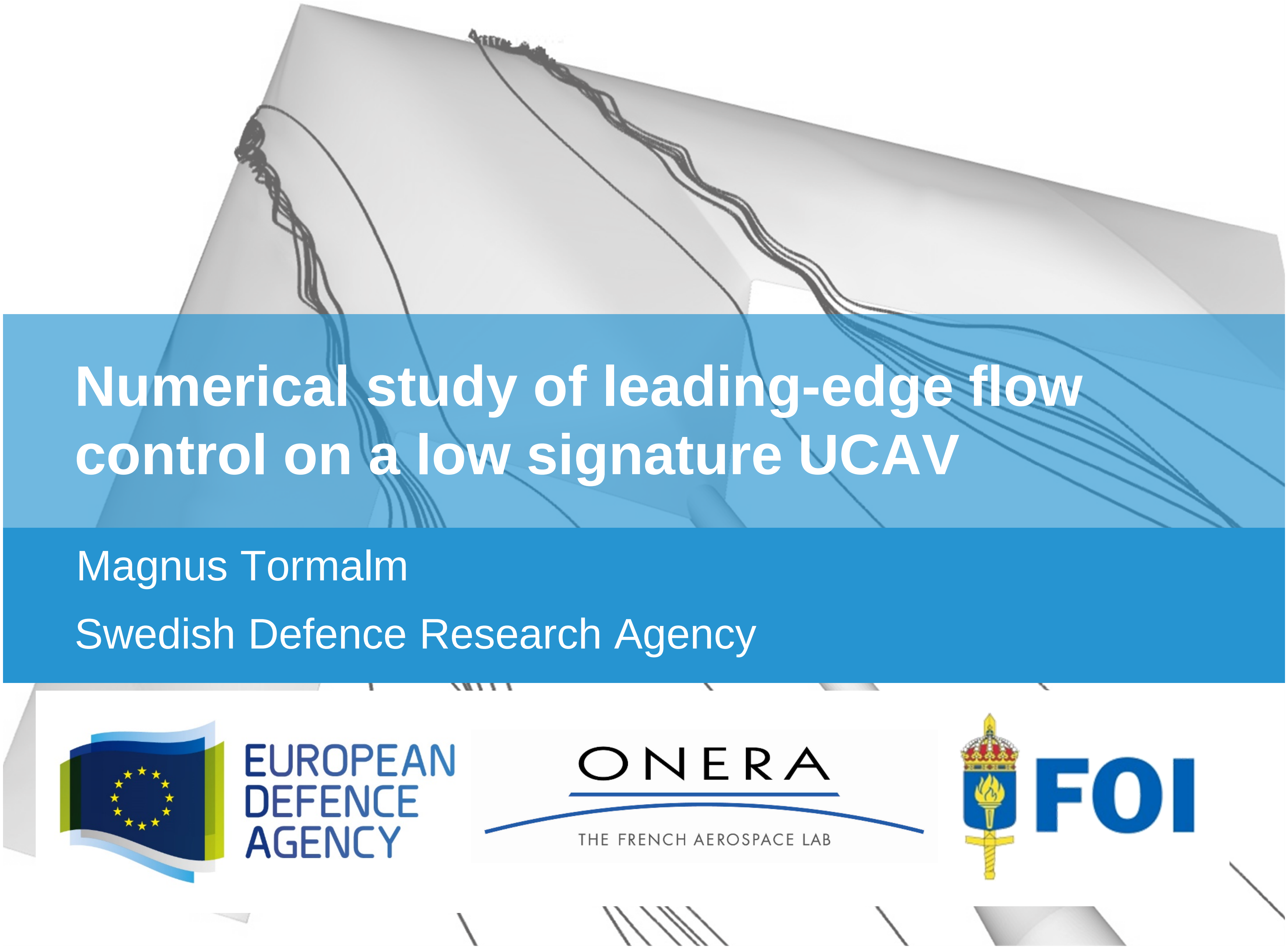
Numerical study of leading-edge flow control on a low signature UCAV



Magnus Tormalm

Swedish Defence Research Agency

EUROPEAN DEFENCE AGENCY

ONERA THE FRENCH AEROSPACE LAB

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The EDA project LECoLoS

- Leading Edge fluidic flow Control of Low Signature UCAV
- Second Joint Investment Programme on Innovative Concepts and Emerging Technologies (JIP-ICET2)
- Started 2015-03-16, duration 24 months, ~30 MM
- Budget 780 k€, EDA contribution 650 k€ (83%)
- Partners:
  - ONERA - Experimentally evaluate LE fluidic control
  - FOI - Numerically design fluidic LE control and validate experimental result
  - PFB (Plastiques Façonnés du Béthunois) - Manufacturing of LE inserts
- Follow work done in NATO STO AVT-161, 201

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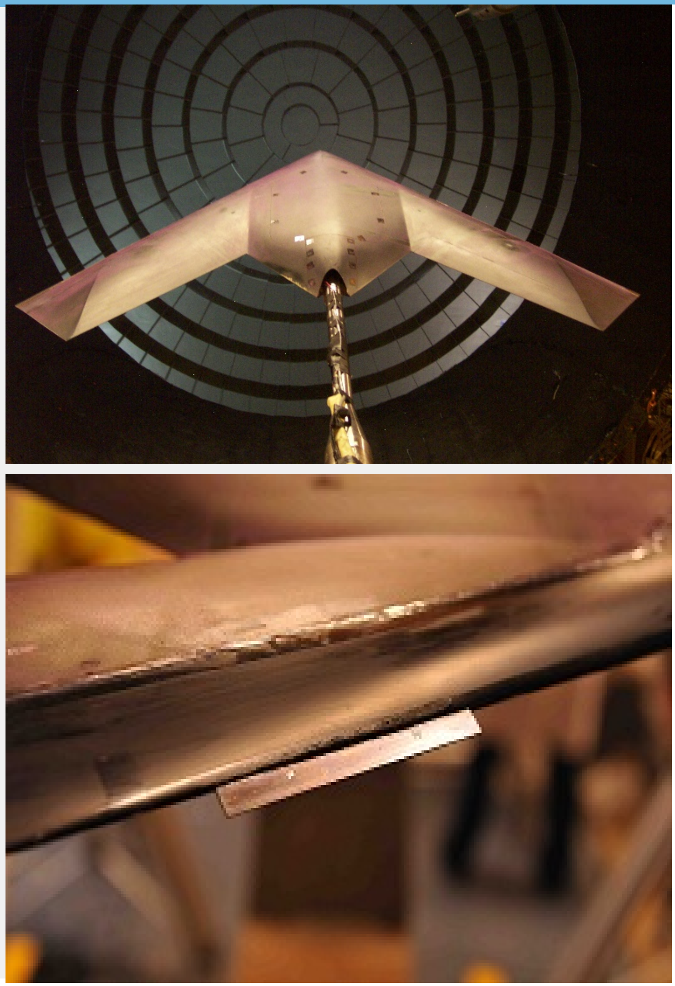
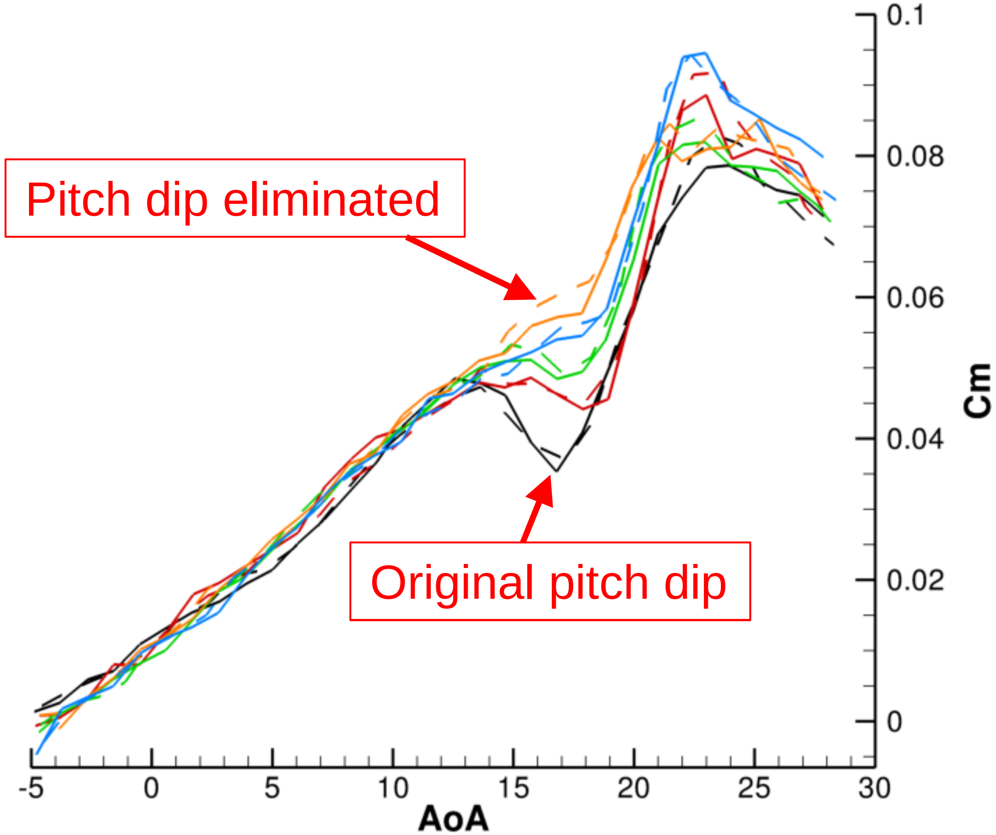
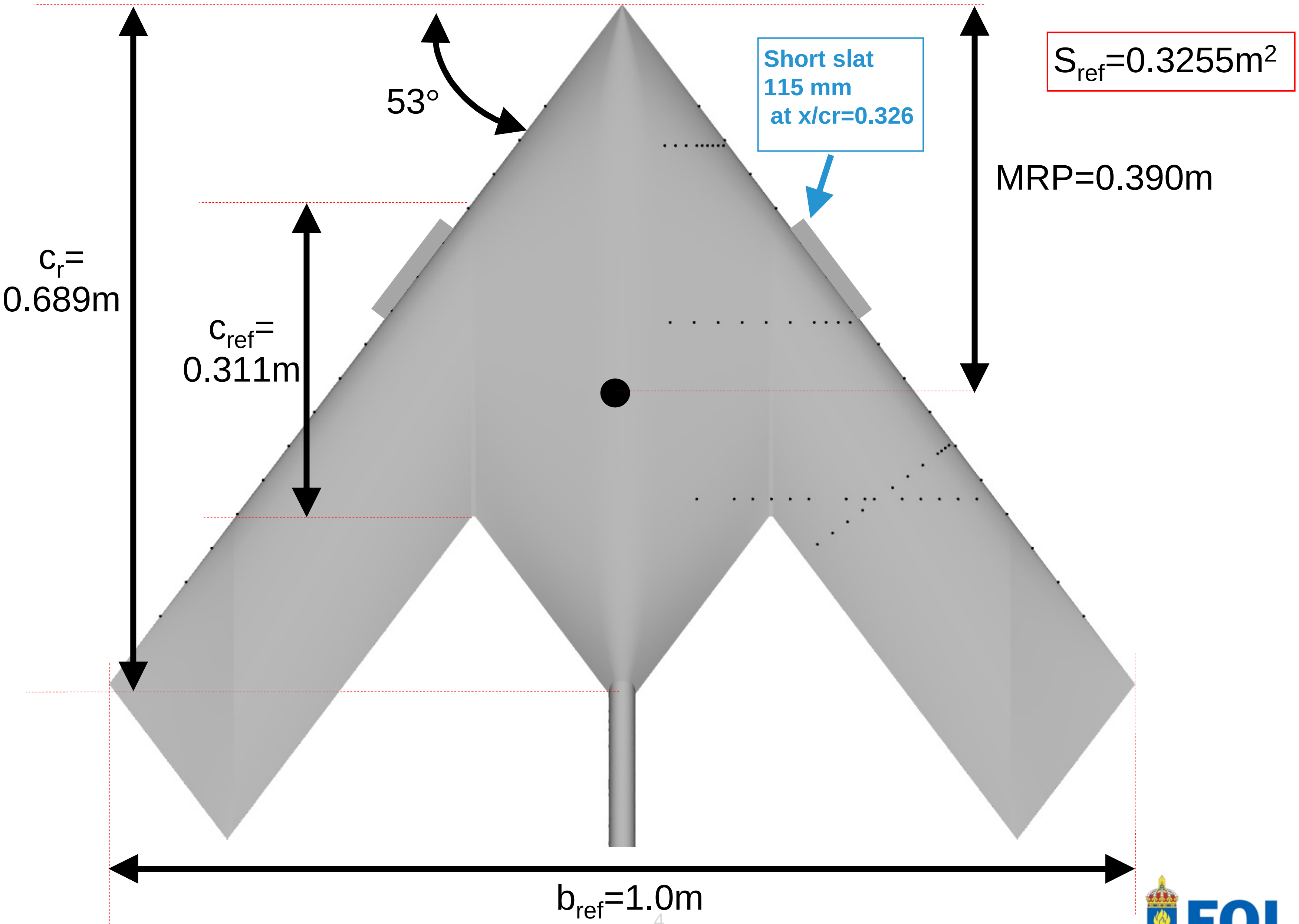
Previous work by ONERA on mechanical slat



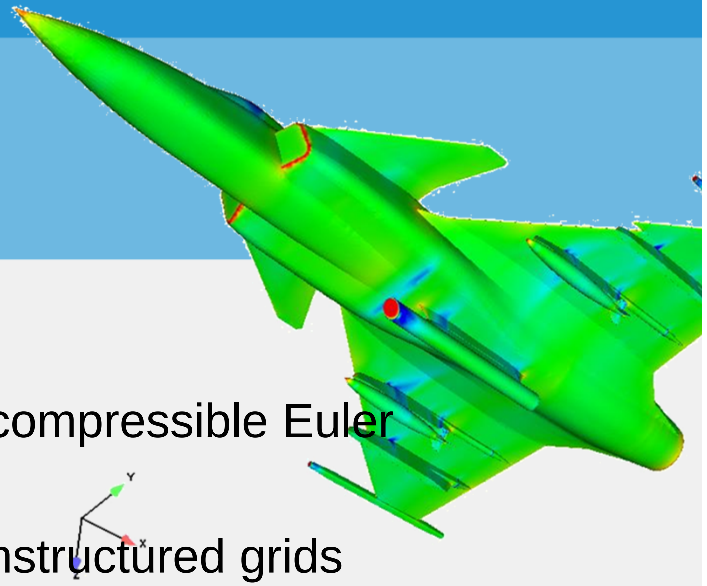
Result from NATO AVT-201 experiment



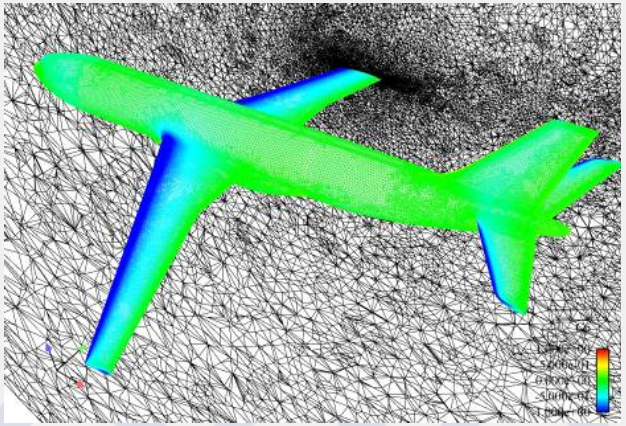
The ONERA SACCON geometry



The flow solver M-Edge

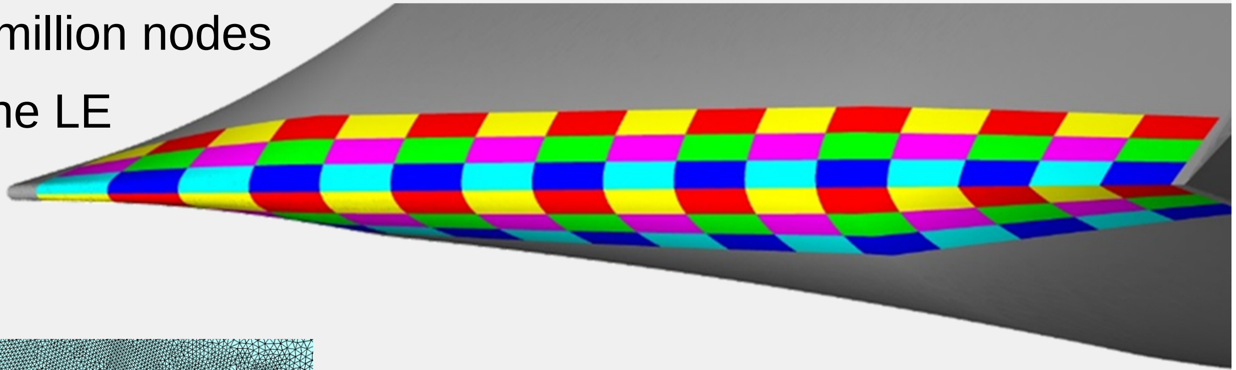


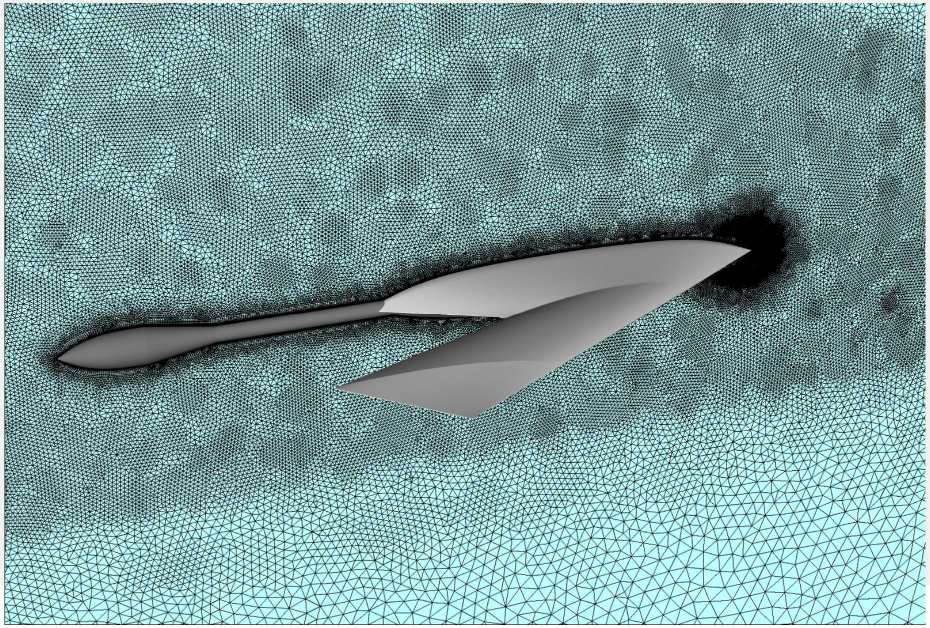
- Developed at FOI since 1997
- Node centered, finite volume flow solver for the compressible Euler and Navier-Stokes
- Steady state and time dependent solutions on unstructured grids
- Dual mesh, fully parallel, high efficiency
- Functionalities:
  - Aeroelastic capabilities
  - Many turbulence models
  - Models for flow control, inlet distortion analysis
  - Adjoint solver for shape optimization
  - Coupling to transition prediction tools
- Enable implementation of unique capabilities

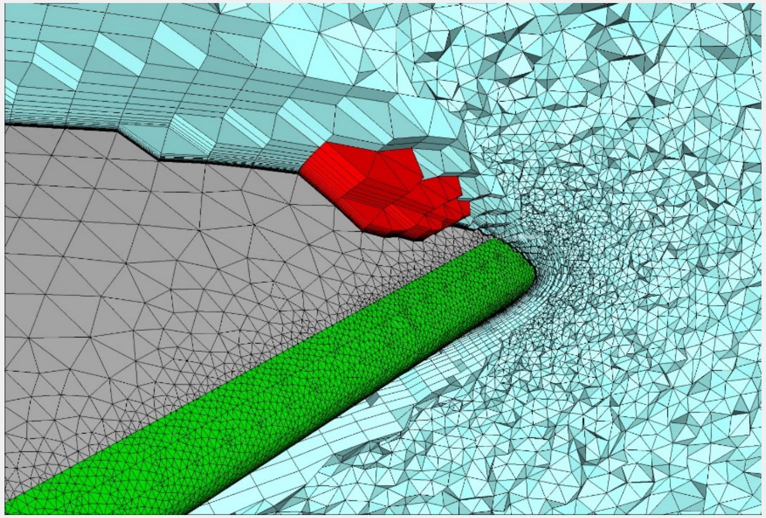


The FOI mesh

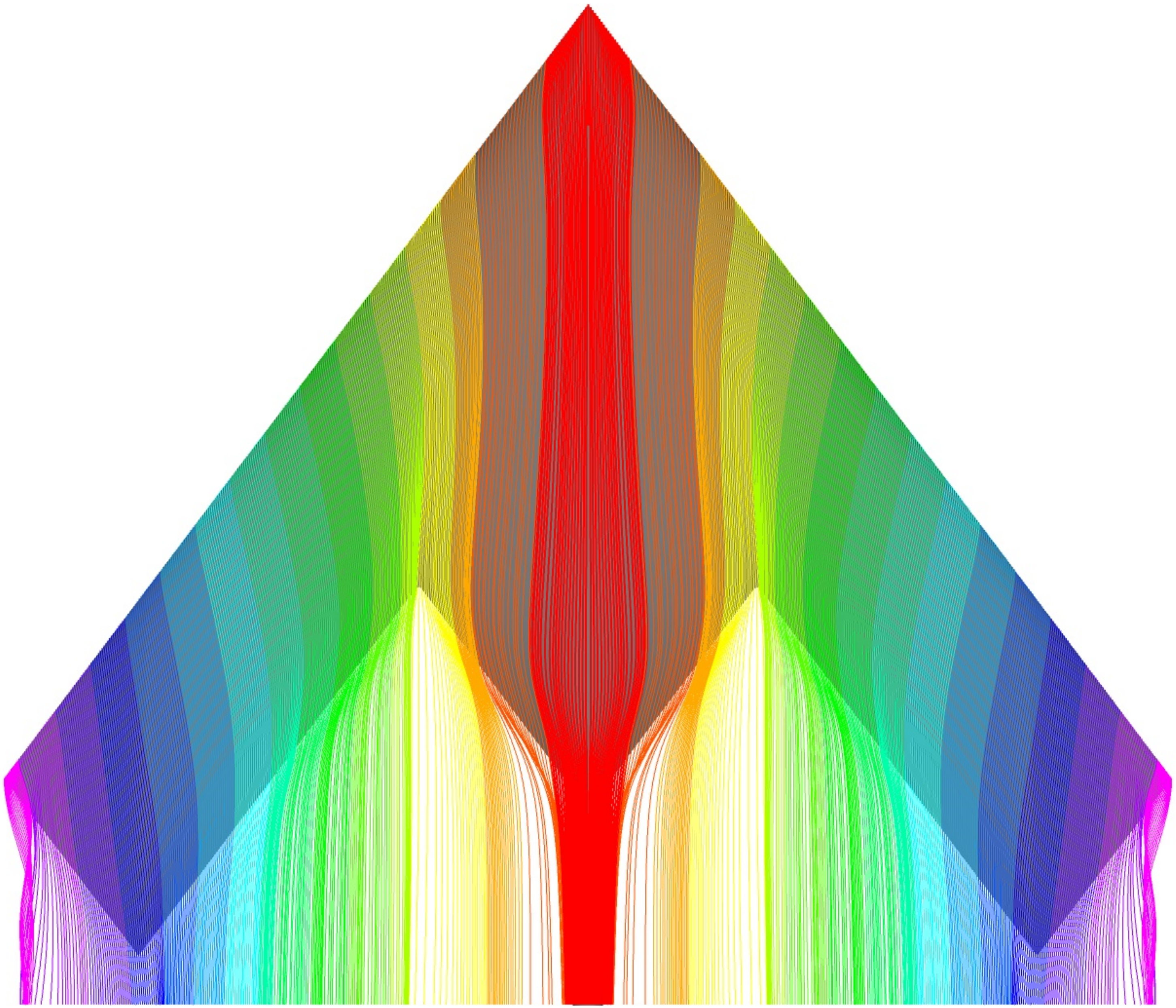
- 7 meshes from 4 to 70 million nodes
- 96 surface patches at the LE
- Slot/patch: 1x50 mm
- Half span only



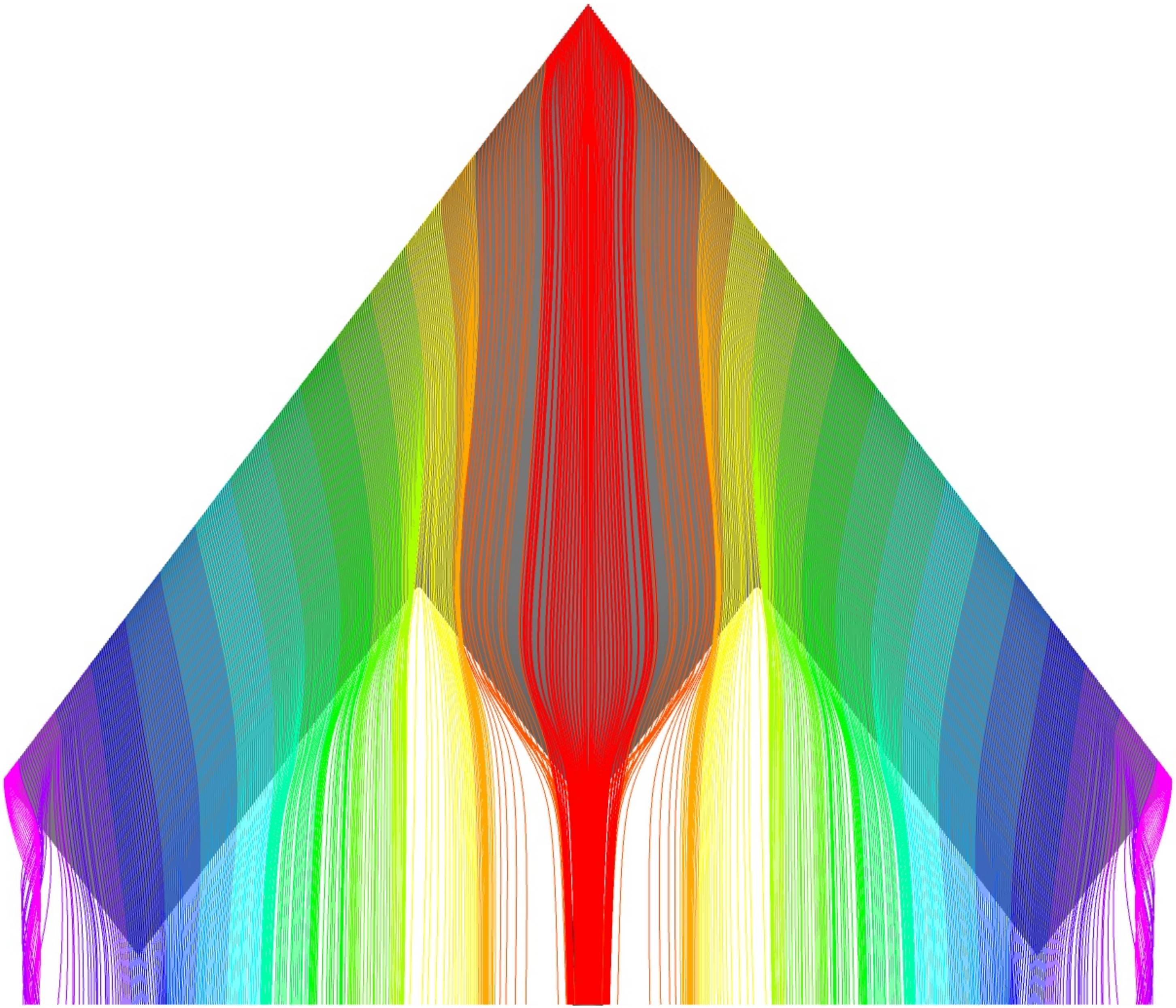




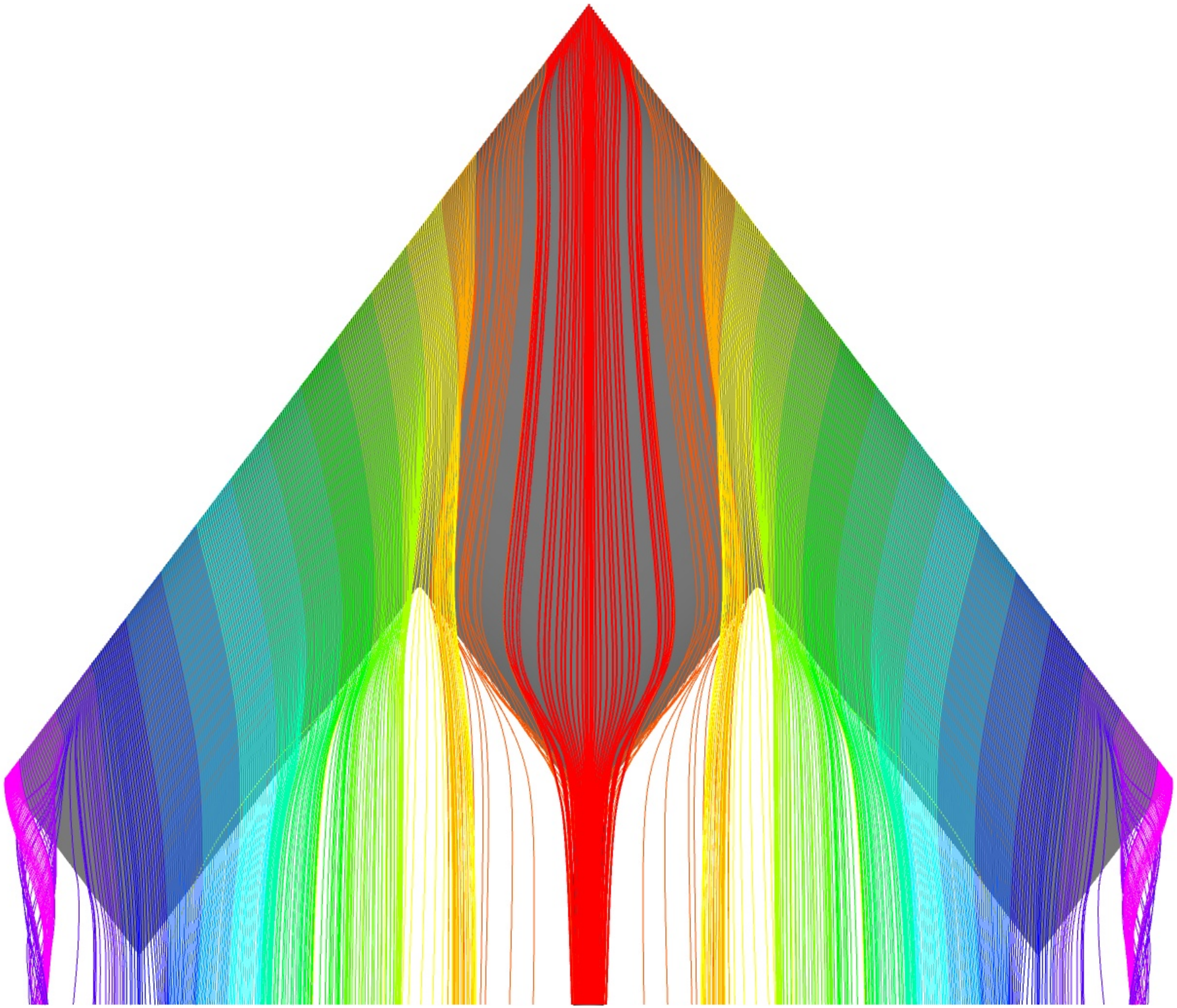
Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 8.00, AoS_{∞}= -0.00



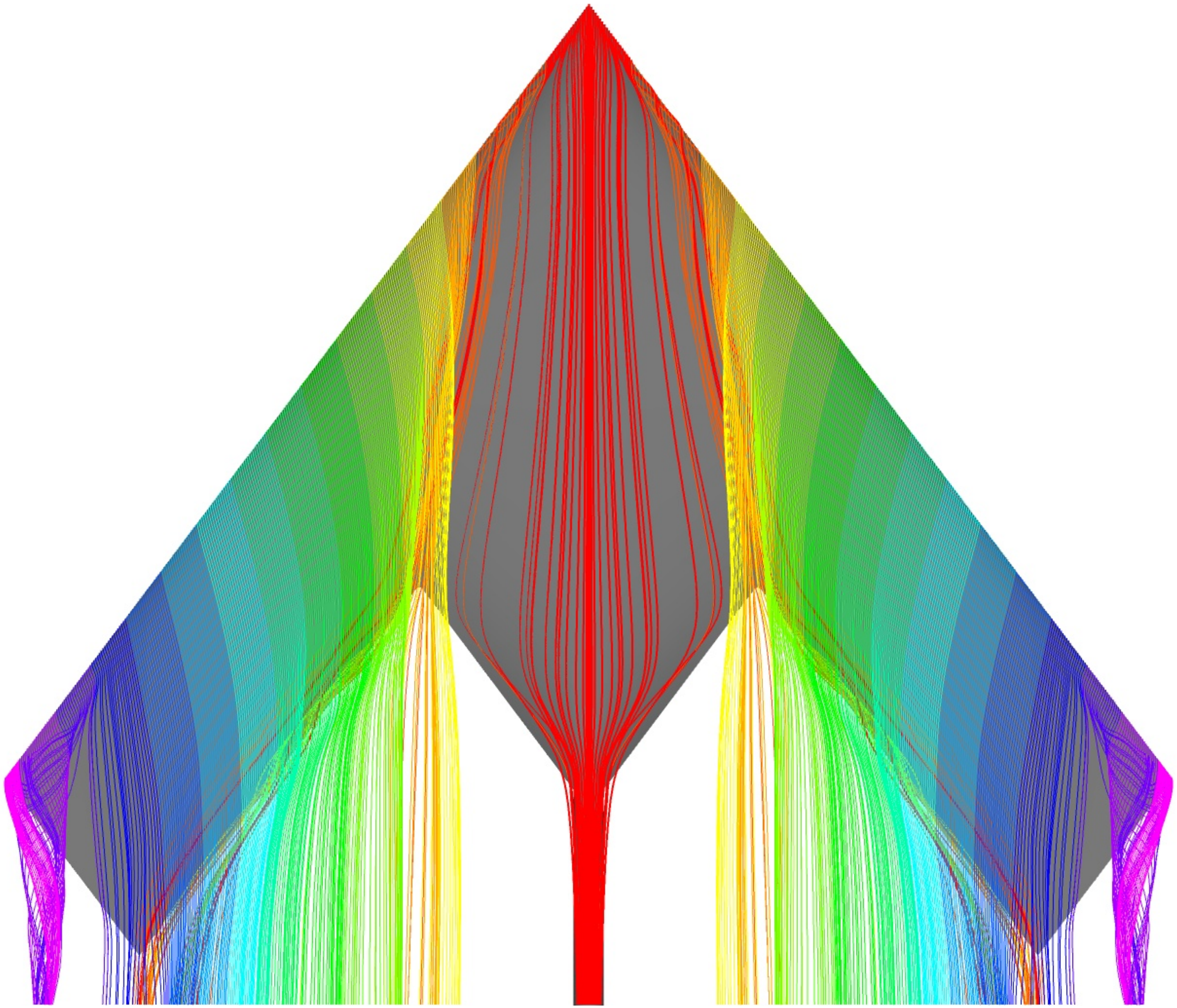
Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 9.00, AoS_{∞}= -0.00



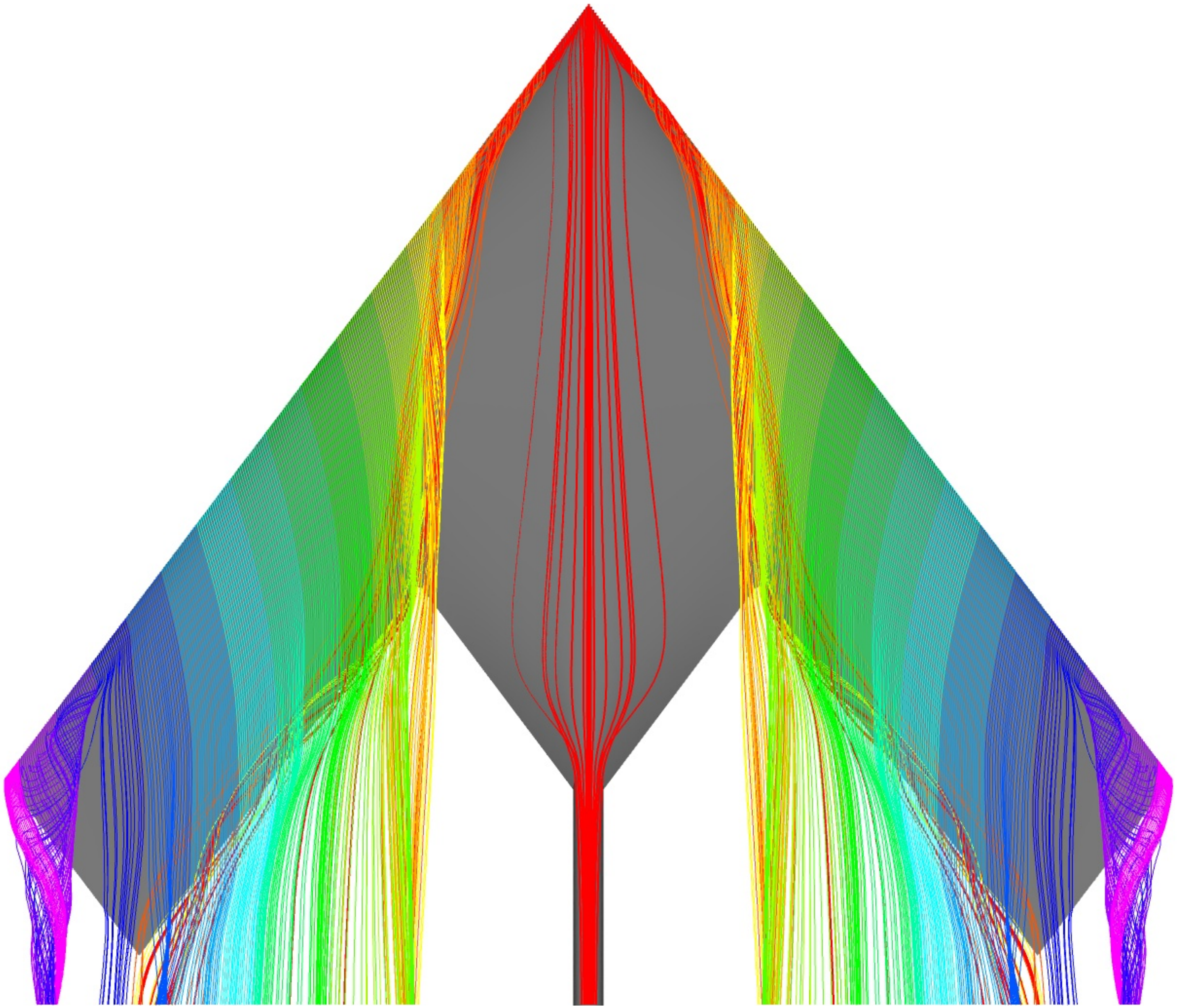
Lecolos: $Mach_\infty$= 0.15, V_∞= 50.00m/s, AoA_∞= 10.00, AoS_∞= -0.00



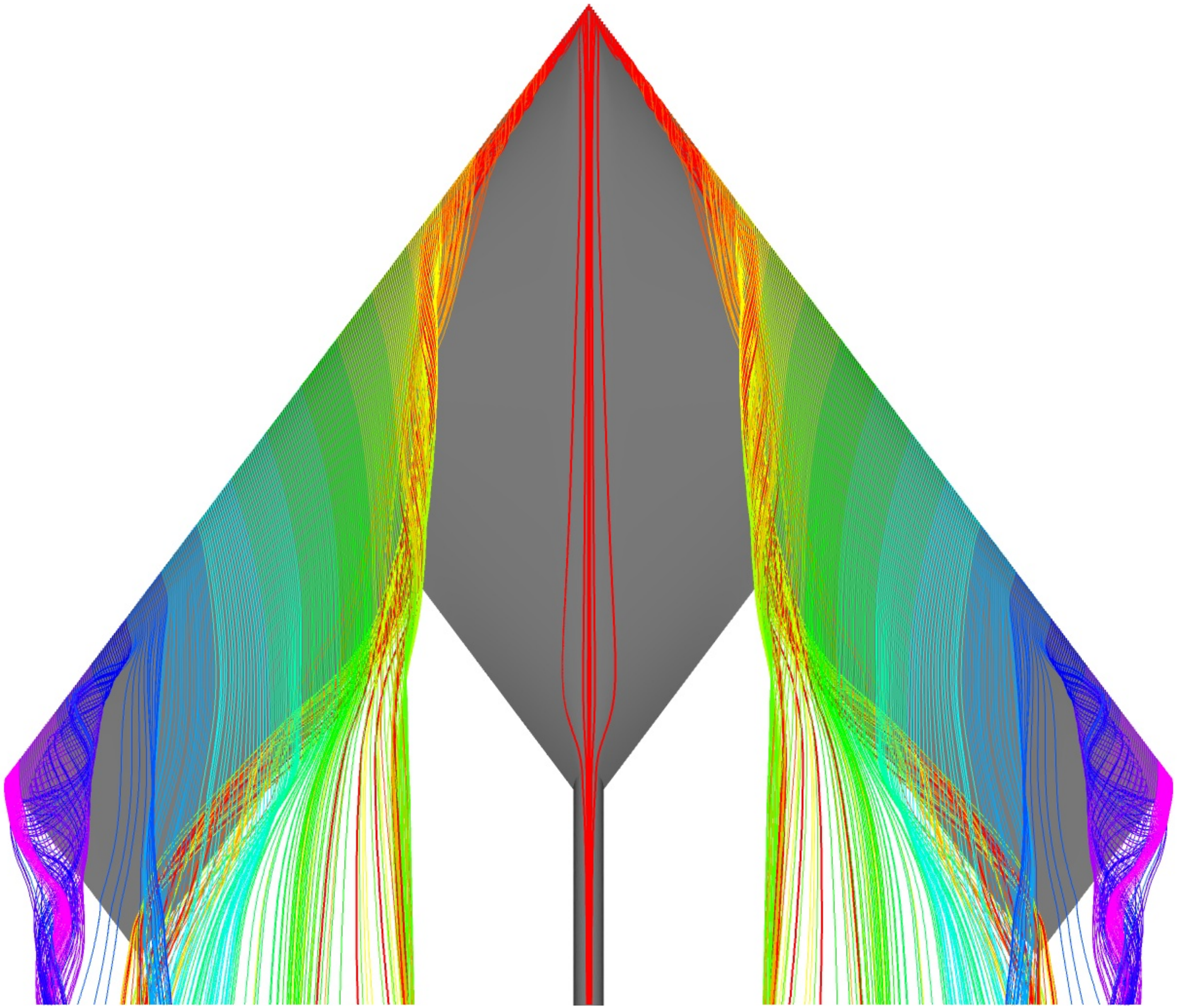
Lecolos: $Mach_\infty$= 0.15, V_∞= 50.00m/s, AoA_∞= 11.00, AoS_∞= -0.00



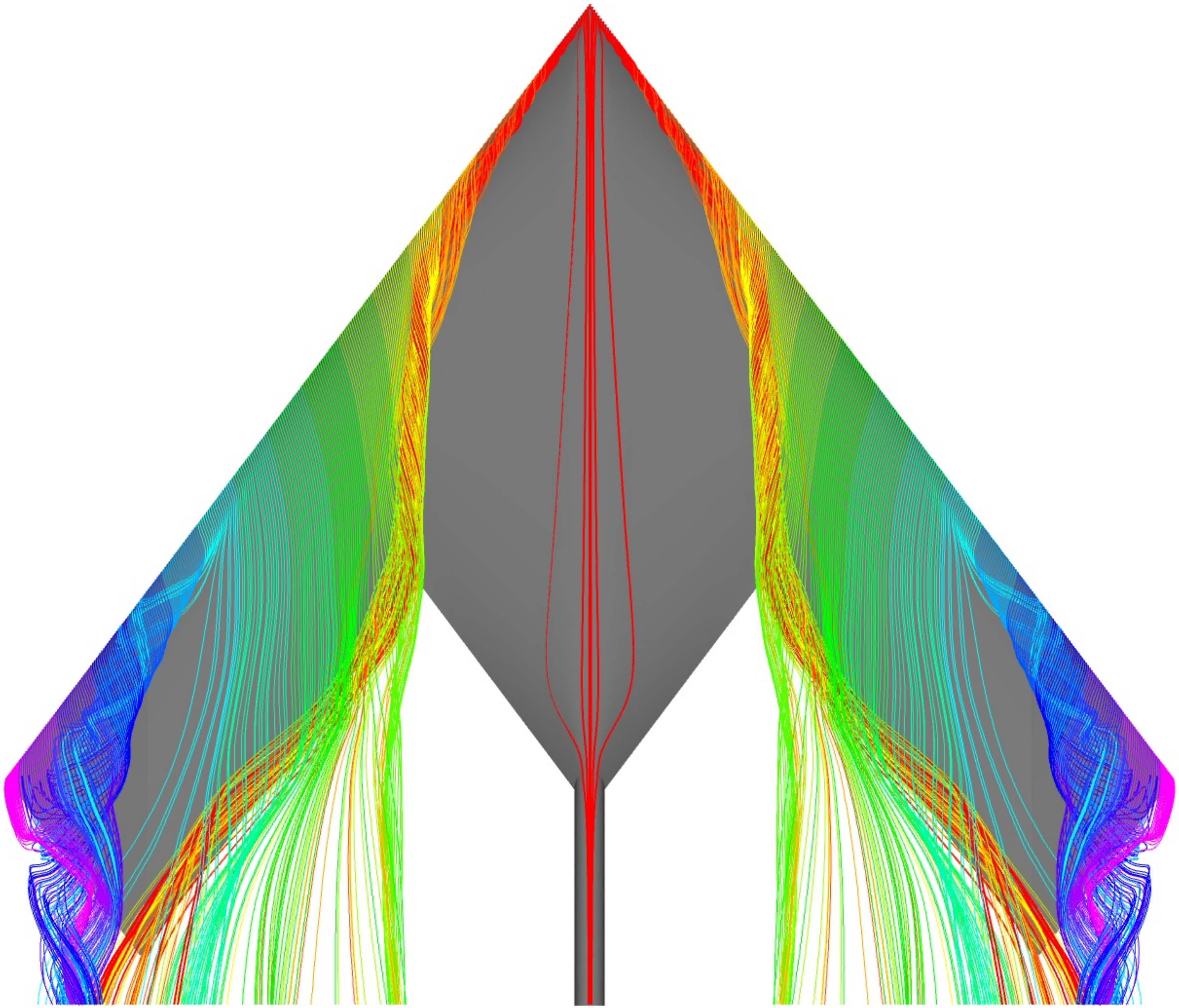
Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 12.00, AoS_{∞}= -0.00



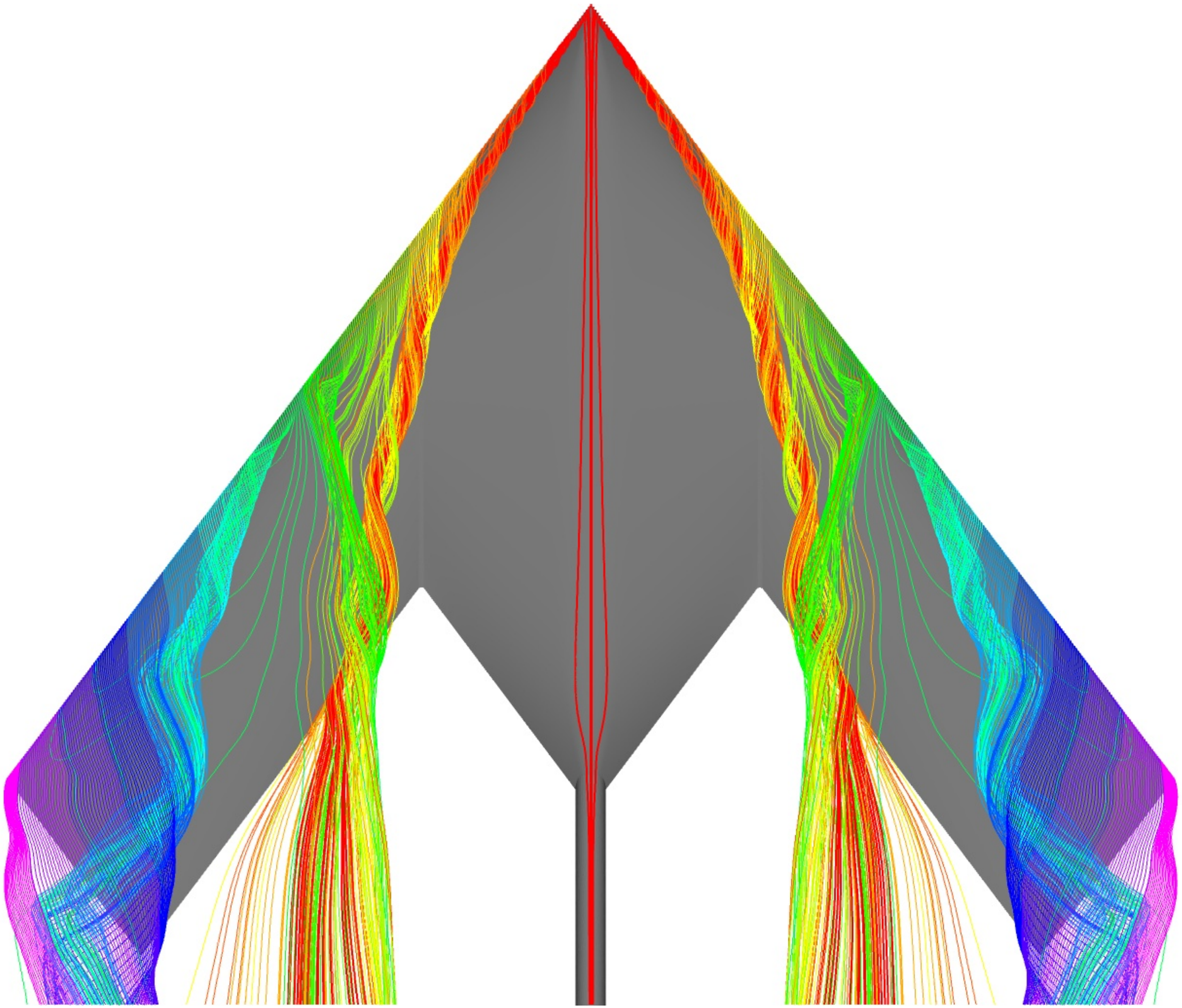
Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 13.00, AoS_{∞}= -0.00



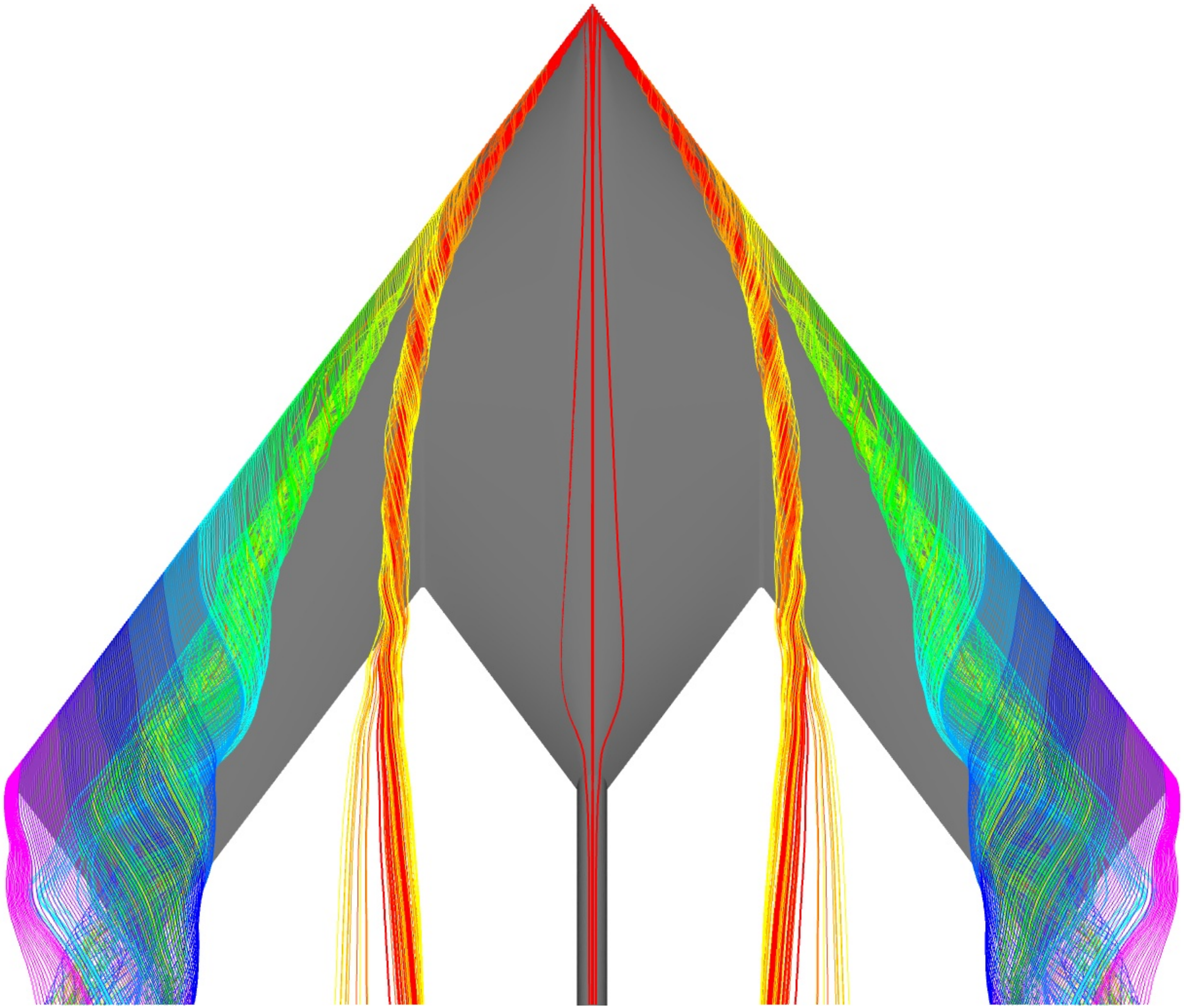
Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 14.00, AoS_{∞}= -0.00



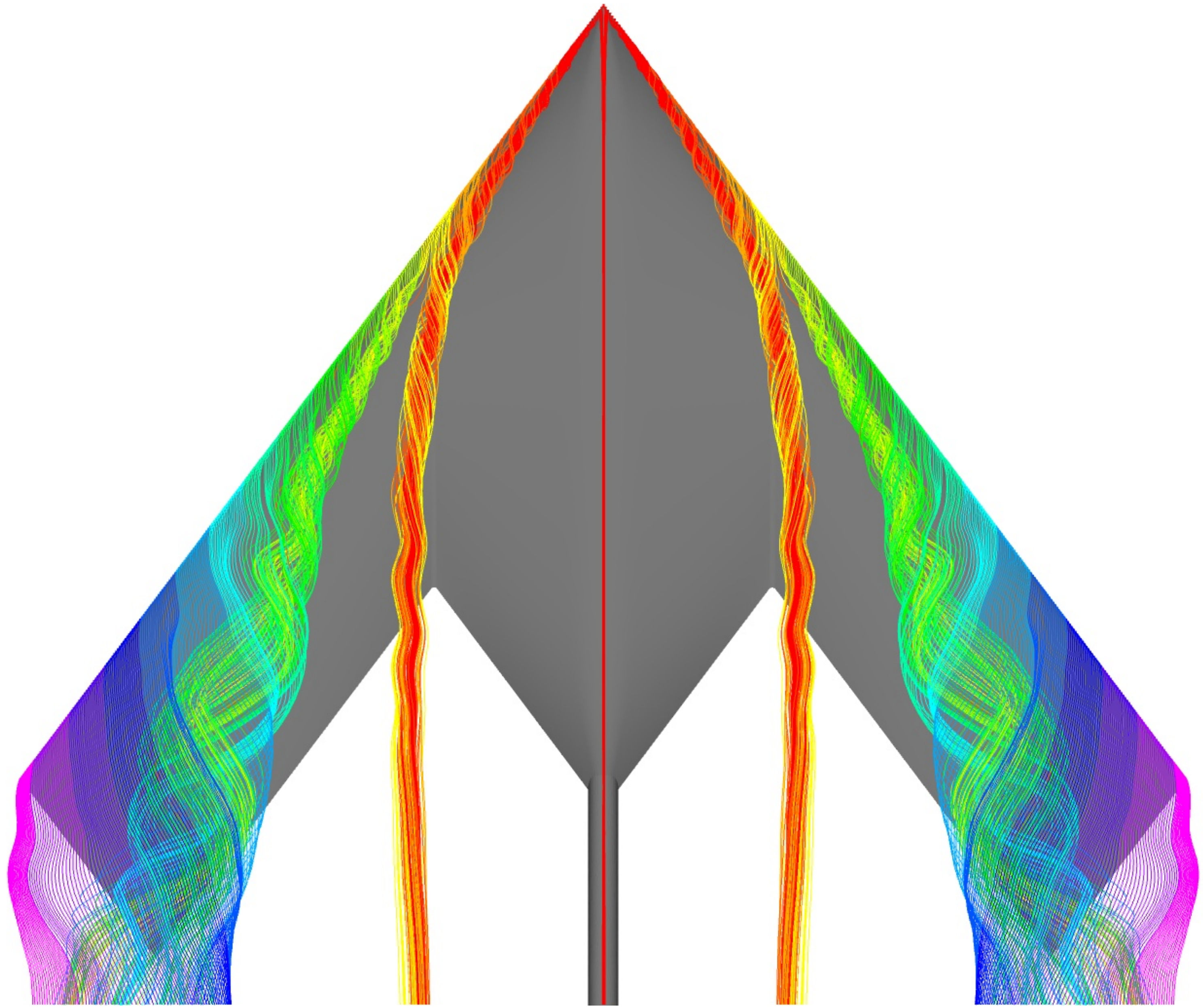
Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 15.00, AoS_{∞}= -0.00



Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 16.00, AoS_{∞}= -0.00



Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 17.00, AoS_{∞}= -0.00



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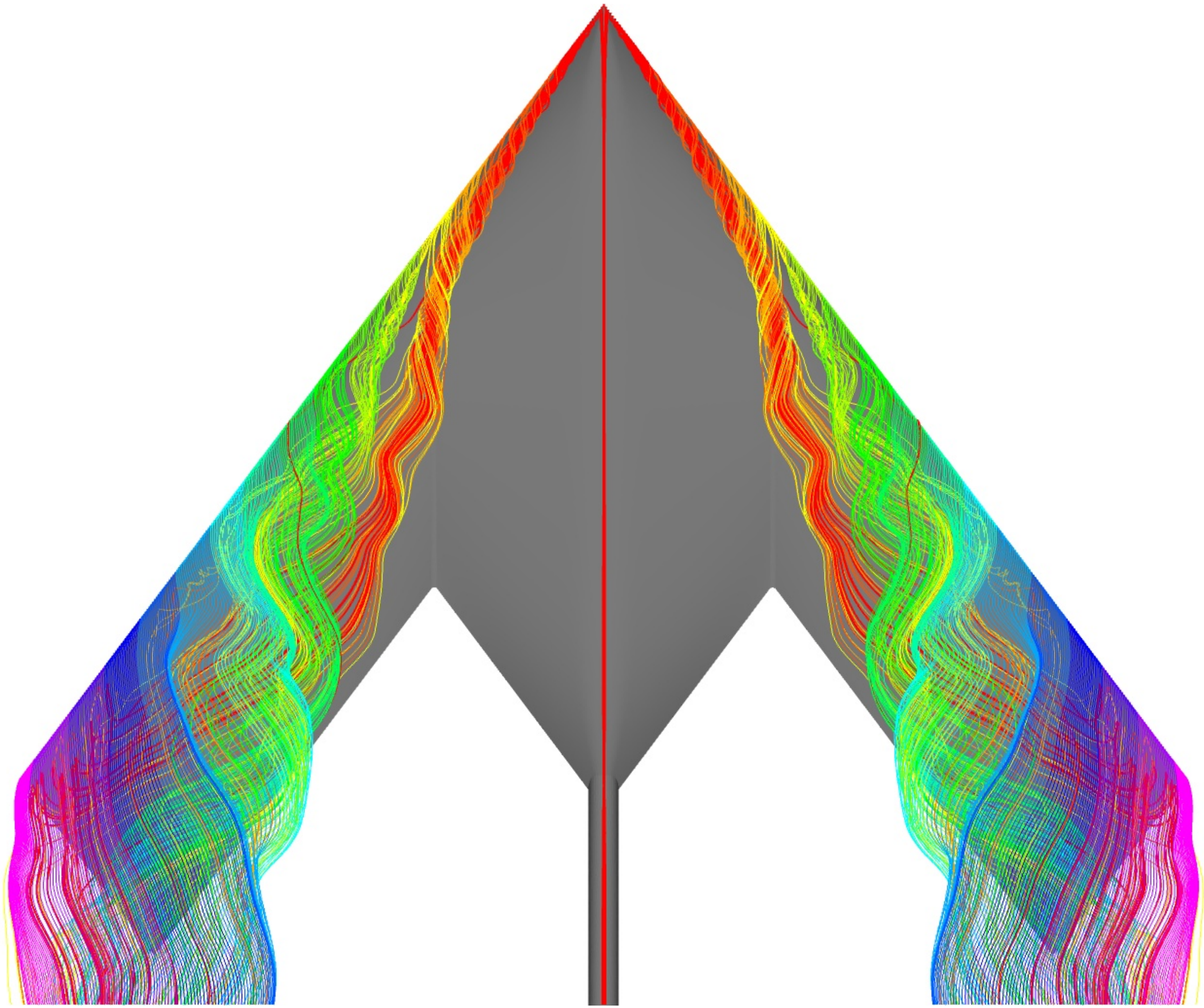
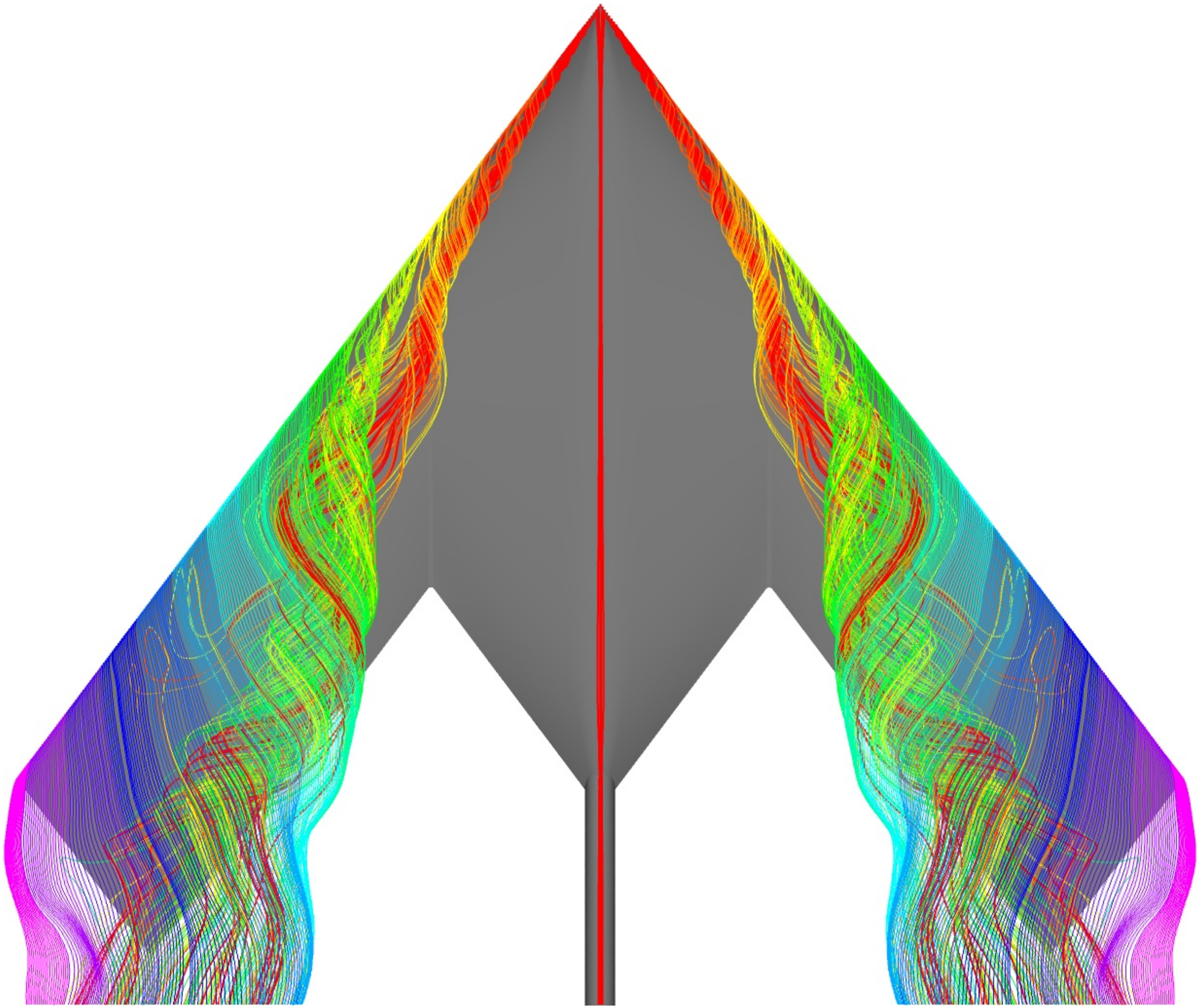
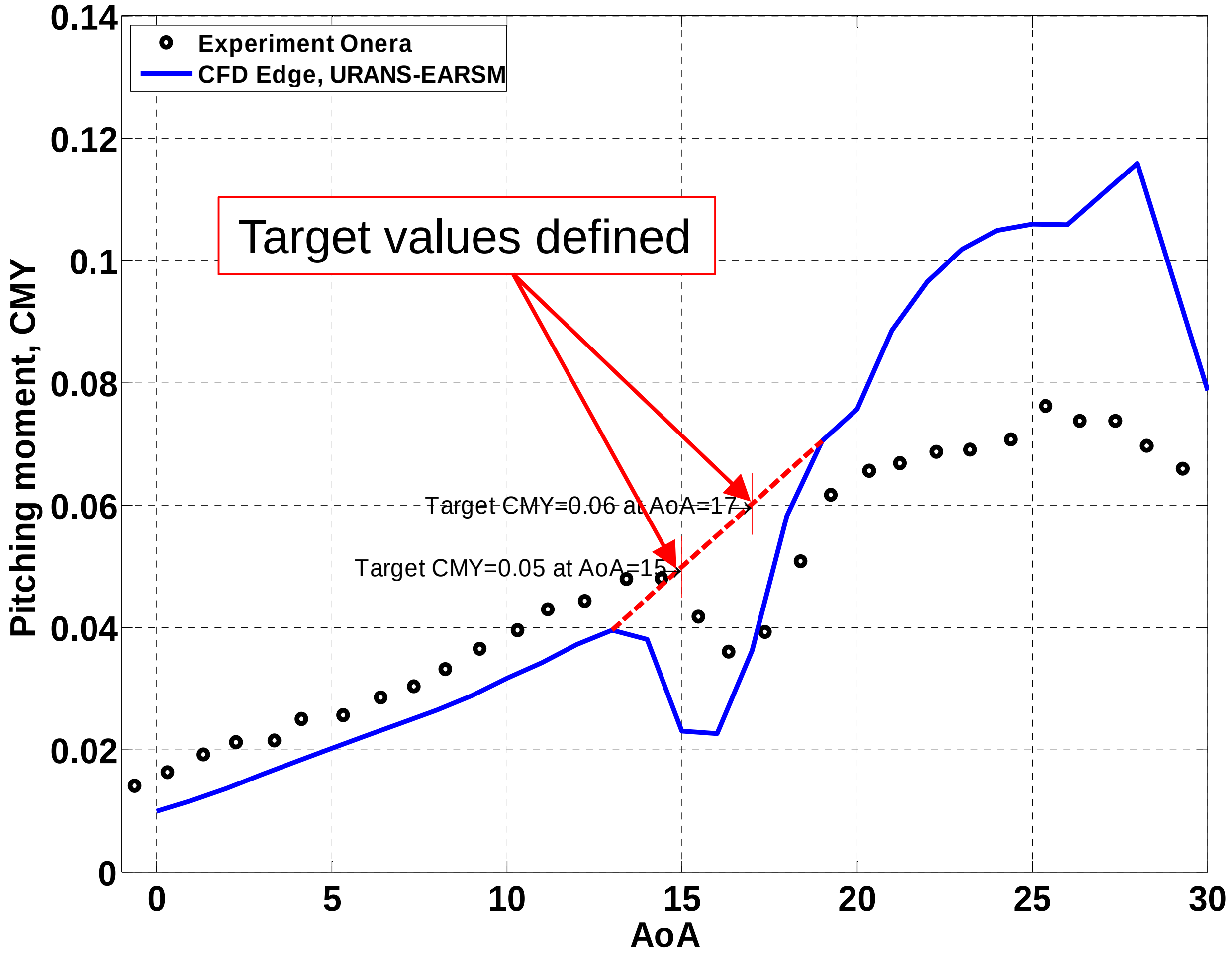


Lecolos: $Mach_{\infty}$= 0.15, V_{∞}= 50.00m/s, AoA_{∞}= 19.00, AoS_{∞}= -0.00



Establish reference without any control devices



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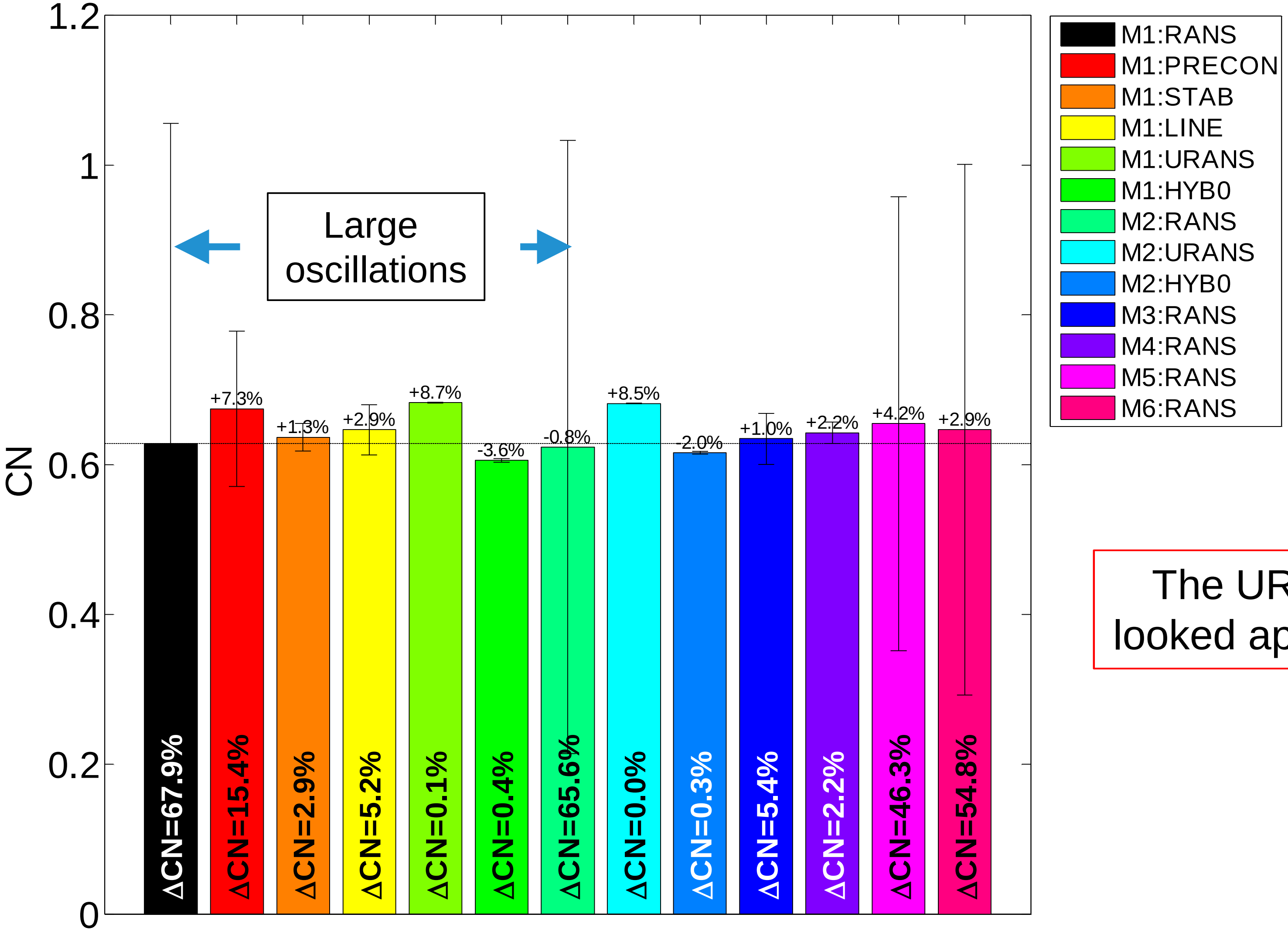
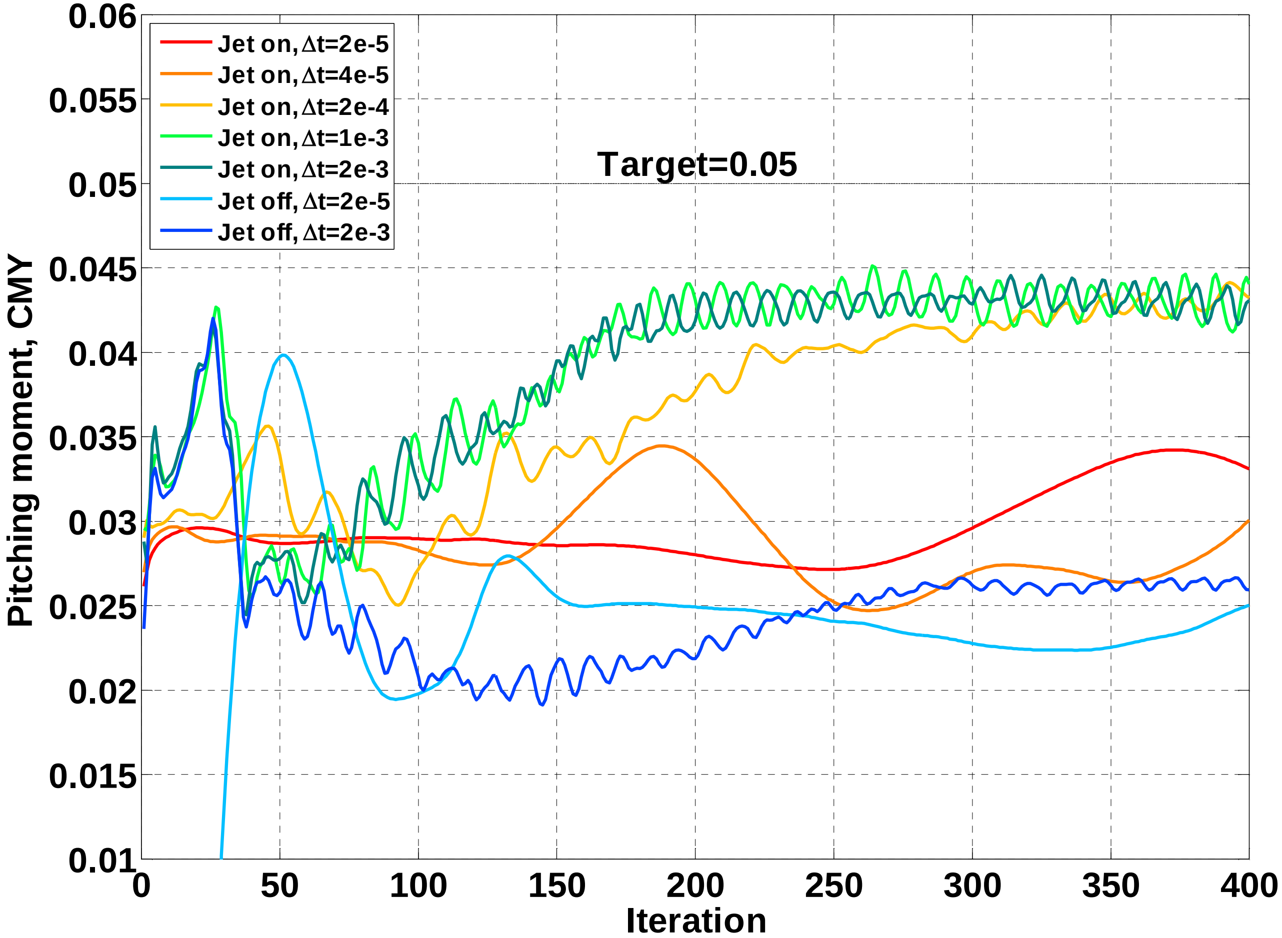
Evaluation of mesh and numerical method



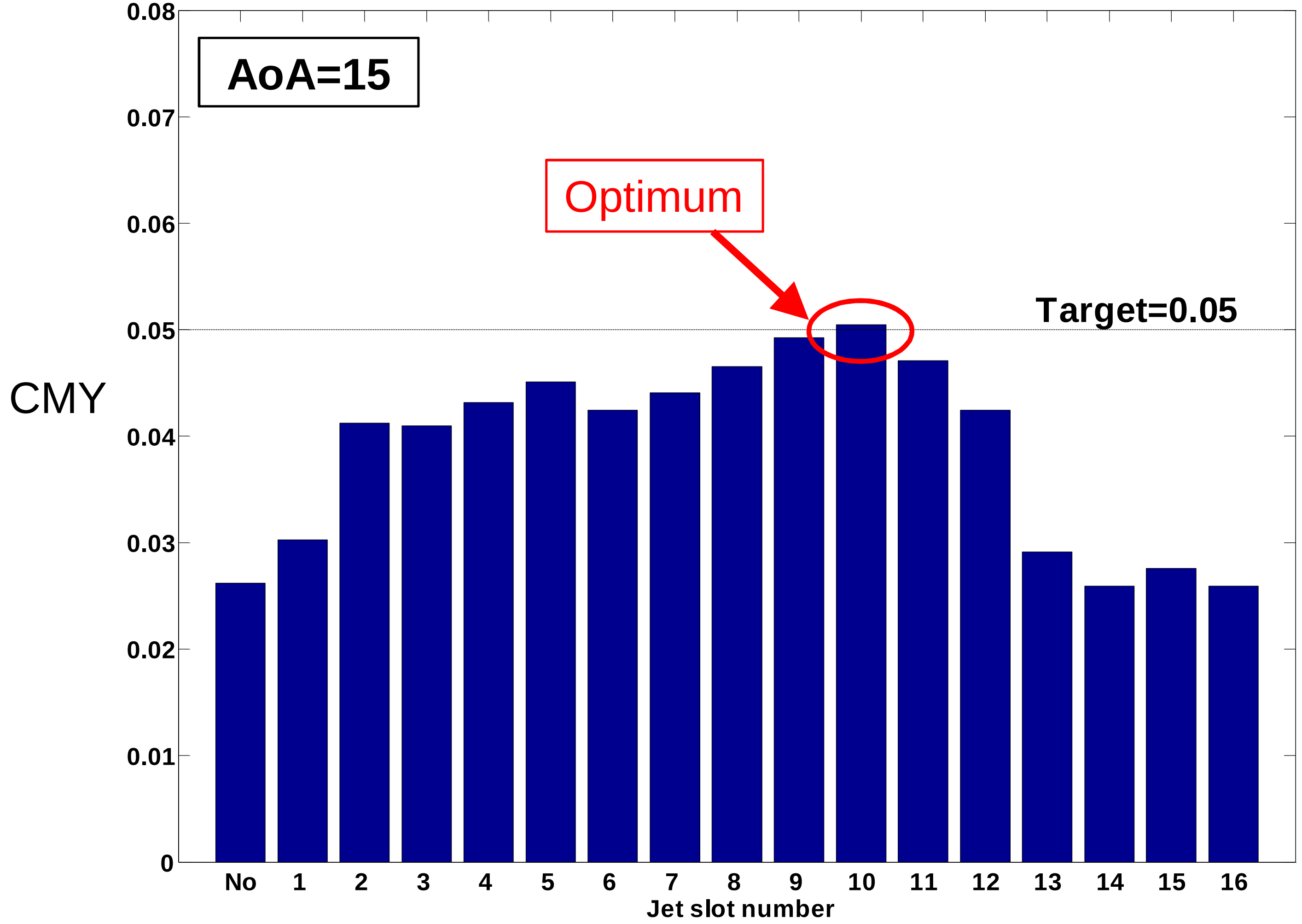
The URANS method looked appropriate but …

The computational method for jets

- Time-dep RANS
- Implicit dual time stepping
- Long time-step
- Δt=0.002s (15% of root chord)
- 40 inner sub-iterations
- Almost 30 flow passes to reach a converged solution



Find optimum jet location at AoA=15



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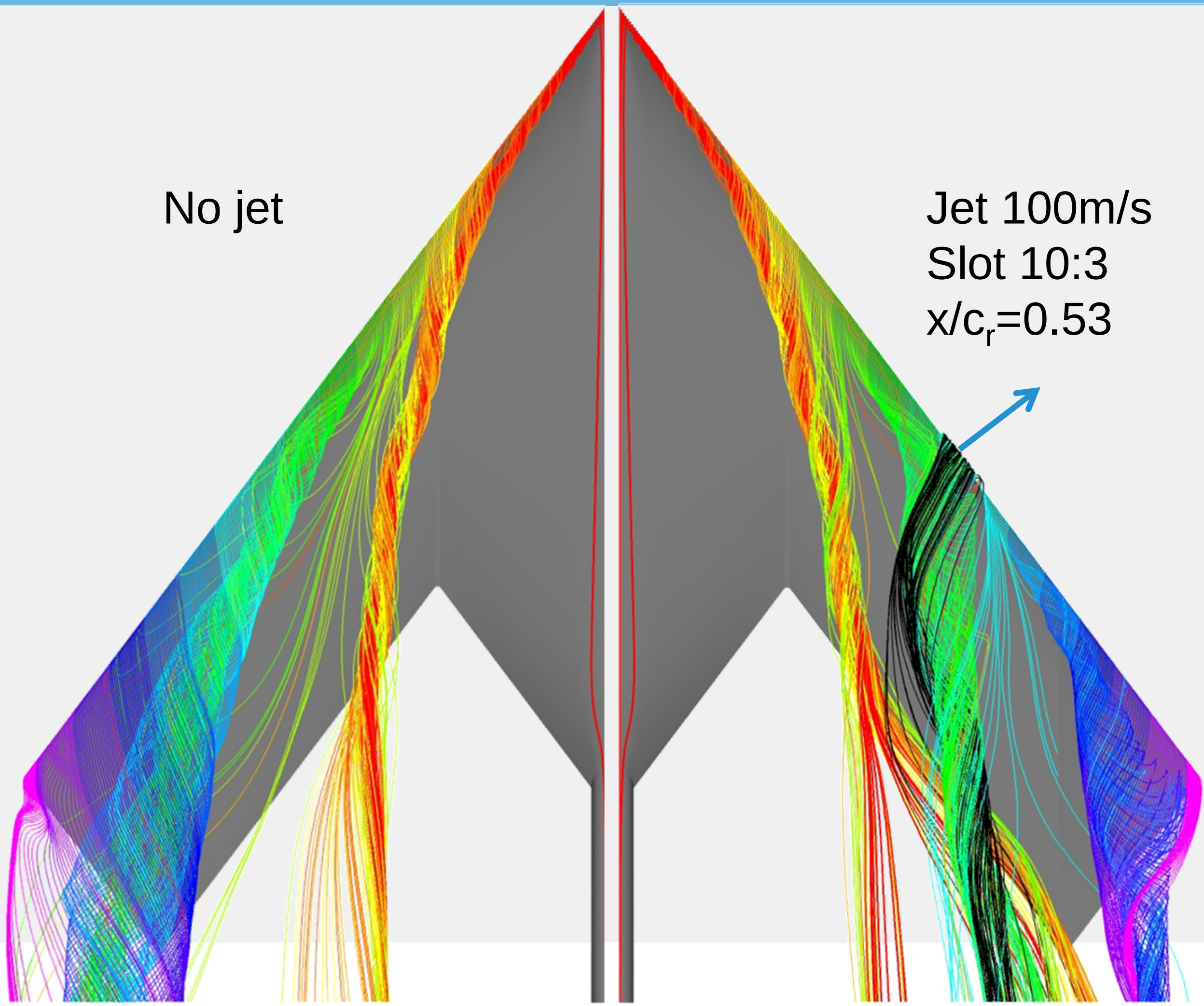
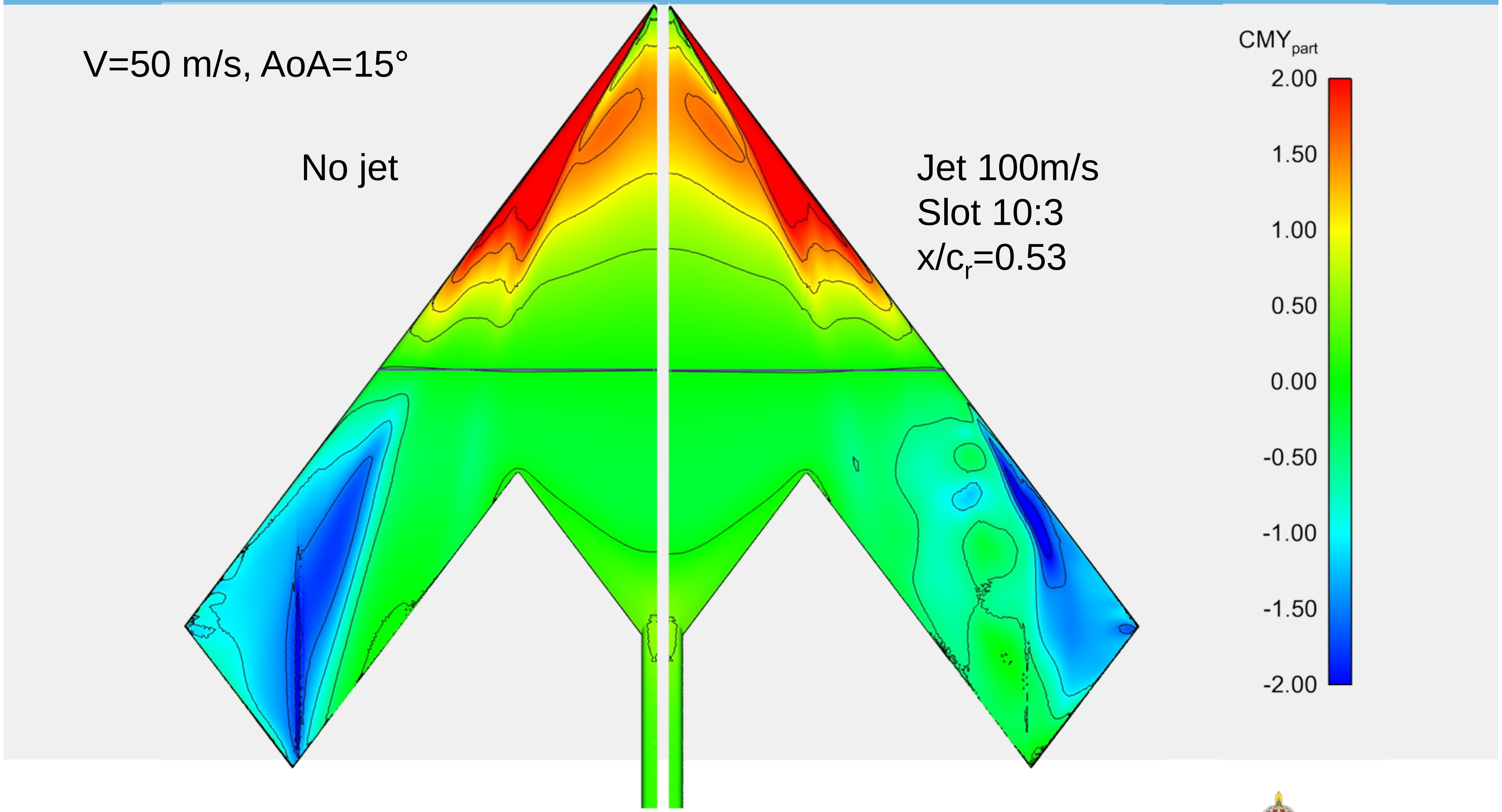
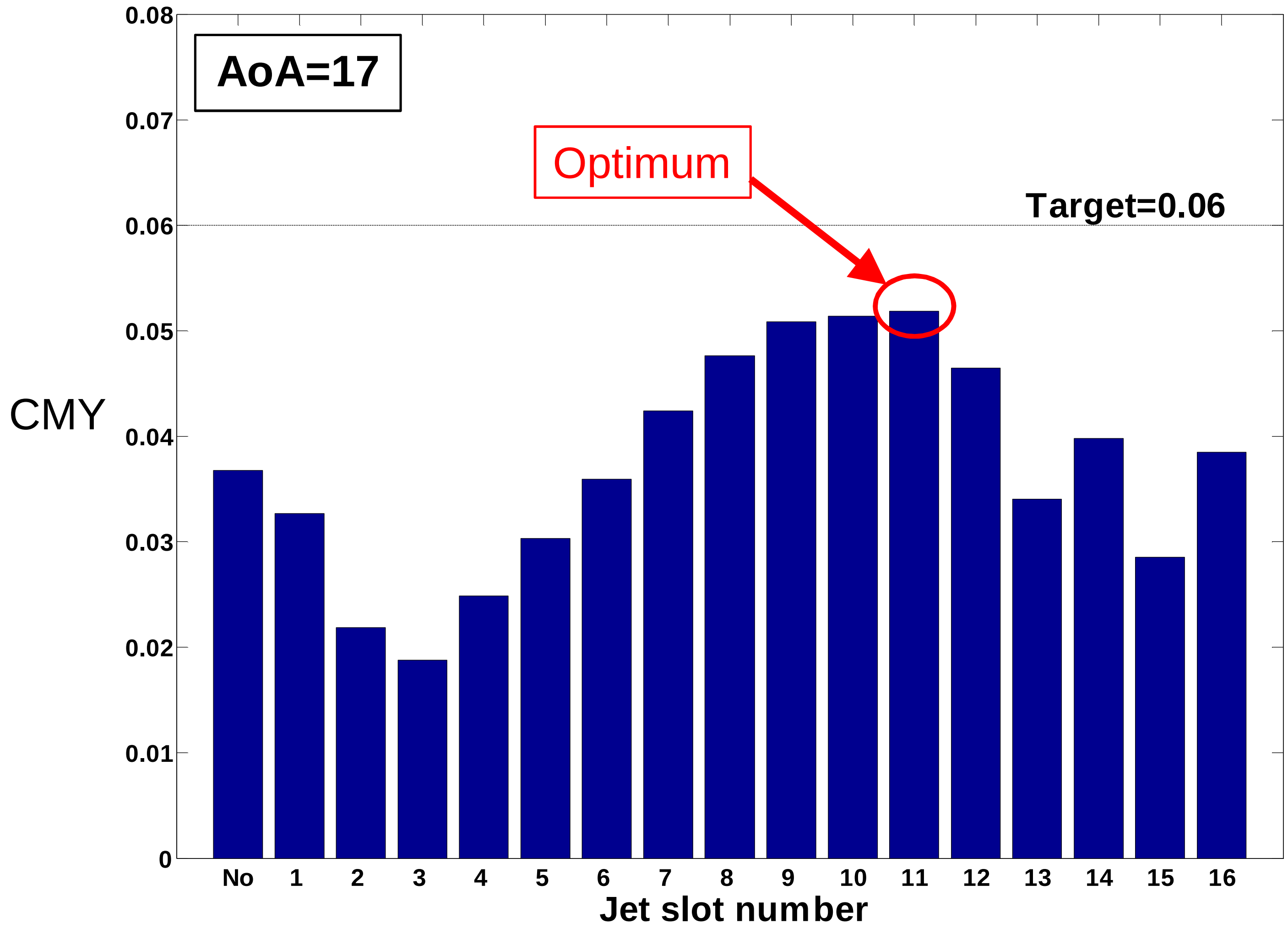
Optimal position of jet at AoA=15



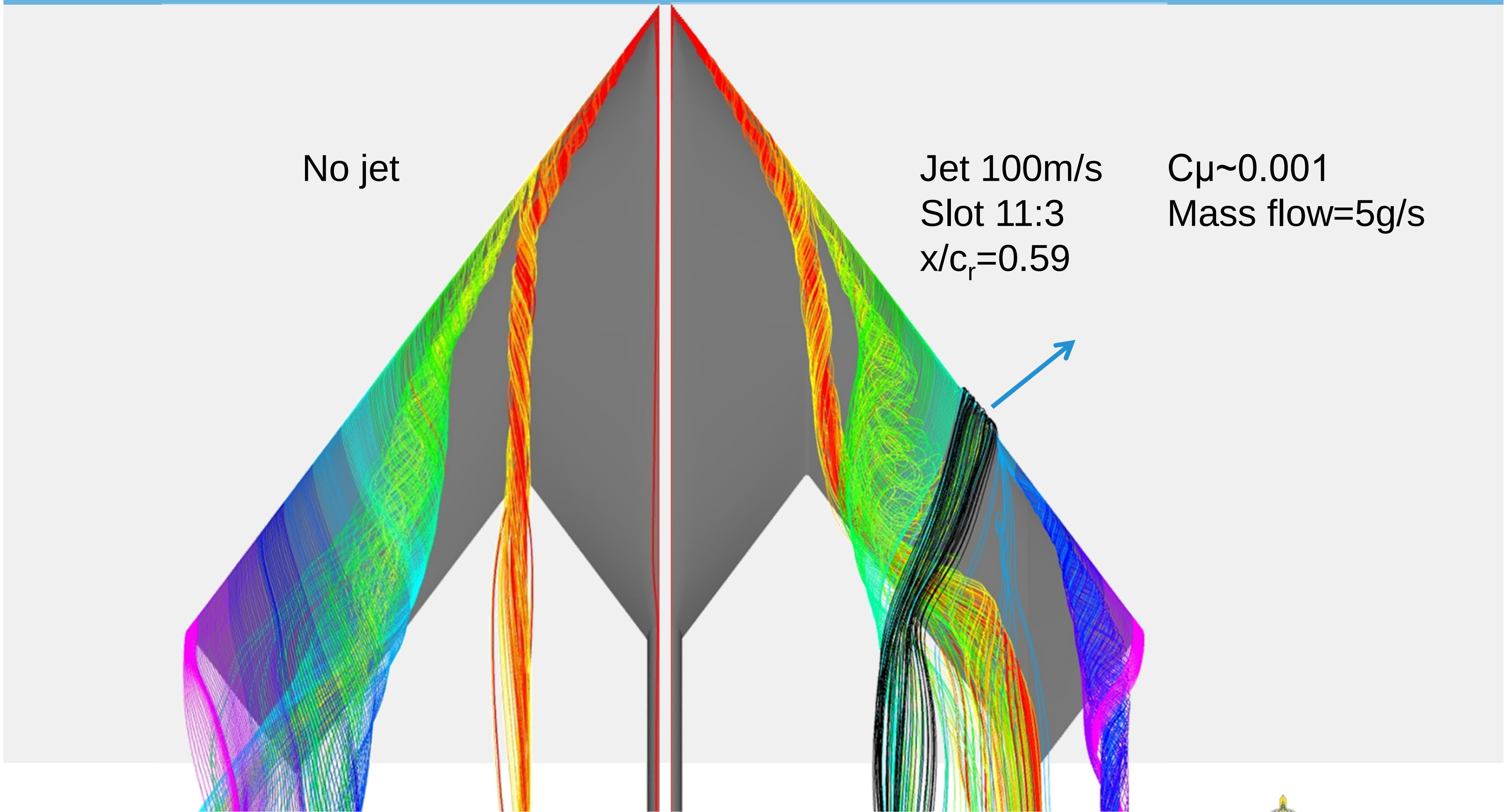
Pitching moment contribution



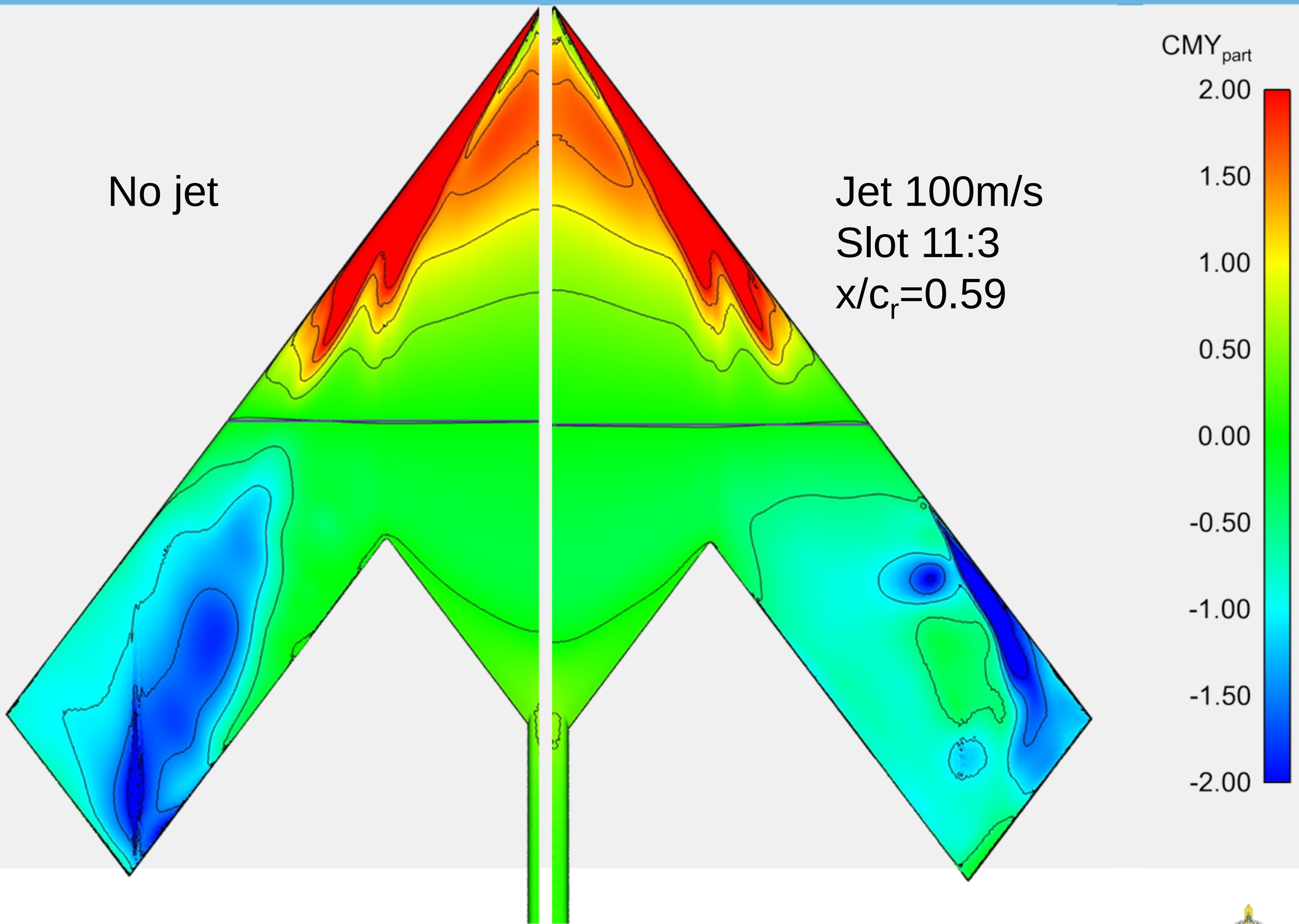
Find optimum jet location at AoA=17



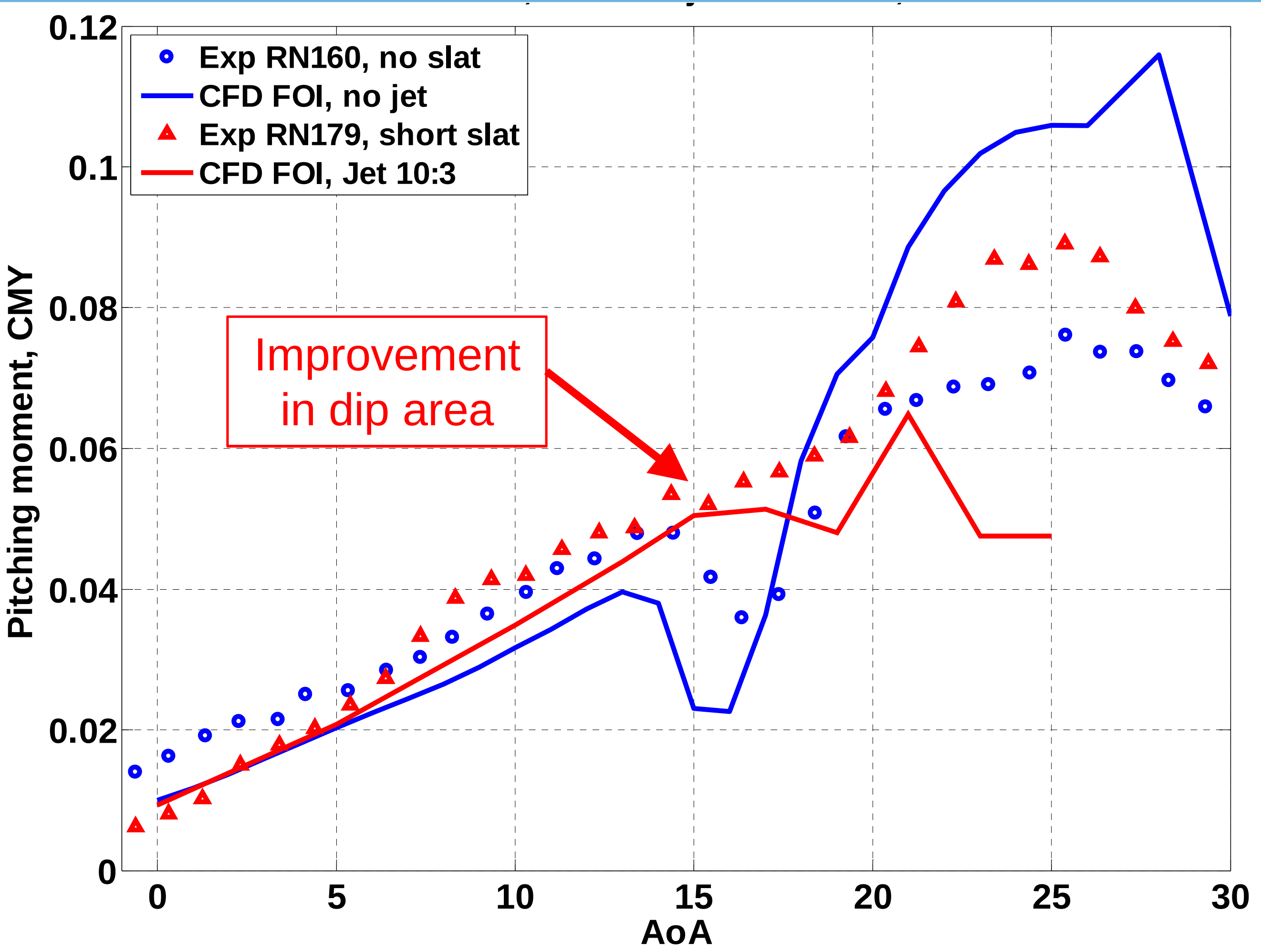
Optimal results of jet 11:3 at AoA=17



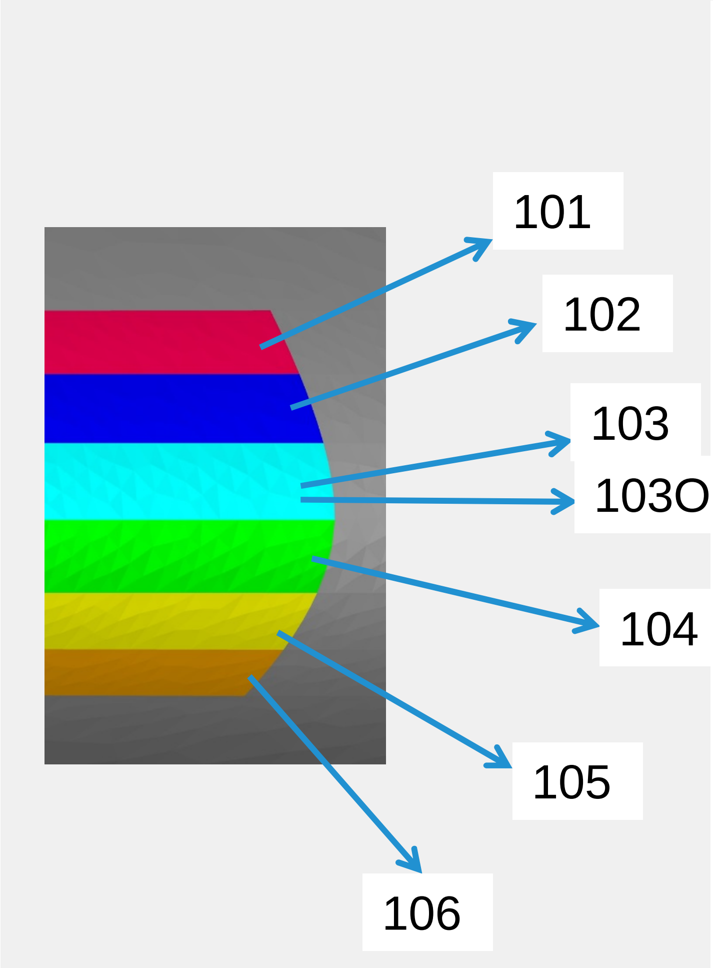
Optimal results of jet 11:3 at AoA=17

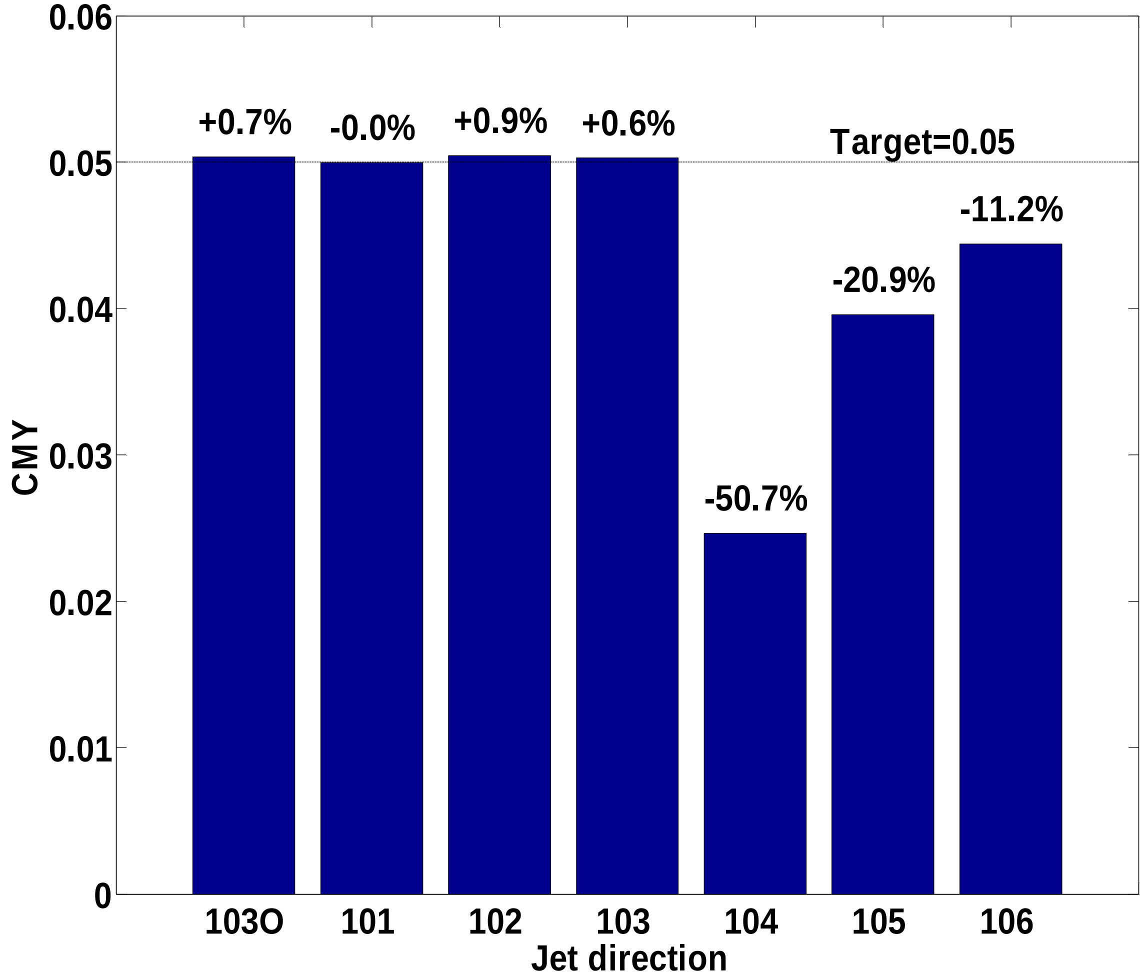


Effect on pitching moment with a jet at slot 10:3

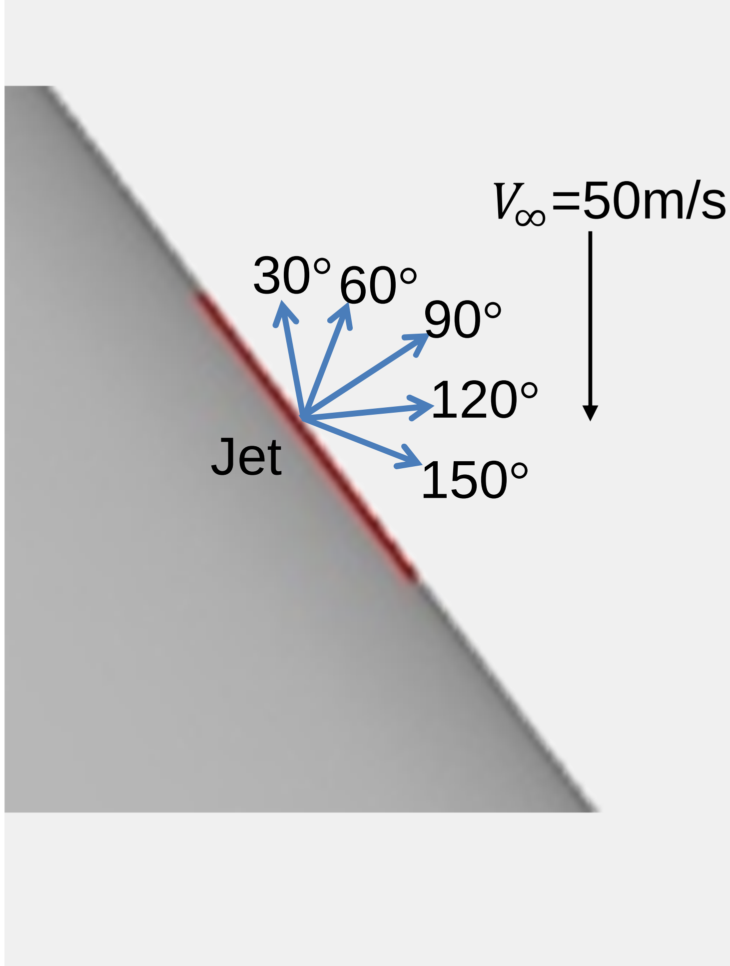


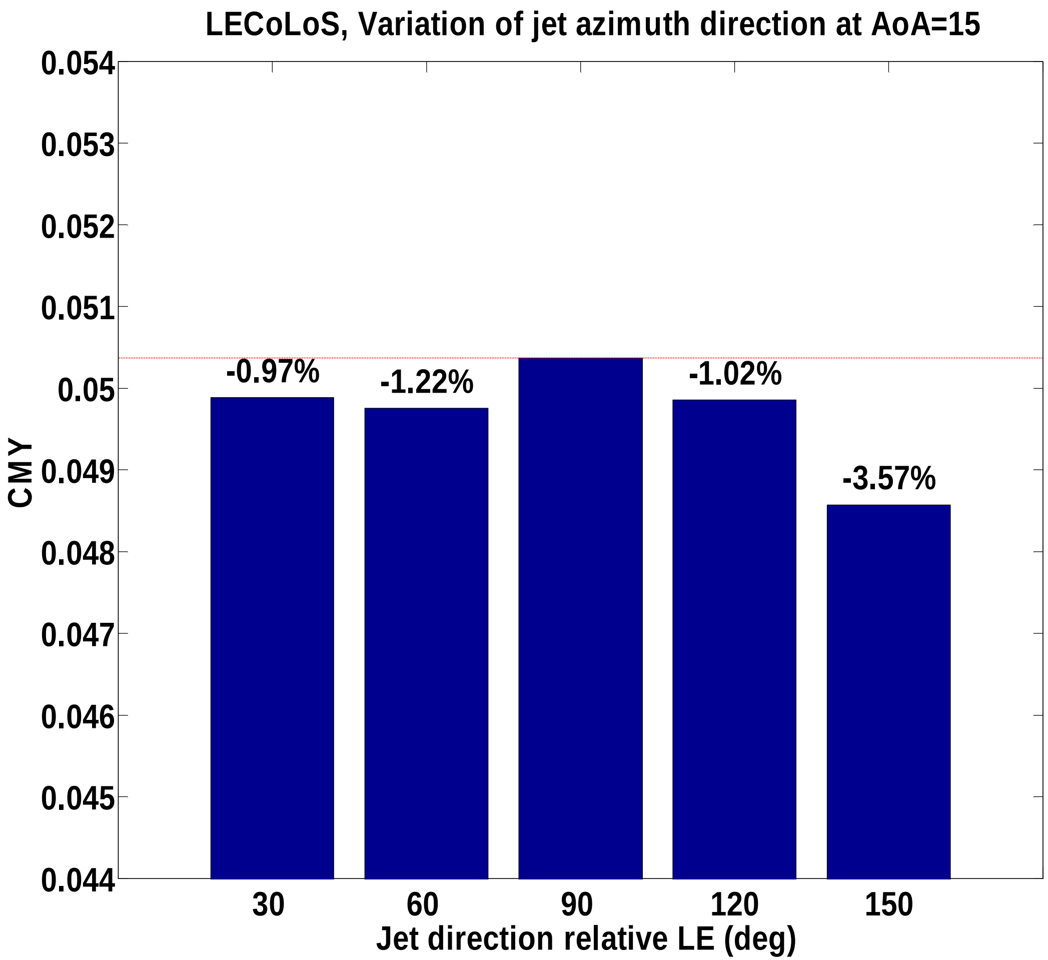
Variation of jet location around LE at AoA=15



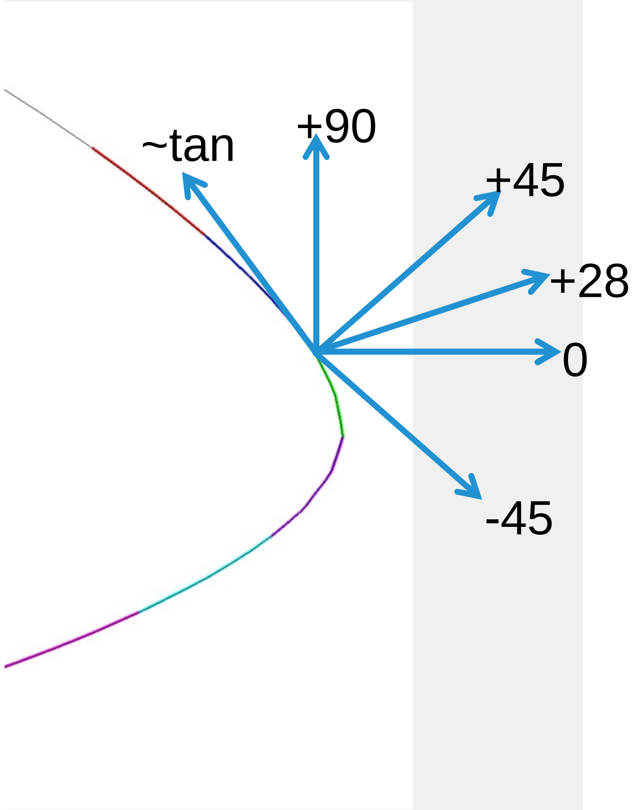


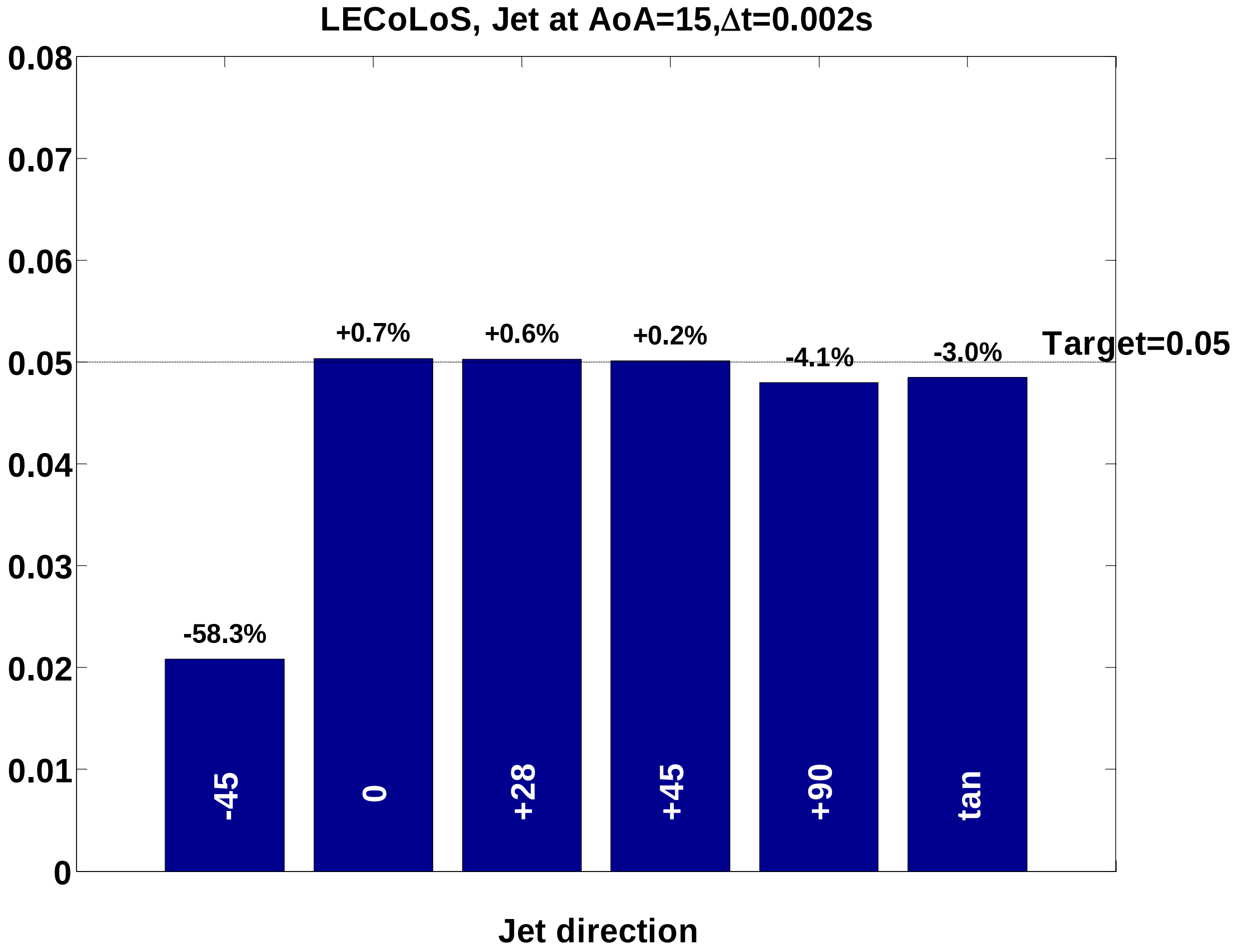
Variation of jet azimuthal direction at AoA=15



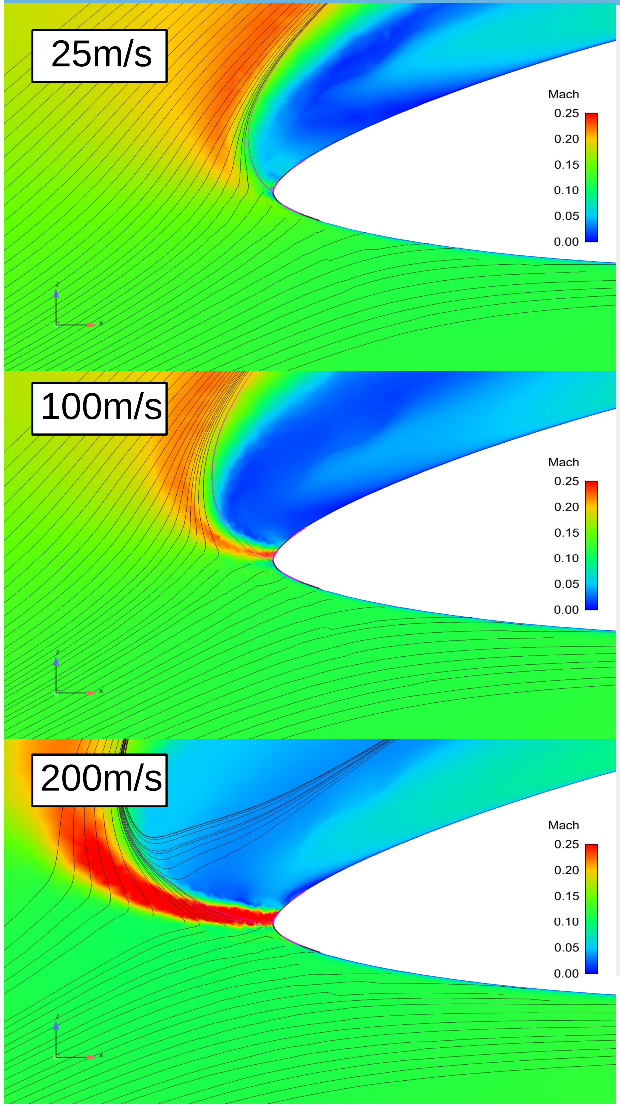


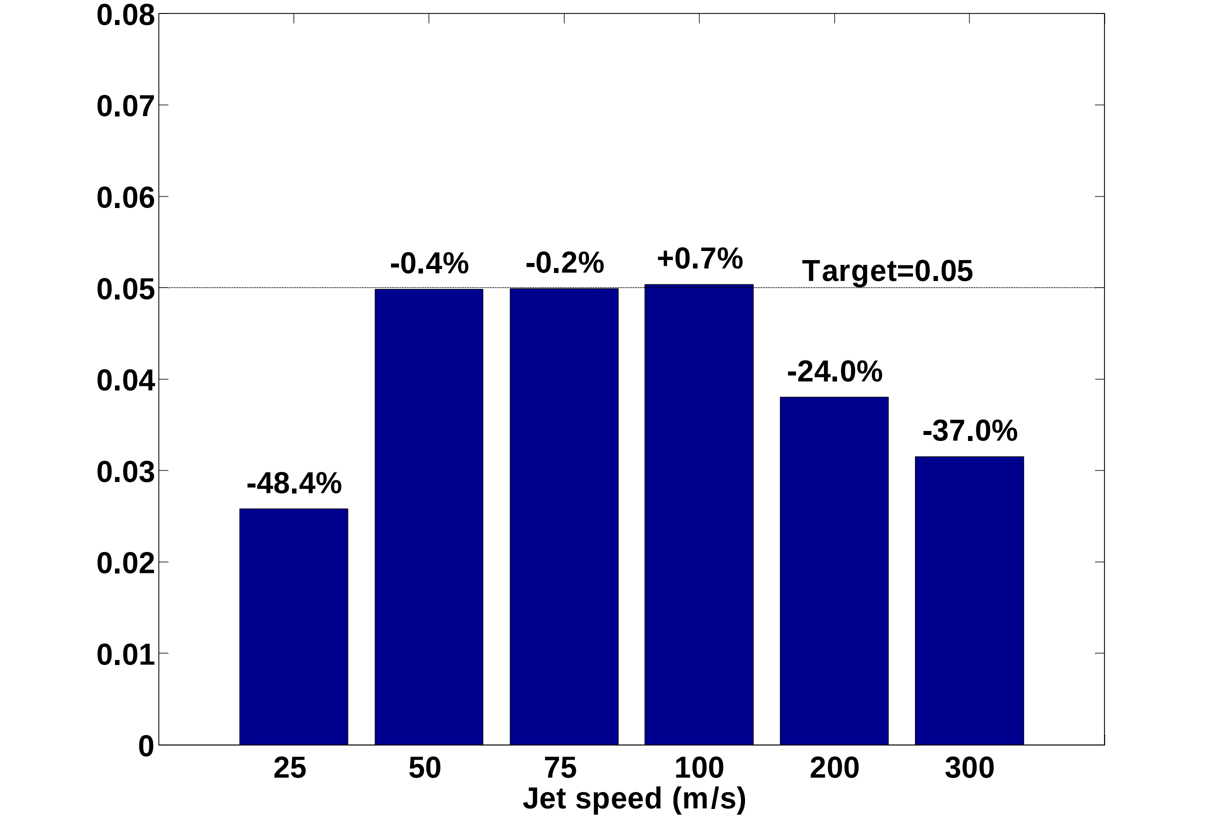
Variation of jet angle at LE





Evaluation of jet speed/mass flow rate





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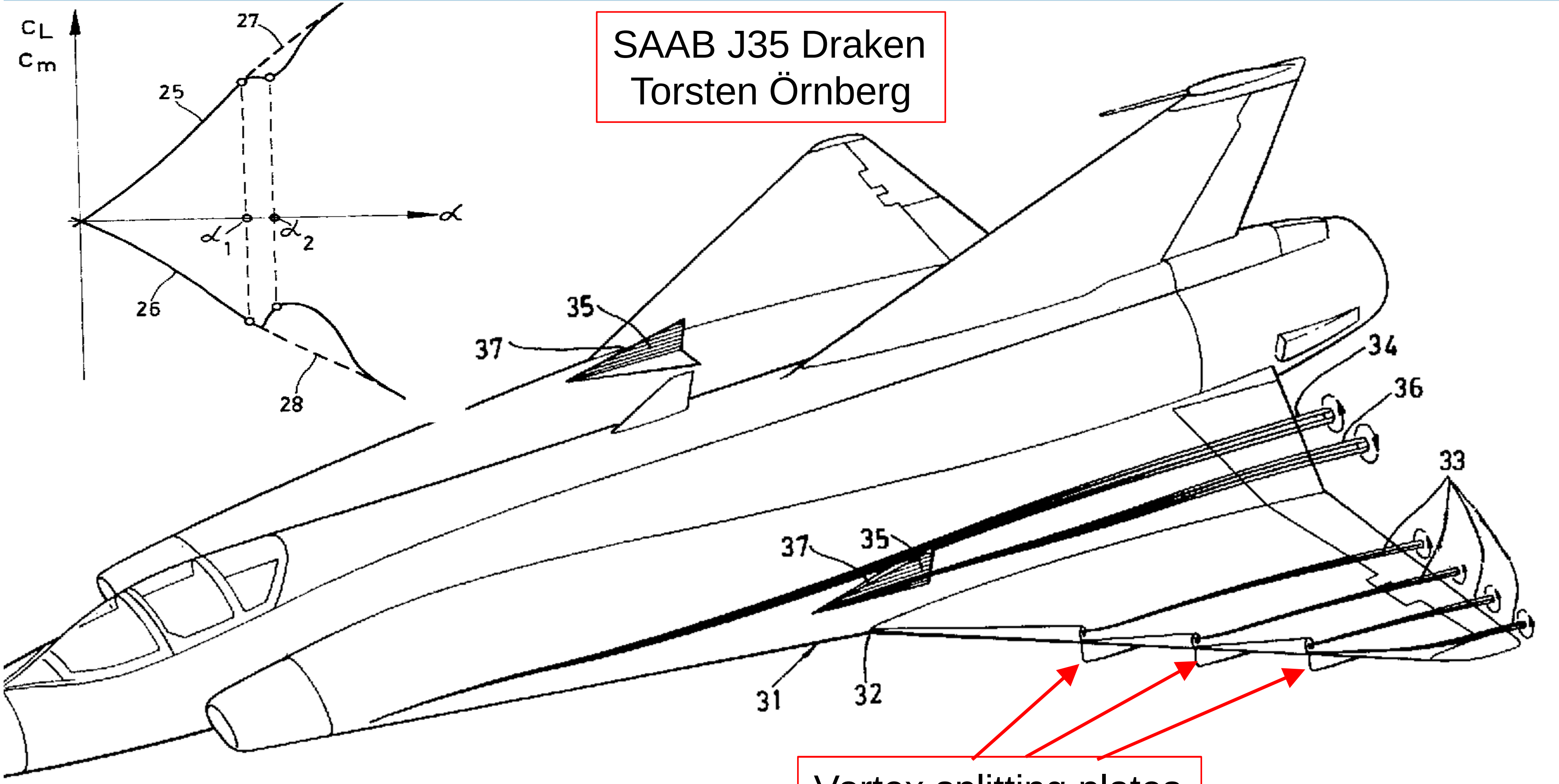
Swedish patent #301089 from 1966



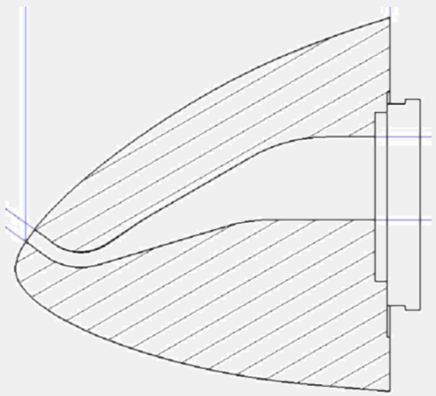
SAAB J35 Draken
Torsten Örnberg

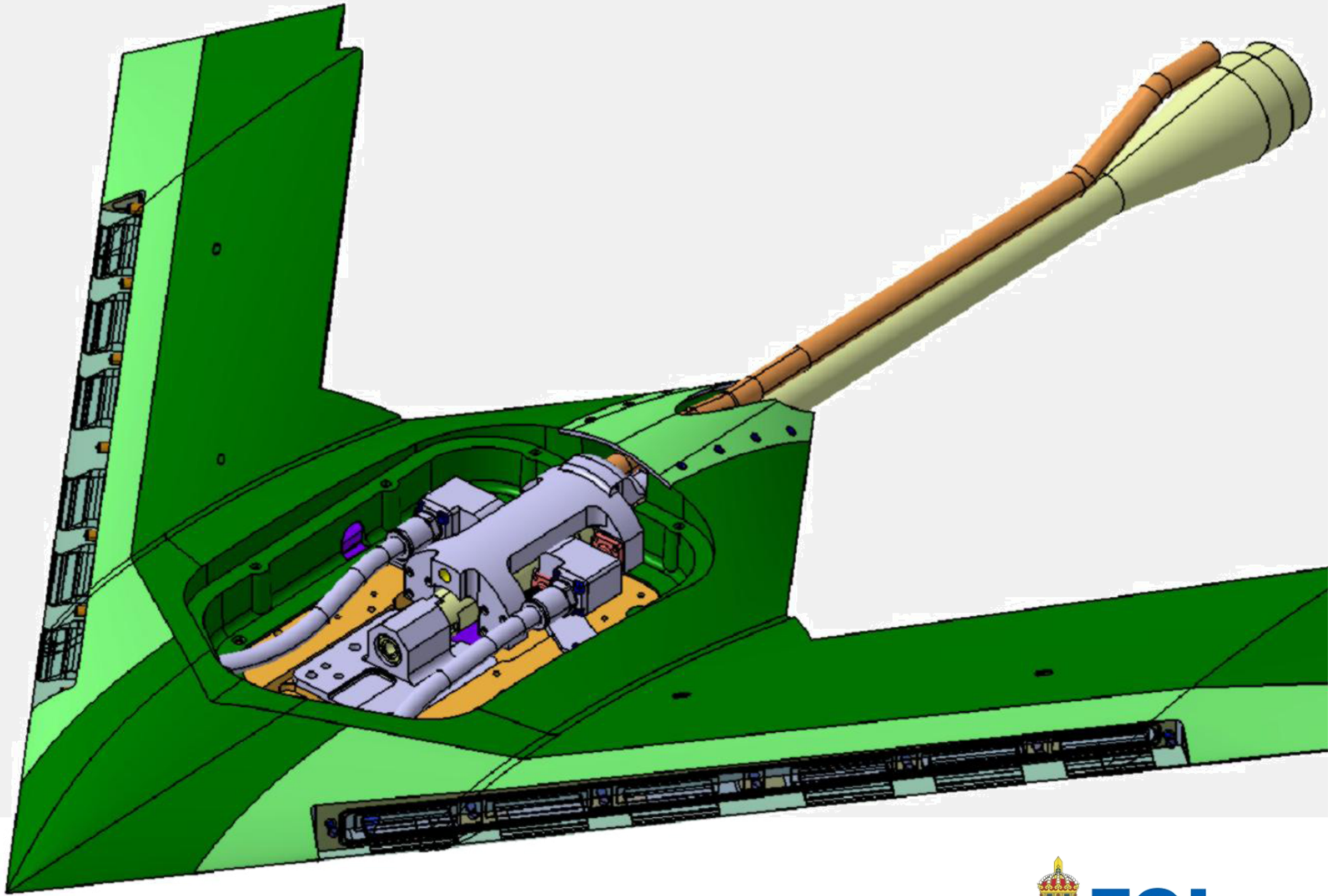
Vortex splitting plates

FOI

Next phase

- Wind tunnel tests planned for fall 2016 at ONERA, Lille L1





Conclusions LECoLoS

- Adding a jet at the leading edge reduces the pitching moment dip found around AoA=15 degrees for the SACCON
- An optimal location of the jet along the leading edge has been found
- The effect of variation of the jet direction relative the leading edge and the mass flow or jet velocity has been assessed
- Time dependent RANS simulation was needed with at least 15 full flow past to reach a stable solution
- The physical effect of the jet is to initiate a split of a larger vortex into smaller and thus distributing the load onto the surface