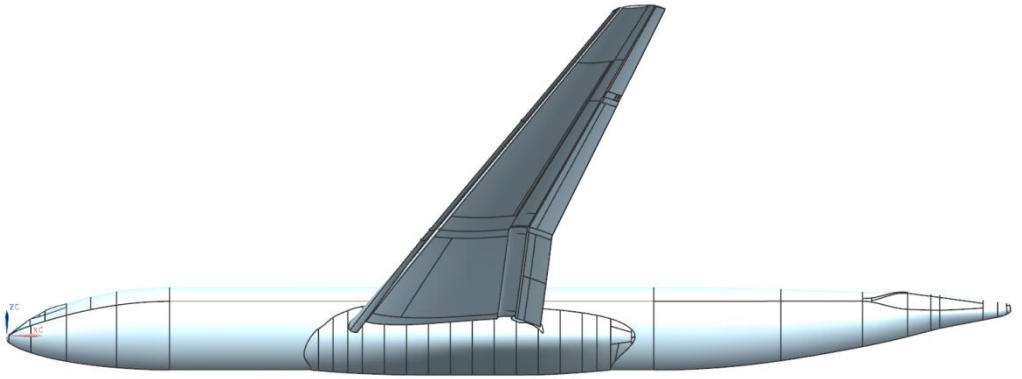
CIAM, Sukhoi NCT and Irkut Contribution to HiLiftPW-2

Vladimir Makarov at all

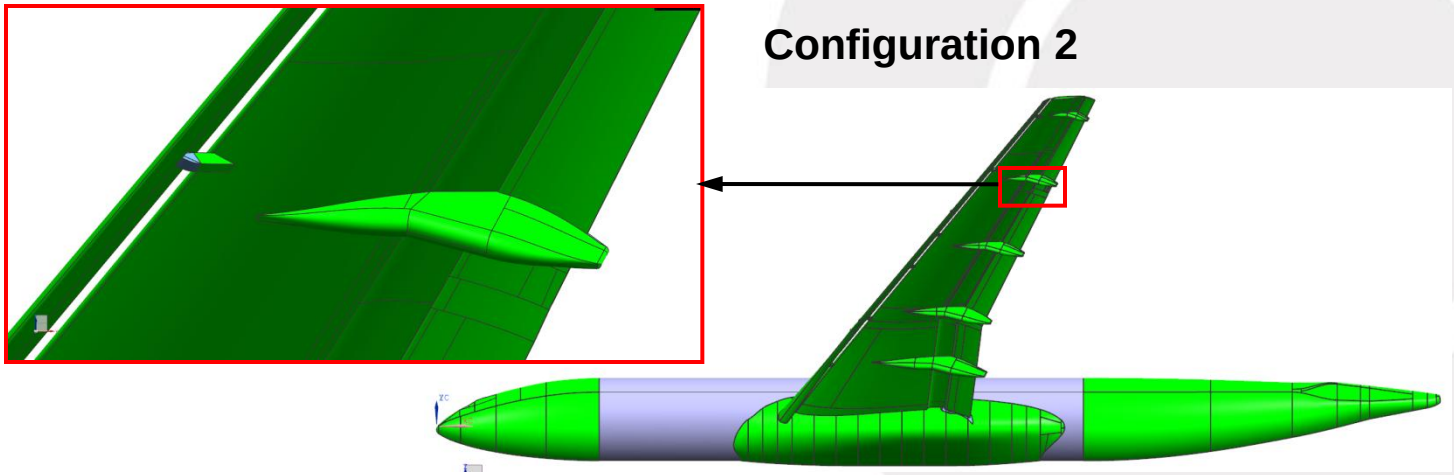
Central Institute of Aviation Motors (CIAM), Moscow, Russia

32nd AIAA Applied Aerodynamics Conference, 2nd High Lift Prediction Workshop Special Session APA-21, June 16-20 2014, Atlanta

The DLR-F11's configuration considered:



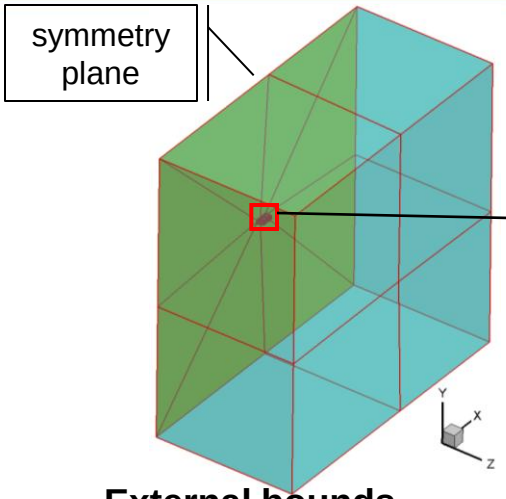
Configuration 2



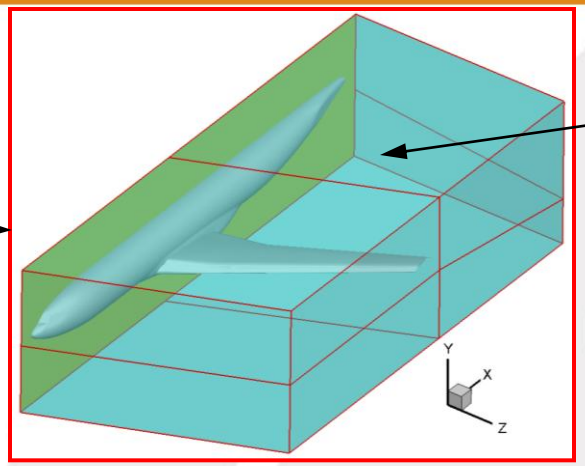
Configuration 4

Mean aerodynamic chord (MAC)	Semispan (b/2)	Wing aspect ration
0.34709 m	1.4 m	9.353

Problem statement:



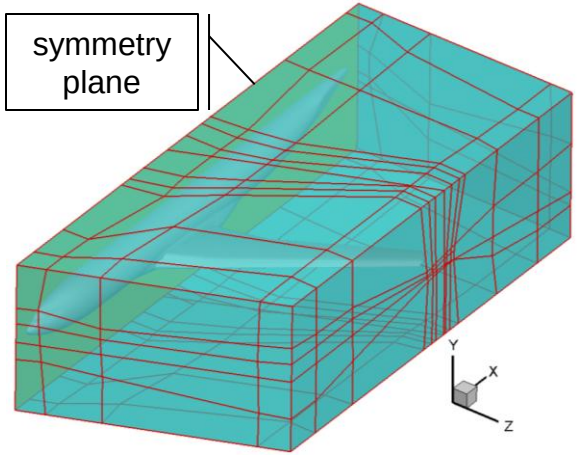
External bounds



Internal bounds

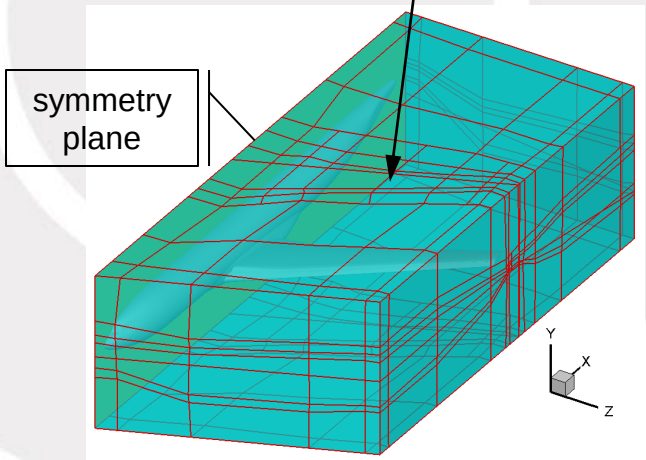
Different mesh topology

External region: 12 blocks



Configuration 2: 335 blocks

Red lines: topology block's bounds



Configuration 4: 480 blocks

External bounds of internal region

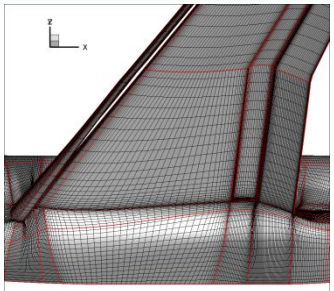
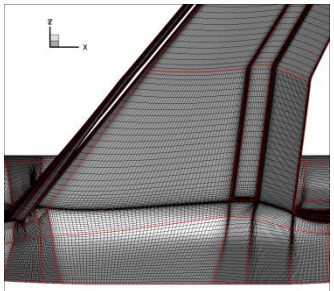
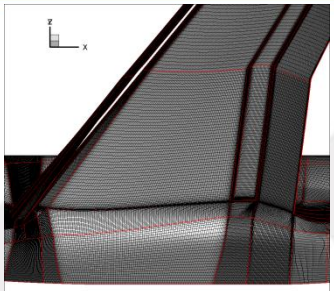
Mesh generation (base principles and details):

All meshes were block-structured and were constructed by the ICEM-CFD

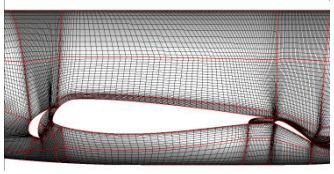
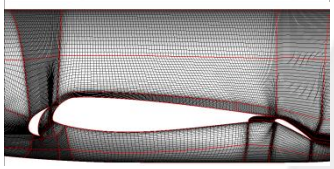
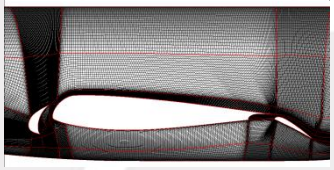
Details of the meshes used

Case	Mesh	No. of cells (million)	First cell heights (m)
Case 1	Coarse	5 756 600	0.00055
	Medium	13 773 390	0.00037
	Fine	43 346 620	0.00024
Case 2	Medium	47 252 565	0.00037

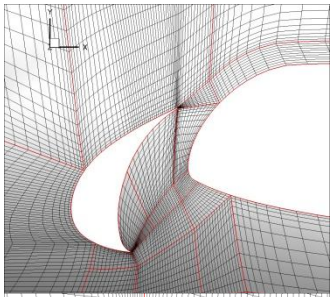
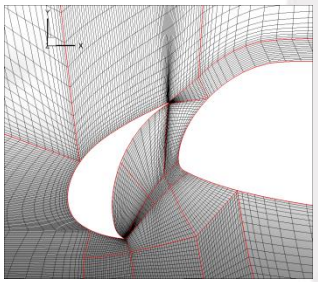
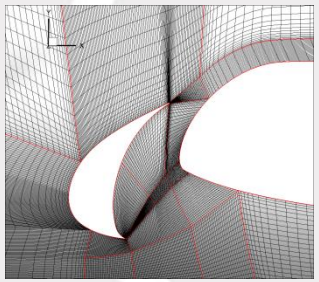
Mesh generation (Case 1 illustration):

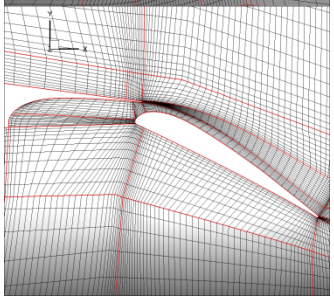
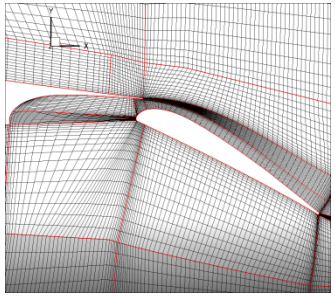
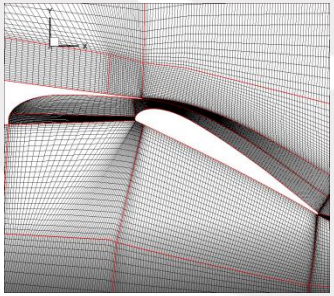
wing-fuselage junction

cut view at wing root

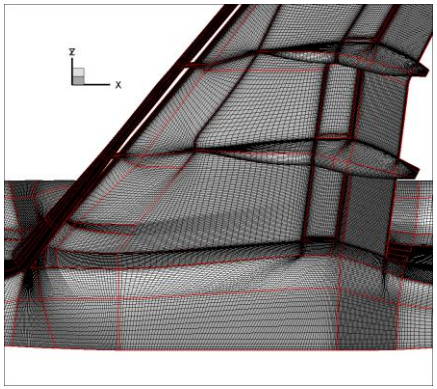
zoom near wing nose

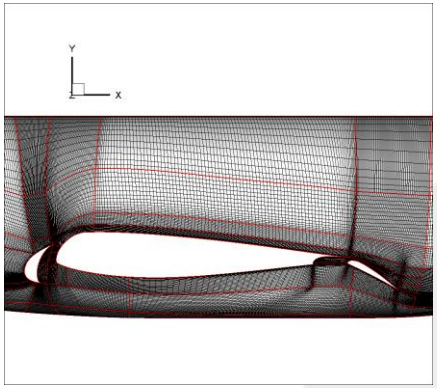
zoom near wing trailing edge

Coarse **Medium** **Fine**

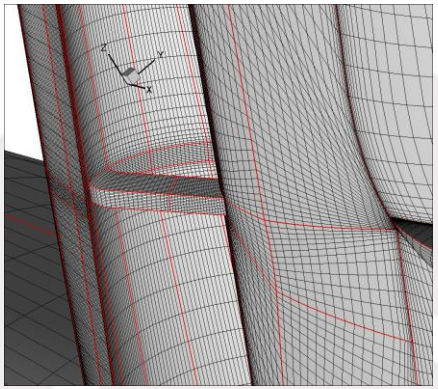
Mesh generation (Case 2 illustration):



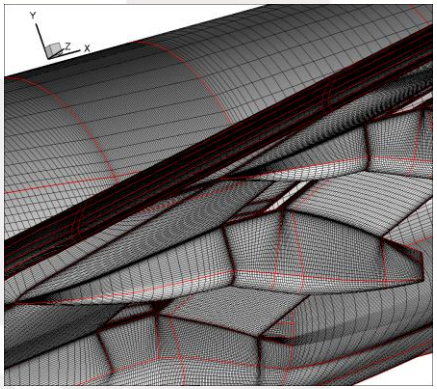
wing-fuselage junction



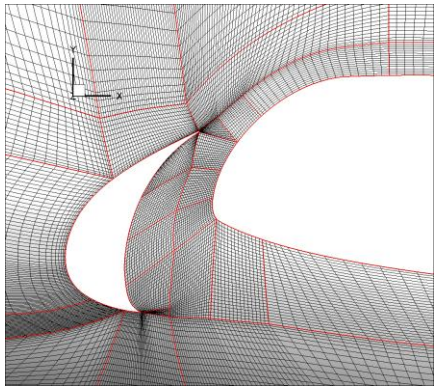
cut view at wing root



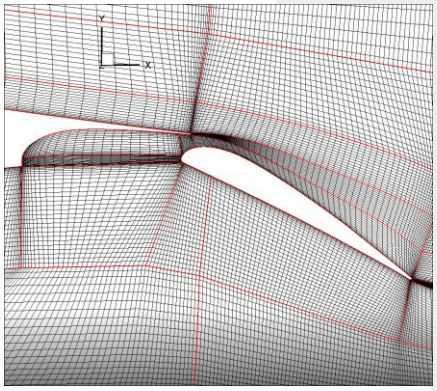
zoom near slat stack junctions



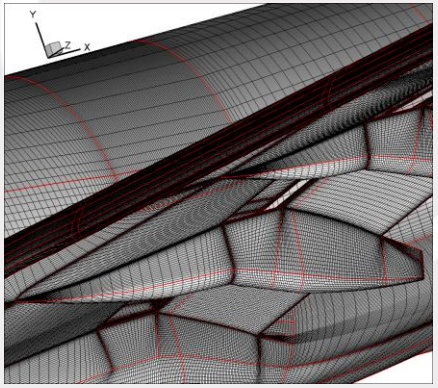
flap stack fairings

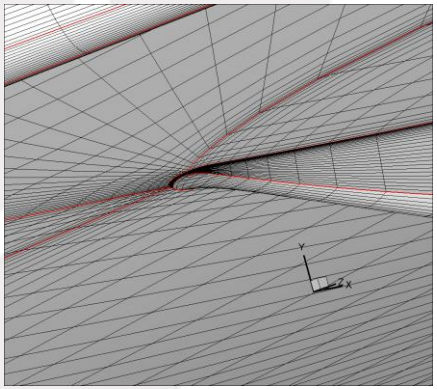


zoom near wing nose



zoom near wing trailing edge





zoom near flap stack fairing junctions

Details of the numerical method and software:

Numerical method:

- 2D/3D Euler/RANS/URANS solver
- Finite volume
- Explicit/implicit time integration
- Second order spatial/time discretization
- Dual time approach for unsteady problems
- Cartesian coordinate system
- Multi-block structured fixed/moving mesh
- Parallel capability shared/distributed memory

Typical performance:

- Courant number up to 1000 (in implicit mode)
- Up to 5, 000, 000 mesh cells for 1 Gb RAM
- Near linear parallel computation speed-up factor

Flow capabilities:

- Inviscid
- Laminar
- Turbulent
- Real/perfect gases
- Turbulent models:
  - Spalart-Allmaras
  - k-ε
  - SST (high and low Reynolds)
- Standart/extended wall function
- Perforated walls
- Particles tracking with wall interaction
- Stationary and/or Rotating frame of reference

Computer platforms:

- Linux (32/64 bit)
- Windows XP/7 64 bit

Results (Case 1):

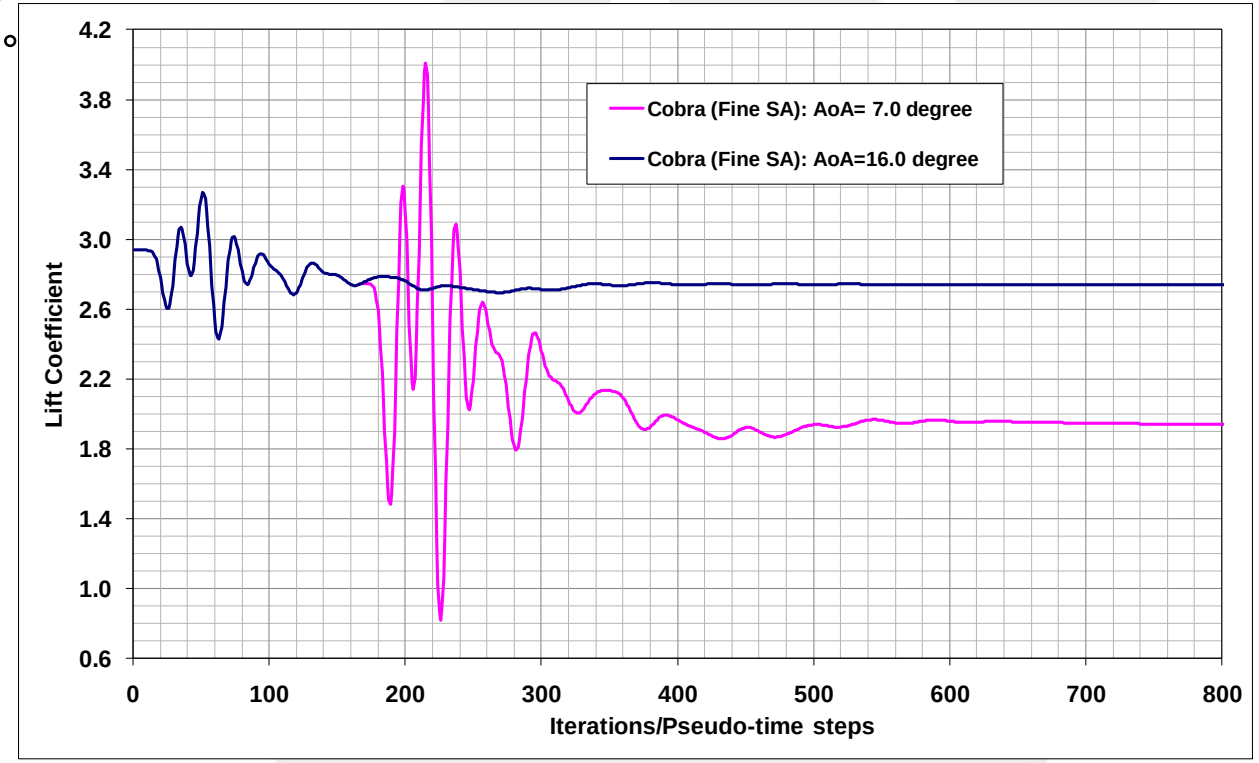
Configuration: configuration 2 of DLR-F11

Free stream Mach number: 0.175

Angle of attack (AoA): 7° and 16 °

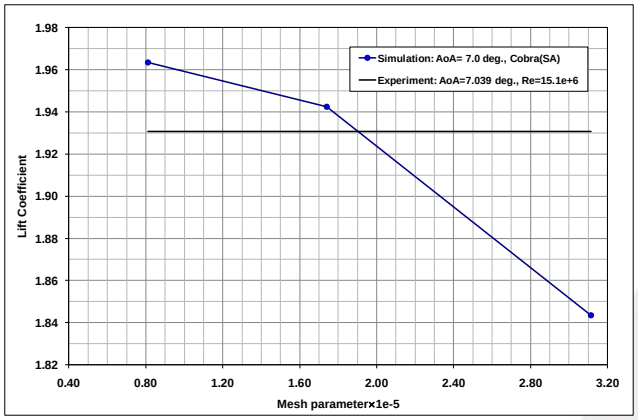
Meshes: coarse, medium, fine

Reynolds number: 15.1 million

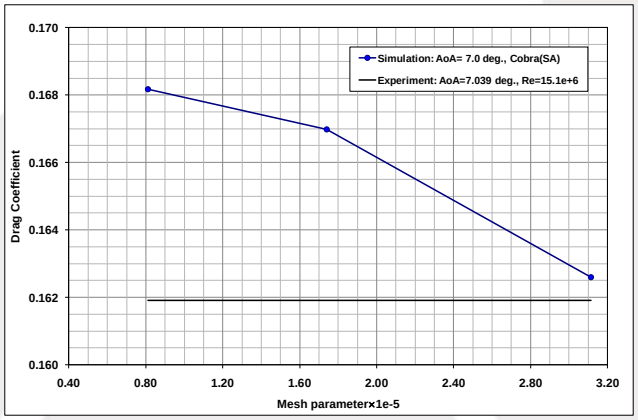


Iteration/pseudo-time convergence of lift coefficient for Case 1

Results (Case 1 mesh convergence):

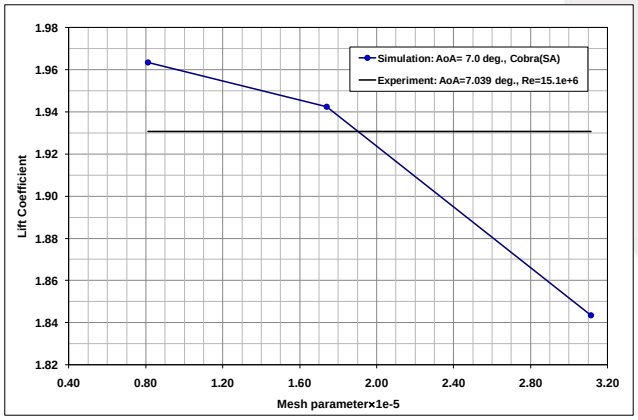


Lift coefficient

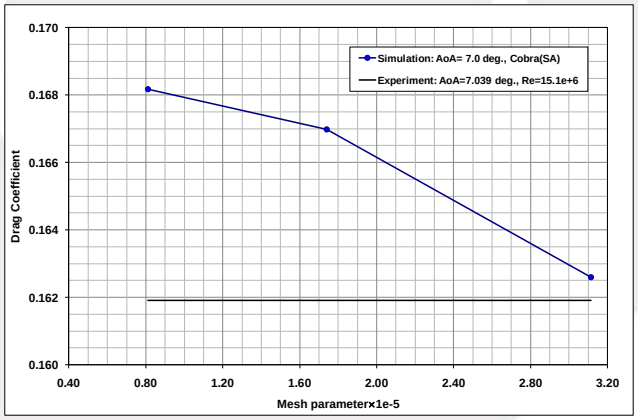


Drag coefficient

Mesh convergence for AoA = 7°



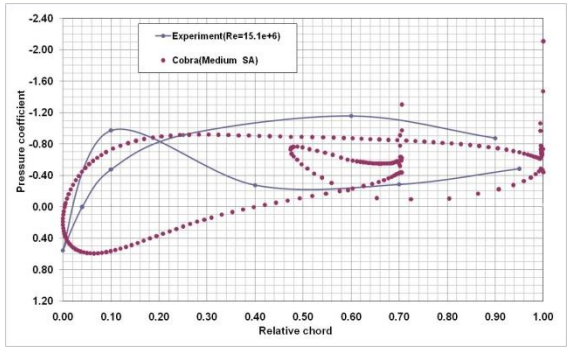
Lift coefficient

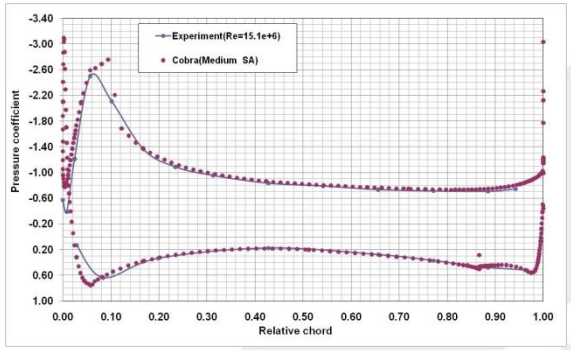


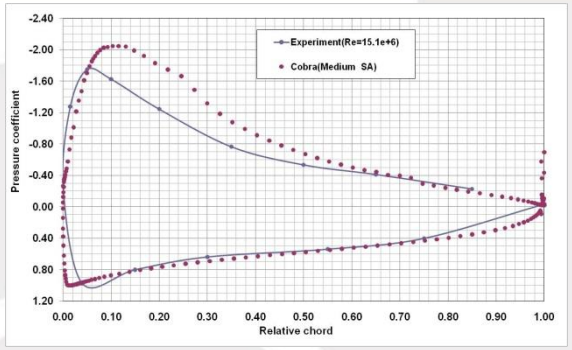
Drag coefficient

Mesh convergence for AoA = 7°

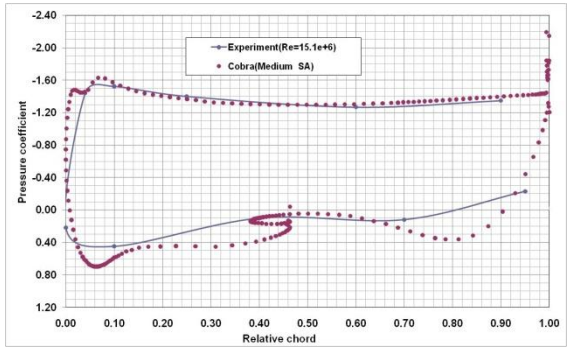
Results (Case 1 pressure coefficient distribution at AoA=7°):

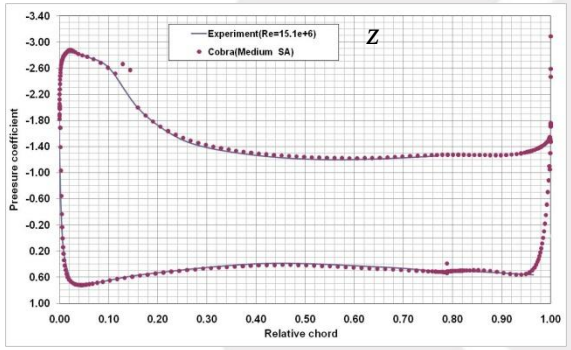


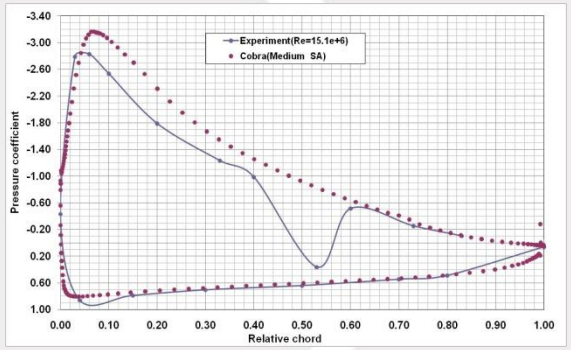




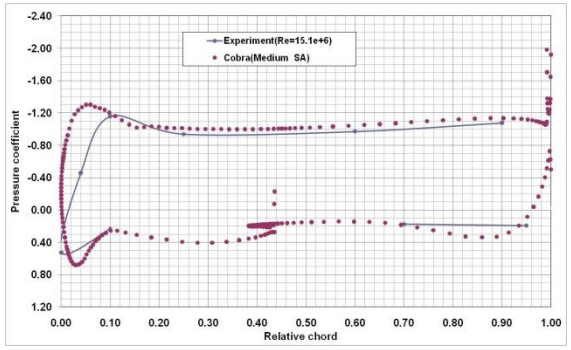
Z=0.150

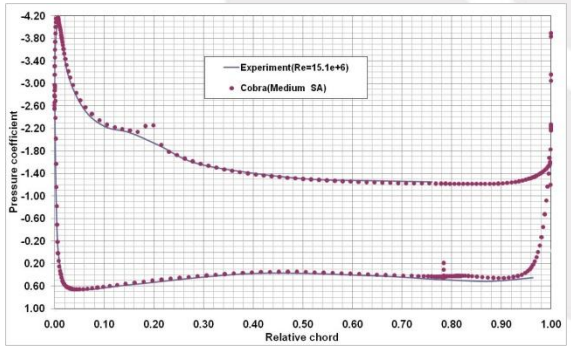


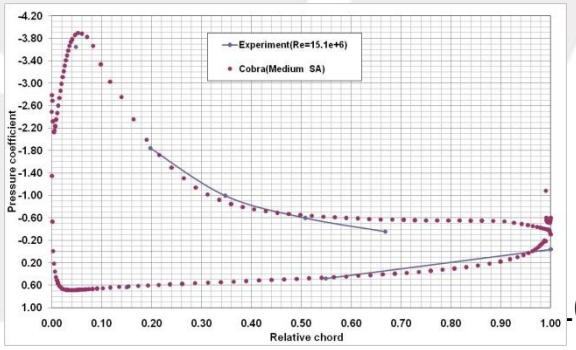




Z=0.449



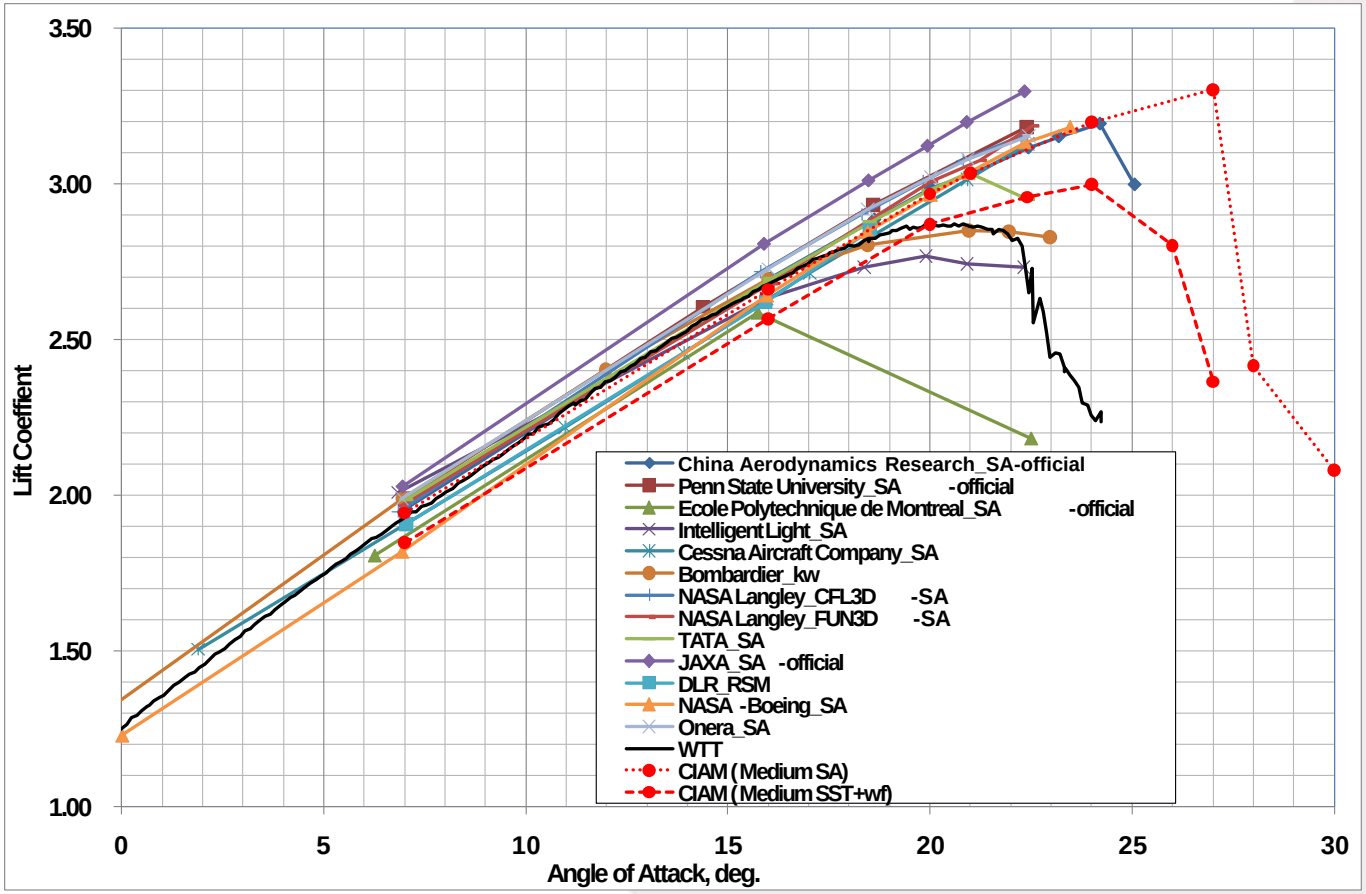




Z=0.891

Slat **Wing** **Flap**

Results (Case 1 Summary):



Summary CL plots from different HiLift PW-2 for Case 1 for medium mesh

Results (Case 2):

Configuration: configuration 4 of DLR-F11

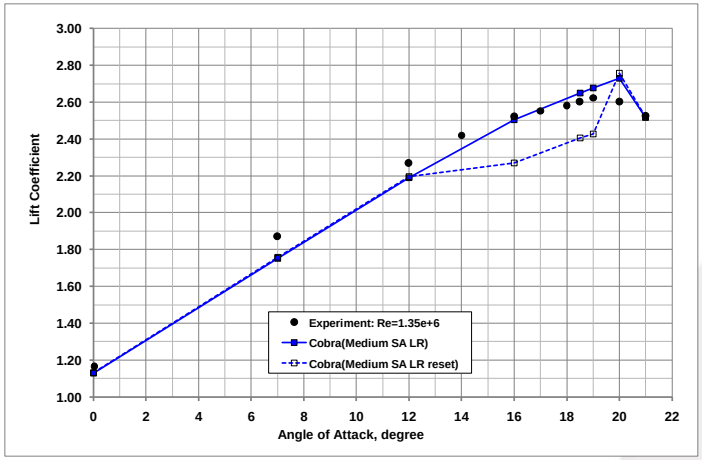
Free stream Mach number: 0.175

Angle of attack (AoA): 0, 7°, 12°, 16°, 18.5°, 19°, 20° and 21°

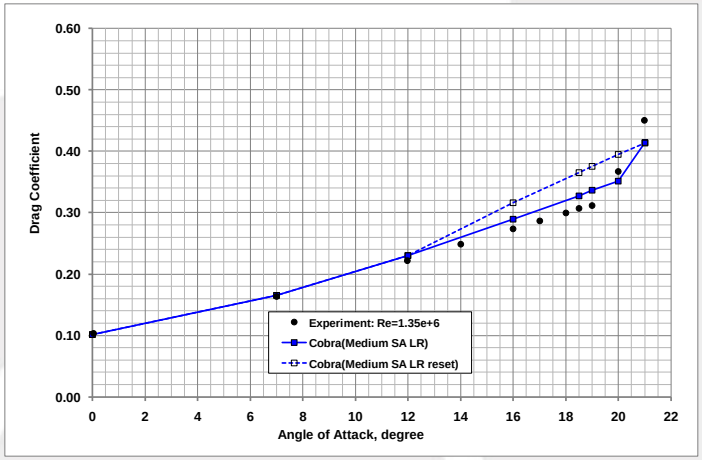
Meshes: medium

Reynolds numbers: low Reynolds 1.35 million (Case 2a) high Reynolds 15.1 million (Case 2b)

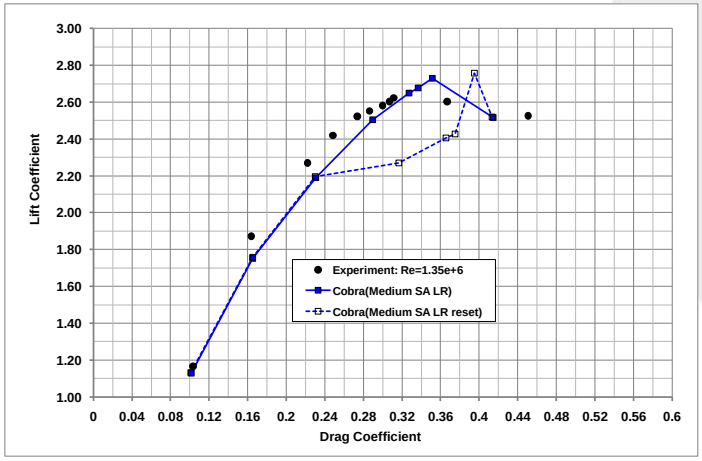
Results (Case 2a aerodynamic characteristics):



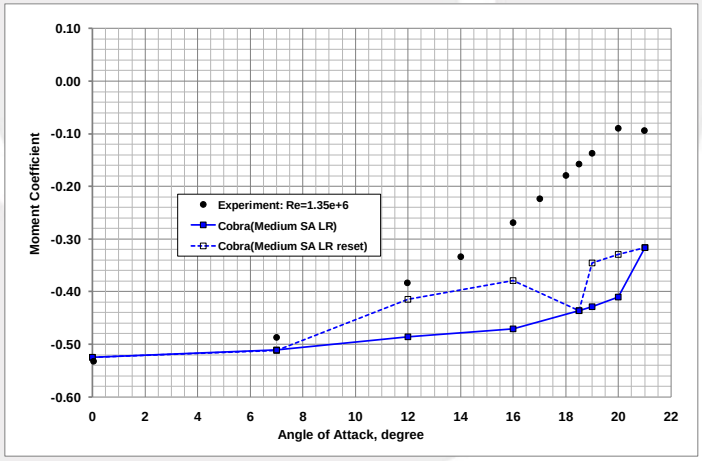
Lift coefficient



Drag coefficient

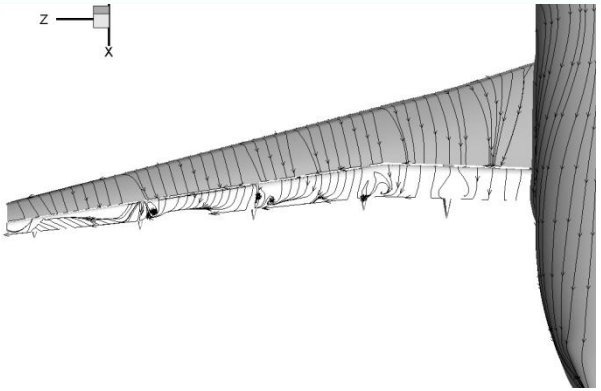


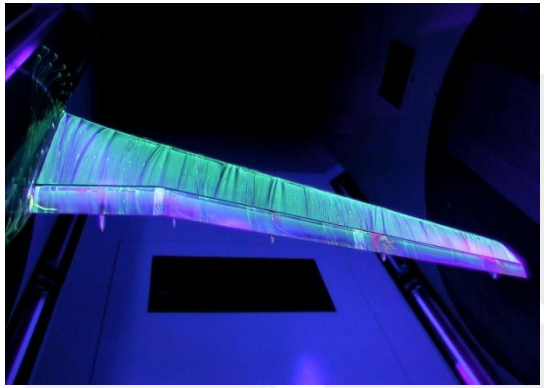
Drag polar



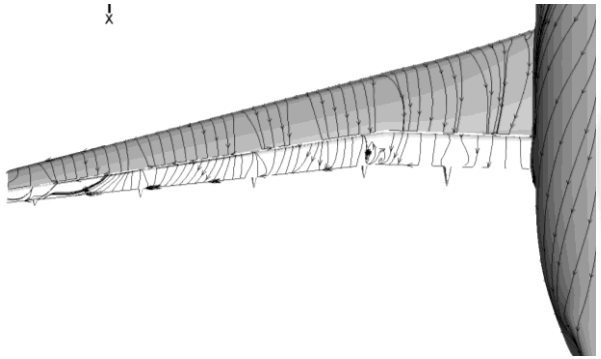
Pitching moment

Results (Case 2a Surface stream lines and oil flow):

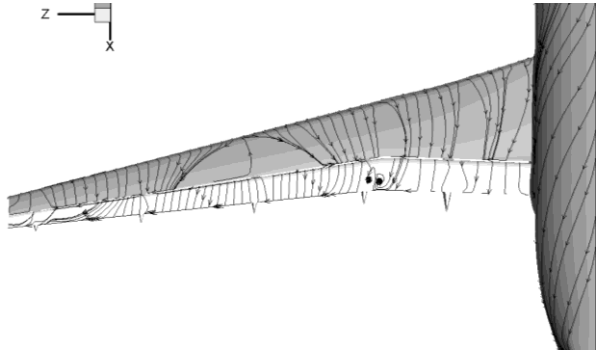


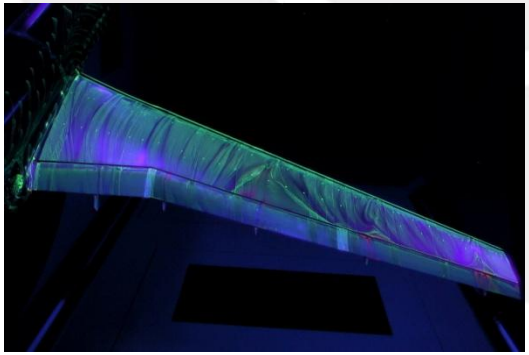


AoA=7°



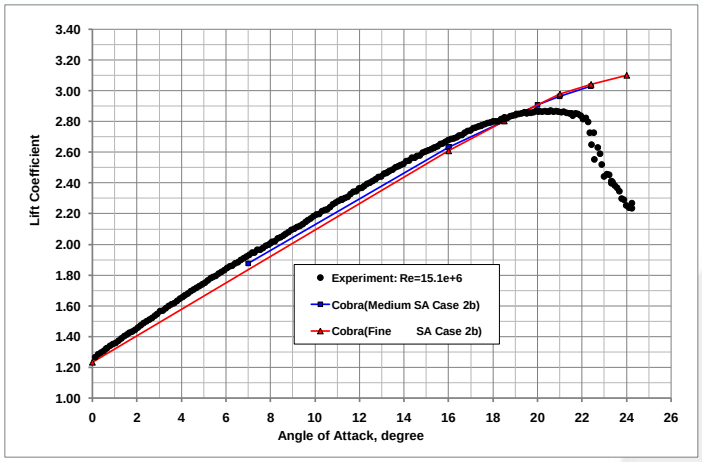
AoA=18.5°



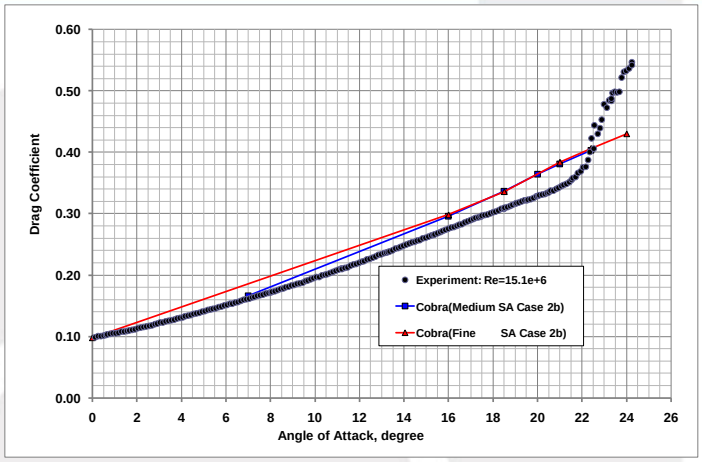


AoA=20°

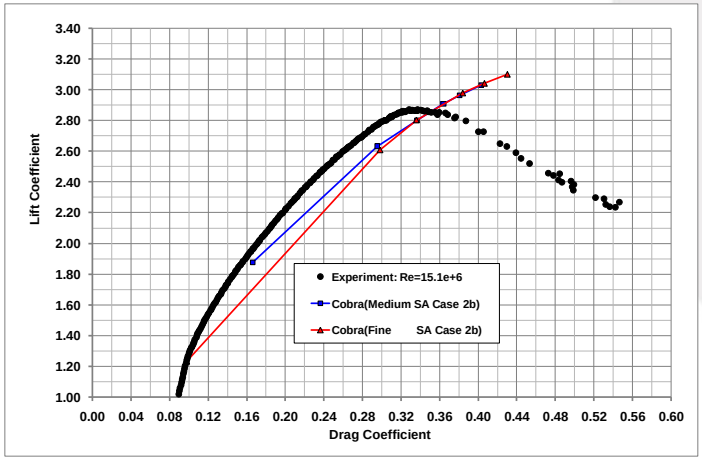
Results (Case 2b aerodynamic characteristics):



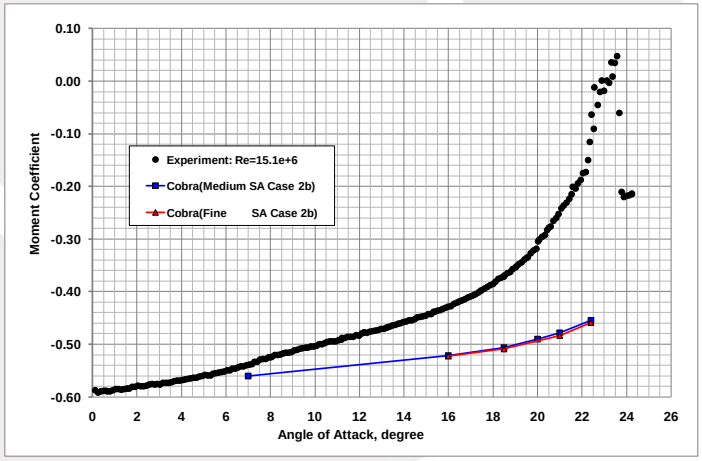
Lift coefficient



Drag coefficient

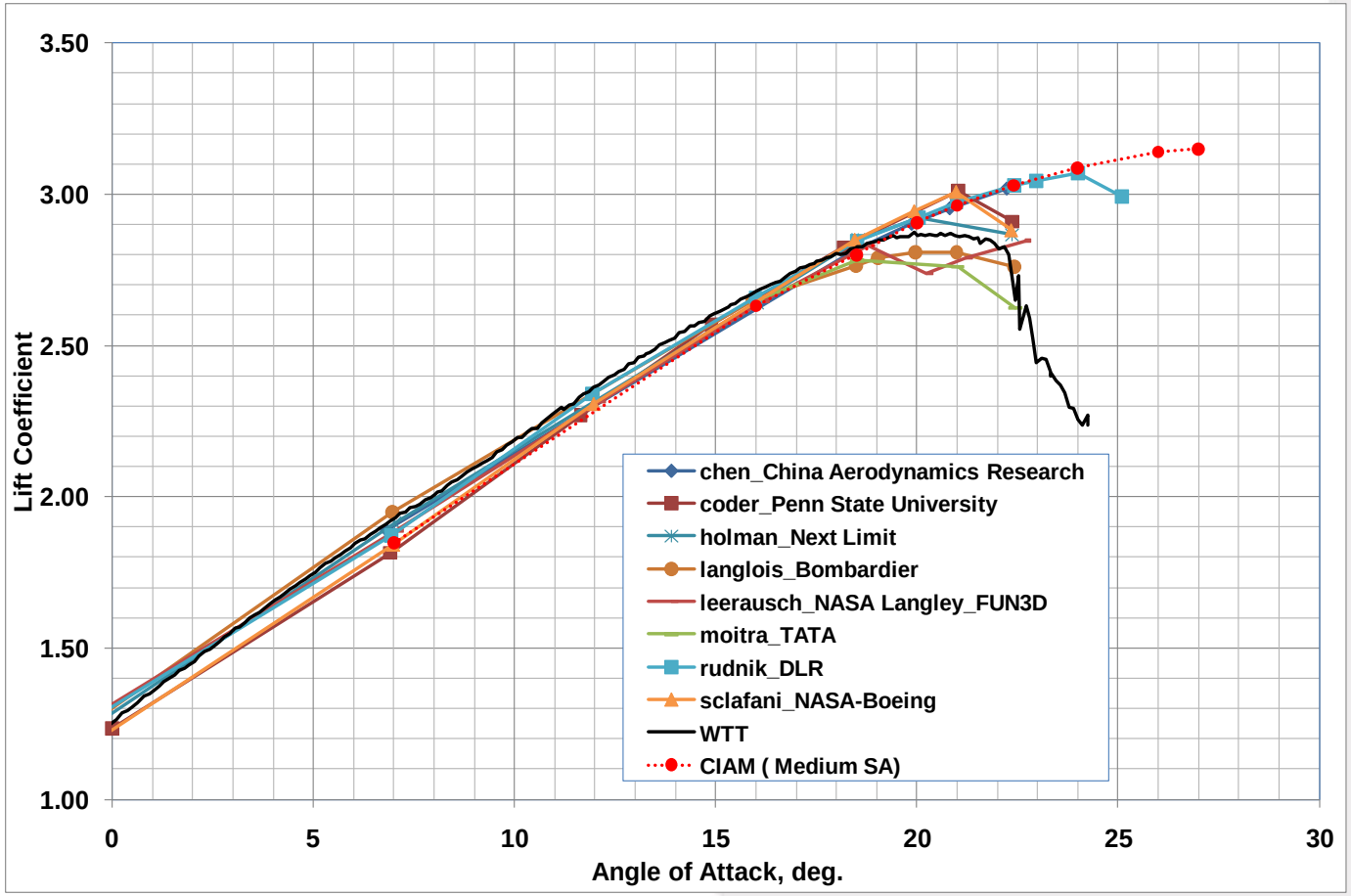


Drag polar



Pitching moment

Results (Case 2b Summary):



Summary CL plots from different HiLift PW-2 for Case 2b

Conclusions:

- **Results of the calculations have different degree of convergence with WTT-data for different parameters**
- **The general tendency is good coordination of CL and dCL/dα with experiment for Case 1 and Case 2b in a linear range and over prediction of CLmax nearly identical for all meshes**
- **For the Case 2a the best coordination of CLmax as the good coordination of dCL/dα takes place, but CL in a linear range is however worse predicted**
- **Values of CD were predicted satisfactory within the limits of the given problem for all cases considered**
- **The results received for the Case 2a have shown a capability of a hysteresis of aerodynamic characteristics during calculations that demands additional study of the reasons of this phenomenon and its physical adequacy in the problem considered**
- **The comparative analysis of the results received by various participants of the HiLiftPW-2 project for calculation of CL vs α curves for various DLR-F11's configurations, has shown, that CIAM's in-house *Cobra* code is among of the majority of the CFD software used in the project**

Acknowledgments:

This work is the results of several fruitful collaborations and we gratefully acknowledge to the Sarov's Institute of Experimental Physics which have provided supercomputer and information resources and to Sukhoi Aircraft Company which have ensured of a great many of works for the *Cobra* preliminary validation

I would like to express special gratitude to Chris Rumsey (NASA) for its persistence and goodwill by publication and report preparation

Thank you for attention…

The World's Forum for Aerospace Leadership