CFD High Lift Prediction Workshop

DLR Contribution to HiLiftPW-3

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PID 026

3rd High Lift Prediction Workshop
Denver, CO June 3-4, 2017

Summary of cases completed: TAU, DLR-SOLAR

Case	Alpha=8, Fully turb, grid study	Alpha=16, Fully turb, grid study	Other
1a (full gap)	yes	yes	
1b (full gap w adaption)	no	no	
1c (partial seal)	no	no	
1d (partial seal w adaption)	no	no	
Other			

Flow Solver: TAU code
Turb. Model: SA-neg
Grid: DLR-SOLAR (part. grid)

Case	Polar, Fully turb	Polar, specified transition	Polar, w transition prediction
2a (no nacelle)	yes	no	no
2b (no nacelle w adaption)	no	no	no
2c (with nacelle)	yes	no	no
2d (with nacelle w adaption)	no	no	no
Other			

Flow Solver: TAU code
Turb. Model: SA-neg
Grid: DLR-SOLAR (com. grid)

Case	2D Verification study	Other
3	yes	
Other		

Flow Solver: TAU code
Turb. Model: SA-neg, SA-noft2, RSM-SSG/LRR-g
Grid: TMR website (man. grids,all level)

Summary of code and numerics used

- **Code Version: DLR TAU code 2016.1.0**
- **Spatial Discretization:**
  - **Main equations: Jameson central, 2nd order;**
    Blend scalar (20%) – matrix (80%) dissipation
  - **Turbulent equations: AUSMDV upwind, 2nd order**
  - **Full NS Discretization**
- **Turbulence Models:**
  - **Spalart-Allmaras-neg (SA-neg), Case 1,2, and 3)**
  - **Spalart-Allmaras w/o ft2 term (SA-noft2), Case 3**
  - **D-RSM SSG/LLR-g (RSM), Case 3**
- **Temp. Integration:**
  - **LU-SGS Backward Euler**
  - **Multigrid, 3V cycle, main and turb. equations**
  - **automatic small AoA increment pitch-up procedure**

⇨ **Basic assessment using DLR standard code set-up for high lift configuration assessment**

Brief overview of grid system(s)

Grid System	Case(s)	If committee grid, report any problems/issues If user grid, reason for generating grid system
Participant: Unstr_DLR-SOLAR_026 (hybrid, hex-dominant)	1a	Test grid generation capabilities for grid families
Committee: B-JSM_UnstrMixed_DLR_SOLAR (hybrid, hex-dominant)	2a, 2c	/

- **Hybrid unstructured grids, hex-based near surfaces, individual grids for all configurations and resolution levels**
- **Grid generation and adaptation approach**
  - **y^+ -manual adaptation, const. first cell height**
  - **grid family approach according to DPW IV, HiLiftPW-1 (SOLAR)**
  - **grid resolution control via source placement**
- **Grids for CRM-HL, Case 1a (adapted for Re = 3.26 x 10^6)**

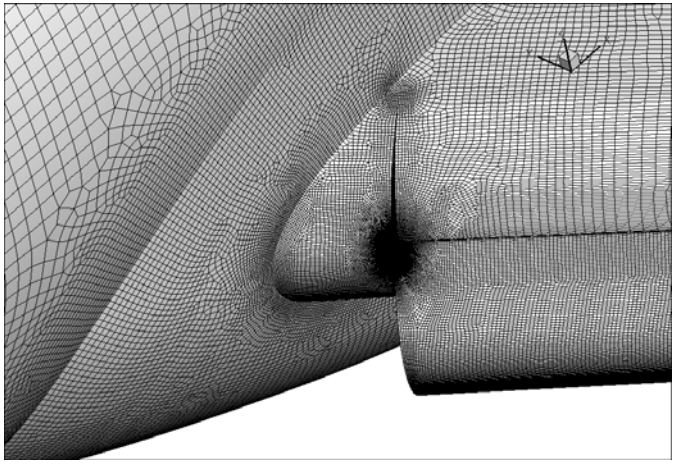
Grid Level	Pts.	Hexas	Surf. Elem.	Tot. Elem.	struct. layers
C	11,454,391	9,626,290	478,765	18,937,064	31
M	36,357,717	31,624,960	986,916	56,466,123	45
F	123,361,893	110,853,302	2,135,844	178,003,709	70

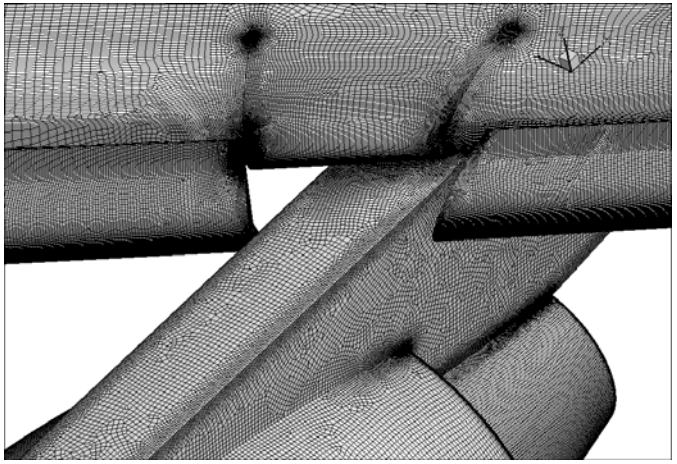
Brief overview of grid system(s)

- **Grids (fine) for JSM, Case 2a and 2c (no geometric simplifications w.r.t CAD)**

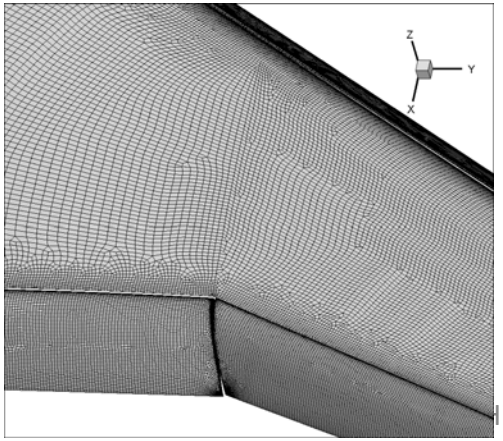
Grid, Config.	Pts.	Hexas	Surf. Elem.	Tot. Elem.	struct. layers
JSM-WB	102,027,077	88,294,364	2,290,359	161,744,029	48
JSM-WBNP	125,621,876	107,248,524	2,712,045	206,920,972	48

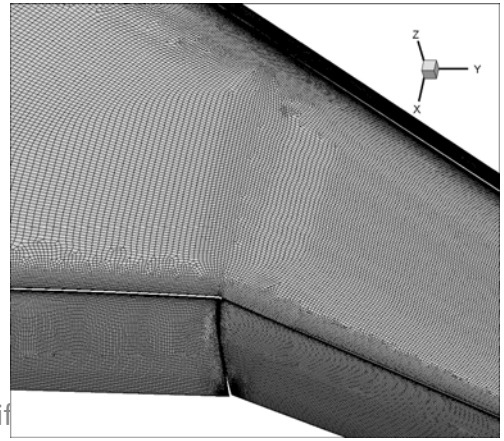
JSM

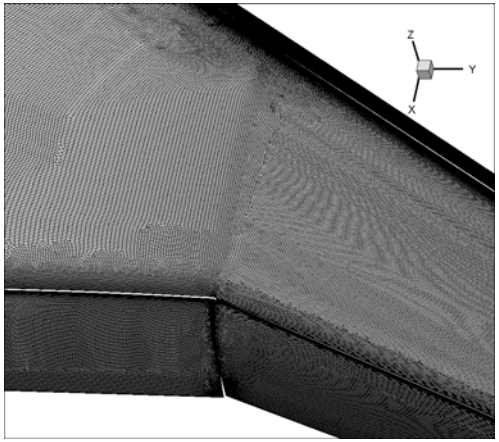




HL-CRM

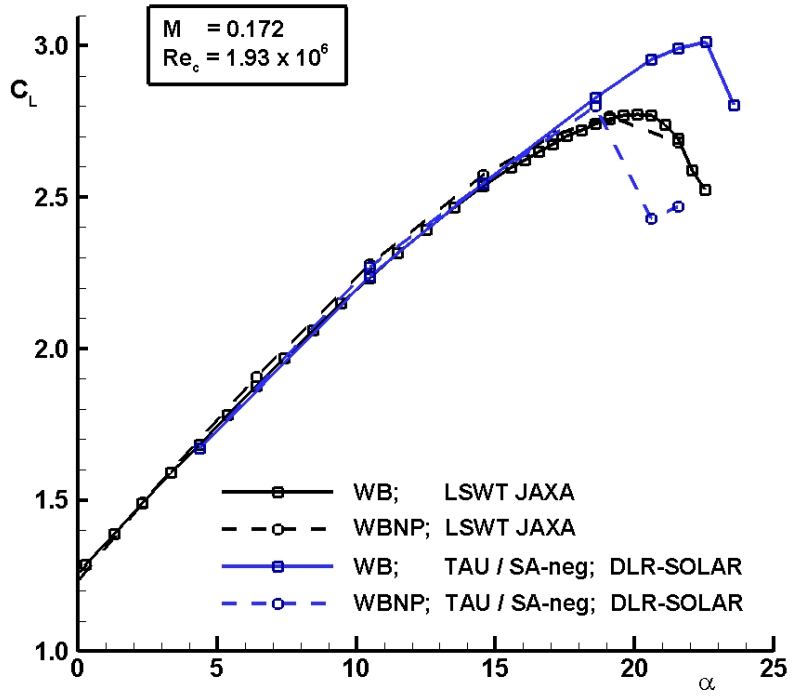


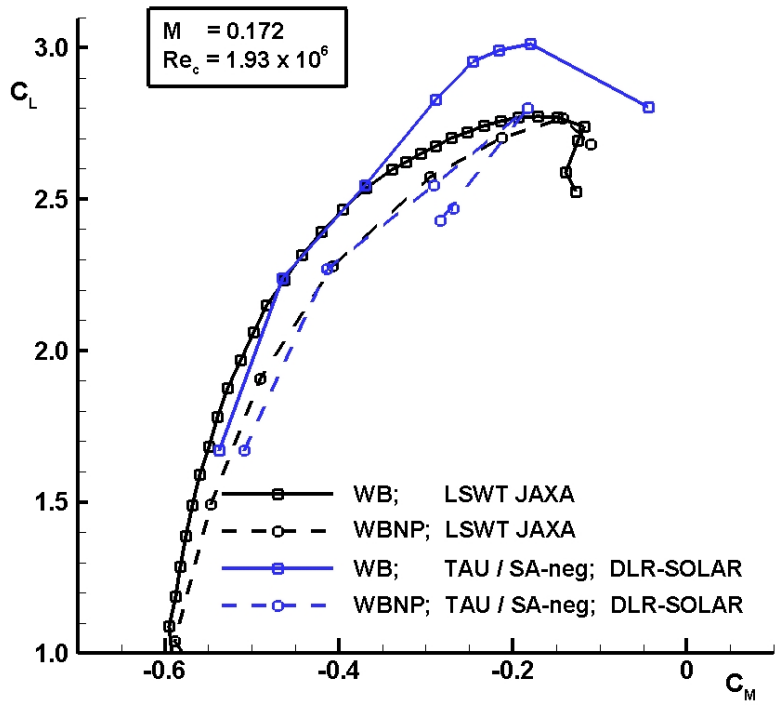




Brief overview of JSM results of DLR

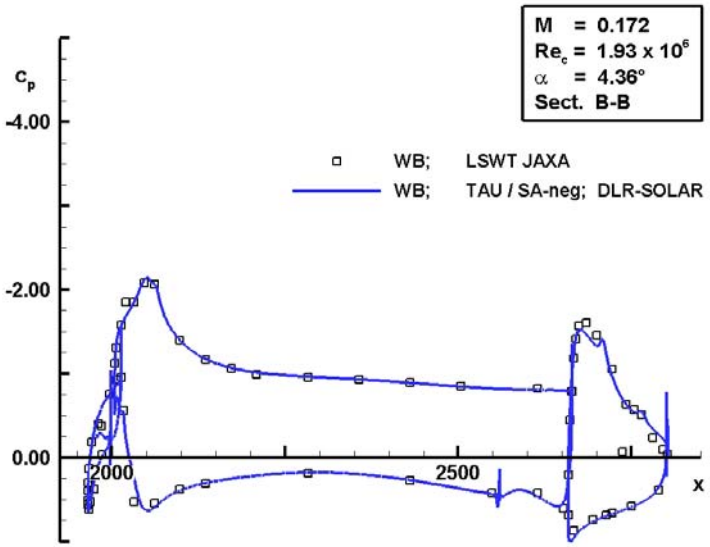
- **Lift curve and pitching moment JSM WB vs. WBNP**

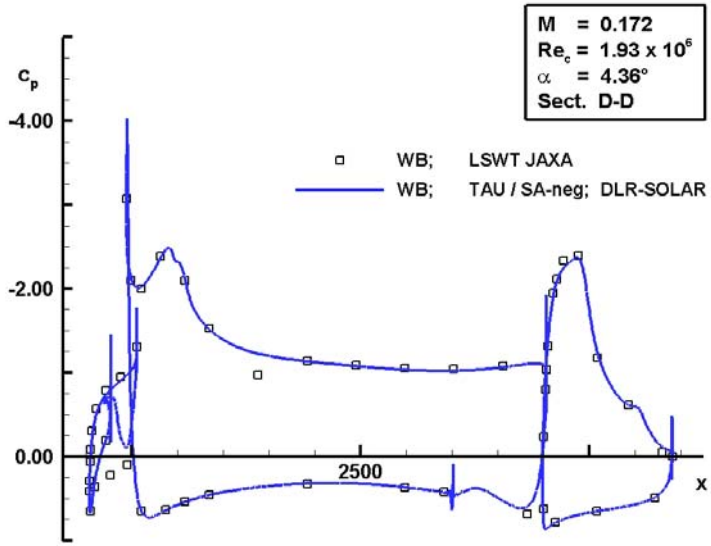


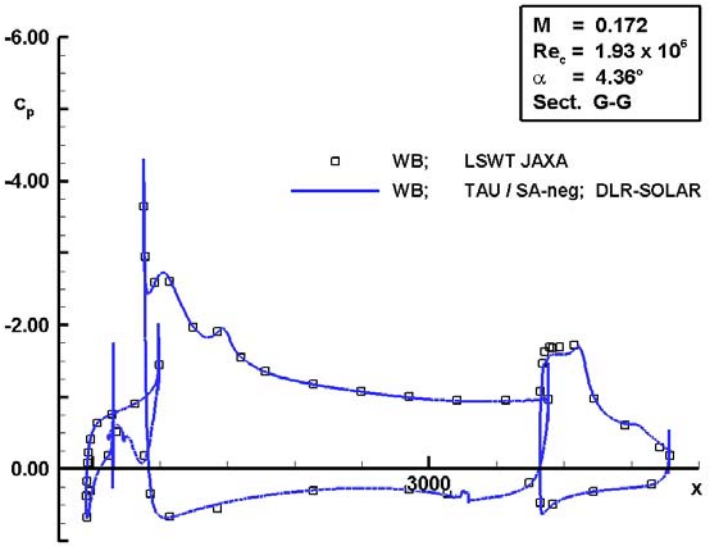


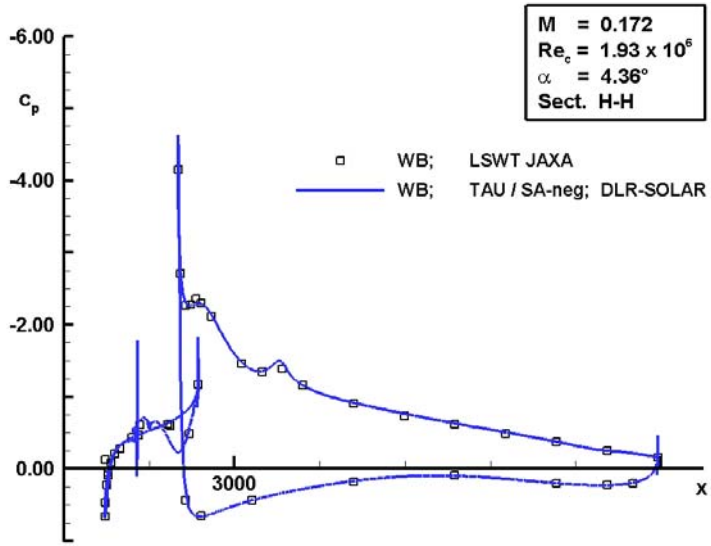
Brief overview of JSM results of DLR

- c_p-distributions JSM WB; α = 4.36°; sect: B-B, D-D, G-G, H-H



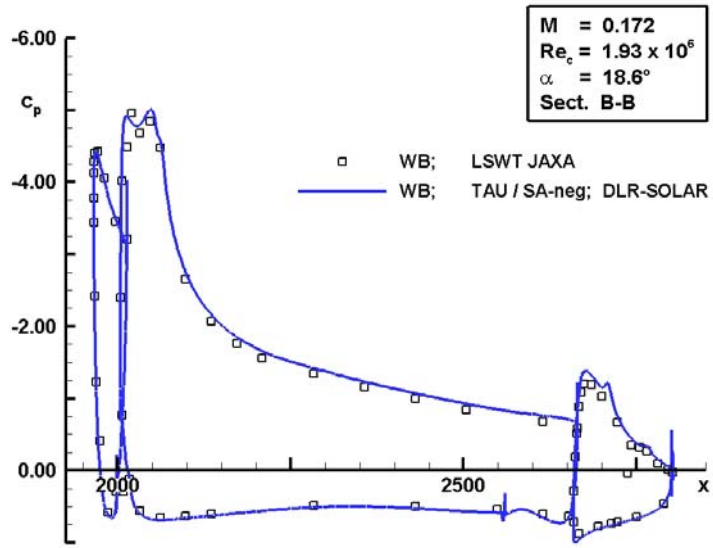


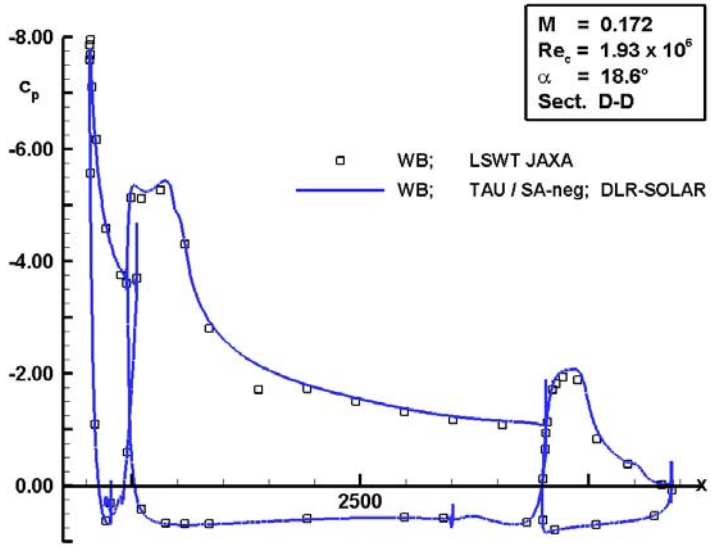


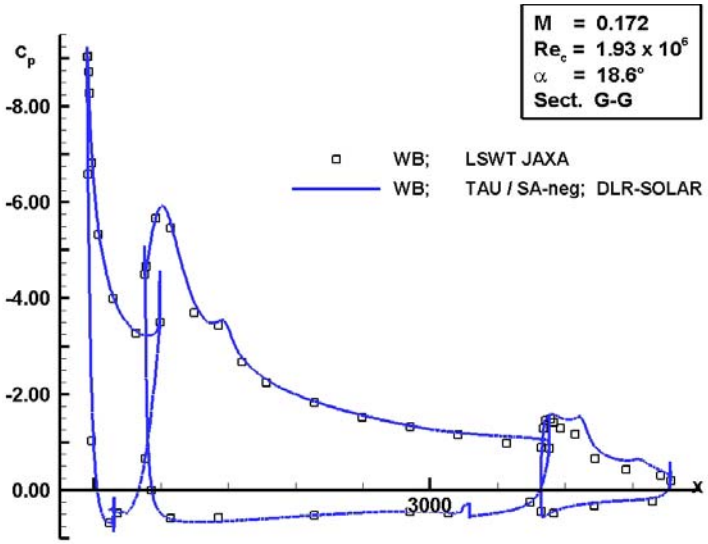


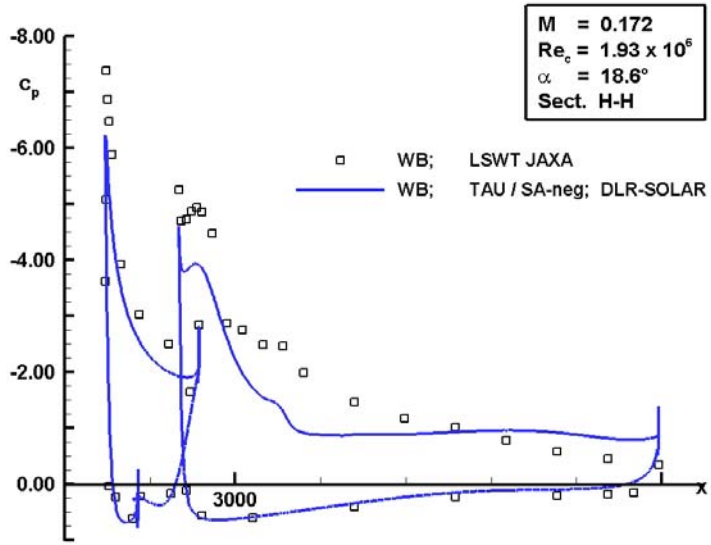
Brief overview of JSM results of DLR

- c_p-distributions JSM WB; α = 18.58°, Sect: B-B, D-D, G-G, H-H



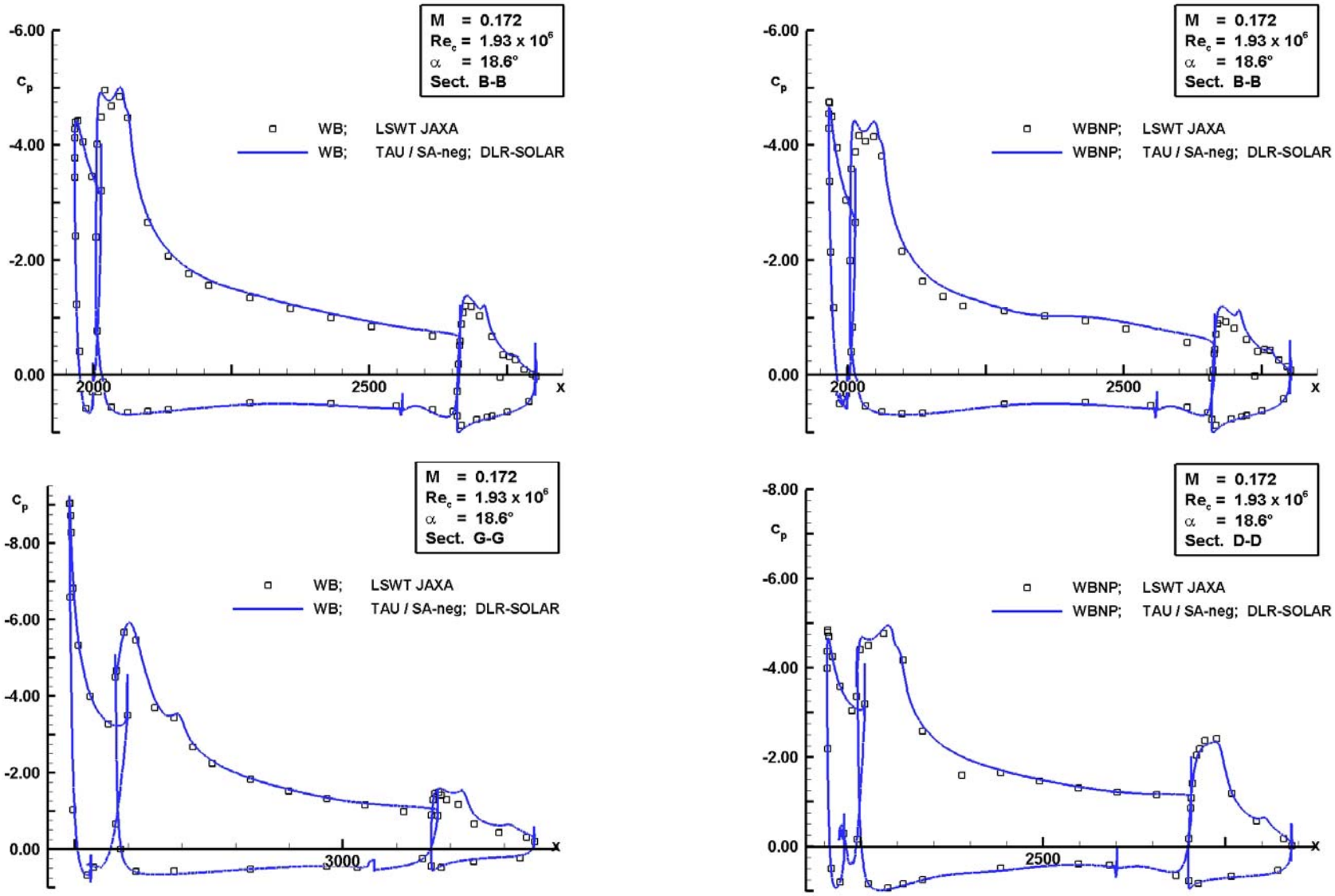






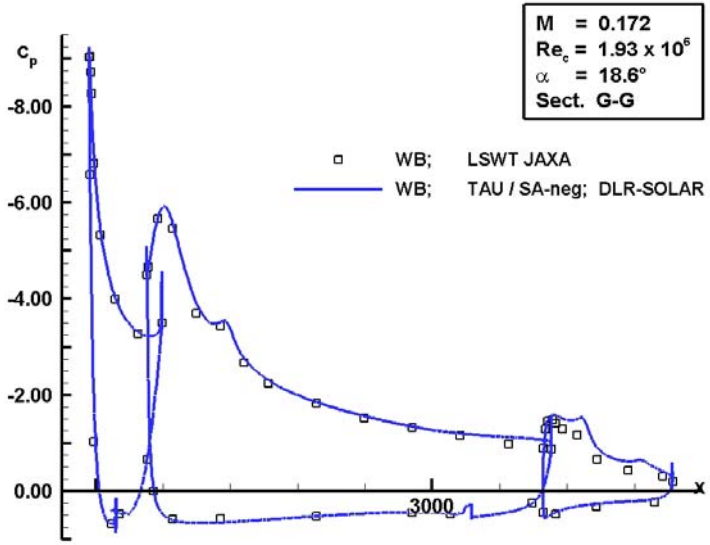
Brief overview of JSM results of DLR

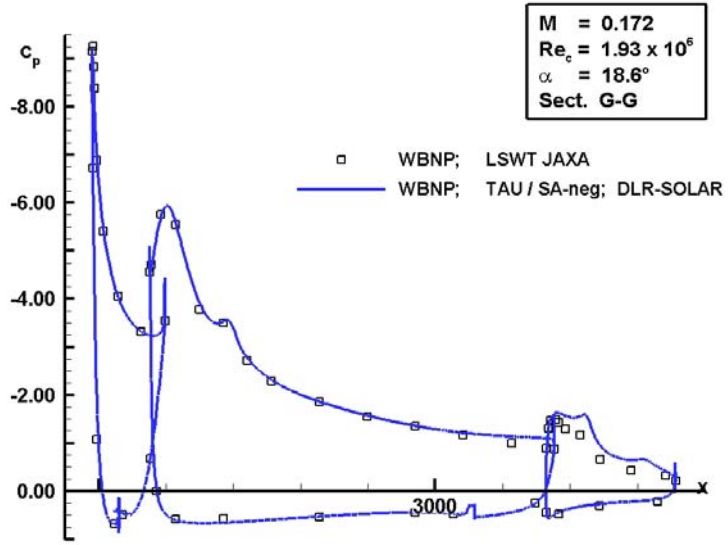
- c_p-distributions JSM WB vs. WBNP; α = 18.58°, Sect: B-B, D-D

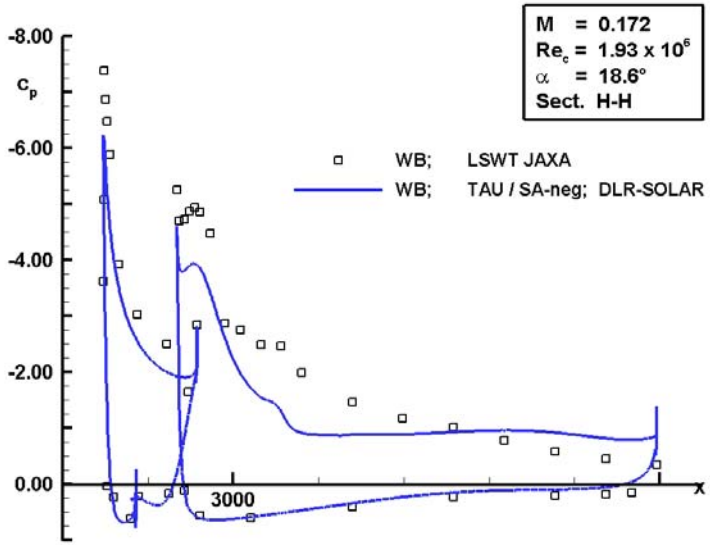


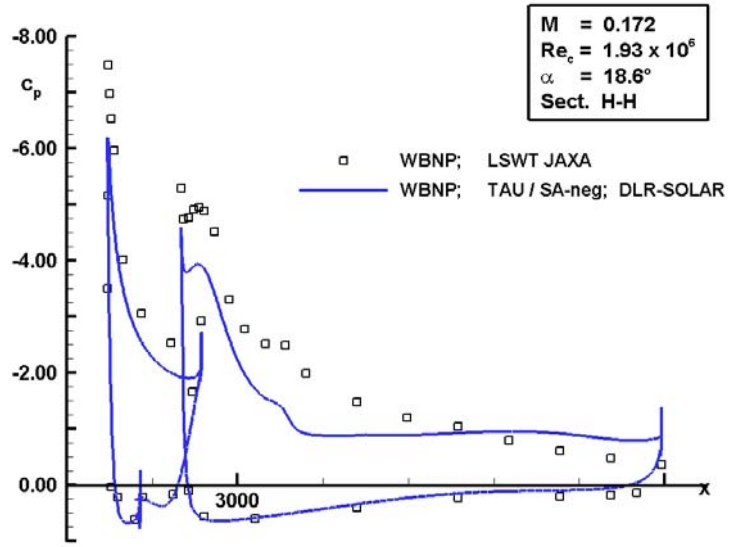
Brief overview of JSM results of DLR

- c_p-distributions JSM WB vs. WBNP; α = 18.58°, Sect: G-G, H-H



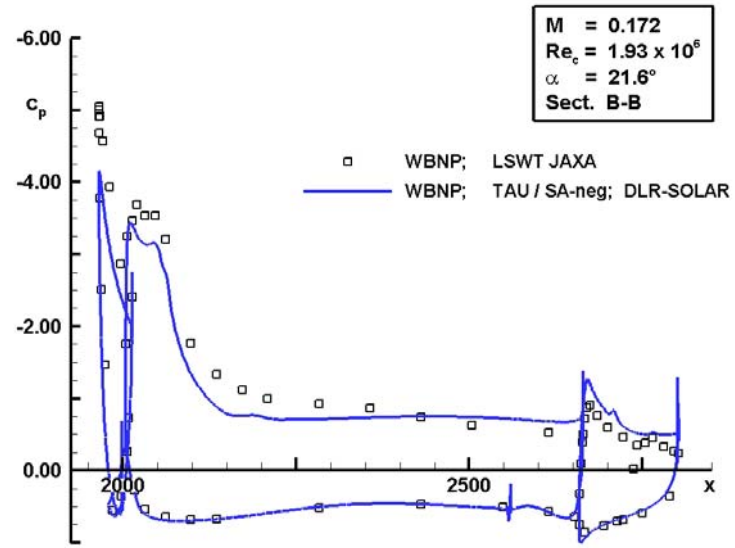


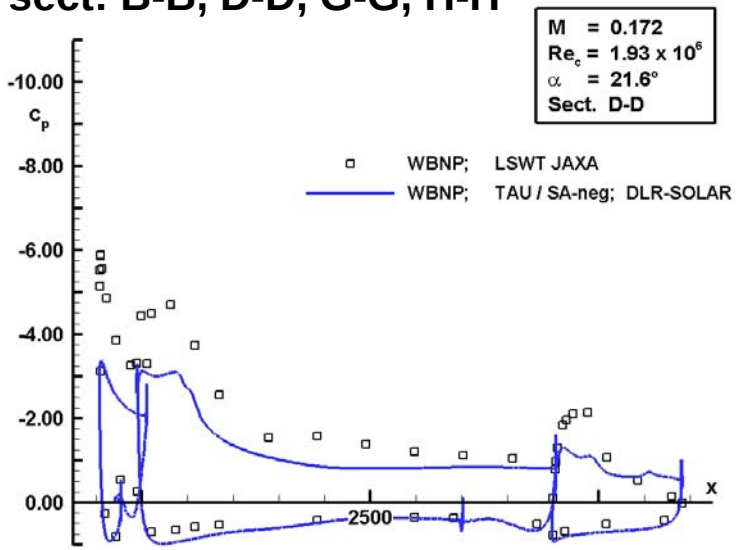


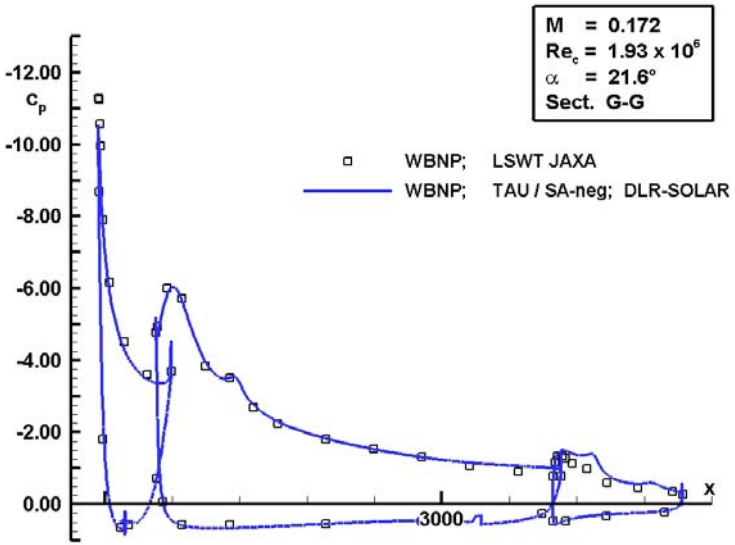


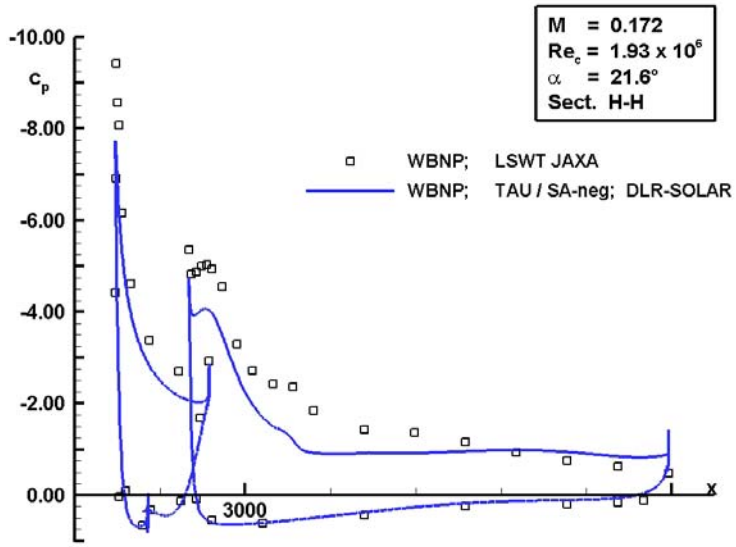
Brief overview of JSM results of DLR

- c_p-distributions JSM WBNP; α = 21.57°; sect: B-B, D-D, G-G, H-H



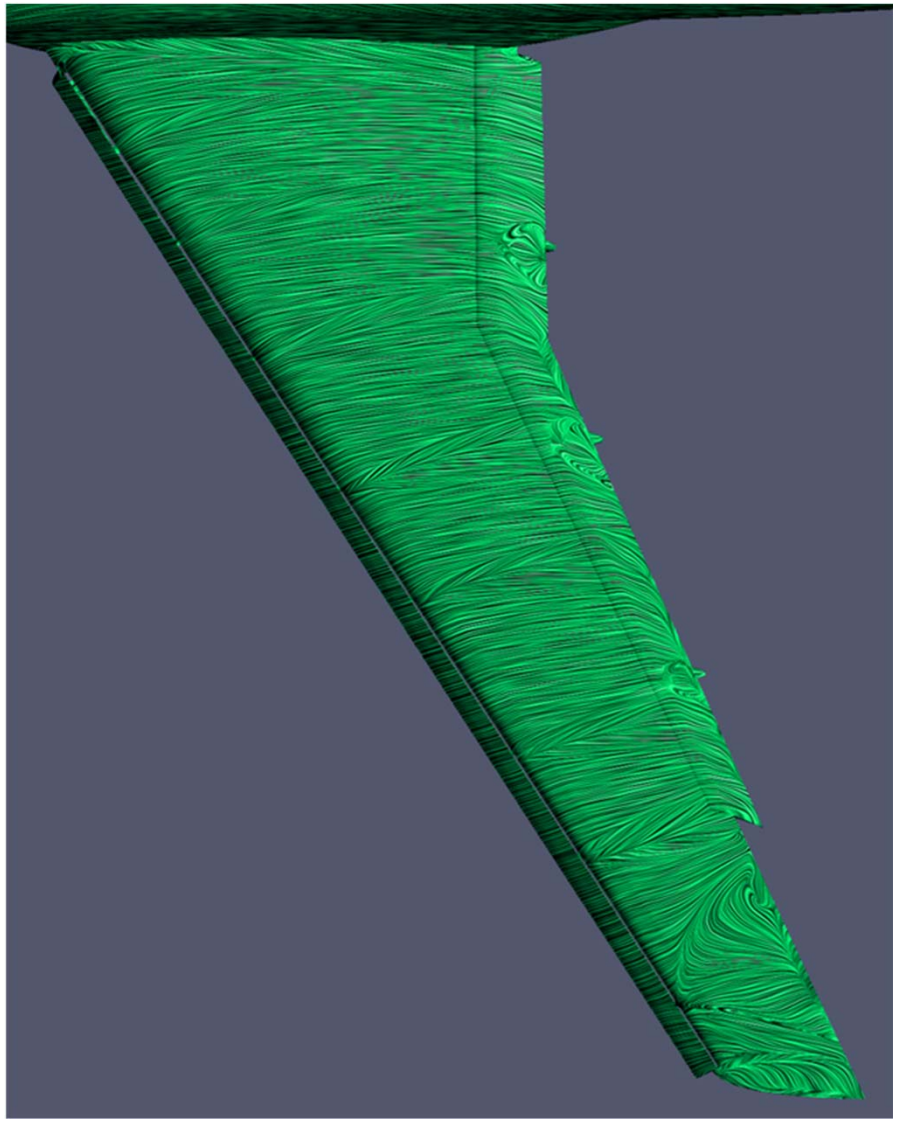






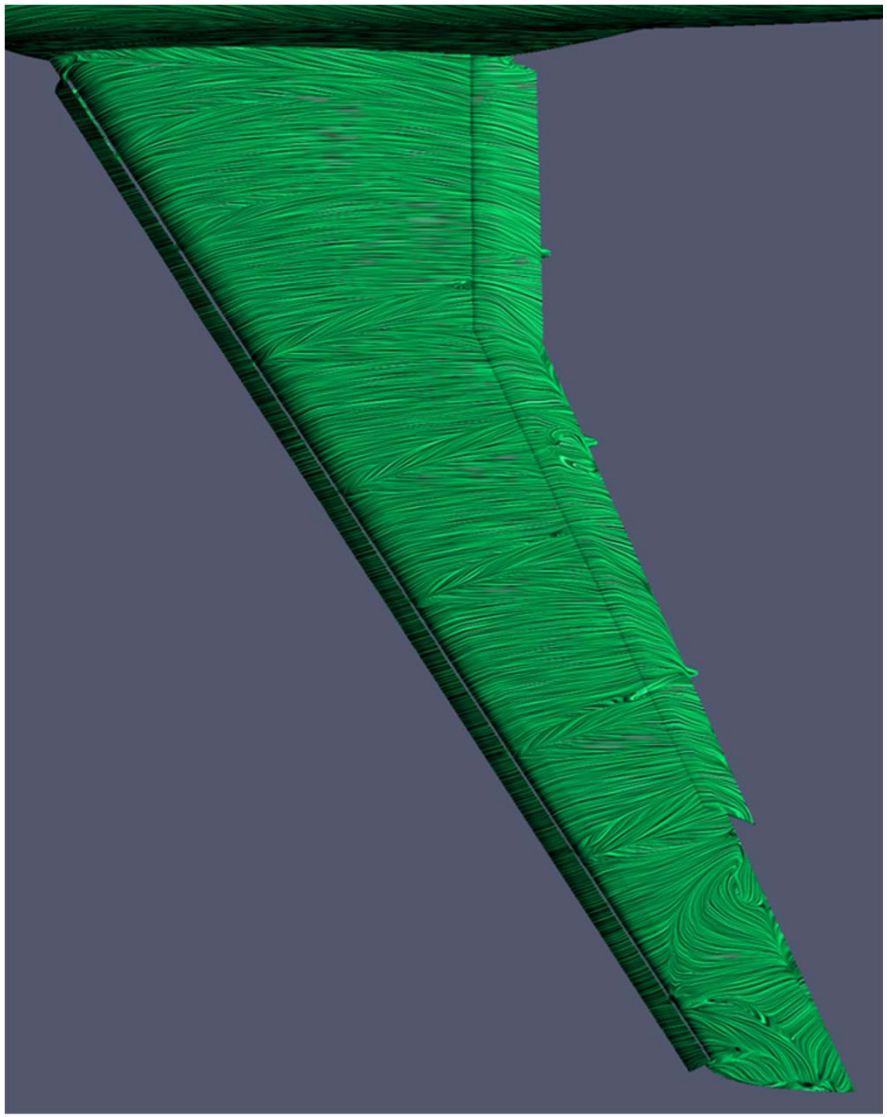
Brief overview of JSM results of DLR

- **Wall streamlines JSM WB; α = 18.36°**



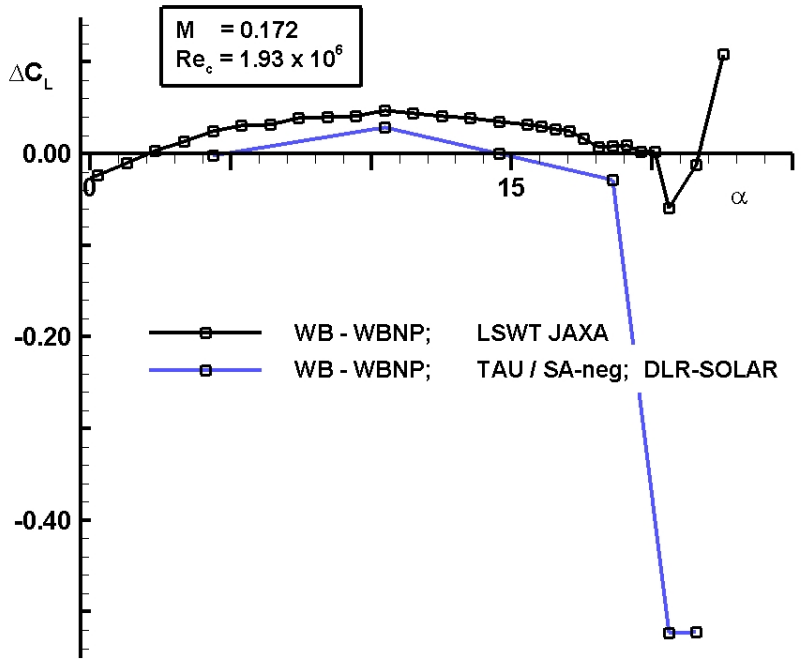
Brief overview of JSM results of DLR

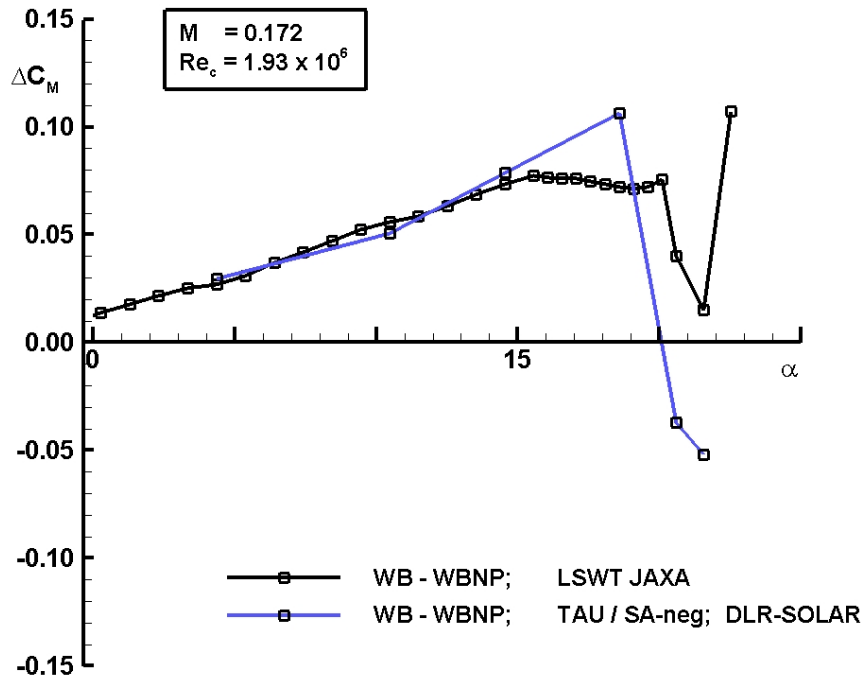
- **Wall streamlines JSM WB; α = 21.57° - but different flow state relative to α_{max}**



Brief overview of JSM results of DLR

- **Increments in lift and pitching moment due to engine integration (JSM WBNP-WB)**

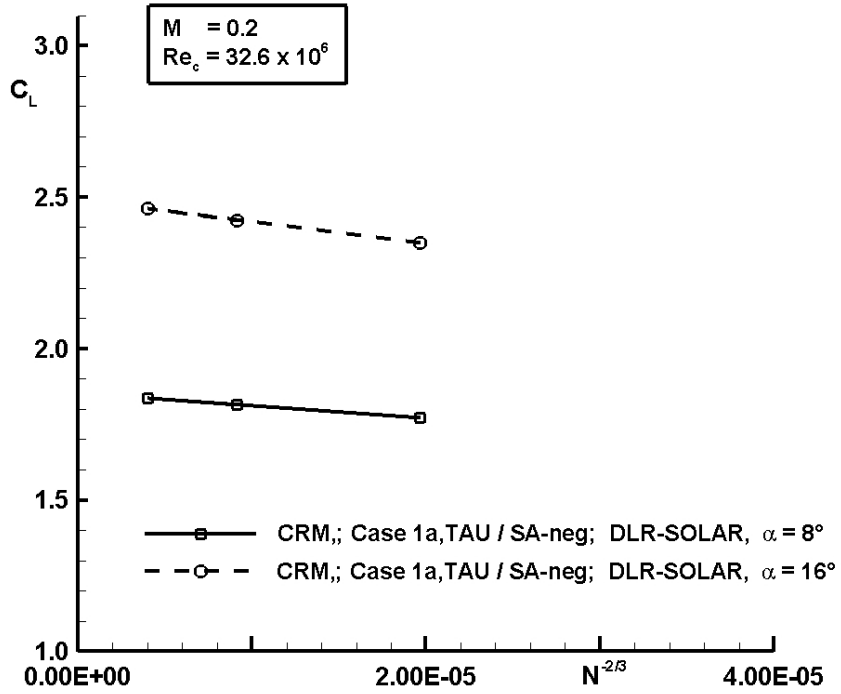


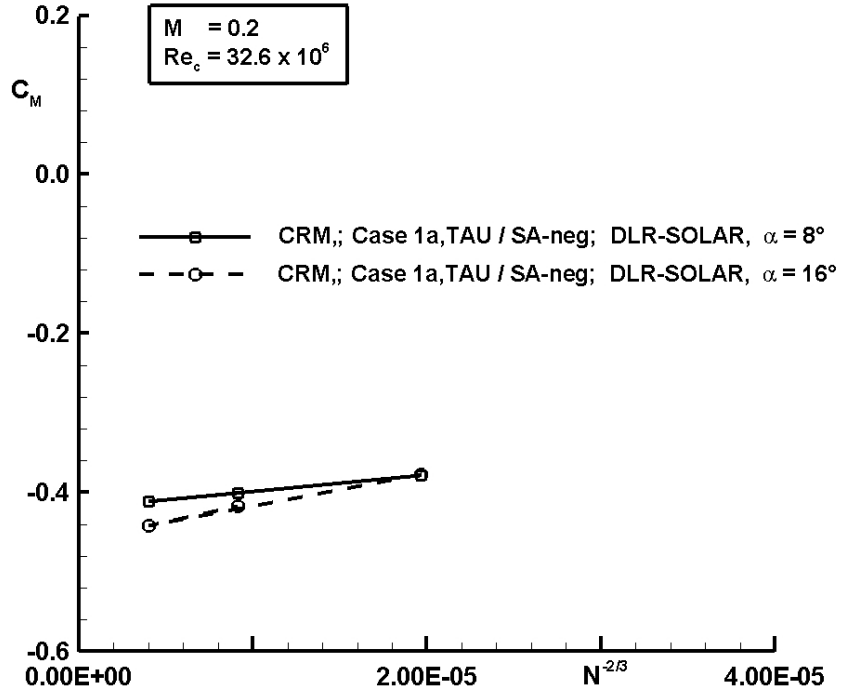


Brief overview of HL-CRM results of DLR

- **Grid resolution influence on lift and pitching moment for α = 8° and 16°**
  HL-CRM, WB , Case 1a (incl. spanwise intersections)

Note: computations for Re = 32 x 10^6 due to adoption of thermodynamic specifications

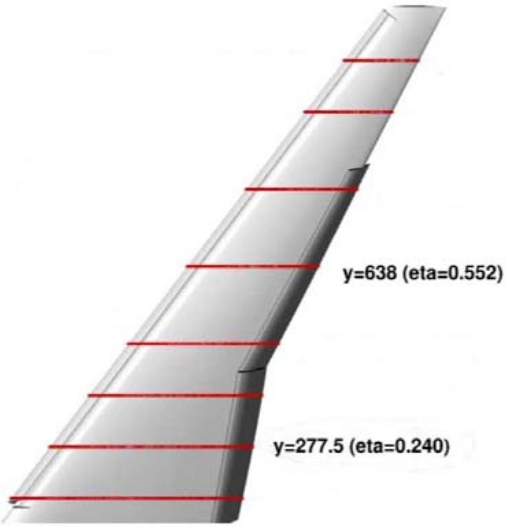


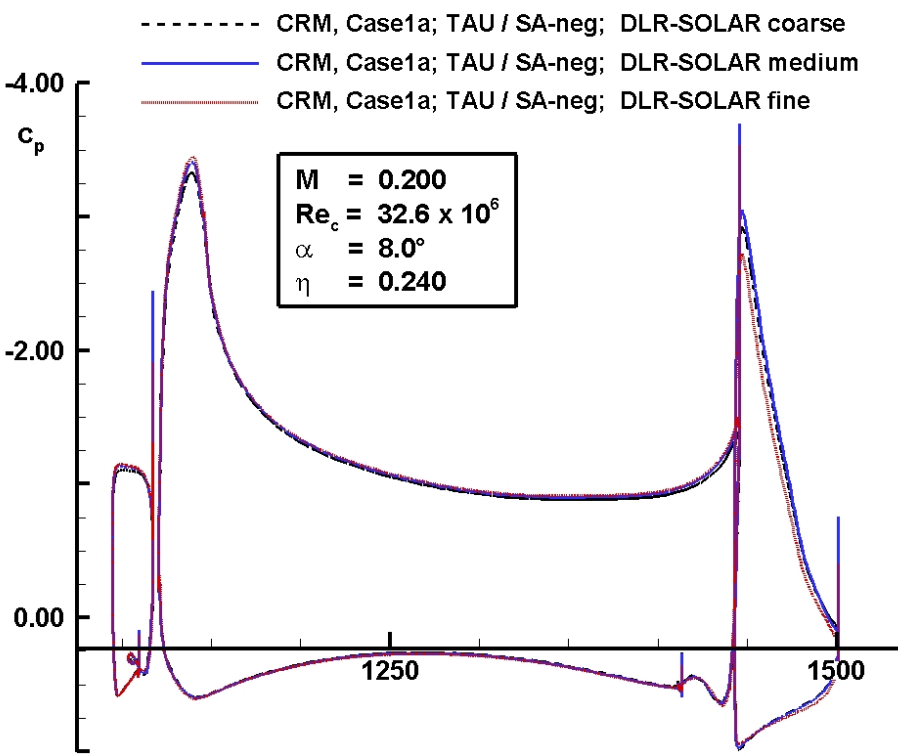


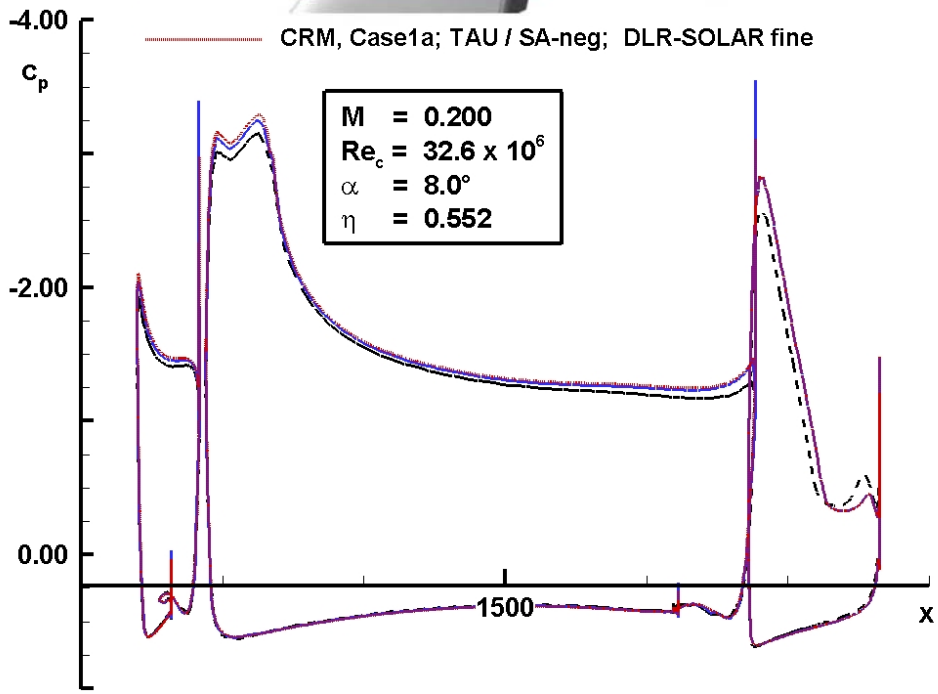
Brief overview of HL-CRM results of DLR

- **Grid resolution influence on c_p-distributions;**

  i/b and o/b 3-element section
  at η = 0.240 and 0.552 for α = 8°;



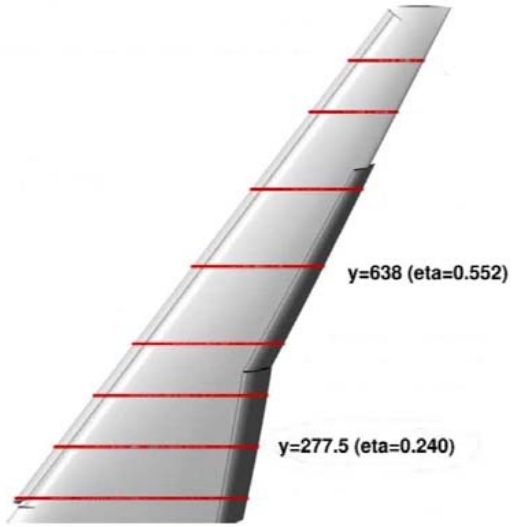


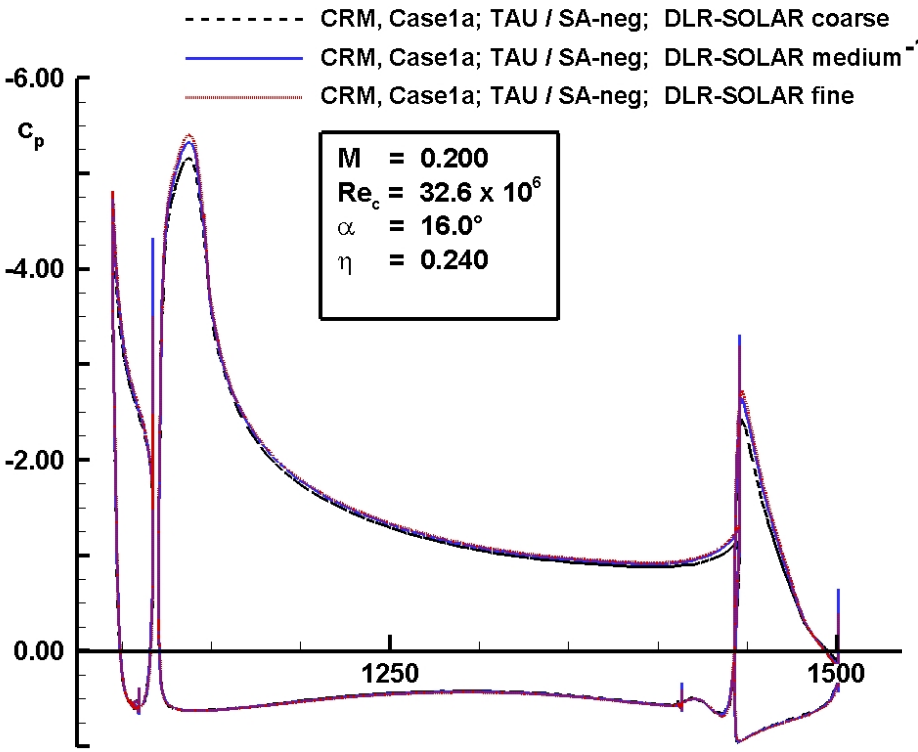


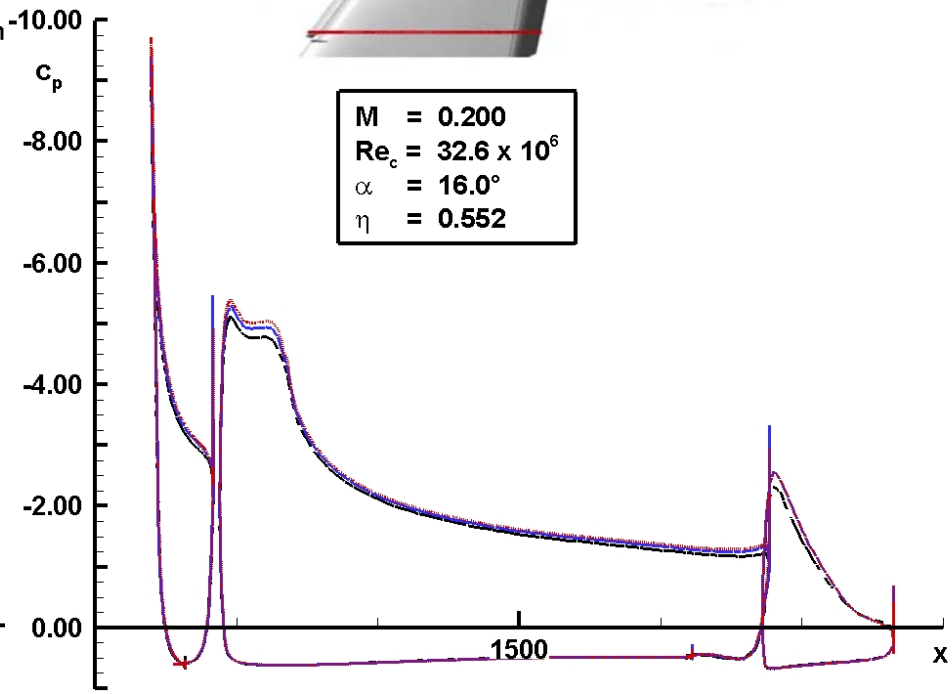
Brief overview of HL-CRM results of DLR

- **Grid resolution influence on c_p-distributions;**

  i/b and o/b 3-element section
  at η = 0.240 and 0.552 for α = 16°;

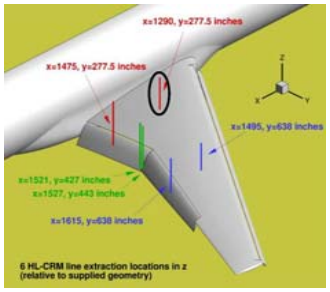


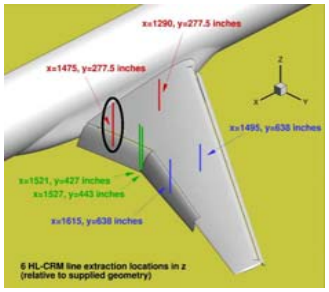


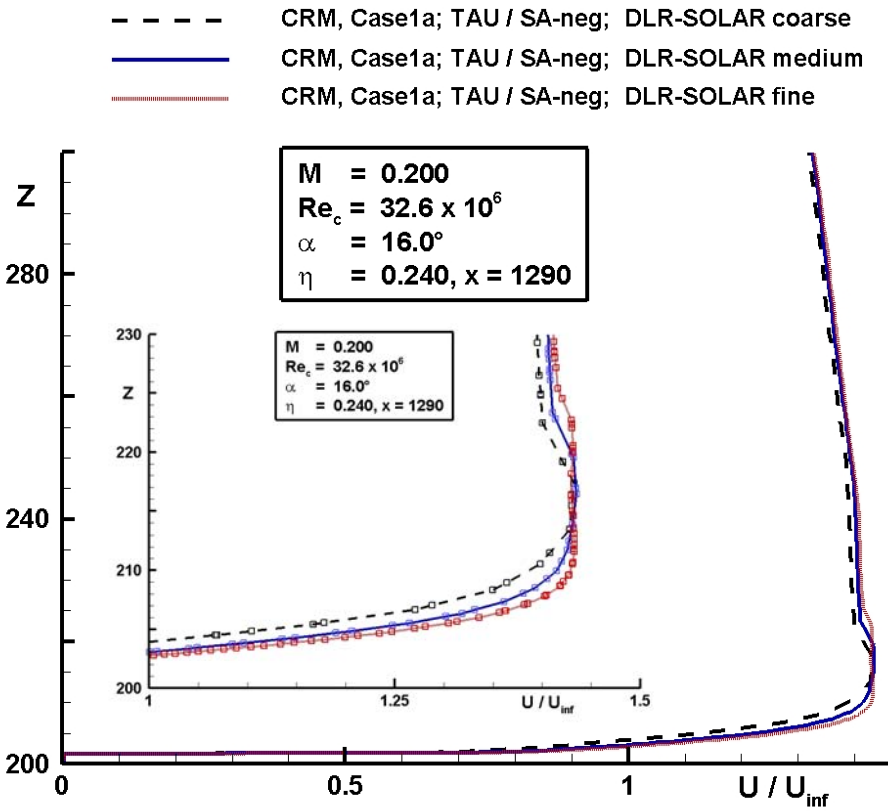


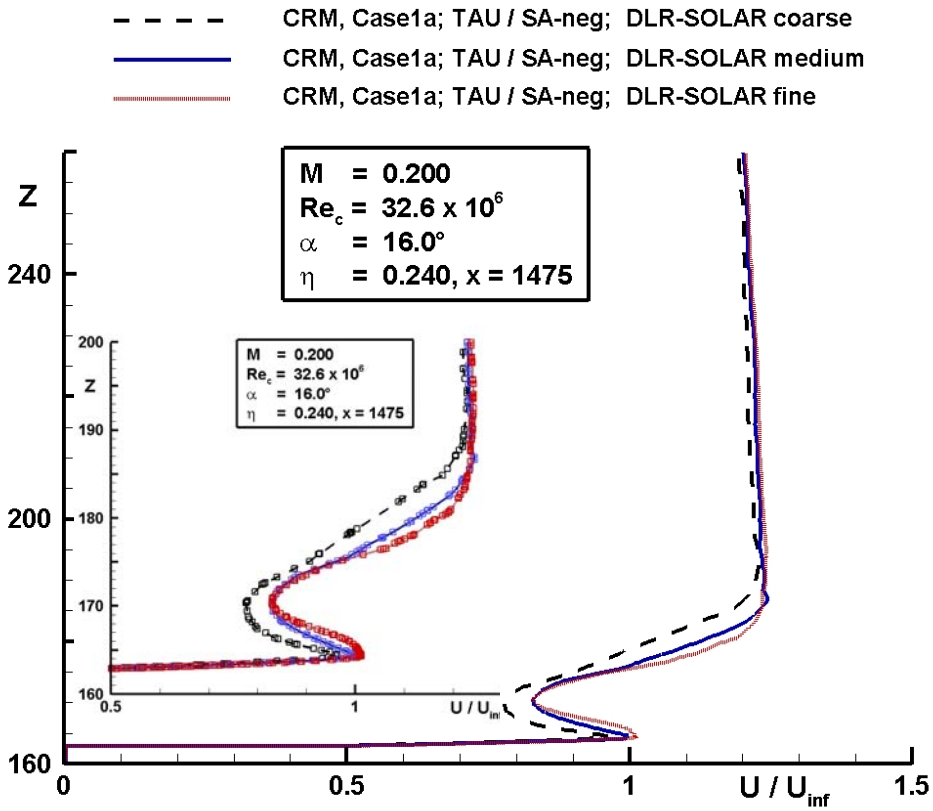
Brief overview of HL-CRM results of DLR

- **Grid resolution influence on velocity profiles; η = 0.240 for α = 16°;**



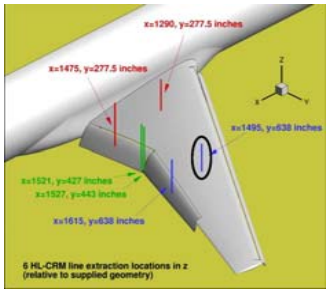


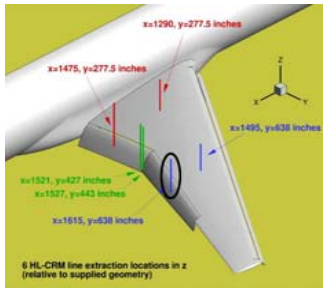


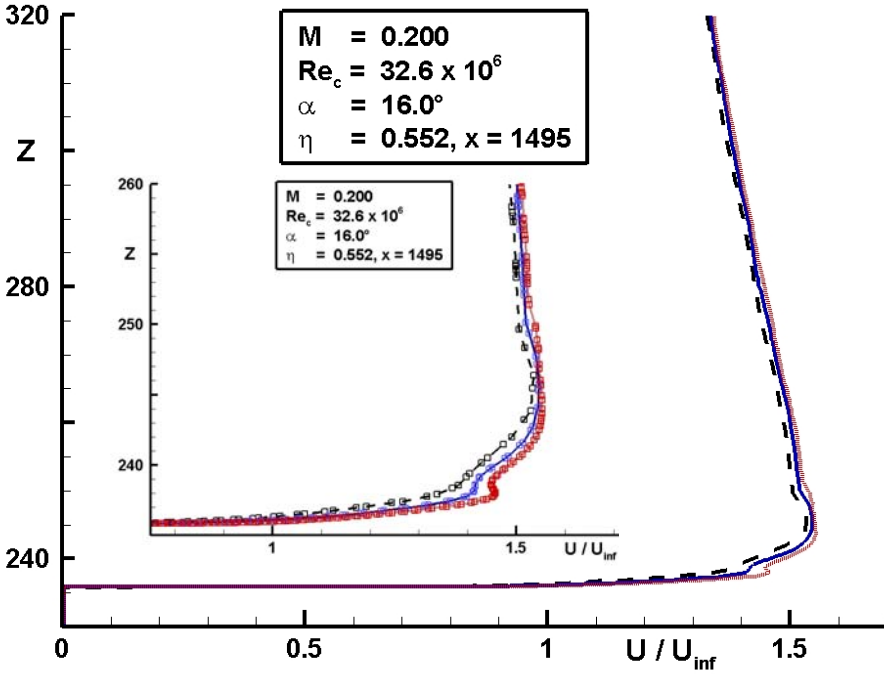


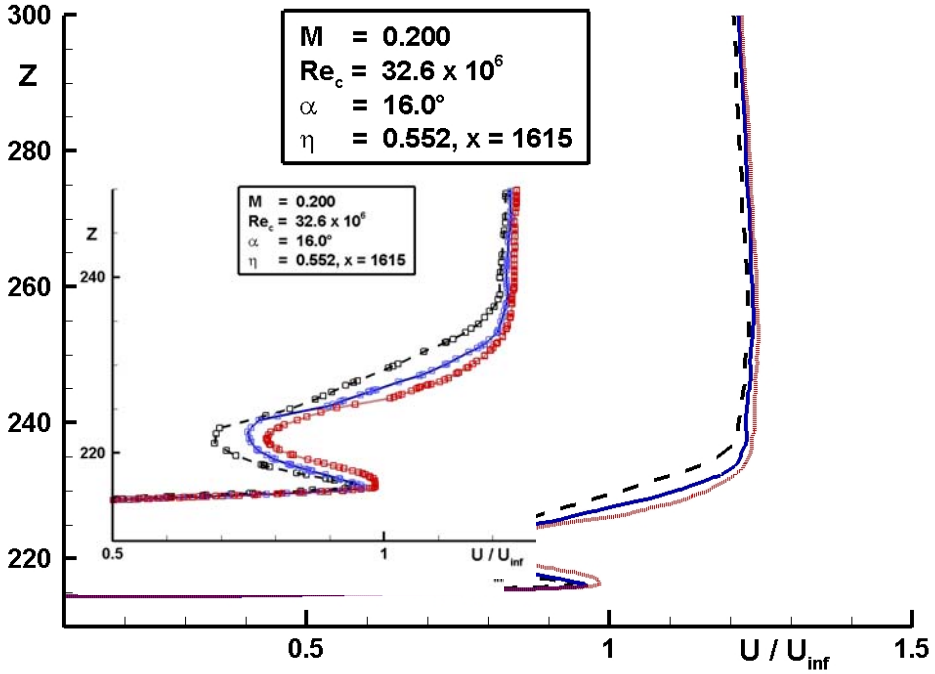
Brief overview of HL-CRM results of DLR

- **Grid resolution influence on velocity profiles; η = 0.552 for α = 16°;**









Summary of DLR computations

- **HL-CRM and JSM computed on DLR generated hybrid unstructured hex-dominant grids using a standard robust best practice numerical set-up**
- **JAXA-JSM Validation exercise:**

  ***Observations*:**

  - **good agreement w.r.t F & M and cp-distributions in the linear lift range**
  - **WB: significant over-prediction of $C_{L,max}$ (24 lcts.) and α_{max} (2.5°)**
  - **WBNP: good prediction of $C_{L,max}$ (4 lcts.) and for α_{max} (0.5°)**
  - **Increments due to propulsion integration in F & M well captured up to α ~ 18°**

  Assessment and thoughts:

  - **Exp.: comparatively very low lift degradation due to propulsion integration**
  - **Configuration with geometrically challenging spots (gapless device setting)**
  - **Computed lift breakdown strongly influenced by separation induced by o/b track not observed in the experiments.**

  ⇨ **limits meaningful assessment of prediction capabilities**

  ⇨ **reason under investigation (grid, TM), but not yet understood**

Summary of DLR computations

- **HL-CRM verification and grid refinement exercise:**

  ***Observations*:**

  - widely 2nd order behavior of F & M w.r.t. grid refinement for linear range
  (ΔC_L ~ 7 lcts. for $\alpha = 8°$ / ΔC_L ~ 11 lcts. for $\alpha = 16°$
  for grid pt. no. variation of a factor of nearly 11

  - Refinement in cp-distributions moderate form coarse to medium, comparatively weak from medium to fine, most pronounced in suction peaks

  - Refinement in evaluated velocity profiles moderate form coarse to medium, comparatively weak from medium to fine, most pronounced in wake regions

  Assessment and thoughts:

  - high quality surface grid resolution

  - Improved gridding quality for wake resolutions required (hex.-blocks, topology)

  ⇨ Effects in cp-distributions as mixture of local refinement and aerodynamic interactions

Outlook for DLR computations

- **Turbulence model variation**
  - **RSM-SSG/LRR-g (in progress) and SA-RC / QCR**

  ⇨ **Assess impact of surface flow patterns (e.g. tracks wakes) on lift breakdown**

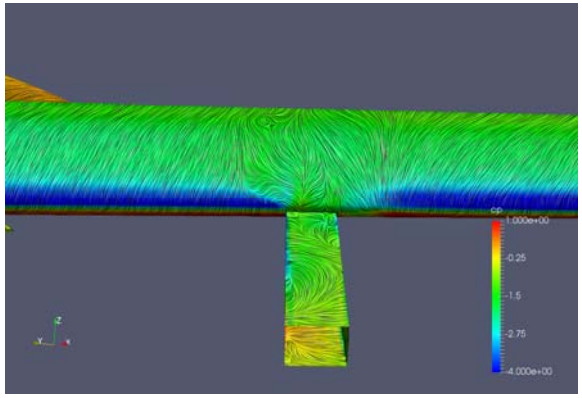
- **Grid resolution study**
  - **local refinement at critical areas (in progress)**

  ⇨ **Assess automatic adaptation potential**

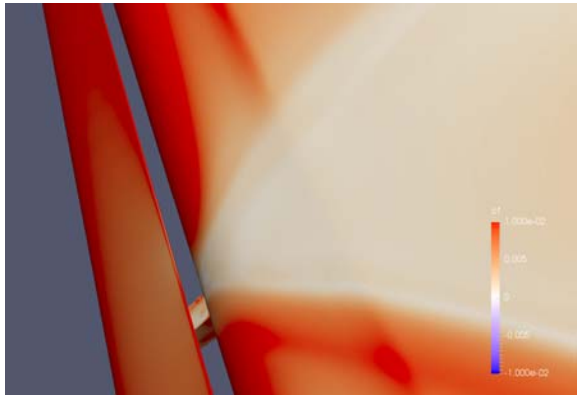
Back-up slides

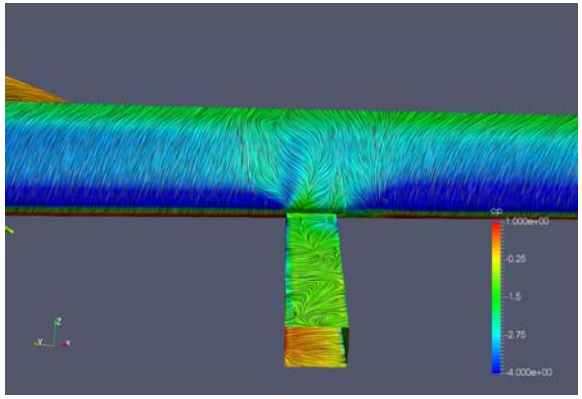
Brief overview of JSM results of DLR

- **Analysis of o/b separation and slat track interference**

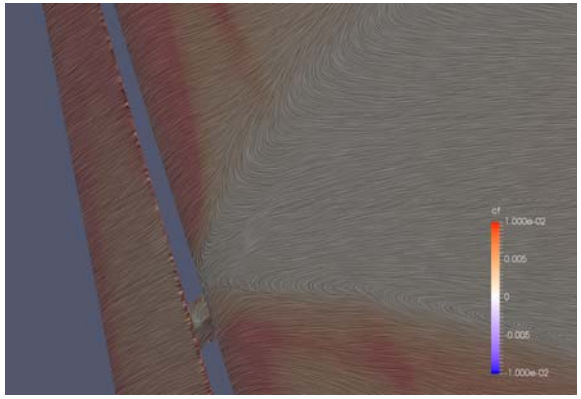


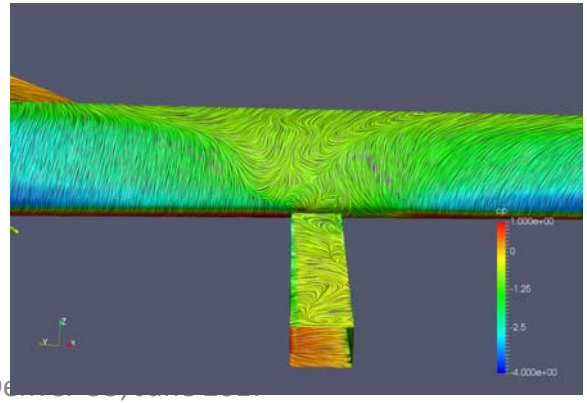
α = 4.36°;



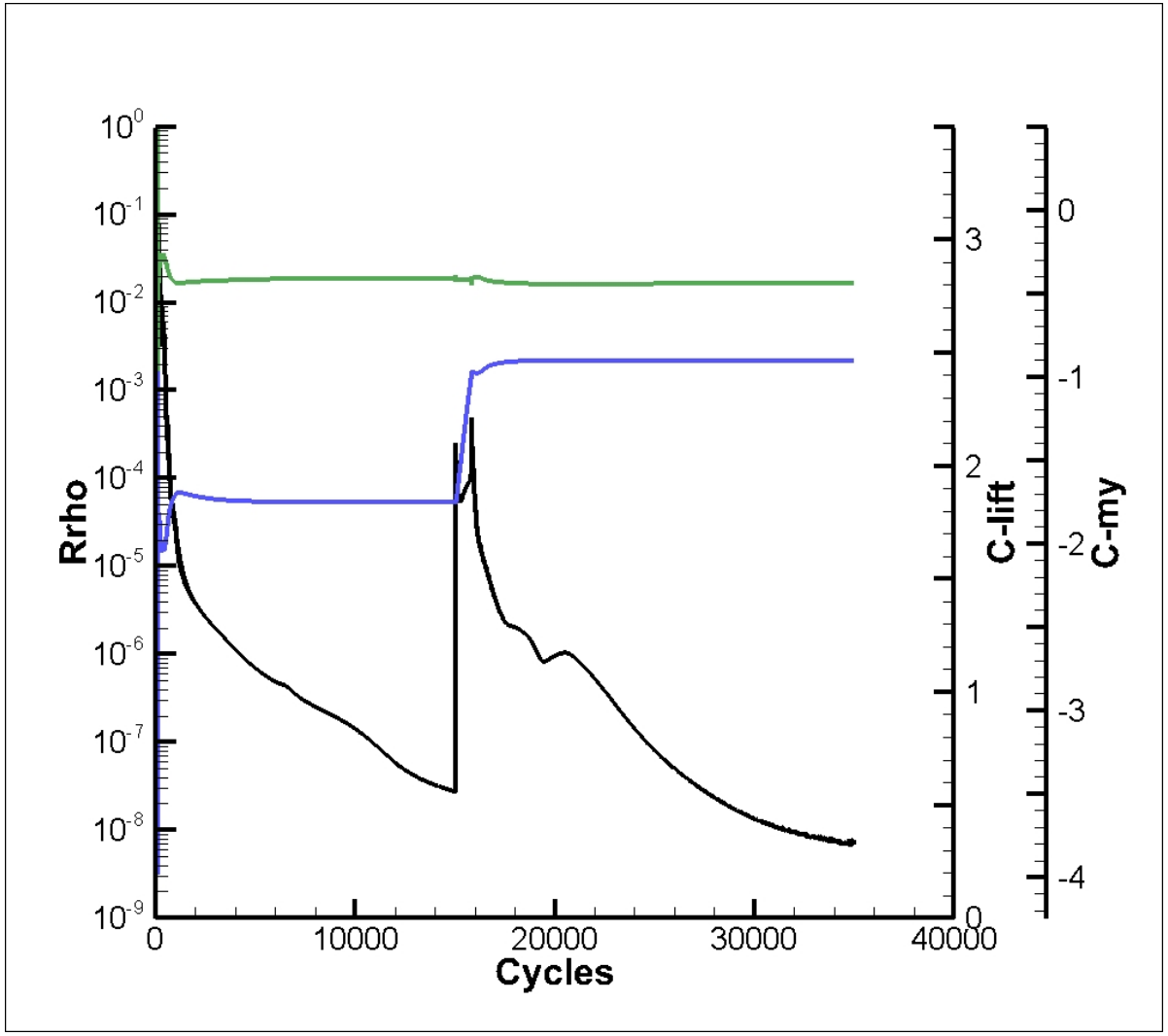


α = 10.47°;





α = 14.54°;

Brief overview of CRM results of DLR

- **Example convergence, fine grid level**