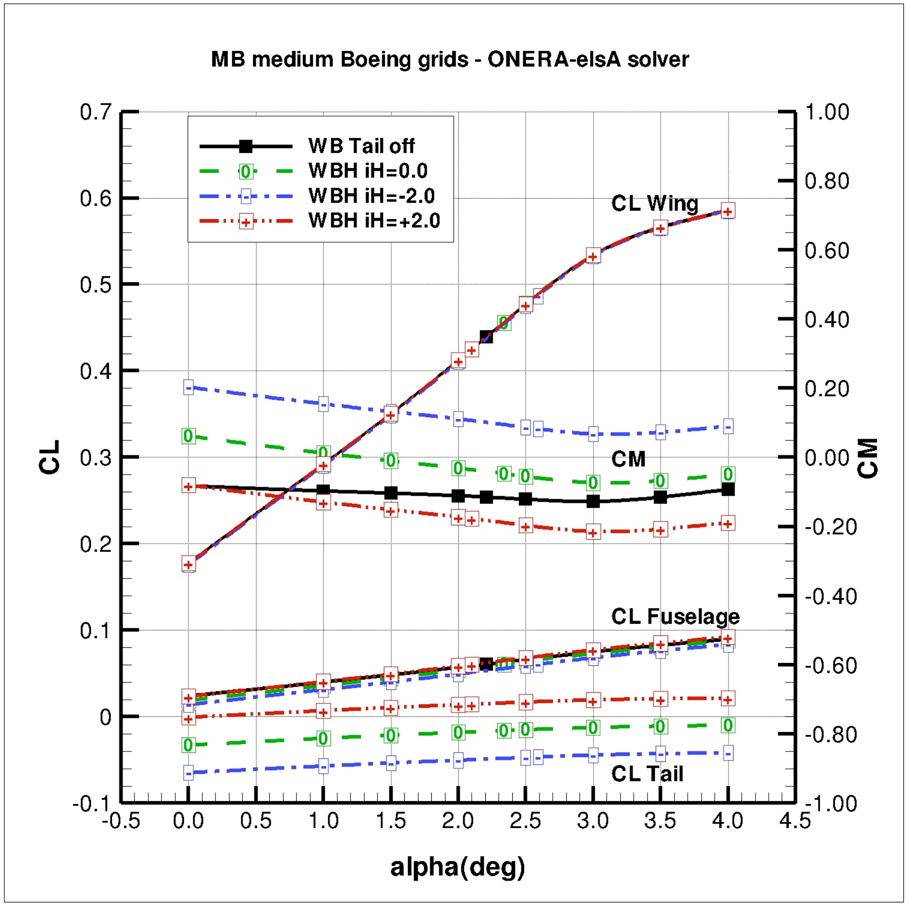
# Case 1.2: Downwash study

***Total lift, lift of the different part of the airplane and pitching-moment***



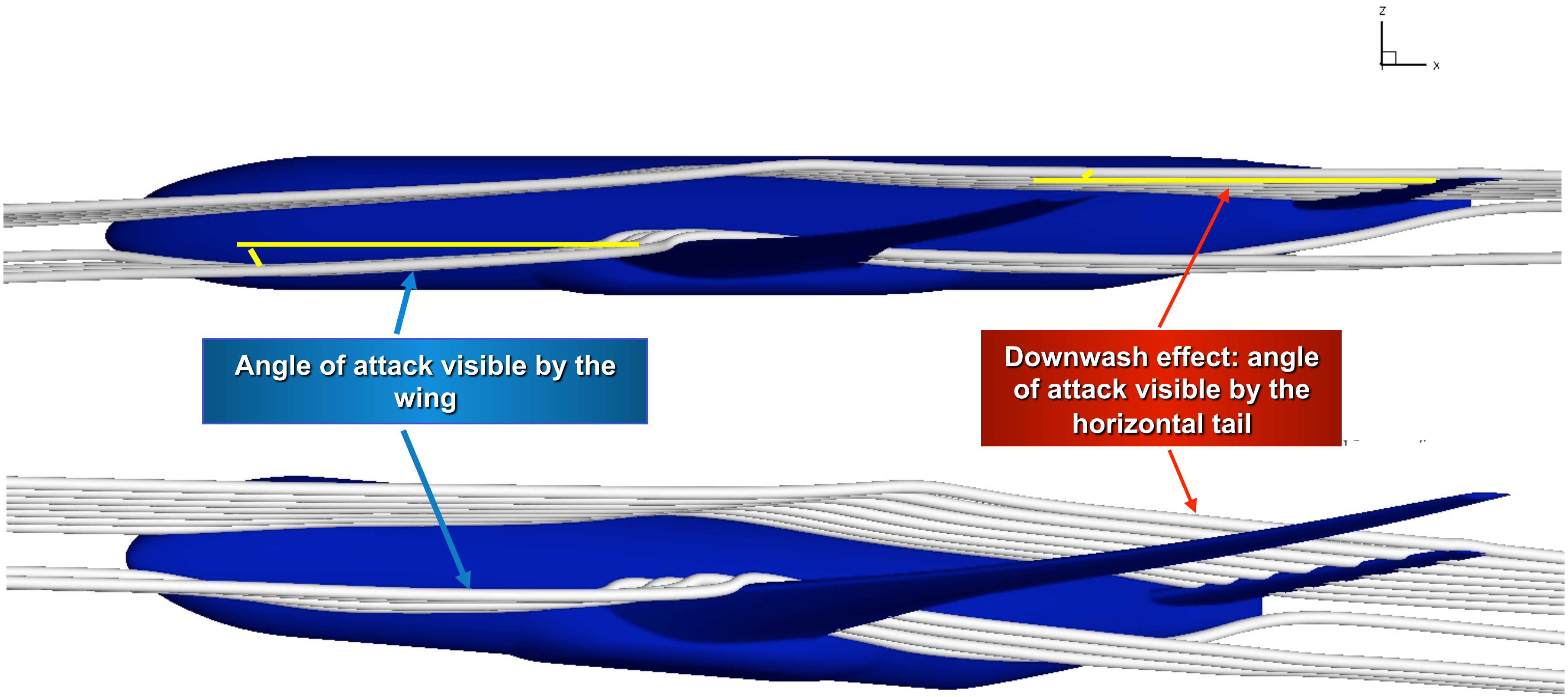




For $i_H$=+2.0° the positive tail lift can not balance the wing rotation

$i_H$=-2.0° and $i_H$=0.0° empennage settings lead to negative tail lift ⇨ right direction to trim the aircraft

# Case1.2: Downwash study

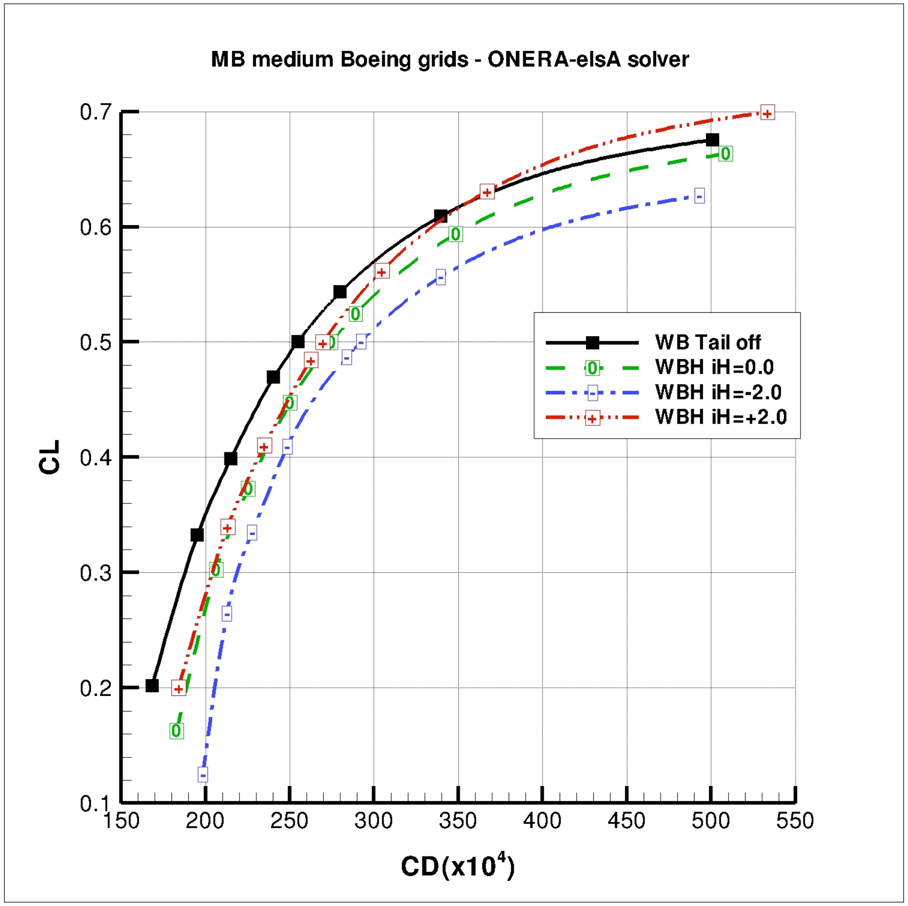
***W/B/H $i_H$=0.0° - CL=0.50 $\alpha$=2.34° $Re_{/c}$=5 $10^6$***

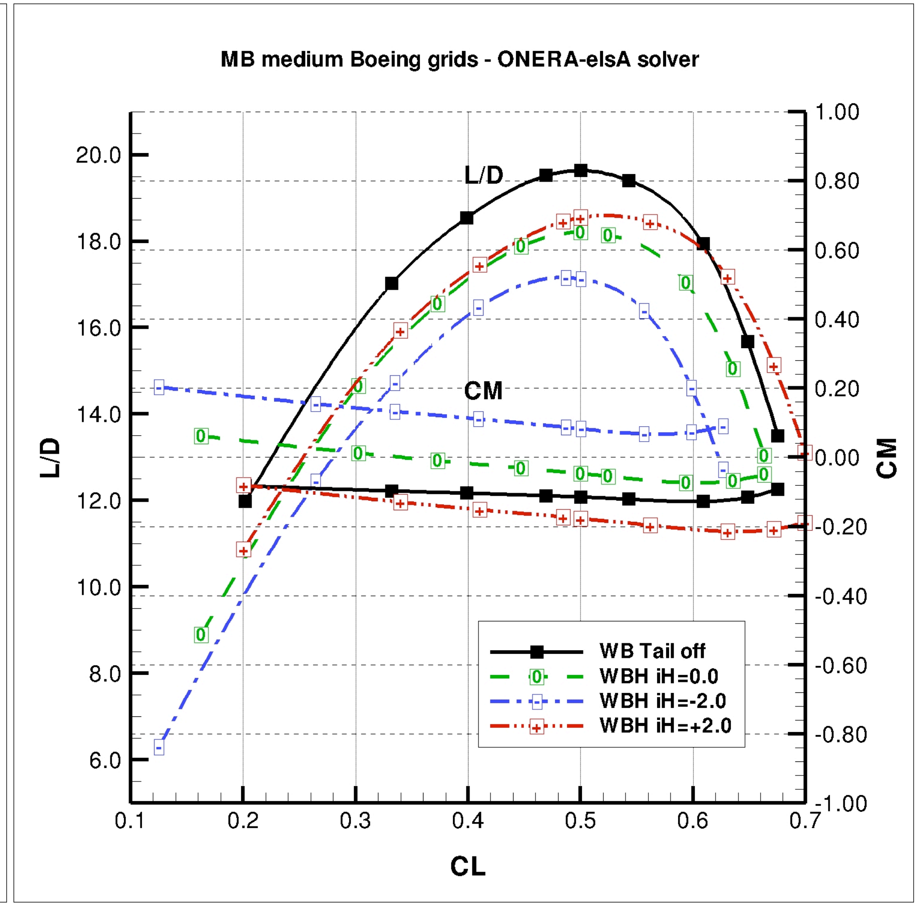



***Downwash effect: deviation of the streamlines on the horizontal tail***

# Case1.2: Downwash study

***Lift-to-Drag ratio v.s Pitching-moment***

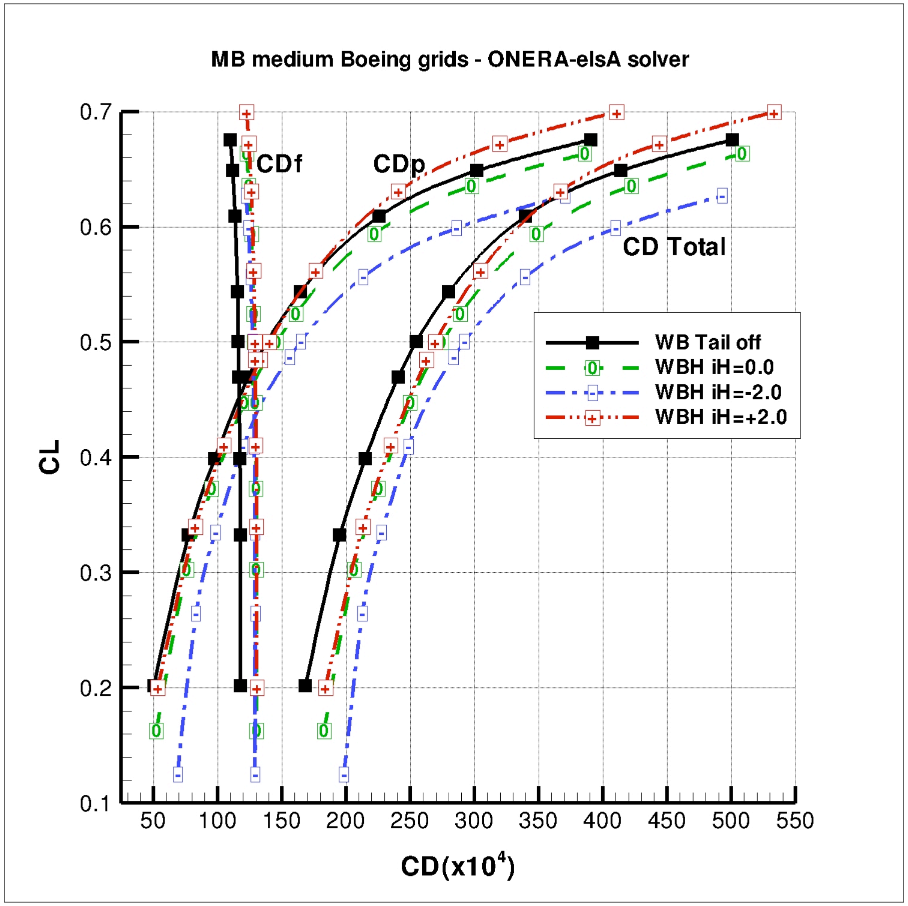


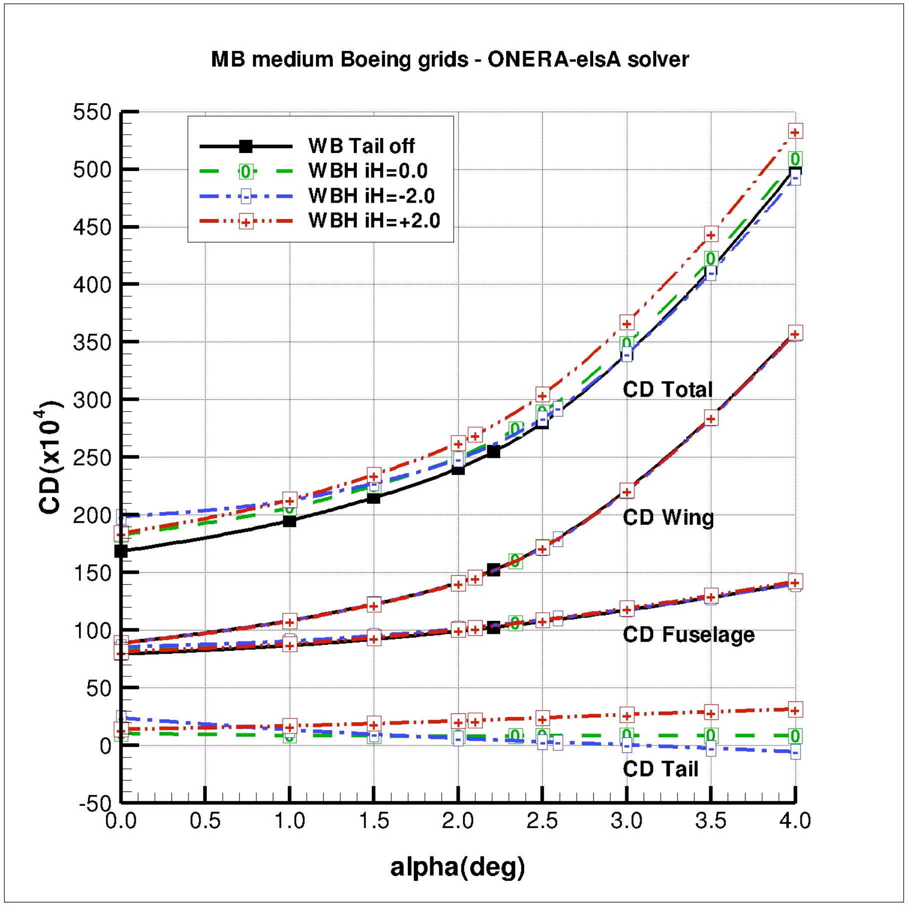




iH=0.0° and iH=-2.0° efficient tail incidences to counter-rotate the wing rotation ⇒ logical penalty on lift-to-drag ratio v.s tail-off

# Case1.2: Downwash study

*Pressure and friction drag – Drag on aircraft components*

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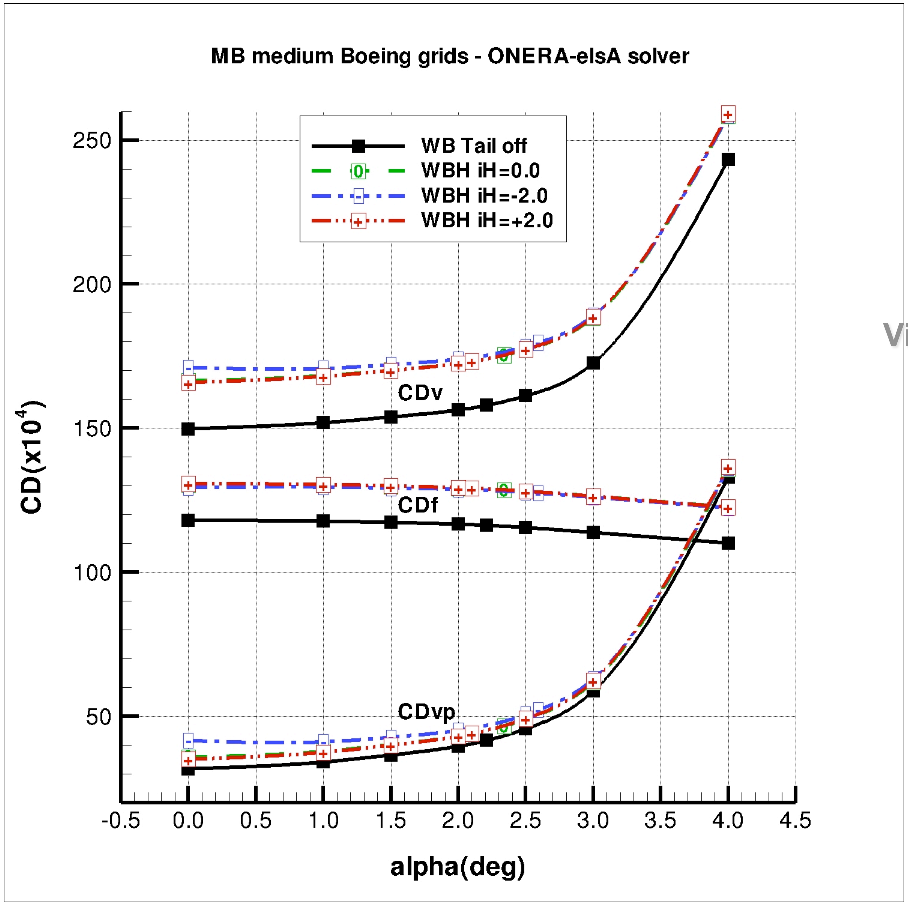
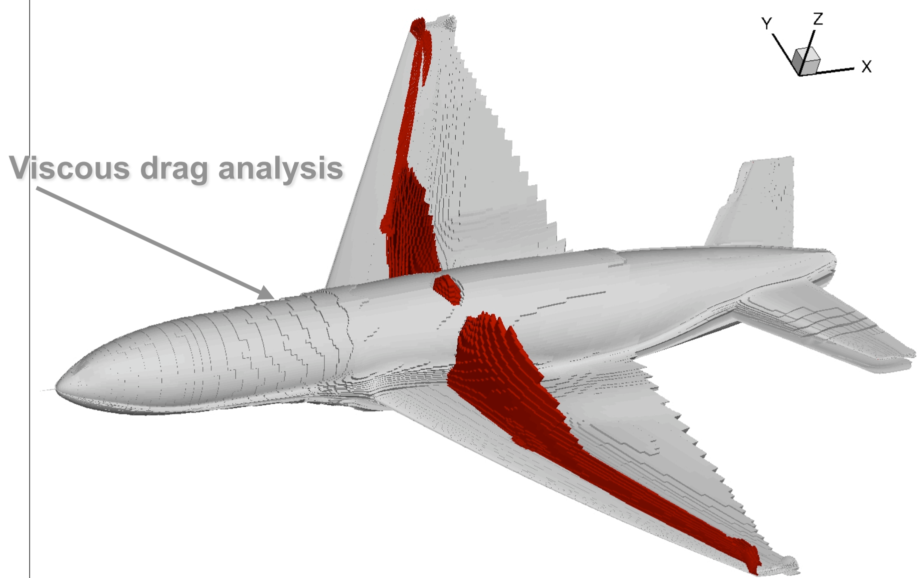
# Case1.2: Downwash study (Far-Field Drag analysis)

*Tail influence on viscous pressure drag component*




*Viscous drag values for the 4 different configurations*




*Viscous drag (in grey) and wave drag (in red) integration volumes form the far-field drag tool*

**More the tail incidence is negative more the penalty on the viscous pressure drag component is important especially for low angle of attack. This effect is limited for CL=0.5**





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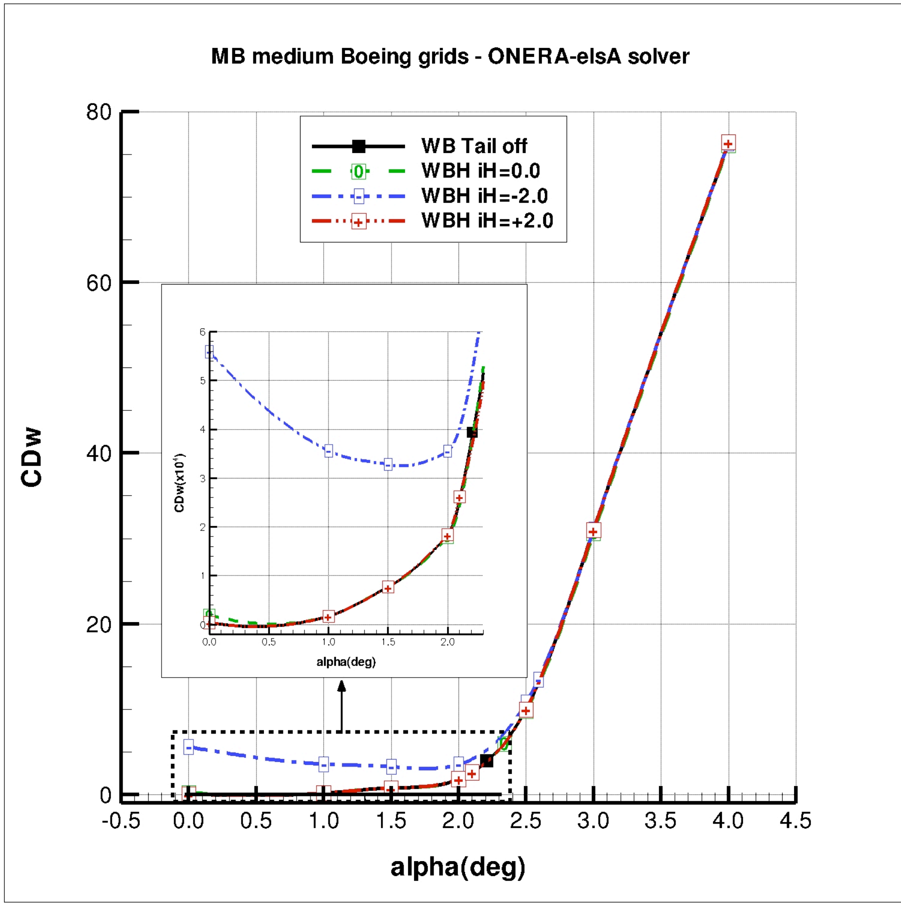
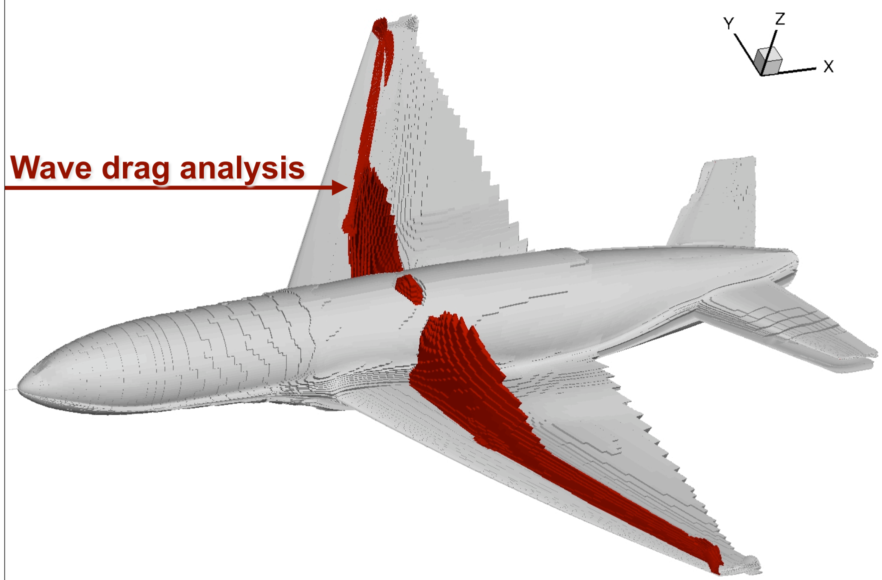
# Case1.2: Downwash study (Far-Field Drag analysis)

*Tail influence on wave drag component*




*Wave drag values for the 4 different configurations*

**Wave drag analysis**




*Viscous drag (in grey) and wave drag (in red) integration volumes form the far-field drag tool*

**Wave drag is produced on the tail for iH=-2.0° at low angles of attack and may appear on the trimmed configuration**

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# Conclusion

- **Case1.1: Grid convergence study**
  - Total drag:
    - Variation: 3.5 drag counts between coarse and fine
    - Variation: 0.5 drag counts of variation between medium and fine ➩ precision required for CFD analysis: 1 drag count
  - Pitching moment:
    - Large variation from -0.0487 to -0.0444 from coarse to fine ➩ precision evaluation on pitching moment: 0.001?

- **Case1.2: Downwash study**
  - CFD provides a powerful solution for trim drag evaluation
    - Good precision level of the calculations in cruise conditions
    - Relative comparisons between configurations with same grid refinement levels give a confident evaluation of drag and pitching-moment increment and effects