Foto: Försvarsmakten/KiimSvensson

Aerodynamics of Conformal Weapons on Fighter Aircraft

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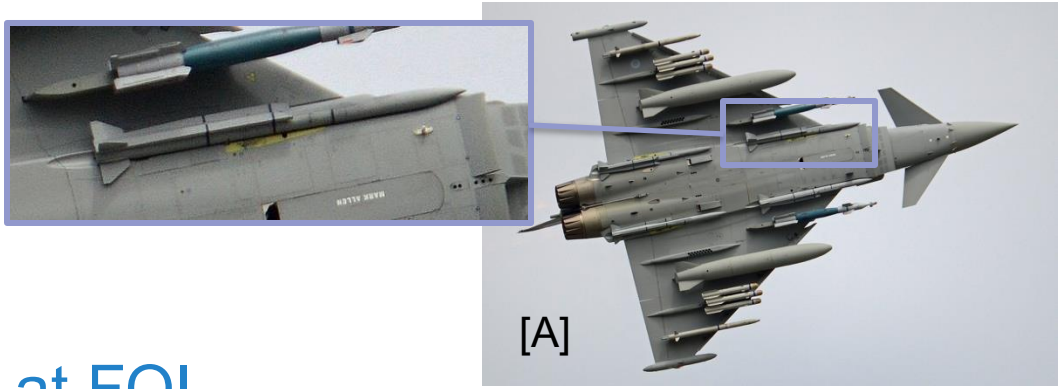
2025-10-14

Background



- Definition
- Internal R&D project at FOI
- CFD study using M-Edge [1]
  - Compressible
  - Steady-state RANS

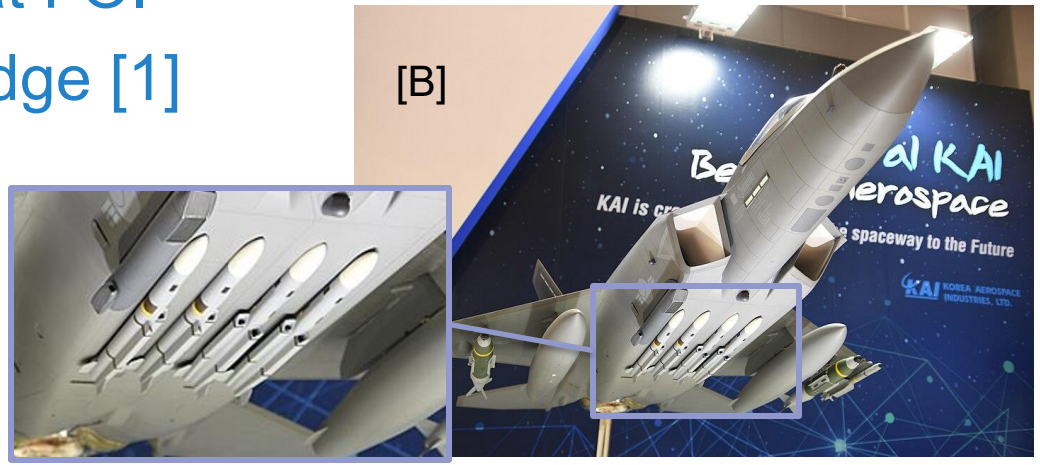
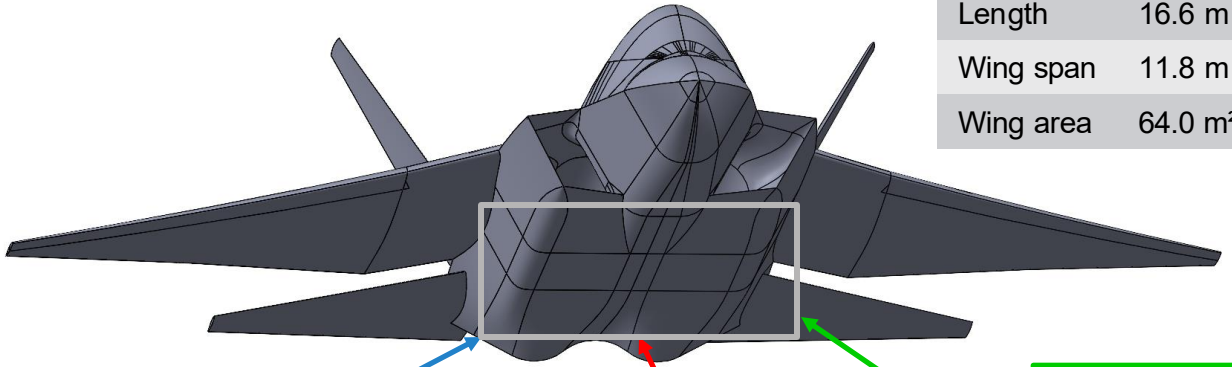


Image credit:
A: Wikimedia commons, User Alan Wilsson, ” Eurofighter Typhoon FGR.4 'ZK356' (35359259191)”
https://commons.wikimedia.org/wiki/File:Eurofighter_Typhoon_FGR.4_%27ZK356%27_(35359259191).jpg
B: Wikimedia commons, User Hunini, ”Korea Aerospace Industries KF-21 Boramae (scale model) right front low-angle view in KAI booth of JA2024 at Tokyo Big Sight October 19, 2024 02”
https://commons.wikimedia.org/wiki/File:Korea_Aerospace_Industries_KF-21_Boramae_(scale_model)_right_front_low-angle_view_in_KAI_booth_of_JA2024_at_Tokyo_Big_Sight_October_19,_2024_02.jpg

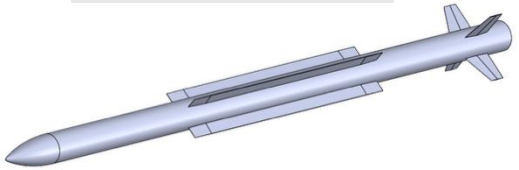
Geometries

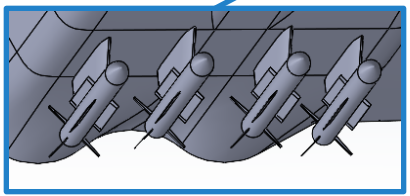
Plain geometry



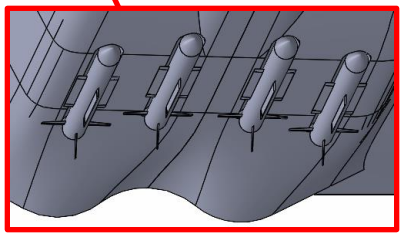
Concept Combat Research Vehicle, CoCoRV v1.1 (NATO AVT-389)	
Length	16.6 m
Wing span	11.8 m
Wing area	64.0 m²

OTC-1 [2] (NATO AVT-316)	
Length	3.45 m
Diameter	0.15 m

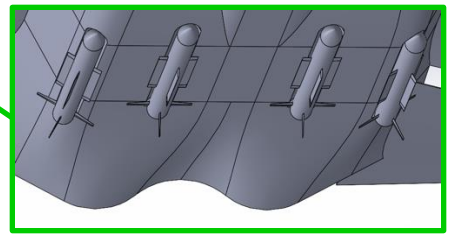




Belly pylon



Belly conformal



Corner conformal

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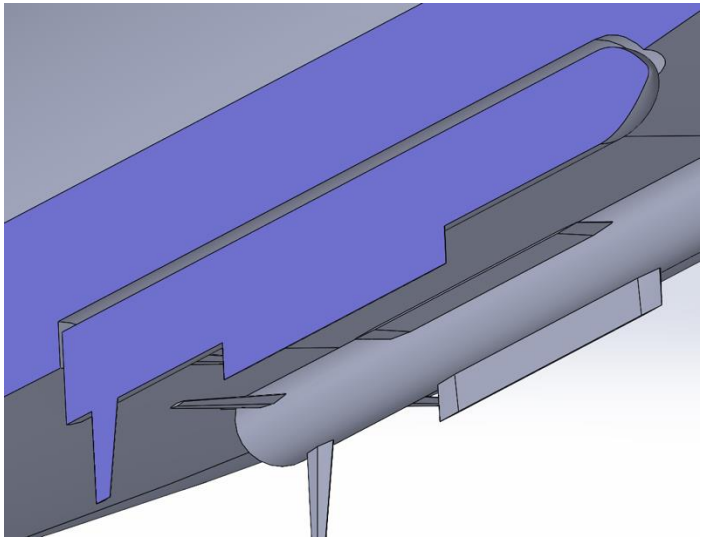
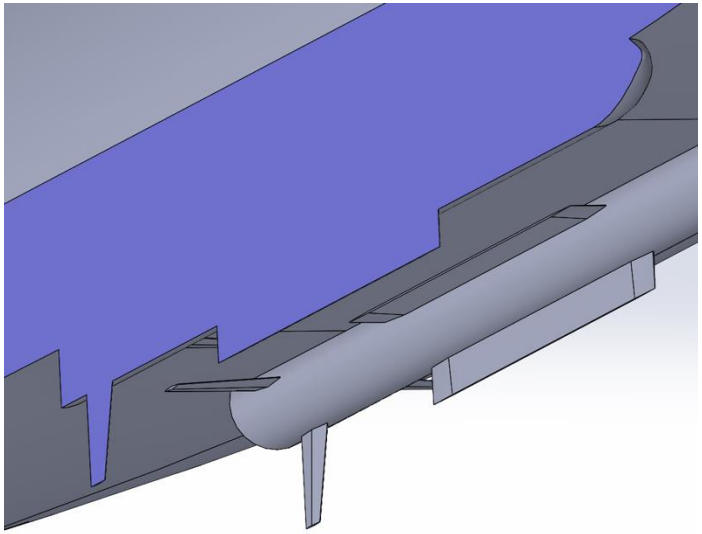
Conformal gap



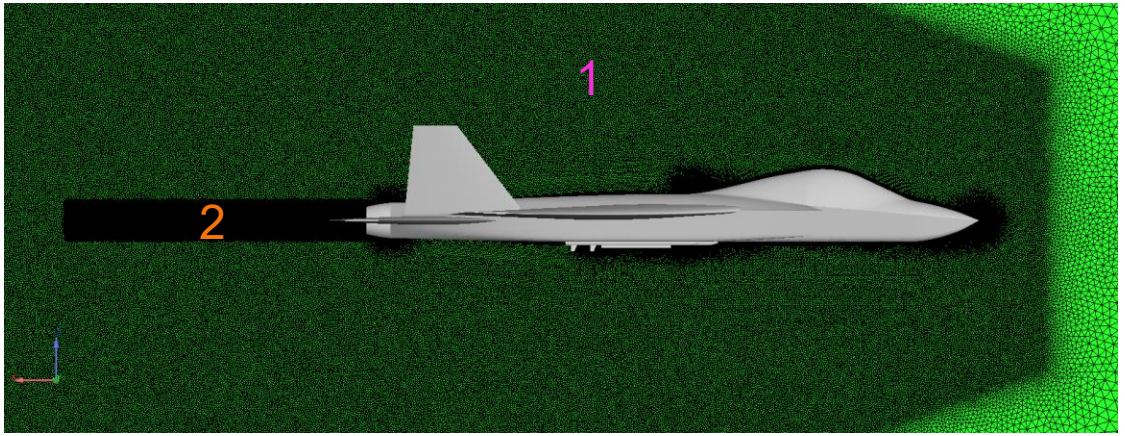
20 mm gap

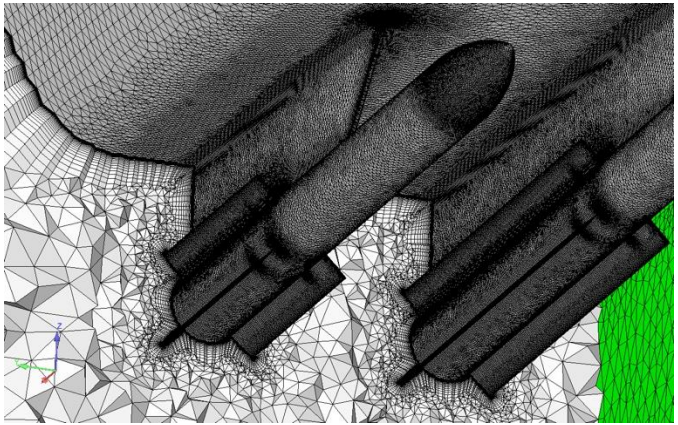


No gap

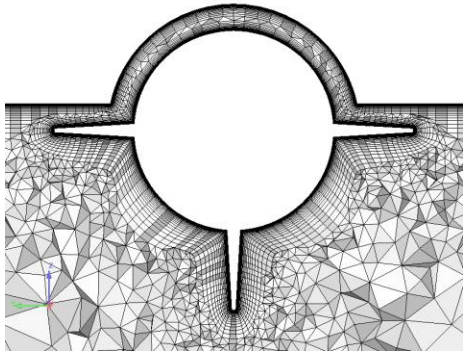
Mesh

Nodes	72 – 95 M
Surface mesh size	1.0 – 60.0 mm
Wall treatment	Resolved, $y^+ \sim 1$
BL initial height	1.0 μm
Refinement zone 1	60.0 mm
Refinement zone 2	10.0 mm

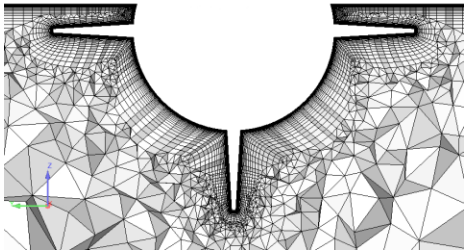




Belly pylon



Belly conformal
20 mm gap



Belly conformal
No gap

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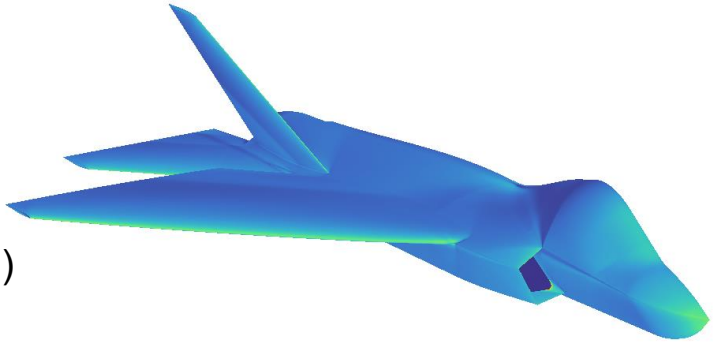
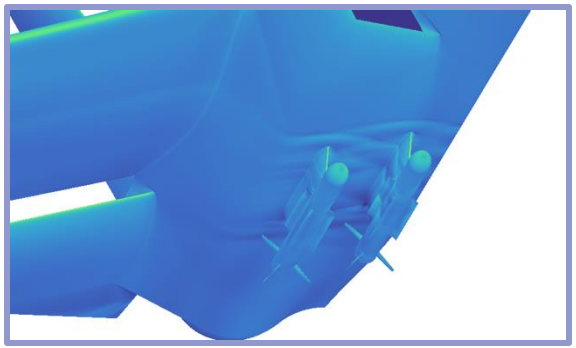
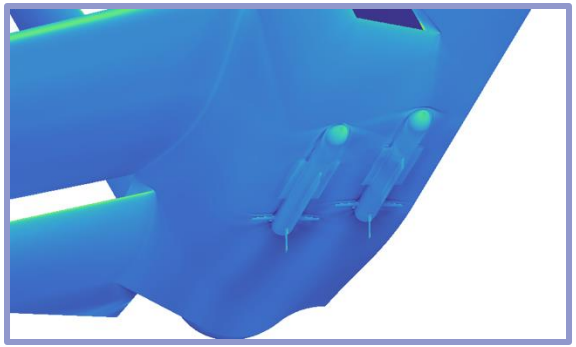
y^+

Mach 2.0, 0 km
(Highest shear stress)

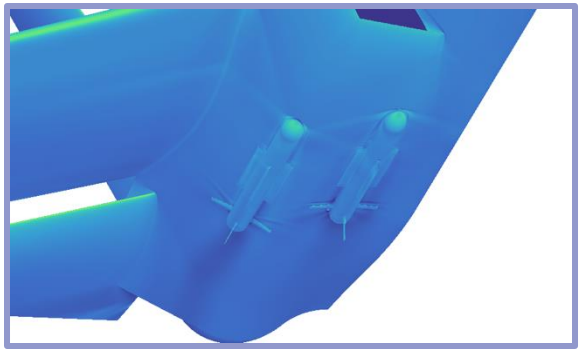




Belly pylon
Mean y^+: 0.58
Max y^+ : 3.15

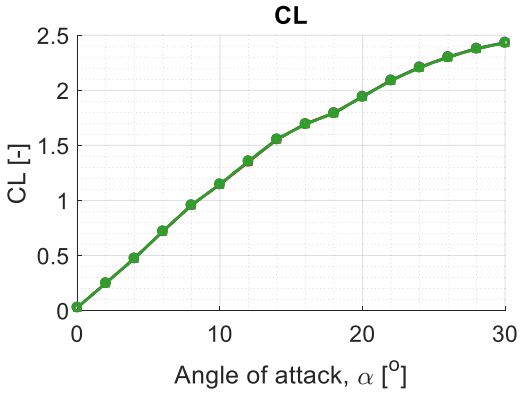


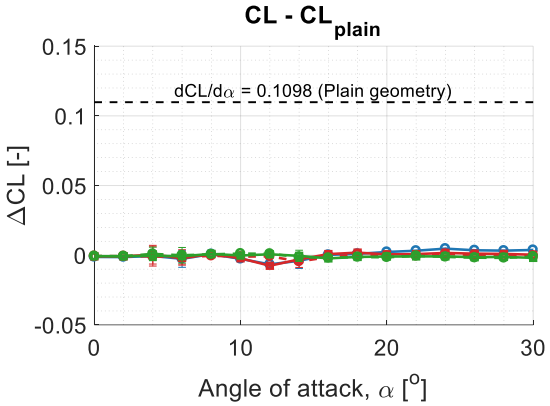
Belly conformal
Mean y^+: 0.57
Max y^+ : 3.87

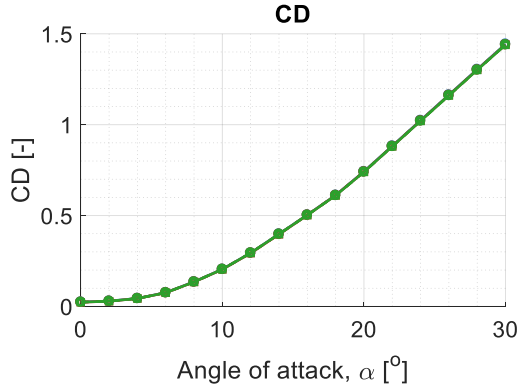


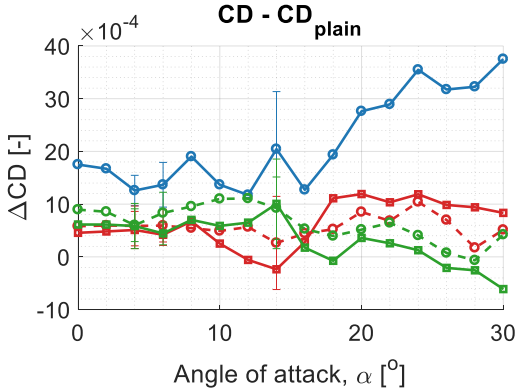
Corner conformal
Mean y^+: 0.57
Max y^+ : 3.64

Comparison – AoA
Mach 0.8, 10 km

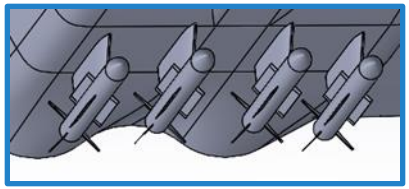






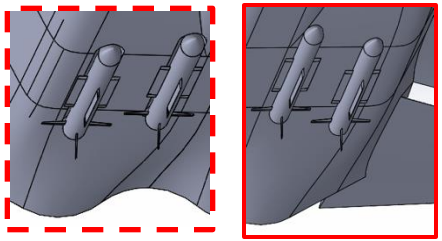


Belly pylon



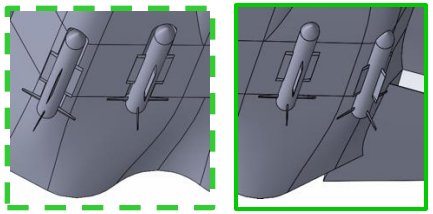
Belly conformal

20 mm gap | No gap



Corner conformal

20 mm gap | No gap



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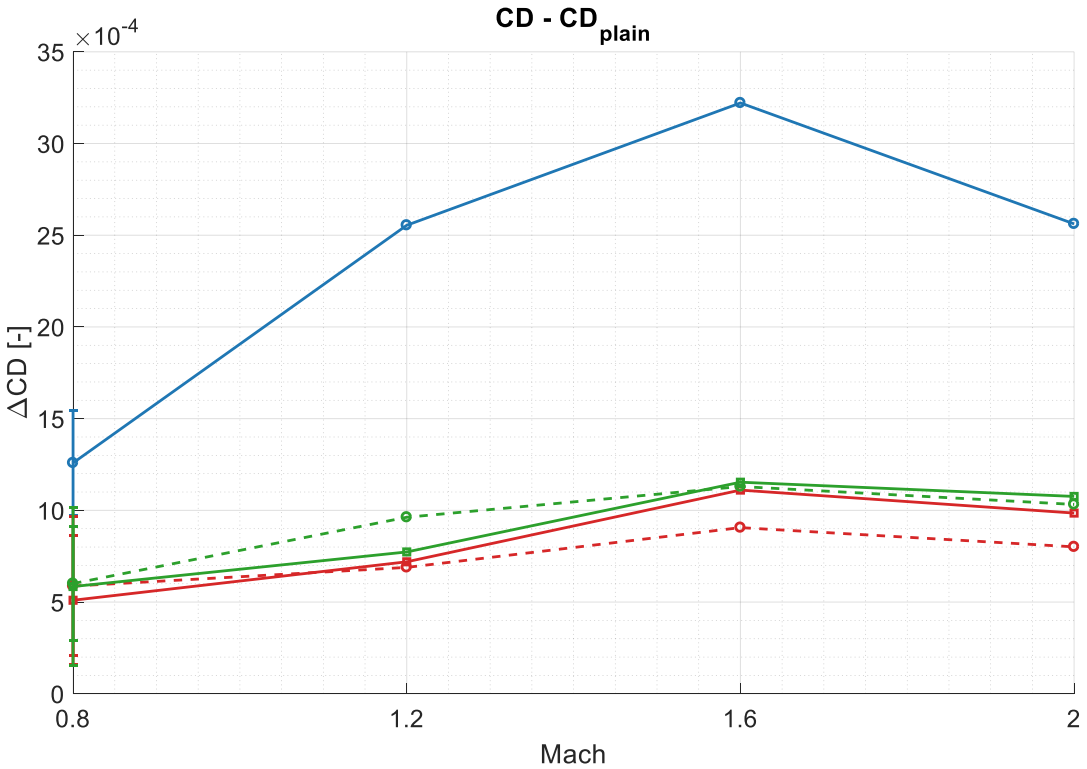
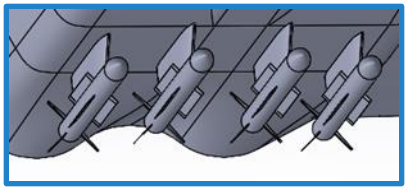
Comparison – Mach
α=4° 10 km

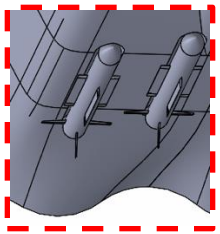


Belly pylon

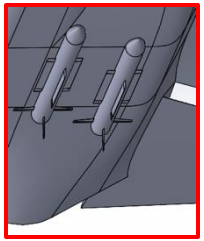


Belly conformal

20 mm gap

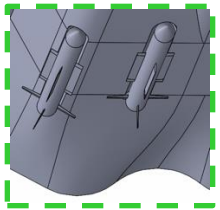


No gap

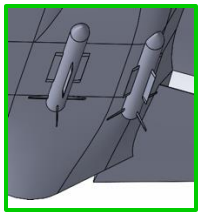


Corner conformal

20 mm gap

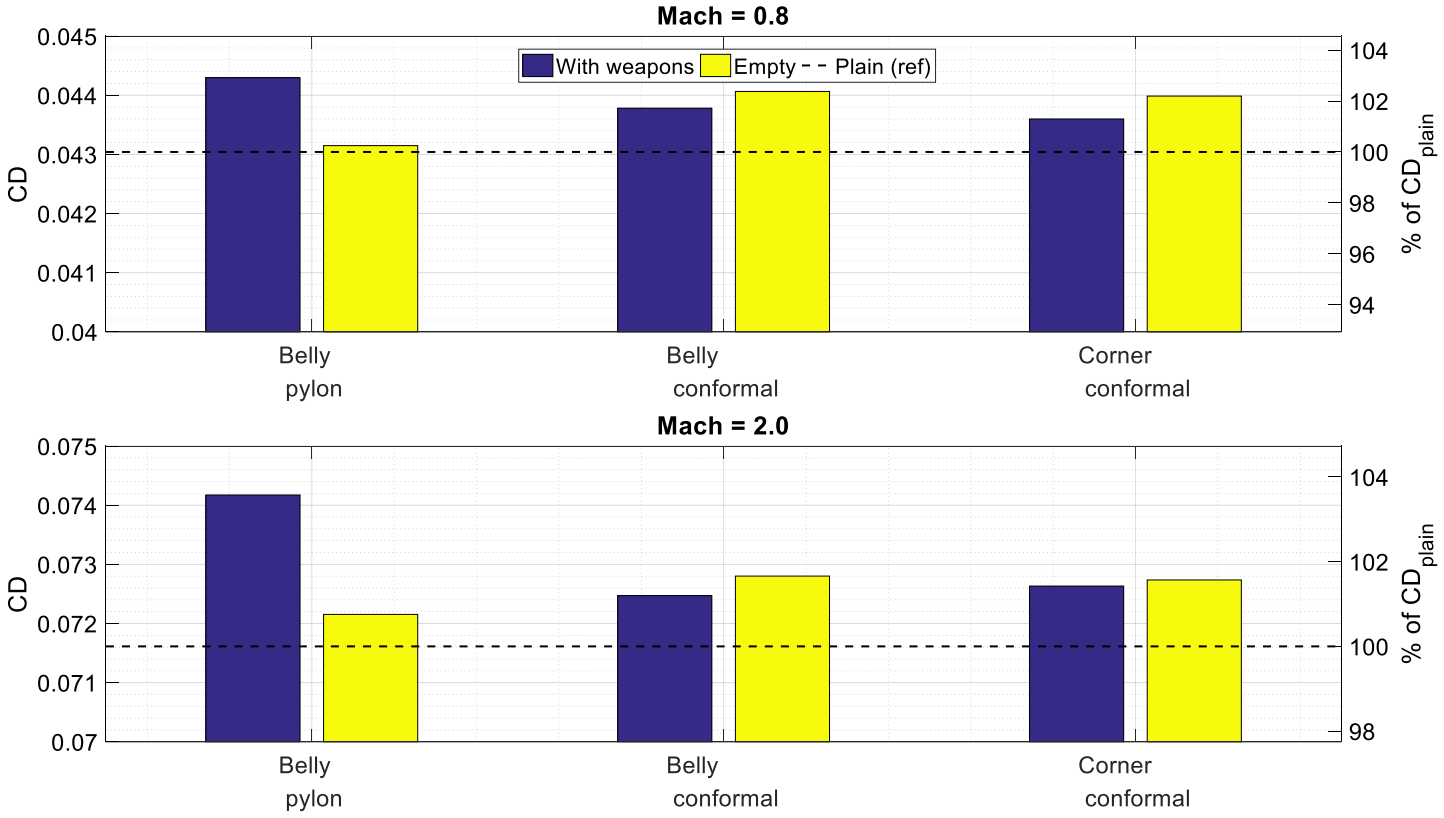


No gap



FOI

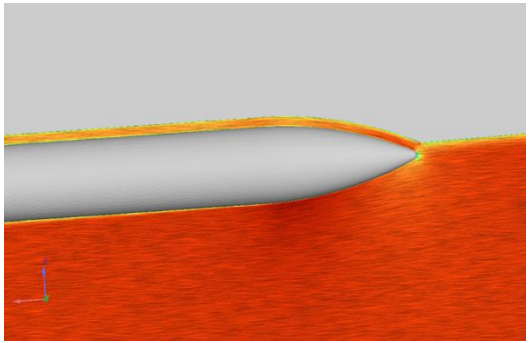
Comparison – Without missiles, 10 km, α=4°

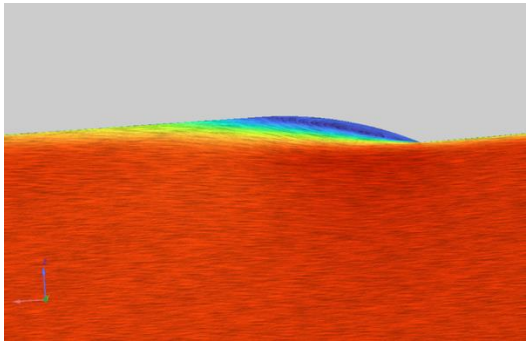


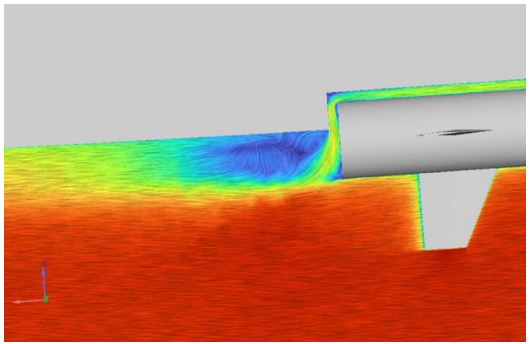
Comparison – Without missiles. Mach 0.8, 10 km, α=4°

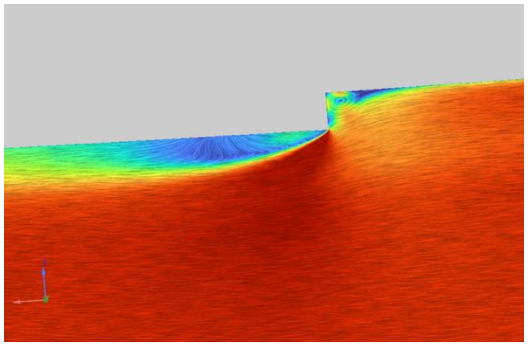
With weapon

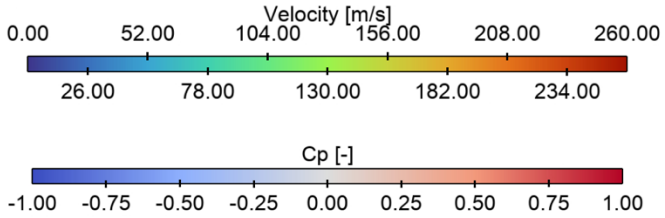
Empty

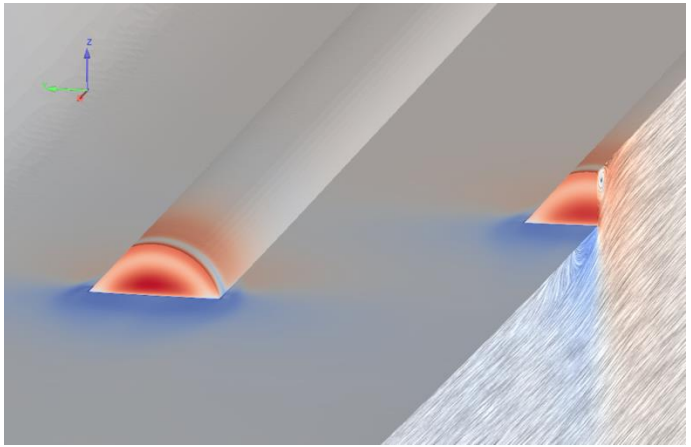












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Summary

- Insignificant effect on lift between geometry configurations
- 1.2–2.8 % of ”Plain” C_D reduction using conformal weapons compared to pylon mounts
- Pylon missiles highest drag, but conformal cavity drag higher than empty pylon drag
- Internal weapons not considered

FOI

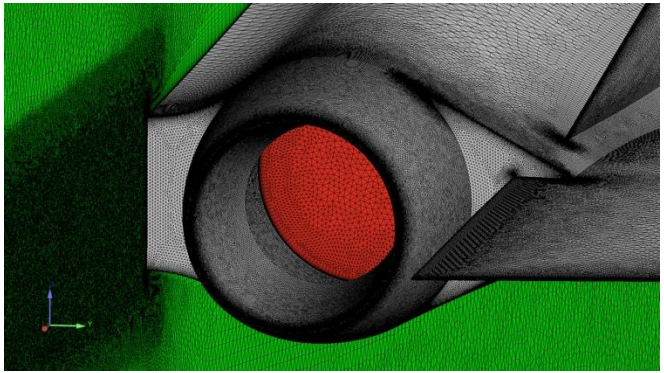
References

1. Eliasson, P., *EDGE, a Navier-Stokes solver for unstructured grids*. FOI-R-0298-SE. Swedish Defence Research Agency, FOI, 2002.
2. Tormalm, M. H., *The Influence of Scale Resolving Simulations in Predictions of Vortex Interaction about a Generic Missile Airframe*. AIAA 2022-1685, 2021.
3. Wallin, S. & Johansson, A. V., *An explicit algebraic Reynolds stress model for incompressible and compressible turbulent flows*. International Journal of Heat and Fluid Flows, **23**(5), 721-730.
4. MIL-E-5007D, *MILITARY SPECIFICATION: ENGINE, AIRCRAFT, TURBOJET AND TURBOFAN, GENERAL SPECIFICATION FOR (15 OCT 1973)*

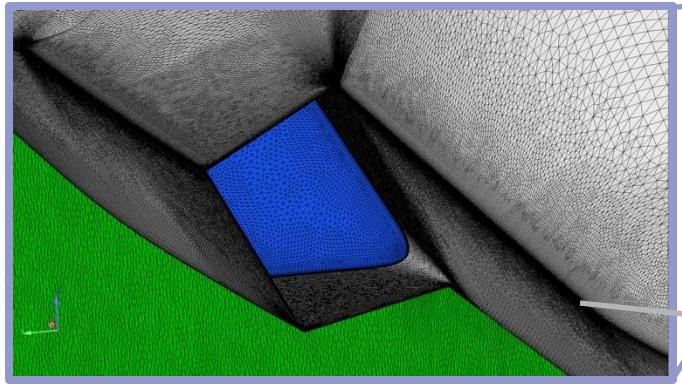
Additional material

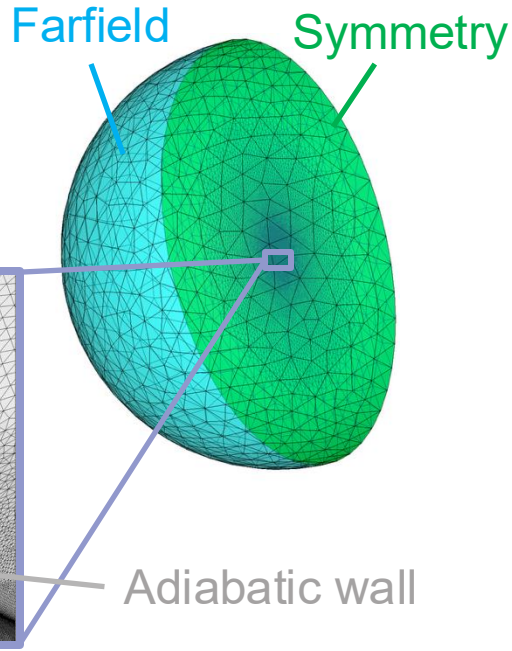
Boundary conditions

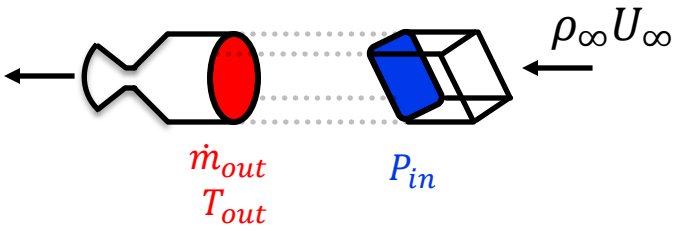
Mass flow rate



Static pressure





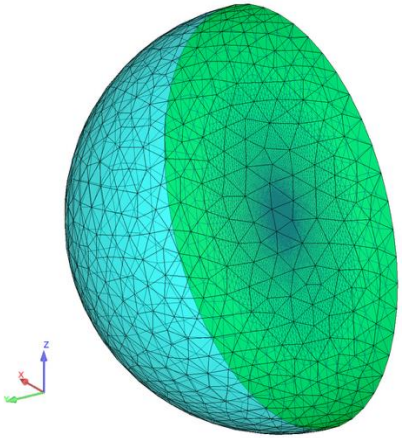


Across all cases:

$$0.97 < \frac{\dot{m}_{in,CFD}}{\rho_\infty A_{in} U_\infty} < 1.05$$

FOI

Mesh & BCs



Farfield, Symmetry,

Static pressure

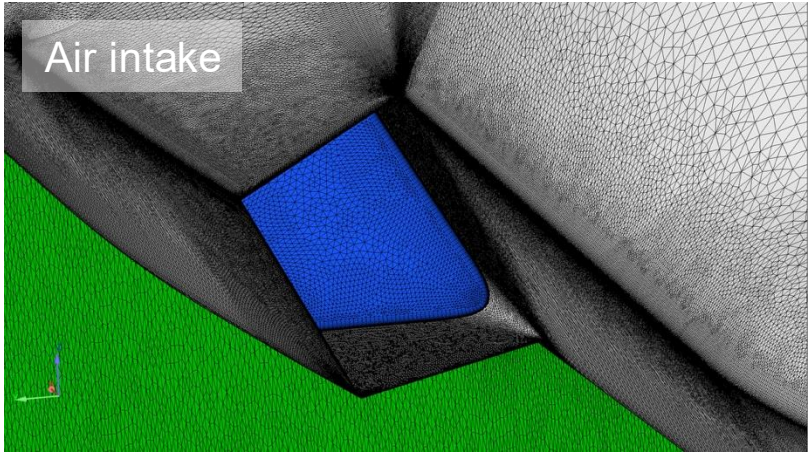
$$\begin{cases} P_{in} = P_\infty, & M_\infty \le 1 \\ P_{in} = P_\infty(1 - 0.075(M_\infty - 1)^{1.35}), & M_\infty > 1. \end{cases} \quad [4]$$

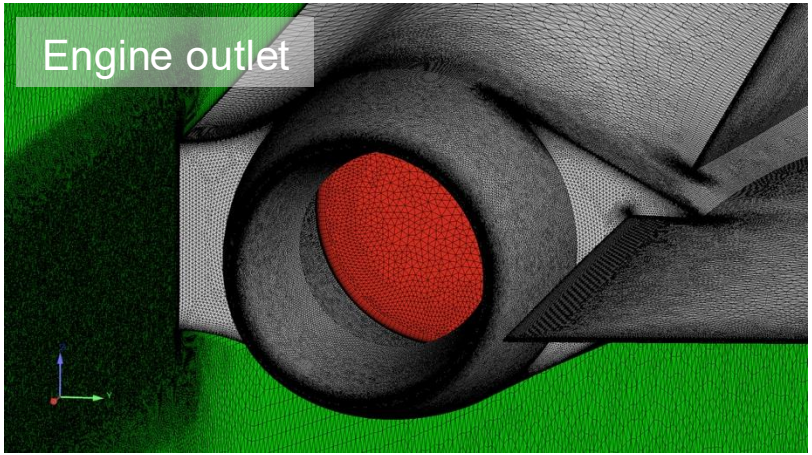
Flow ratio $0.97 < \dfrac{\dot{m}_{in,CFD}}{\rho_\infty A_{in} U_\infty} < 1.05$

for all cases.

Mass flow

$\dot{m}_{out} = \rho_\infty A_{in} U_\infty, \quad T_{out} = 1000\ K$





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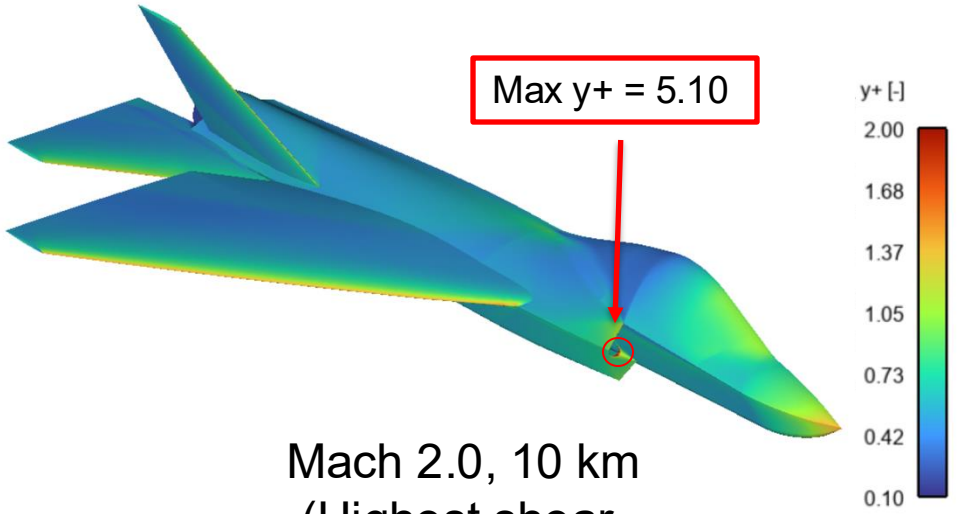
Mesh independence & y+

Plain w/o weapons

Mesh	Coarse	Medium	Fine*
# of Nodes	16 M	72 M	179 M
C_L	0.0121	0.0122	N/A
C_D	0.0231	0.0230	N/A
C_{MY}	-0.0164	-0.0162	N/A

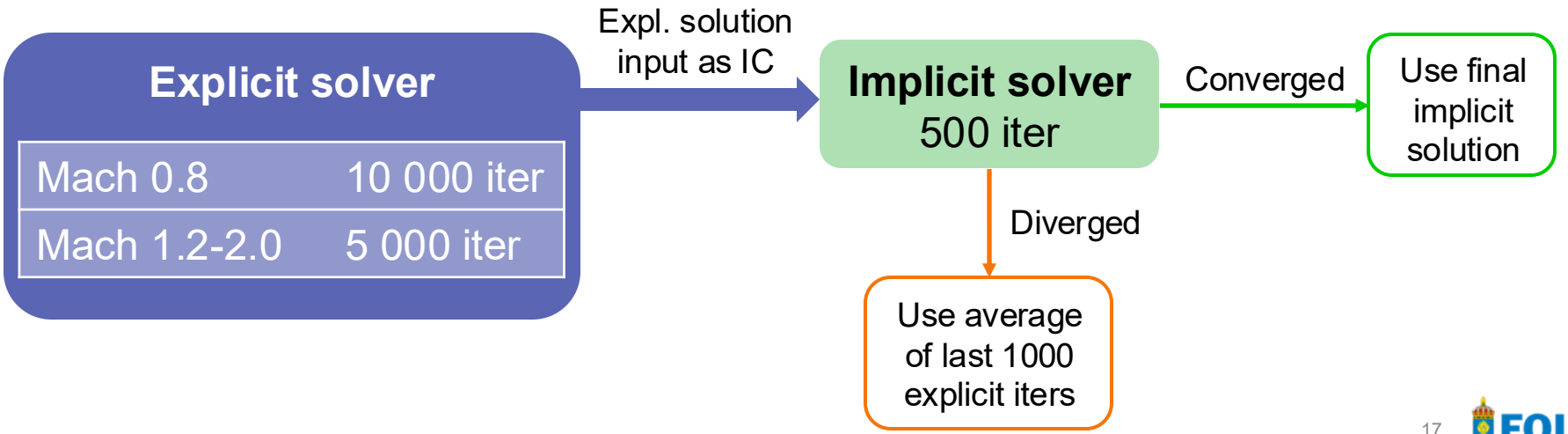
*: Failed mesh processing due to size



Mach 2.0, 10 km
(Highest shear
stress case)

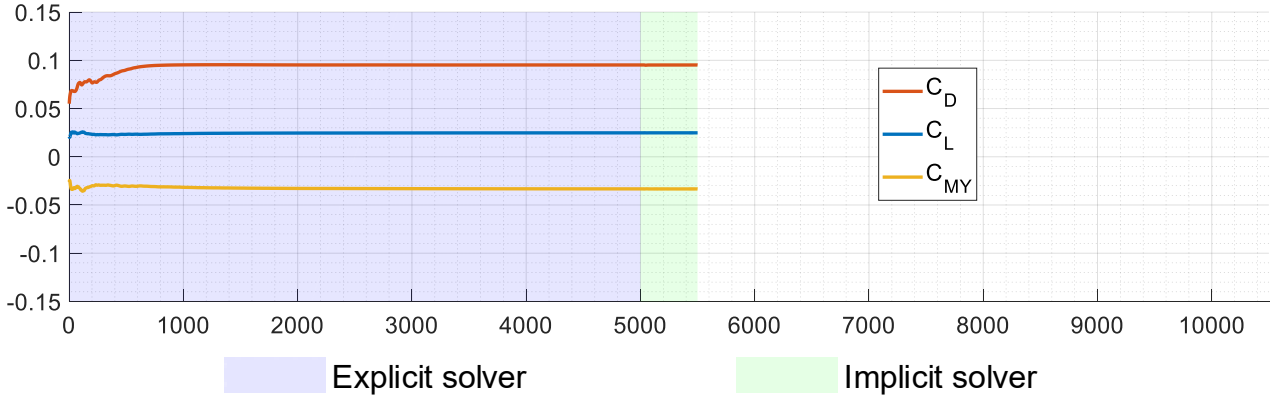
Solver

- Turbulence model: **W&J EARSM + Hellsten k-omega** [3]
- Multigrid & Implicit residual smoothing utilized

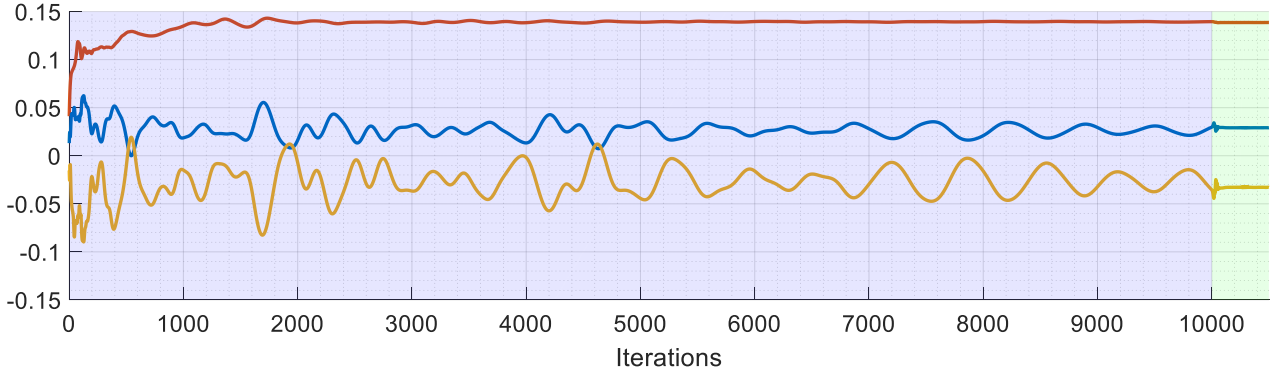


Example: Plain geometry, 10km, α=0°

Mach 2.0



Mach 0.8



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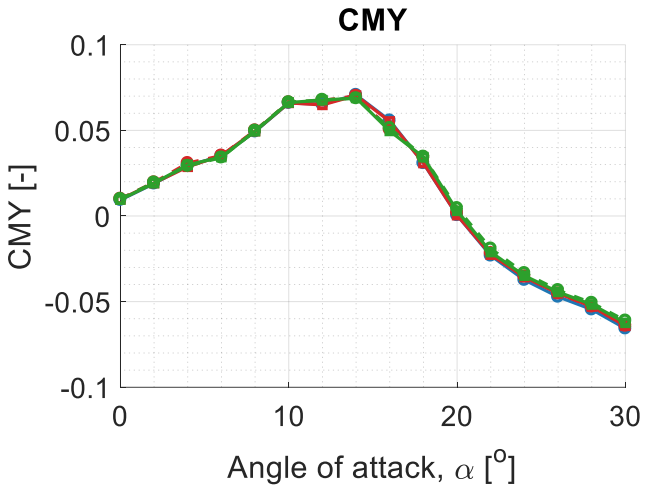
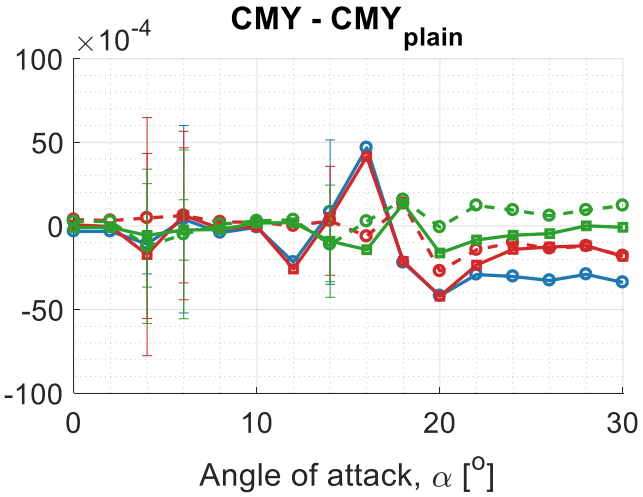
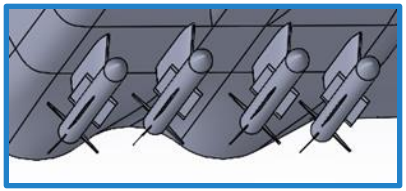
Comparison – CMY vs. α at neutral point
Mach 0.8, h=10 km





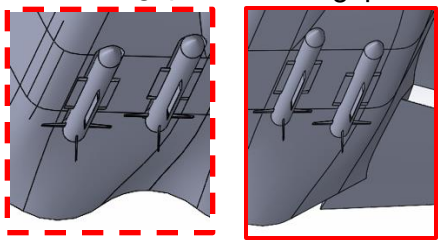
Belly pylon



Belly conformal

20 mm gap

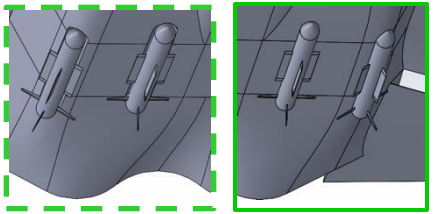
No gap



Corner conformal

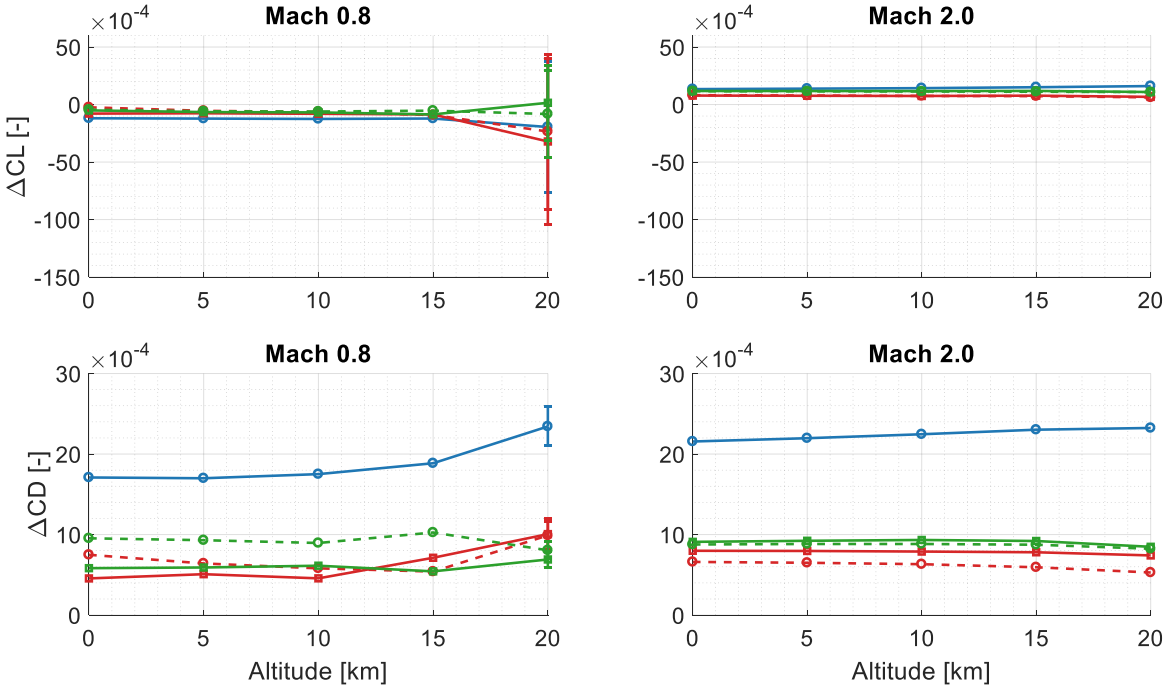
20 mm gap

No gap

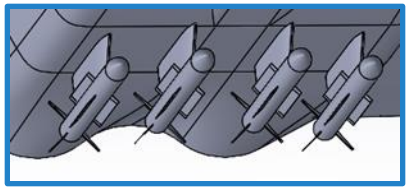


FOI

Comparison – Altitude, α=0°

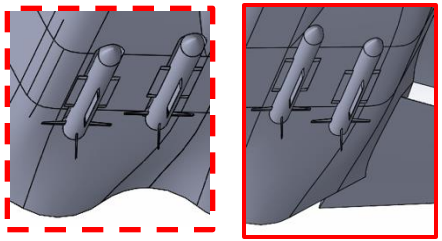


Belly pylon



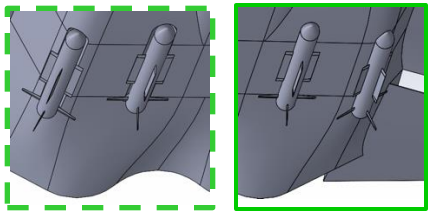
Belly conformal

20 mm gap | No gap



Corner conformal

20 mm gap | No gap



FOI