CFD High Lift Prediction Workshop

HiLiftPW-3
Case 2 Results

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Outline

CFD High Lift Prediction Workshop

- **Case Description**
- **Participant List**
- **Results**
  - **Overview**
  - **Forces/Moments**
  - **Pressures and Skin Friction**
  - **Velocity Profiles**
- **Conclusions**

Case Description

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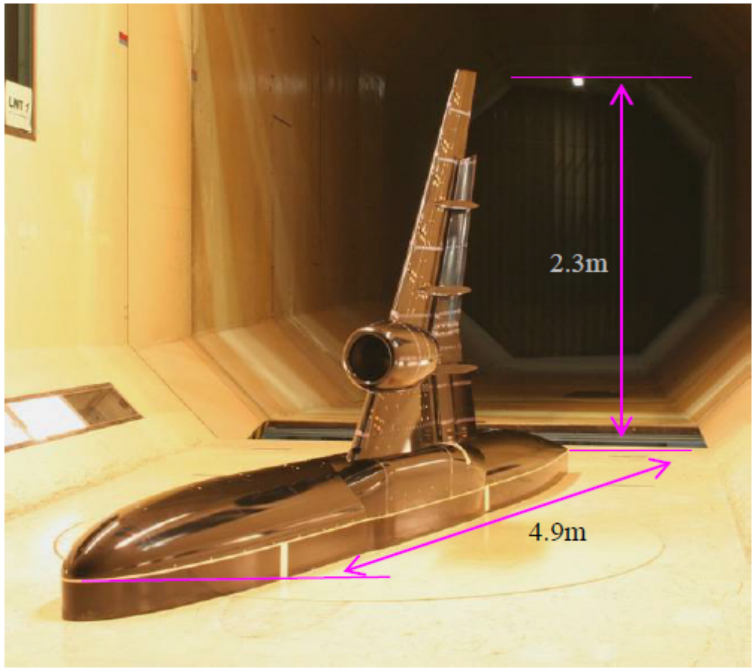
Case 2: Nacelle Installation Study

Flow solutions are required to assess the effects of adding a nacelle and pylon to the high lift system. At a minimum, flow solutions should be provided for ***at least one workshop-supplied medium grid.***

Geometry

The **JAXA Standard Model (JSM)** is a wing-body high lift system that will be studied in a nominal landing configuration (single segment baseline slat and single segment 30° flap) with support brackets on, and nacelle/pylon on/off. The experiment used a semi-span model with a 60 mm peniche standoff, but requested computations are "free air."



Case Description (2)

NOTE: The model BL was NOT tripped in the WT to ensure turbulent flow

Case Parameters and Requirements

Case 2a: Nacelle/Pylon OFF (REQUESTED)

Mach Number	0.172
Alphas	4.36, 10.47, 14.54, 18.58, 20.59, and 21.57°
Reynolds Number based on MAC	1.93 million
Reference Static Temperature	551.79°R (=33.40°C=92.12°F)
Reference Static Pressure	747.70 mmHg (=14.458 PSI)
Mean Aerodynamic Chord (MAC)	529.2 mm model scale
Important Details:	• Run simulations FULLY TURBULENT and/or WITH SPECIFIED TRANSITION and/or WITH TRANSITION PREDICTION METHODS. • All simulations are "free air"; no wind tunnel walls or model support systems.

Case 2b: Nacelle/Pylon OFF with Adaptation (OPTIONAL)
Use grid refinement based on automatic solution adaptation and/or solution-guided grid regeneration to provide the required flow solutions using the parameters from Case 2a.

Case 2c: Nacelle/Pylon ON (REQUESTED)
Using the parameters from Case 2a, provide flow solutions for high lift configuration with the nacelle/pylon assembly ON.

Case 2d: Nacelle/Pylon ON with Adaptation (OPTIONAL)
Using the parameters from Case 2a, provide flow solutions for high lift configuration with the nacelle/pylon assembly ON using grid refinement based on automatic solution adaptation and/or solution-guided grid regeneration.

Participant Data

- 51 total datasets
- 48 Case 2a
- 38 Case 2c
- 4 datasets with flow transition
- 3 datasets with grid adaptation

PID	Author	Model	Code	2a	2b	2c	2d	Case 2 committee grid	Case2 participant grid	Tecplot Symbol
001.1	Chen	SA	Mflow	I		I		E		A solid
002.1	Ashton	SA	OpenFOAM	I		I		E		B solid
002.2	Ashton	SA	Star-CCM+	I				E		B dash
003.1	Zastawny	SST	Star-CCM+	y		y		D		C solid
003.4	Zastawny	SST-gamma	Star-CCM+	y				D		C dot-dot-dash
004.1	Glasby	SA-neg	Kestrel/COFFE	y				C1		D solid
004.3	Nichols	BSL	Kestrel/KCFD	y				C2		D dot-dash
004.4	Nichols	SA	Kestrel/KCFD	y				C2		D dot-dot-dash
005.1	Coder	SA-AFT	OVERFLOW	I		I		A		E solid
006.1	Edge	SA-RC-QCR	CFD++	y		y		D		F solid
007.1	Michal	SA-QCR	GGNS	y	y	y	y	C1	participant (?)	G solid
008.1	Yasuda	SA-noft2	Cflow	y	y	y	y	D	e-JSM	H solid
009.1	Mor-Yossef	SST-2003	Arion	I				C2		I solid
009.2	Mor-Yossef	SST-2003	Arion	I				E		I dash
011.1	Ito	SA-noft2-R	TAS	y		y		D		K solid
011.2	Ito	SA-noft2-R-QCR2000	TAS	y		y		D		K dash
012.1	Li	SA-QCR	CFD++	y		y		C2		L solid
013.1	Konig	LBM-VLES	PowerFLOW	y		y			participant (?)	M solid
014.1	Lofthouse	SARC	Kestrel	y		y		C2		N solid
014.2	Lofthouse	SARC+DDES	Kestrel	y		y		C2		N dash
015.1	Wang	SA	TRIP	y		y			participant (?)	O solid
016.1	Pogosyan	RSM-SSG/LRR-w	LOGOS	y		y			participant (?)	P solid
016.2	Pogosyan	SA	LOGOS	y		y			participant (?)	P dash
016.3	Pogosyan	SST	LOGOS	y		y			participant (?)	P dot-dash
017.1	Risley-Settle	SA-neg	TAU	y		I		B		Q solid
017.2	Risley-Settle	SA-neg	TAU	y		y			f-JSM	Q dash
019.1	Scalabrin	SA	SU2	y		y		C2		S solid
020.1	Nichols	Wilcox2006	TENASI			I		E		T solid
020.3	Nichols	SST+SAS	TENASI	y				E		T dot-dash
020.4	Nichols	SST+SAS	TENASI	y		I			c-JSM	T dot-dot-dash
021.1	daSilva	SA	BRU3D	y		y		E		U solid
022.1	Pulliam	SA-RC-QCR2000	OVERFLOW	y		y		A		V solid
022.2	Pulliam	SA	OVERFLOW	y				A		V dash
023.1	Yousuf	SA-RC-QCR	BCFD	y		y		E		W solid
024.1	Tamaki	SA-noft2-R	UTCart	y		y			participant (?)	X solid
025.1	Cimpoeru	SST-V-sust	zCFD	I		I			participant (?)	Y solid
026.1	Rudnik	SA-neg	TAU	y		y		B		Z solid
030.1	Langlois	Wilcox88	Dragon	y				E		b solid
030.2	Langlois	Wilcox88	Dragon	y		y			b-JSM	b dash
030.3	Langlois	Wilcox88	Dragon	y				E		b dot-dash
030.4	Langlois	Wilcox88	Dragon	y		y			b-JSM	b dot-dot-dash
031.1	Brionnaud	WALE	XFlow	I		I			participant (?)	d solid
032.1	Jansson	FEM adaptive	Unicorn		I		I		participant (?)	e solid
033.1	Jensen	SA-QCR2000	LAVA	y		y		A		f solid
033.2	Jensen	SA	LAVA			y			participant (?)	f dash
035.1	Wurst	SA-noft2	PHASTA	y		y		C1		h solid
036.1	Luo	SST	FUN3D	I		I		C1		m solid
036.2	Luo	SA-neg	FUN3D	I		I		C1		m dash
036.3	Luo	k-kL-MEAH2015	FUN3D	I				C1		m dot-dash
036.6	Luo	SST (mod)	OpenFOAM	I		I			participant (?)	m dash 0.8
039.1	Powell	SA	FUN3D	I		I		C2		q solid

Comparison of Lift Curve Results – All Simulations

Case2a (No Nacelle/Pylon) and Case2c (Nacelle/Pylon)

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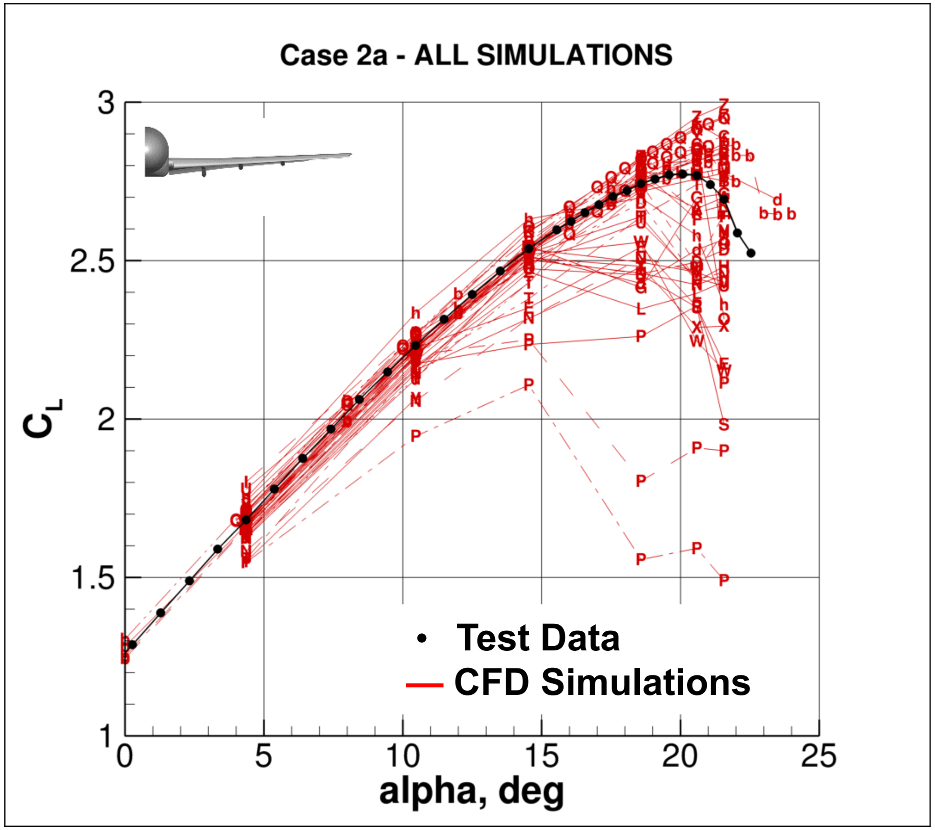
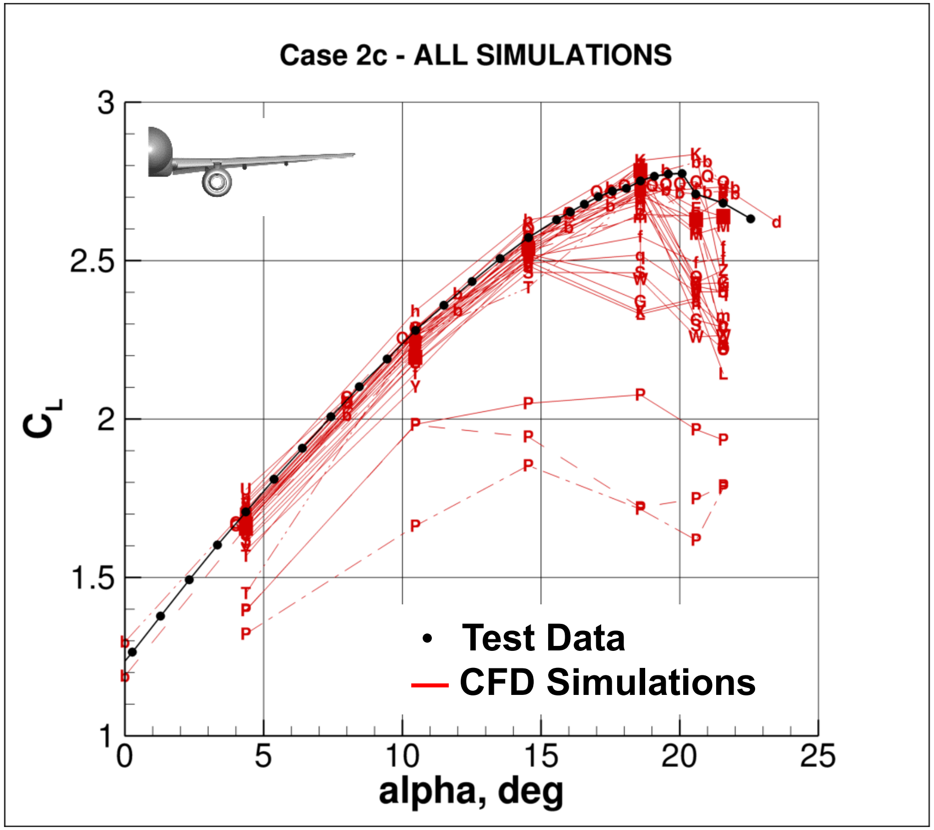
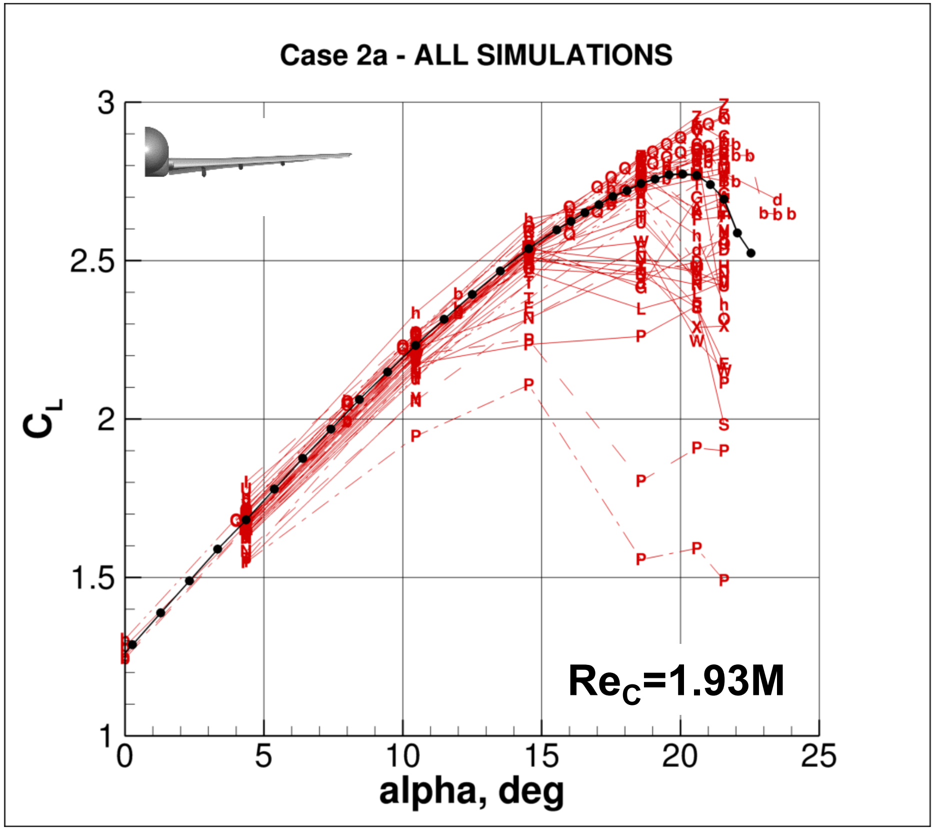


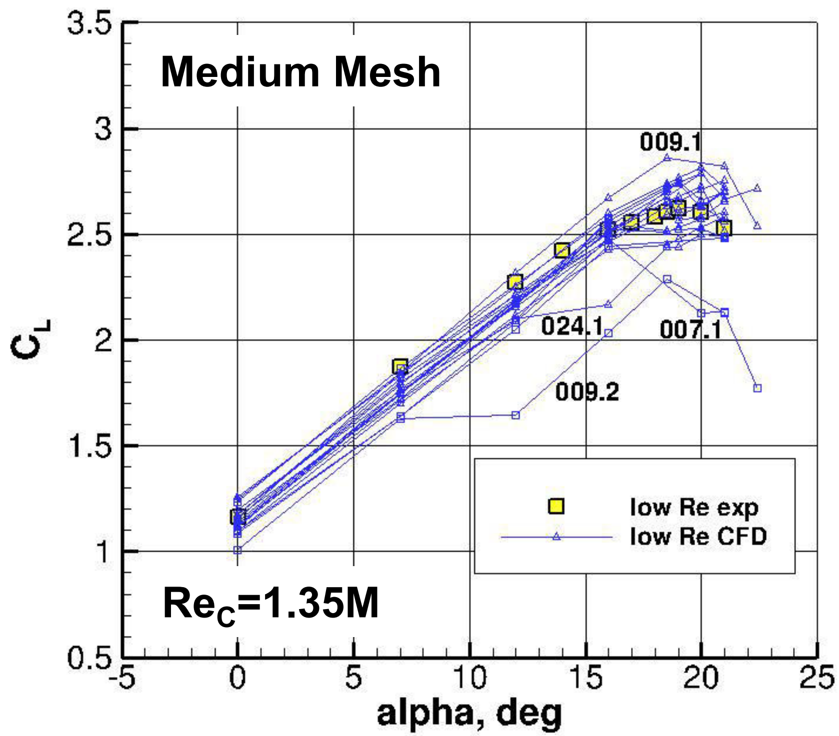


- Generally good agreement between most simulations and test data for both Case2a at the lower angles-of-attack.
- Most simulations tend to slightly under-predict lift for Case2c
- There is significant scatter in the results at higher angles-of-attack

Comparison of Lift Curve Results with HiLiftPW-2



DLR-F11 Wing/body Configuration



- Similar agreement between CFD and test data along lift curve.
- Slightly better agreement in linear portion for JSM.
- Larger scatter near stall for JSM.

Comparison of Drag Polar Results – All Simulations

Case2a (No Nacelle/Pylon) and Case2c (Nacelle/Pylon)

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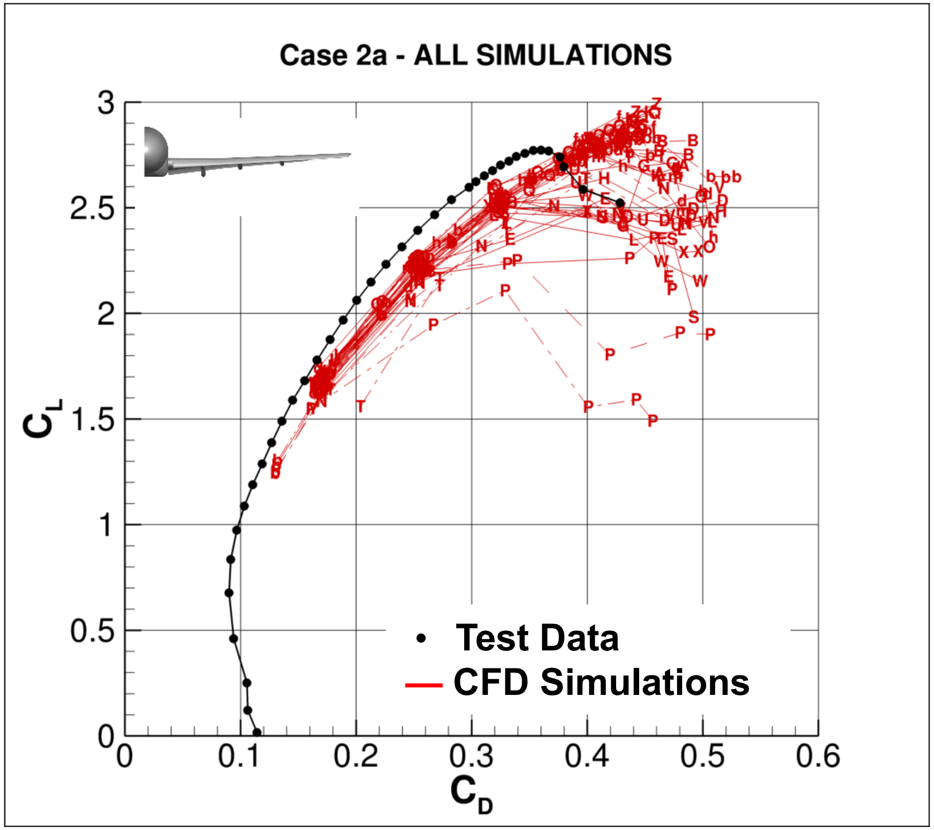

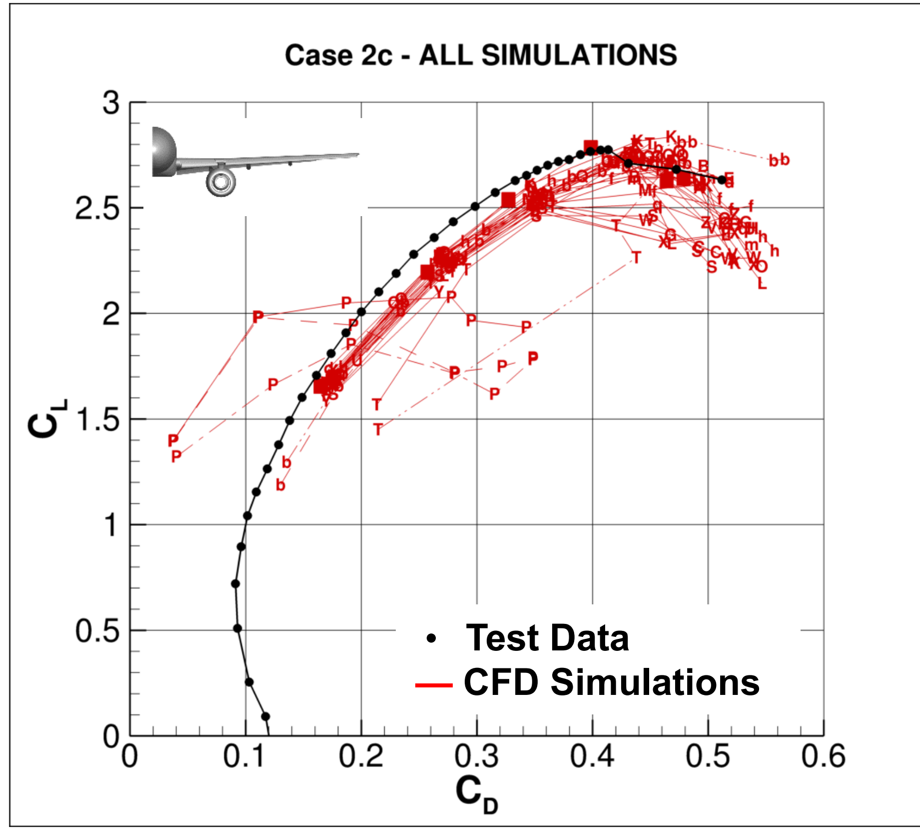

- All simulations predict higher total drag relative to test data at all angles-of-attack.
- Most solutions appear to better predict drag at CL_{max} for Case2c than for Case2a
- Datasets P and T are clear outliers for Case2c

Comparison of Drag Polar Results with HiLiftPW-2

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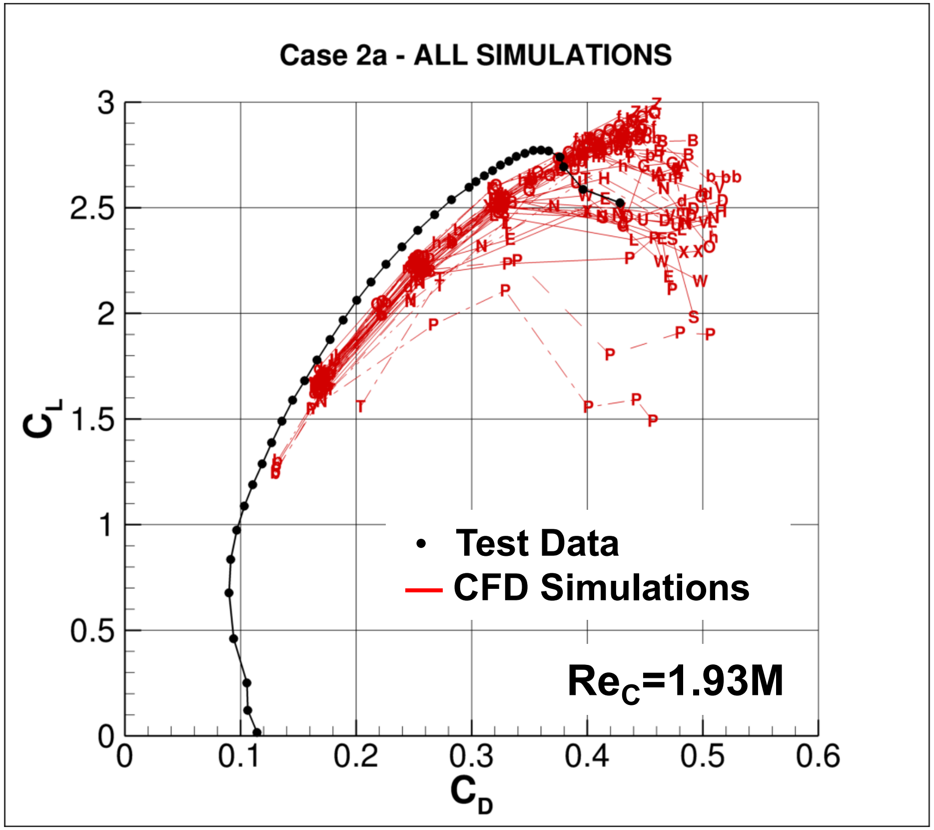

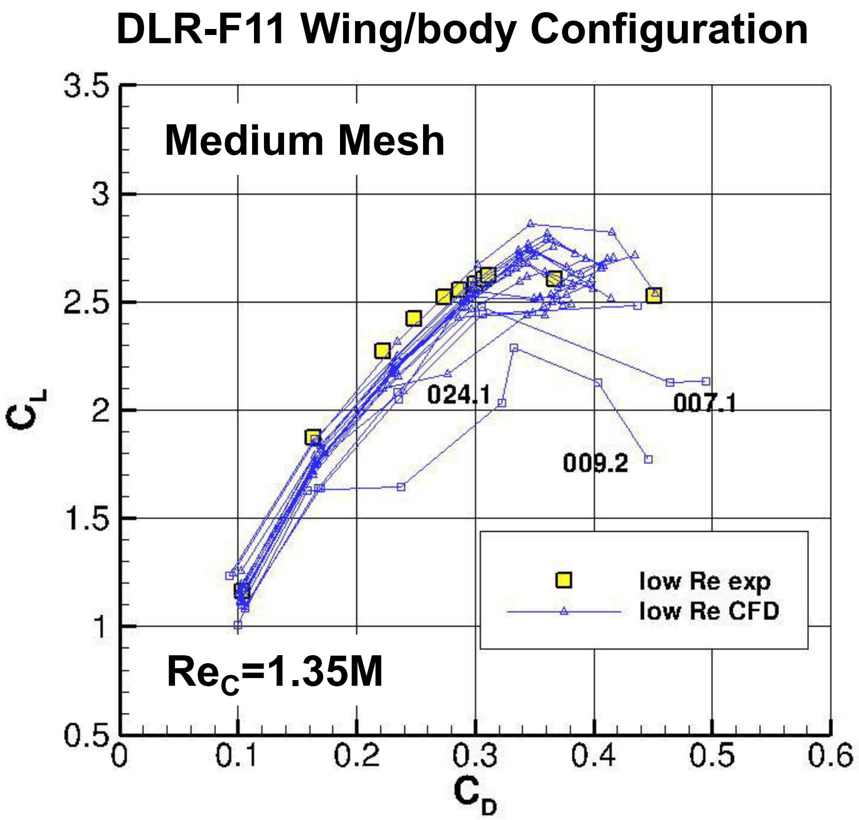

- Similar results between JSM and DLR-F11 CFD simulations

Comparison of Pitching Moment Results – All Simulations

Case2a (No Nacelle/Pylon) and Case2c (Nacelle/Pylon)

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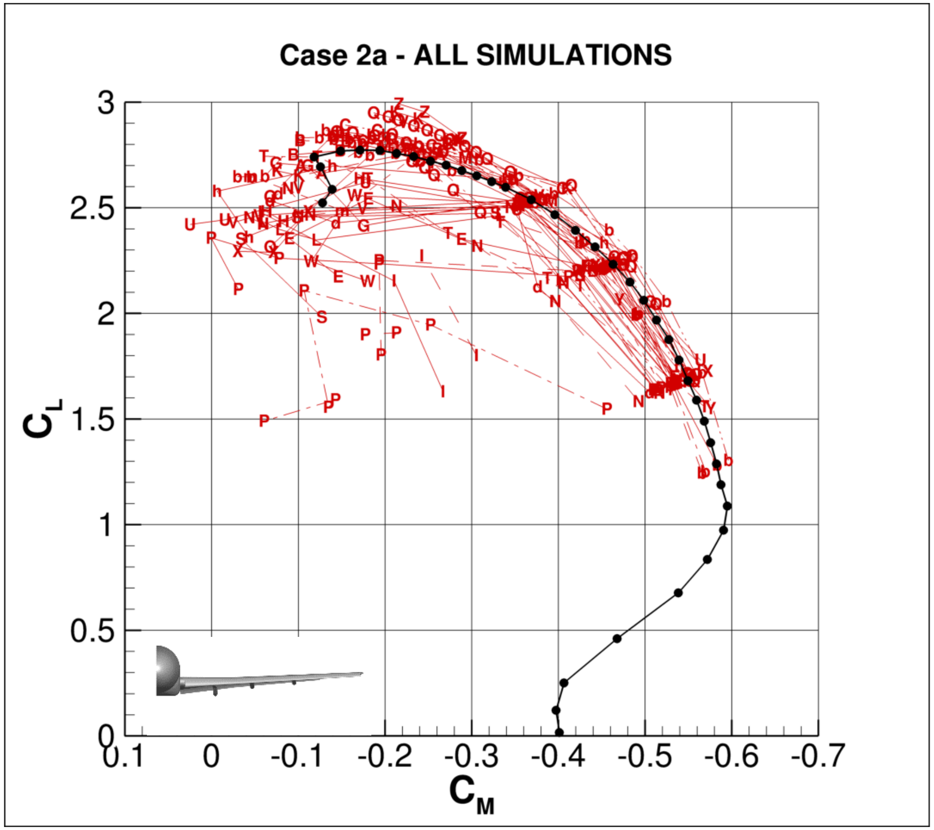

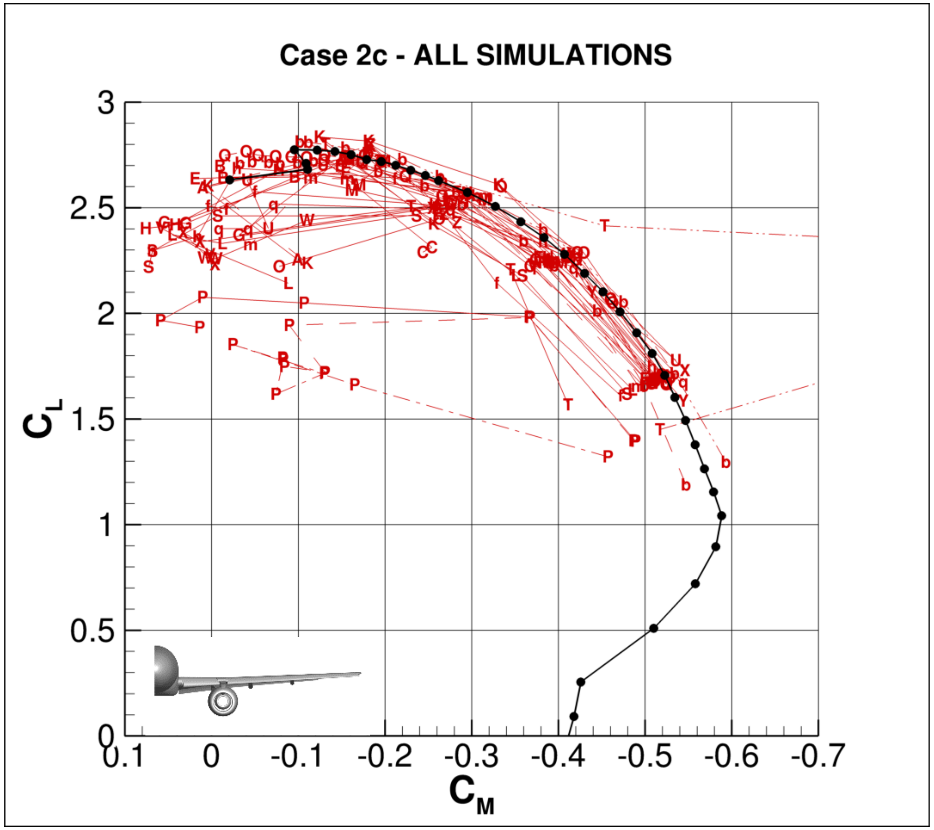

- For both Case2a and Case2c, many simulations correlate well with test data up to stall.
- Datasets P and T are clear outliers for Case2c

Comparison of Pitching Moment Results with HiLiftPW-2

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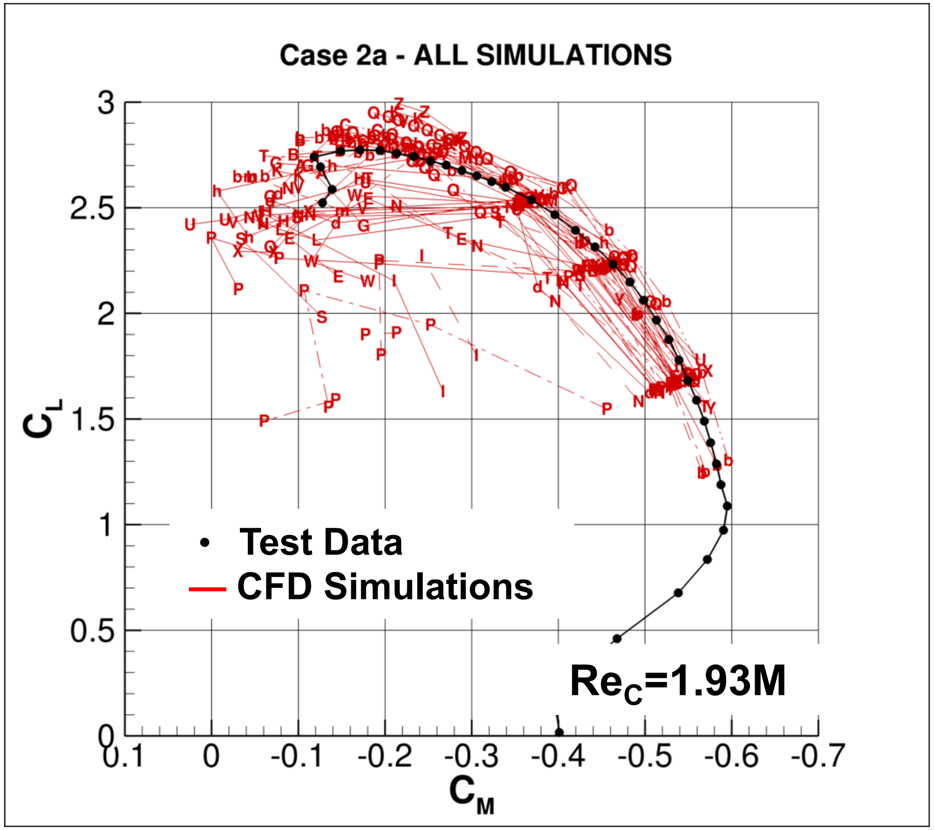
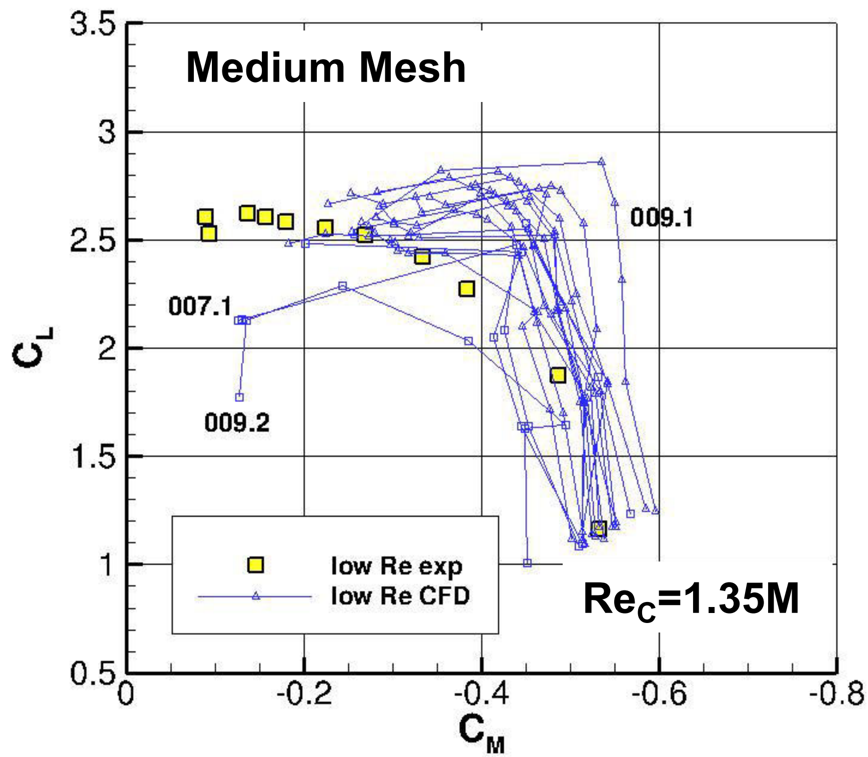


DLR-F11 Wing/body Configuration



- Much better correlation of pitching moment between CFD simulations and test data for JSM compared with DLR-F11, despite similar correlations of lift with test data.

Comparison of ΔCL, ΔCD, ΔCM
Nacelle On (Case2c) – Nacelle Off (Case2a)

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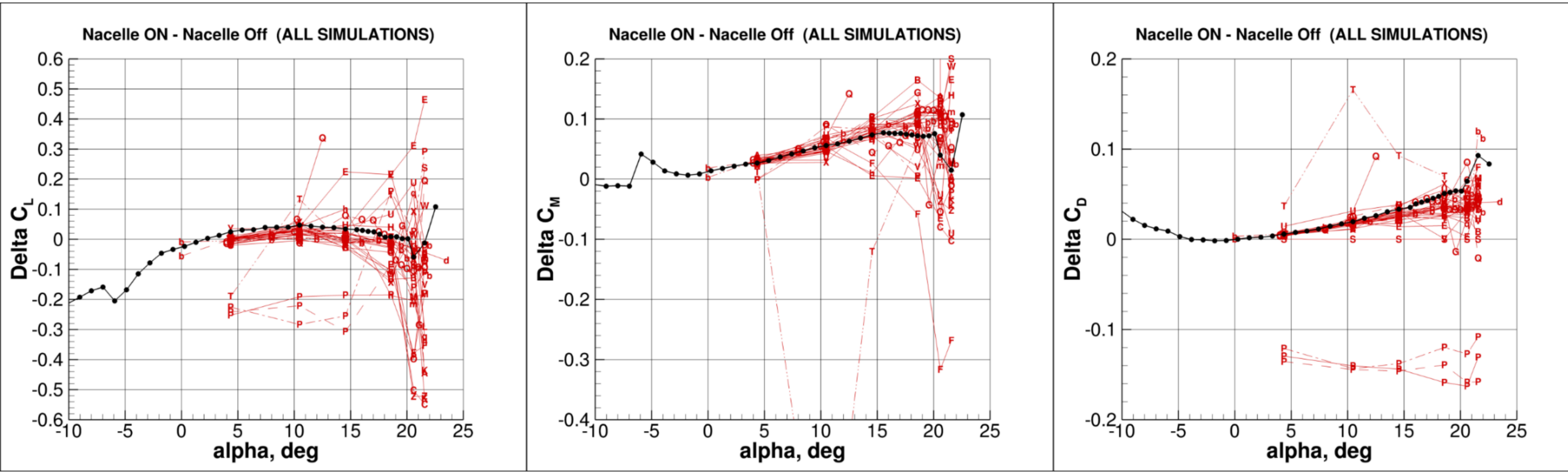

- In general, most solutions appear to predict the nacelle/pylon increment for lift, drag, and pitching moment well at lower angles of attack
- There is significant scatter in the results at higher angle-of-attacks
- Datasets P and T are clear outliers

Comparison of CL Iterative Convergence

Case2a: Alpha=18.58° (Sorted by Turbulence Model)

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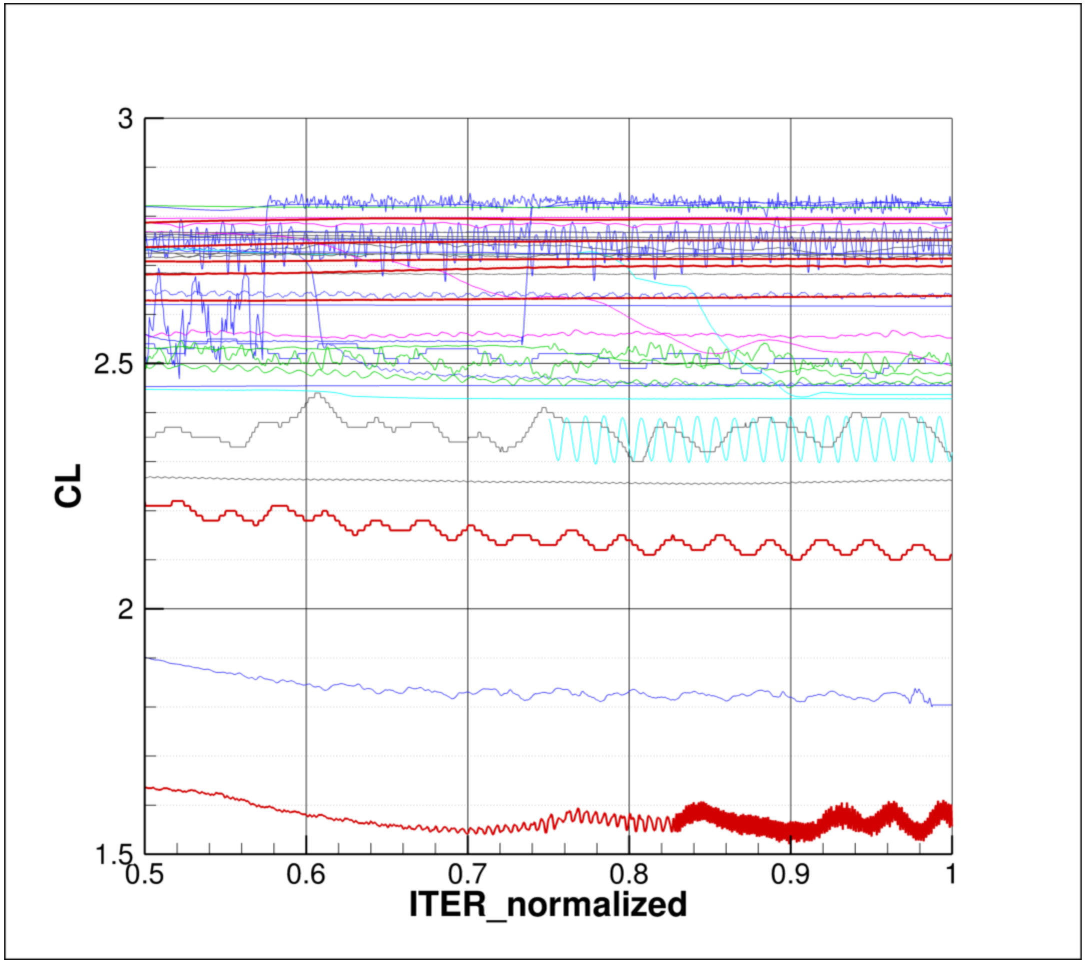

SST, SST-SAS, SST-GAMMA
SA, SA-neg, SA-noft2, SA-AFT
SA-noft2-R, SARC
SA-QCR, SA-QCR2000
SA-RC-QCR
Other

- In general, the solutions where CL correlate well with test data appear to be well converged.

Comparison of Lift Curve by Turbulence Model

Spalart-Allmaras (SA) Variants (Case2a)

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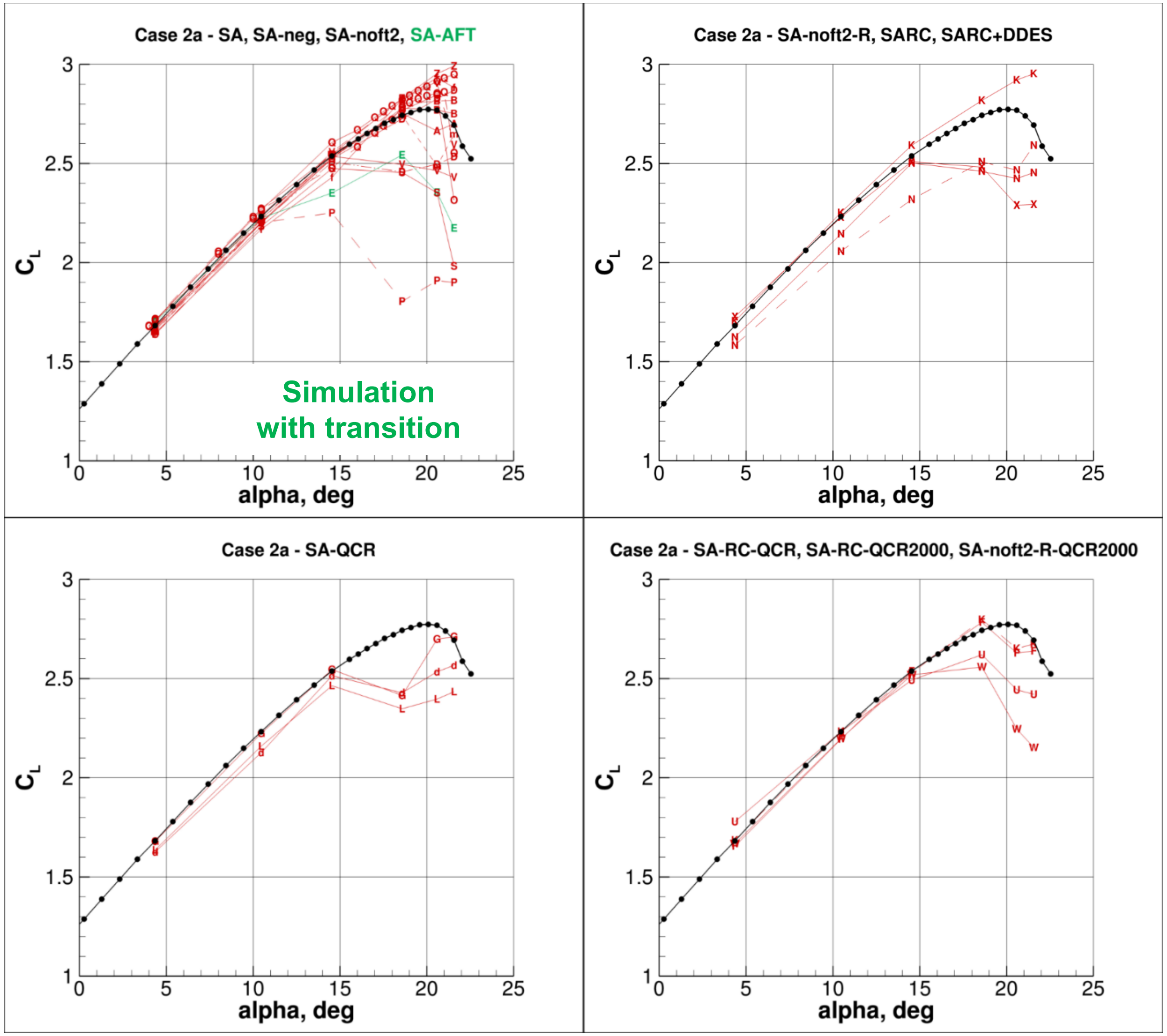
- Standard SA model is the most widely used. All CFD simulations match well with each other and test data at lower angles-of-attack.
- Larger variability with addition of RC terms
- More consistent results with addition of QCR terms only
- Most consistent results with SA with RC and QCR terms
- Results do not capture lift at stall in any consistent way



Comparison of Lift Curve by Turbulence Model

Menter SST Variants and Advanced Models (Case2a)

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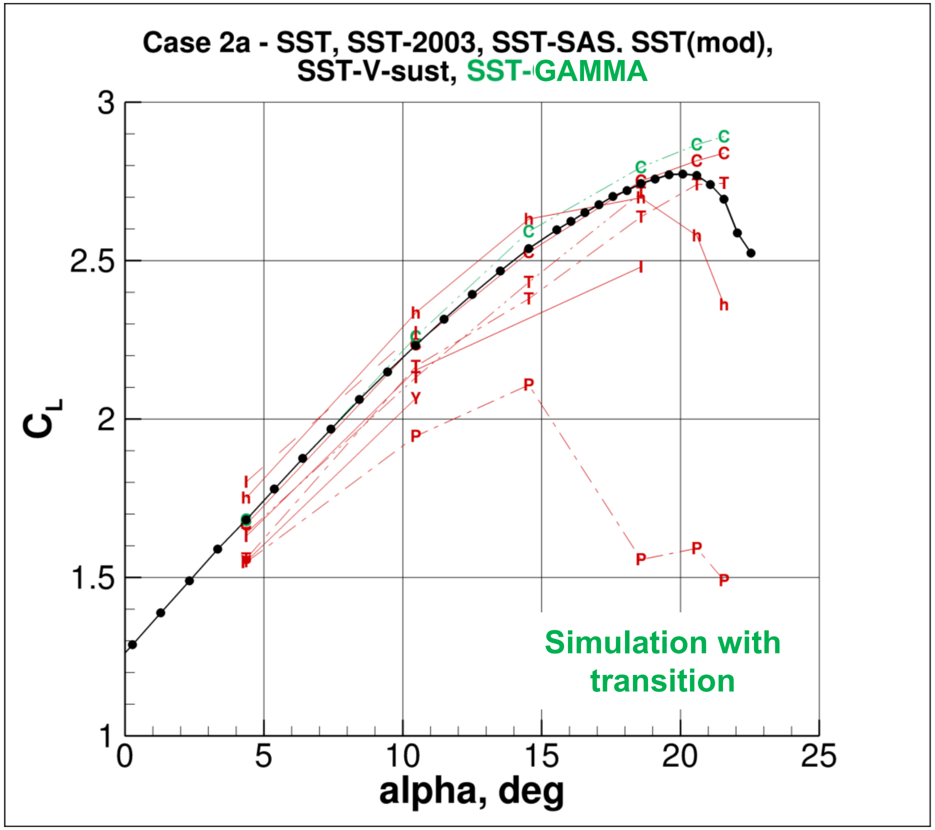

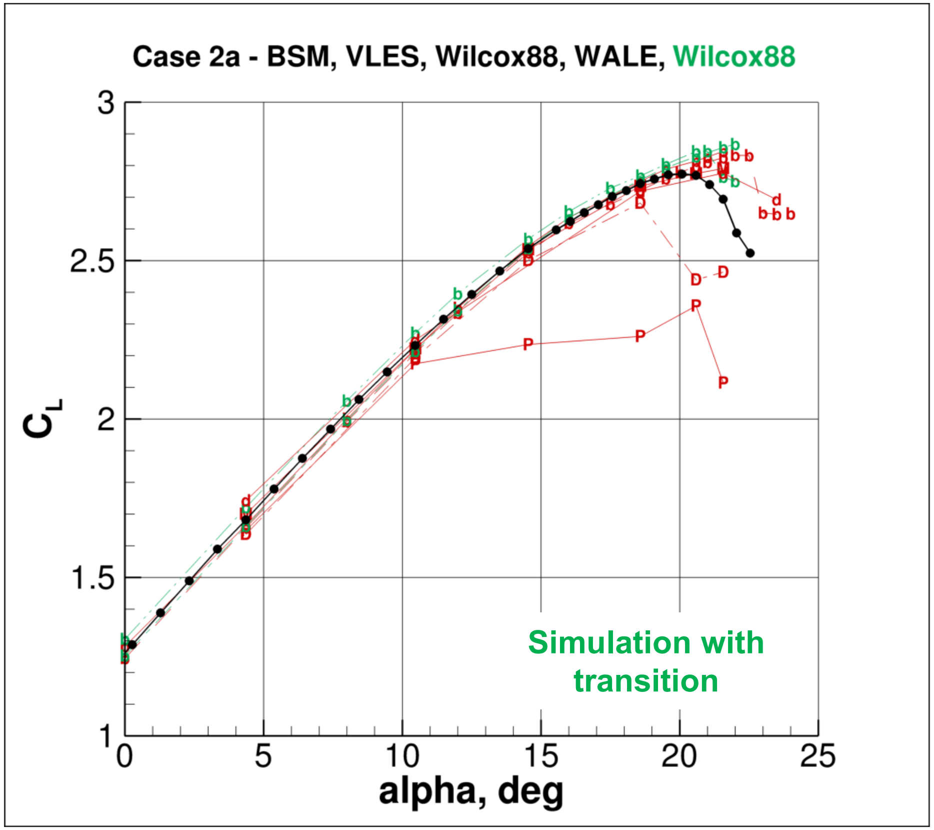

- Simulations using SST model show significantly larger amount of scatter at all angles-of-attack compared with SA model results.
- Simulations with advanced turbulence models show the closest correlation with JSM lift data.

Comparison of Pressure Distributions by Grid Type

Case2a: Alpha=18.58° Section A-A – Structured Overset

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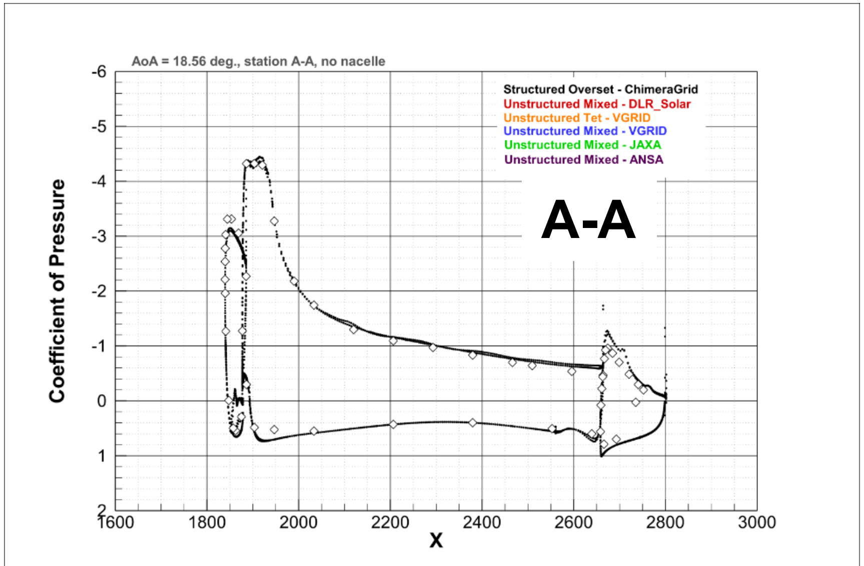
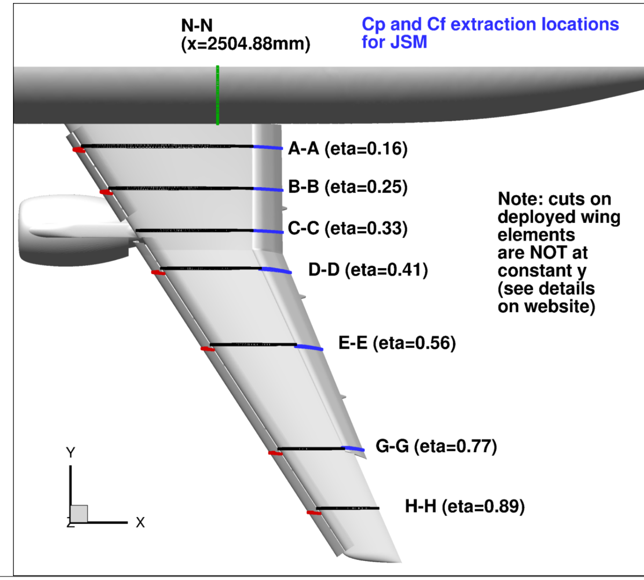
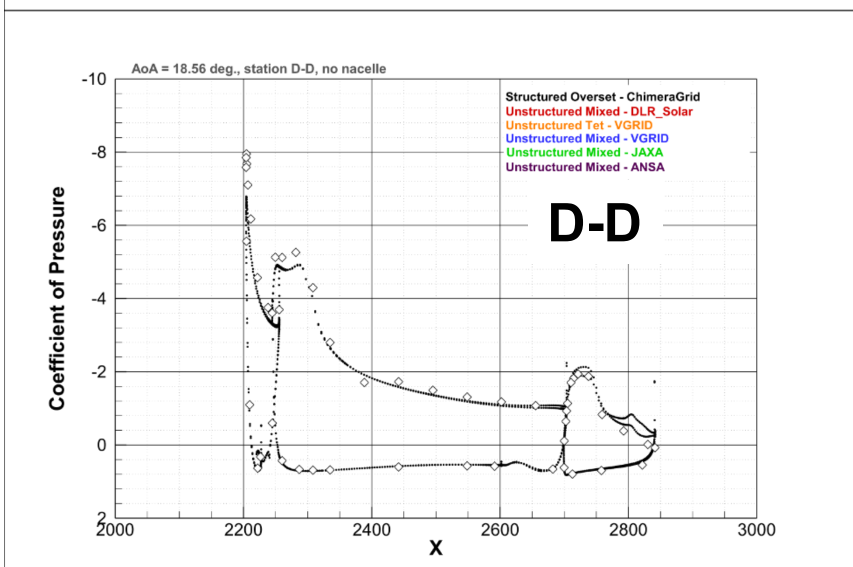
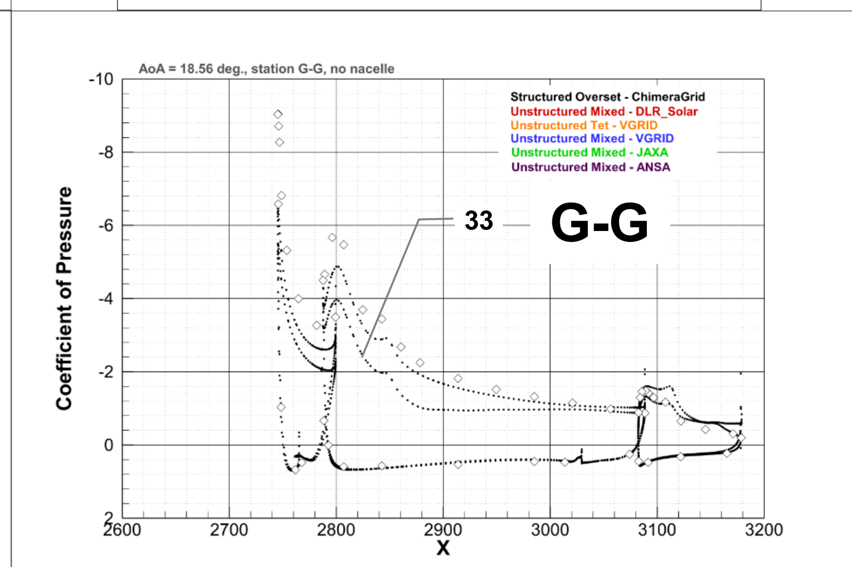
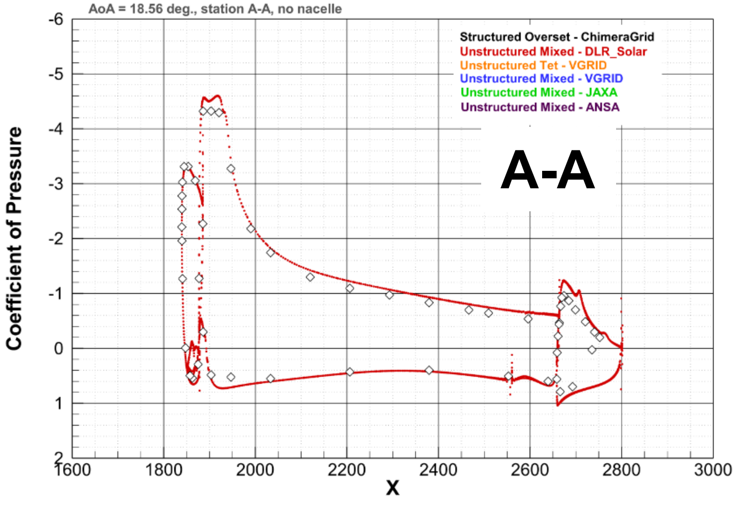


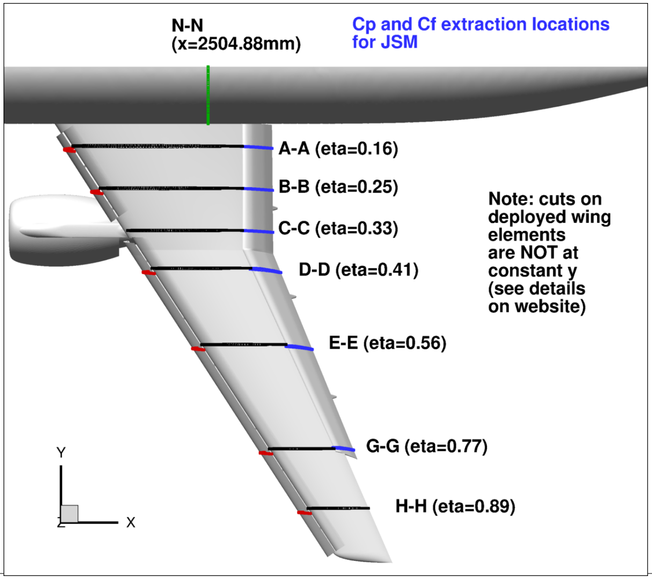


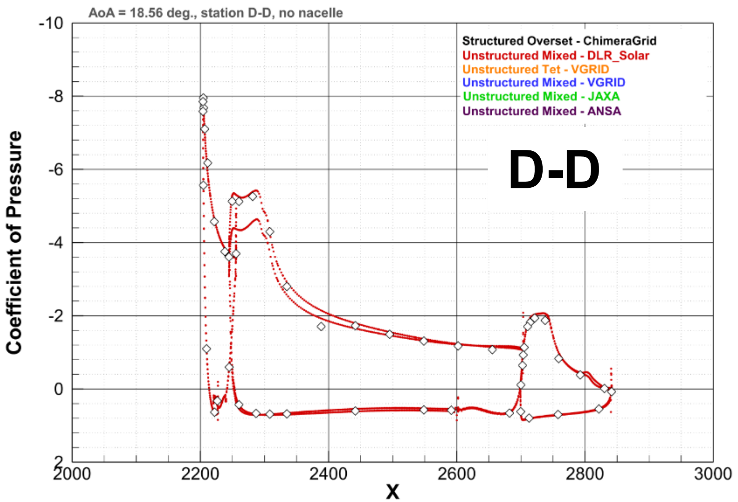


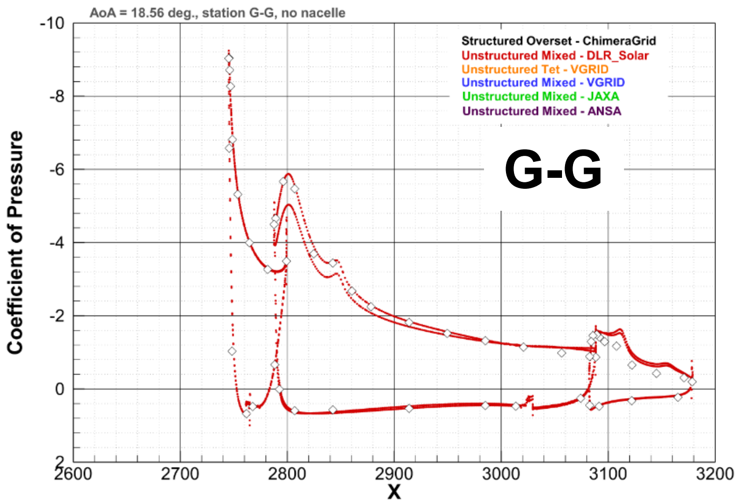


Comparison of Pressure Distributions by Grid Type
Case2a –Unstructured Mixed SOLAR



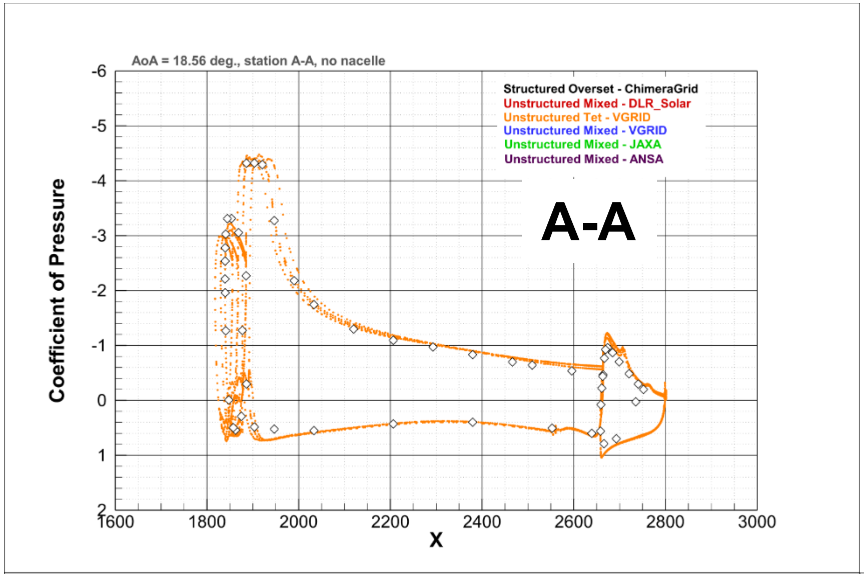


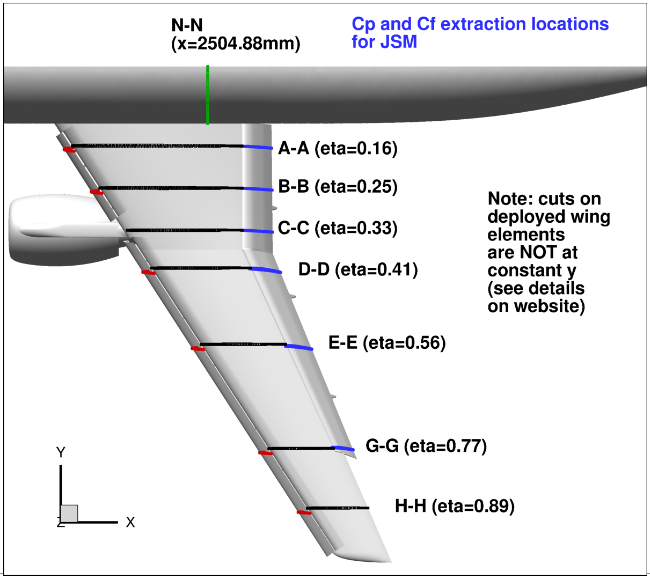


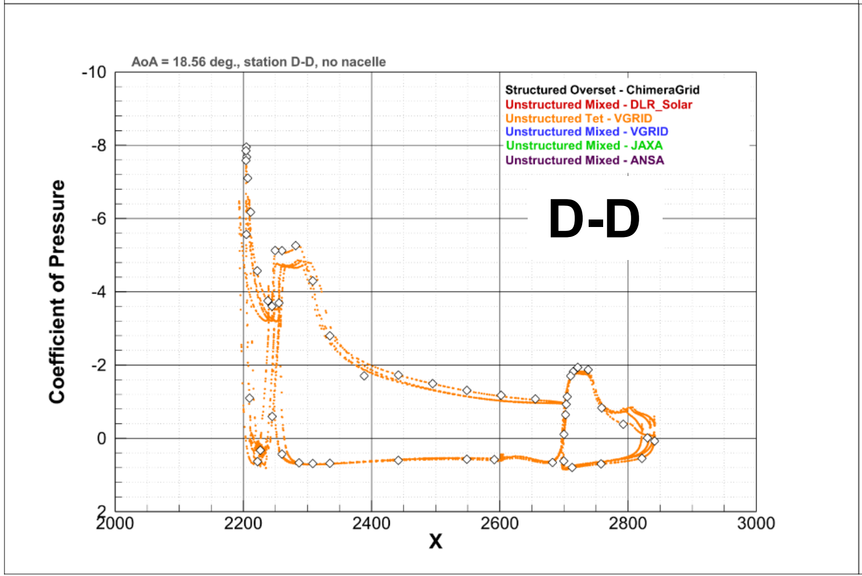


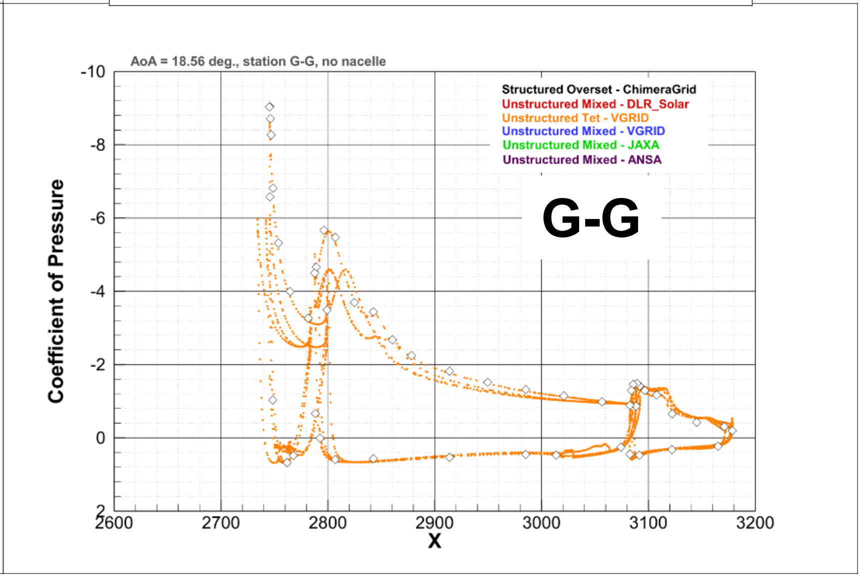
Comparison of Pressure Distributions by Grid Type

Case2a –Unstructured Tet VGRID









Comparison of Pressure Distributions by Grid Type

Case2a –Unstructured Mixed VGRID

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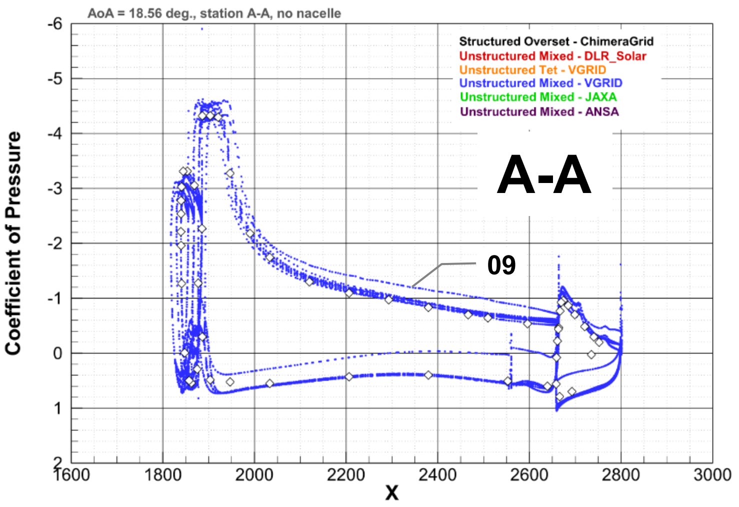

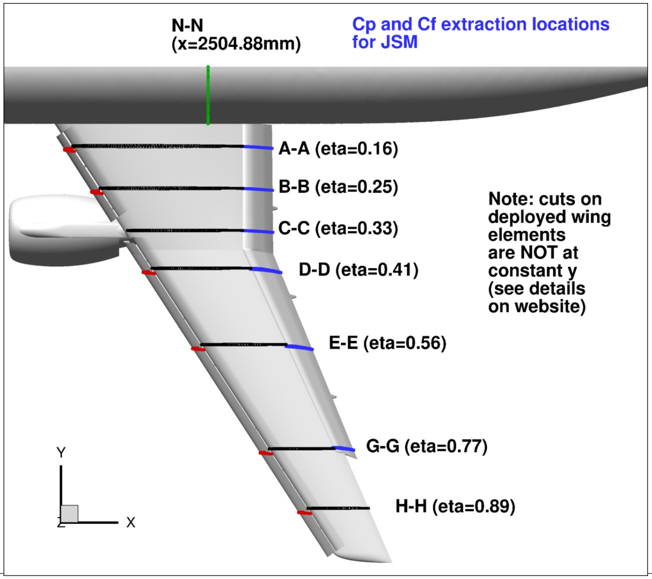

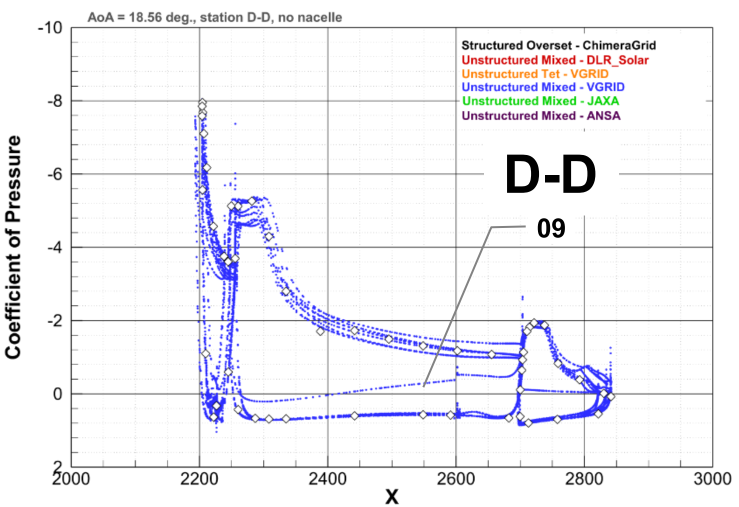

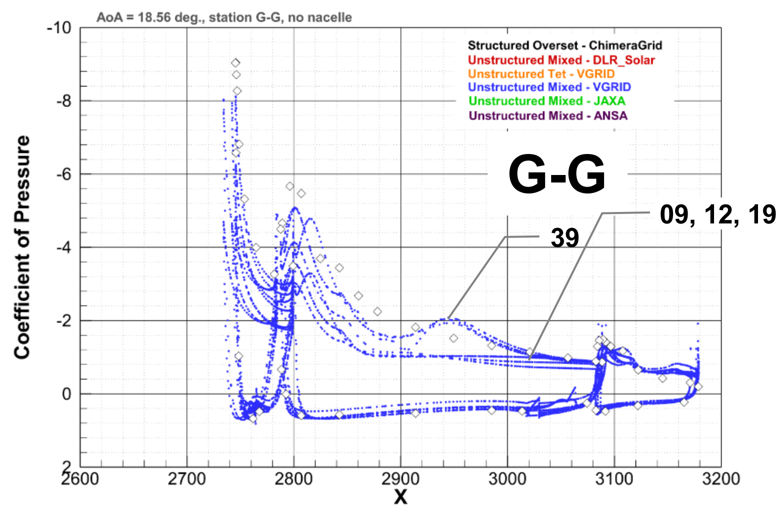

Comparison of Pressure Distributions by Grid Type
Case2a –Unstructured Mixed JAXA

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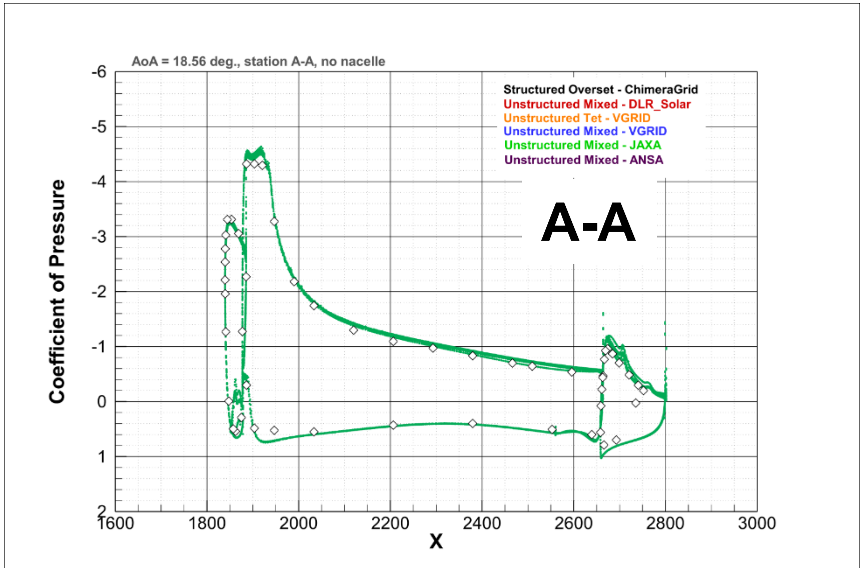

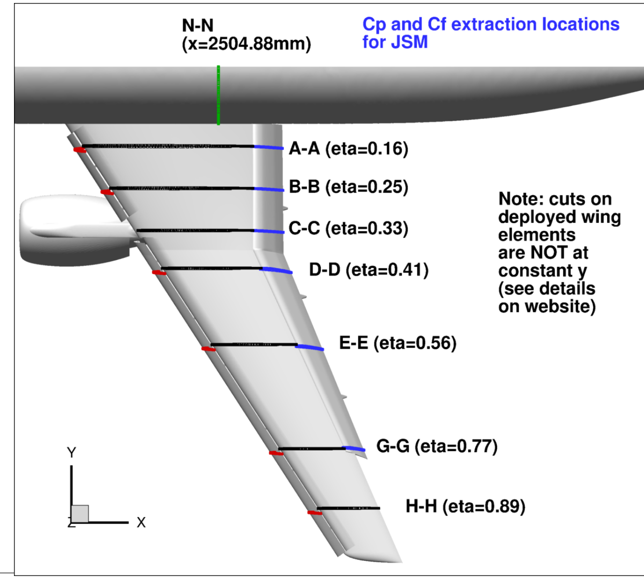

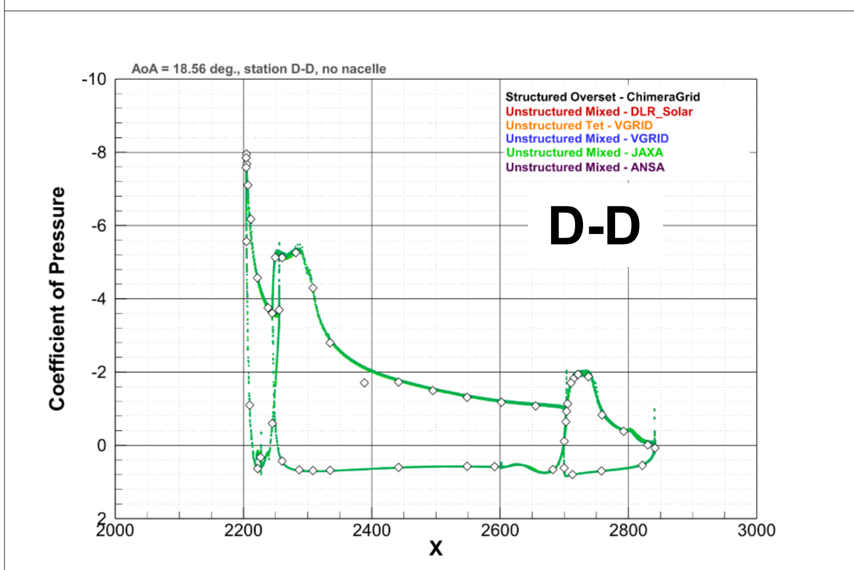

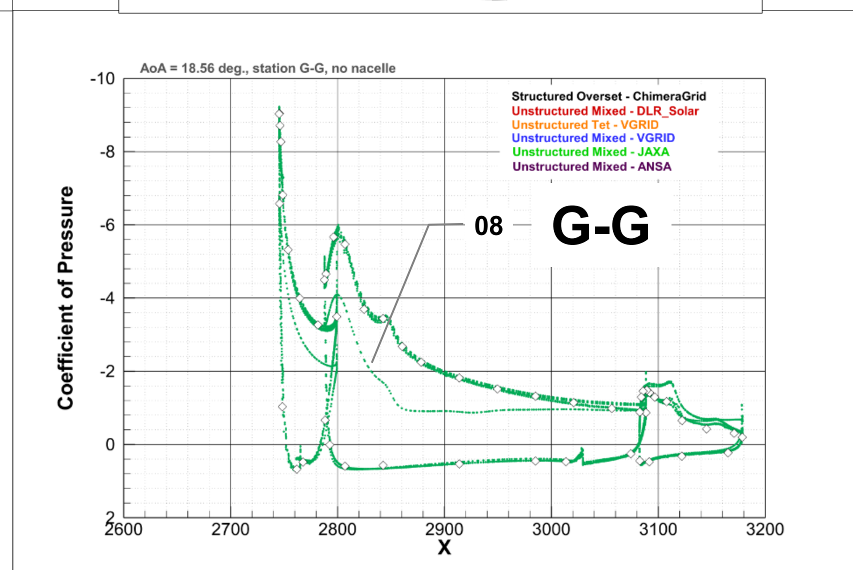

Comparison of Pressure Distributions by Grid Type

Case2a –Unstructured Mixed ANSA

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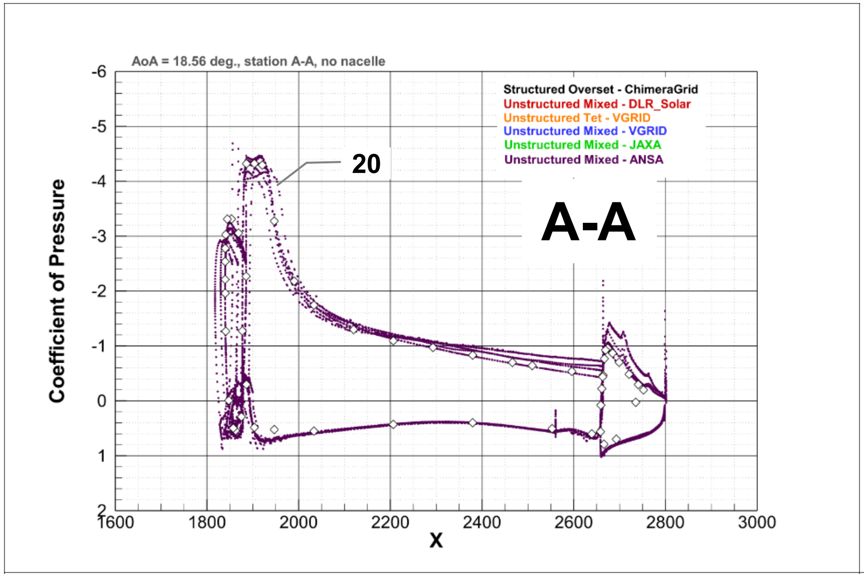

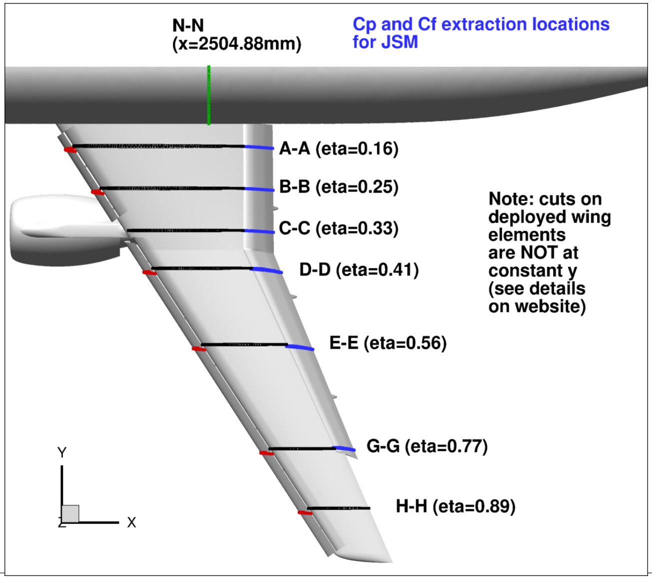

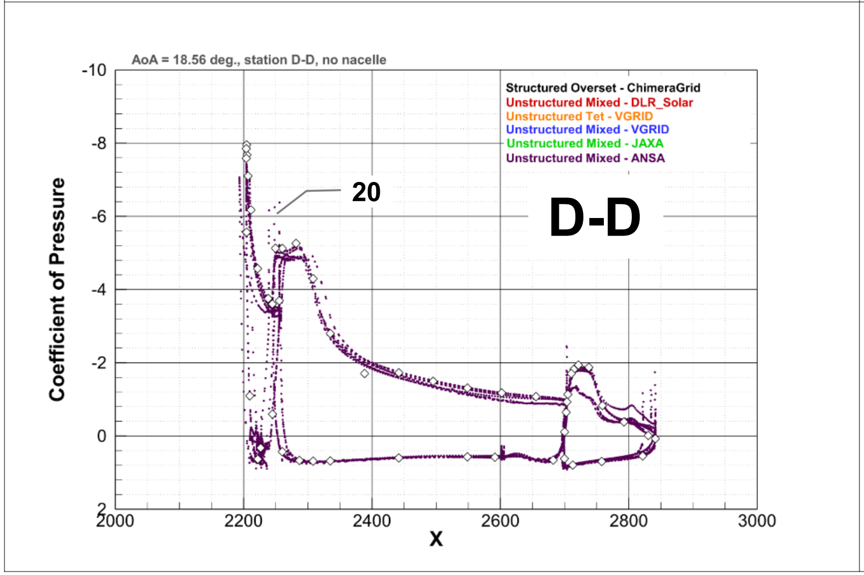

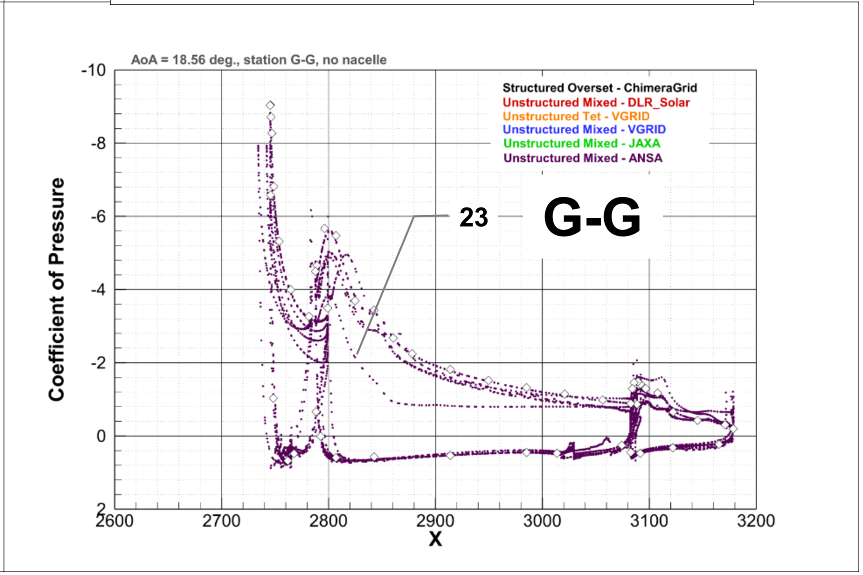

Comparison of Flap Pressure Distributions

Case2a: Alpha=18.58°– All Simulations, by Grid Type

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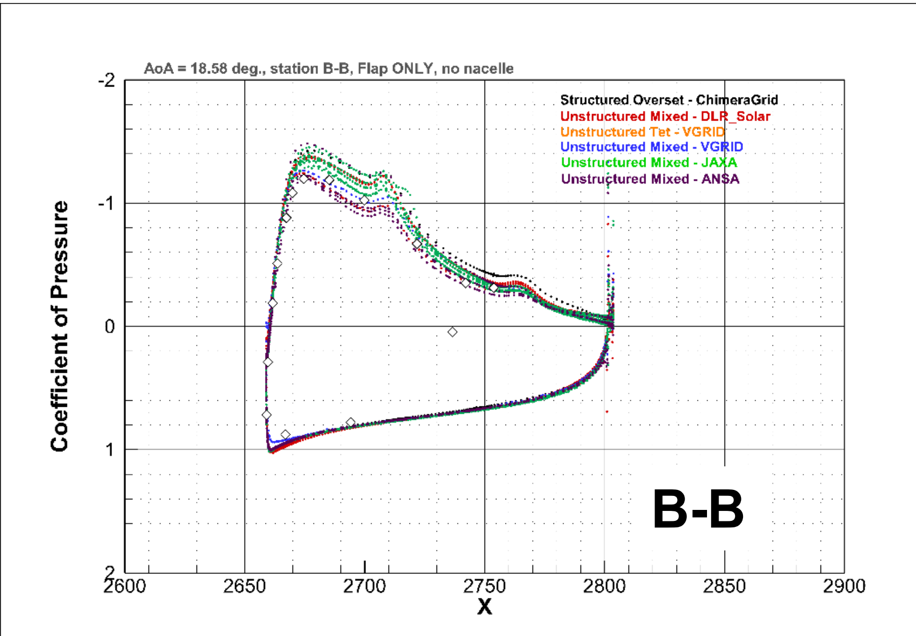
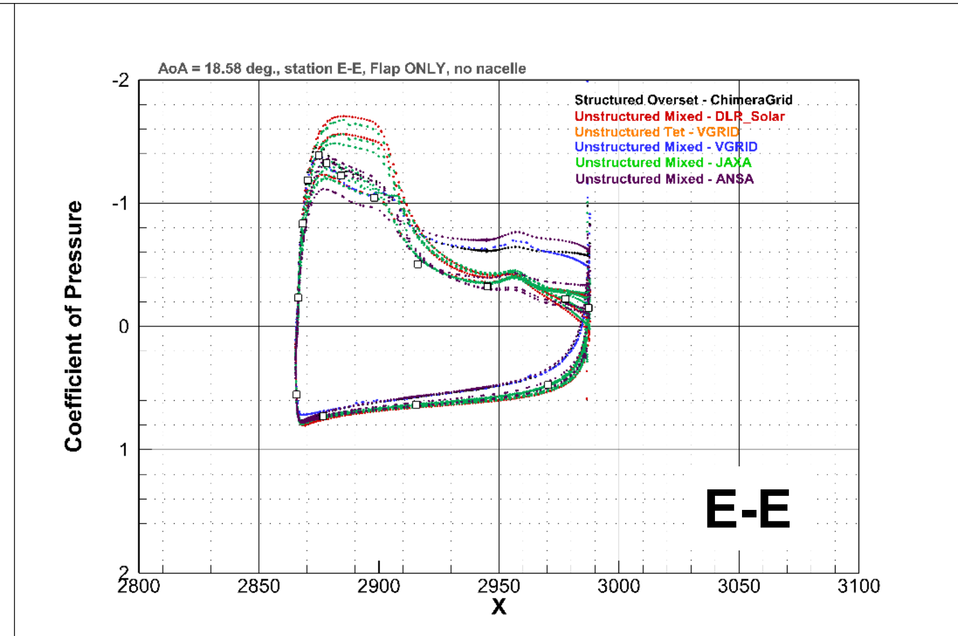
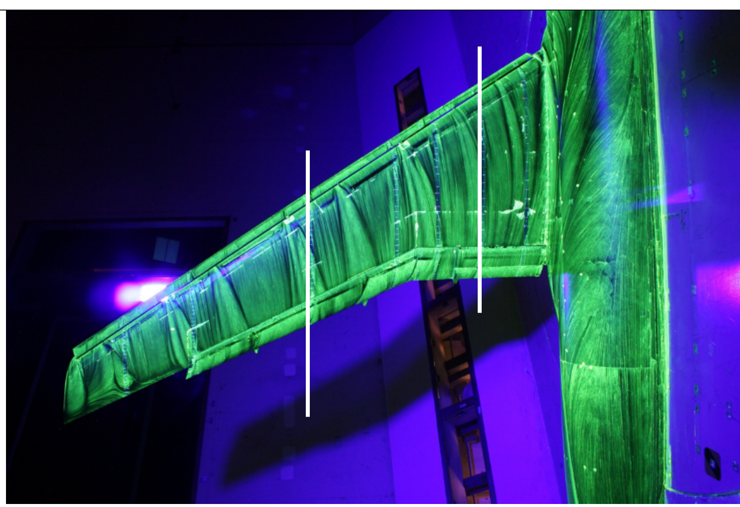
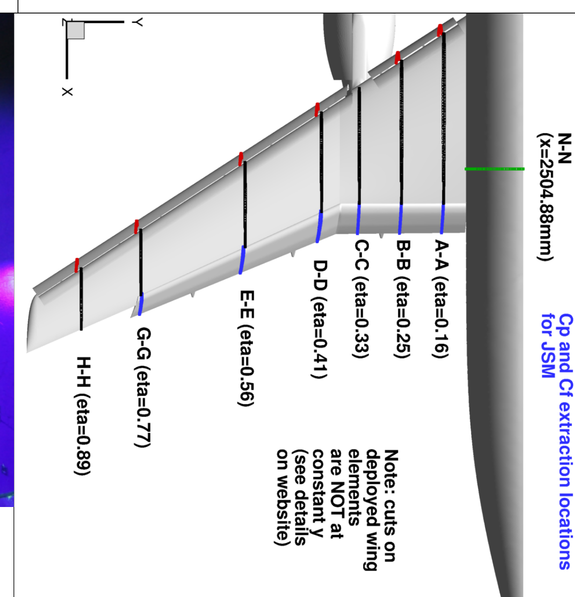
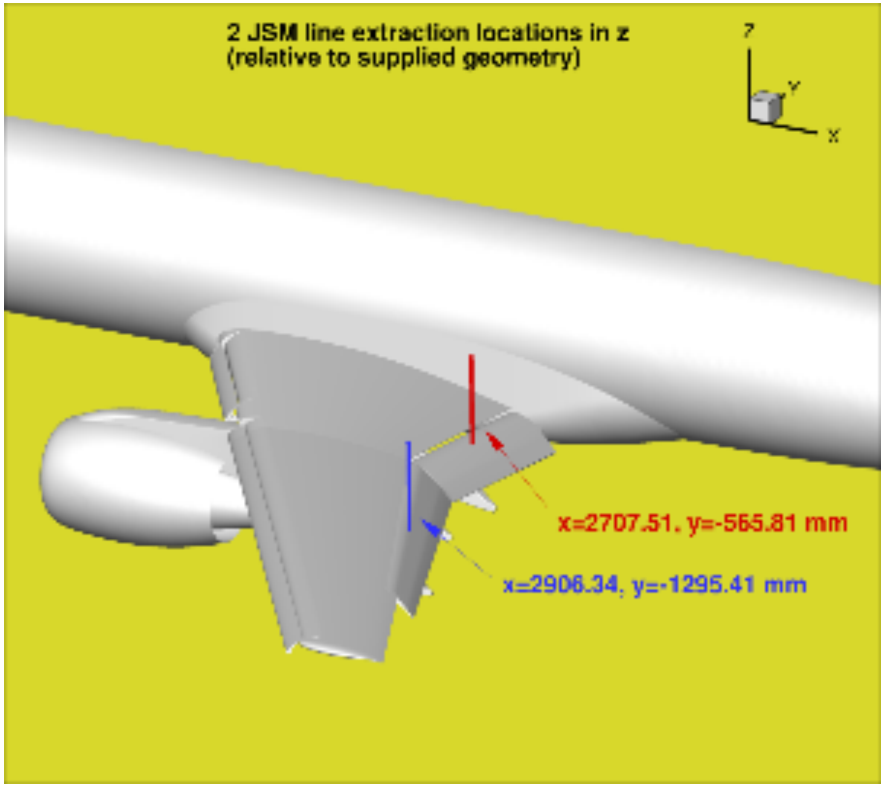


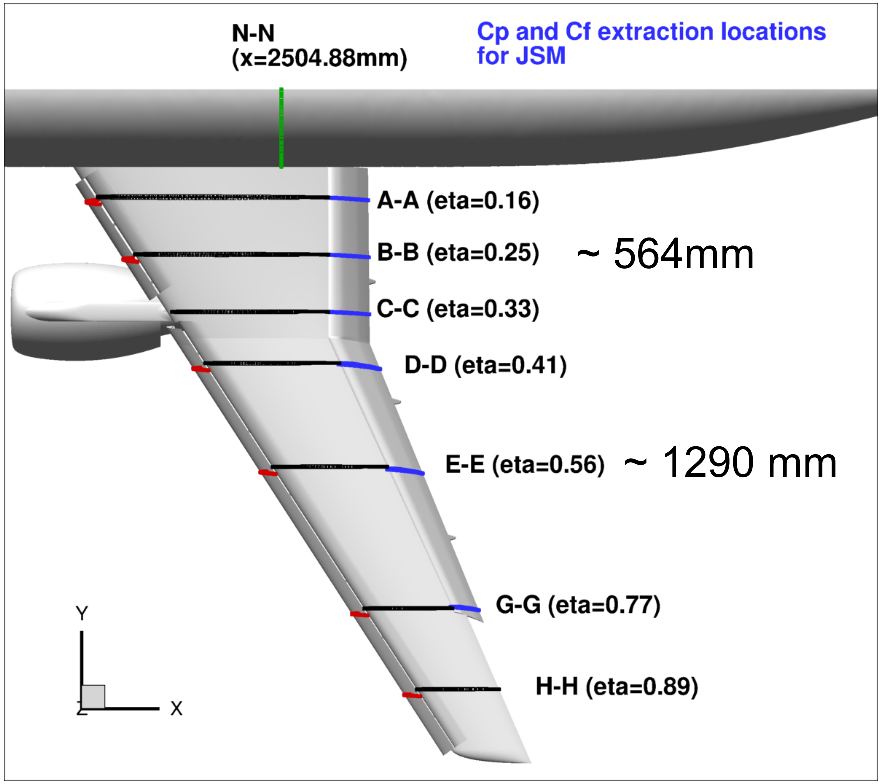






Location of Velocity Profiles





- Locations of the two requested flap velocity profiles essentially align with pressure cut locations B-B and E-E, respectively.

Comparison of Velocity Profiles

Case2a – Inboard, Outboard Locations (by Grid Type)

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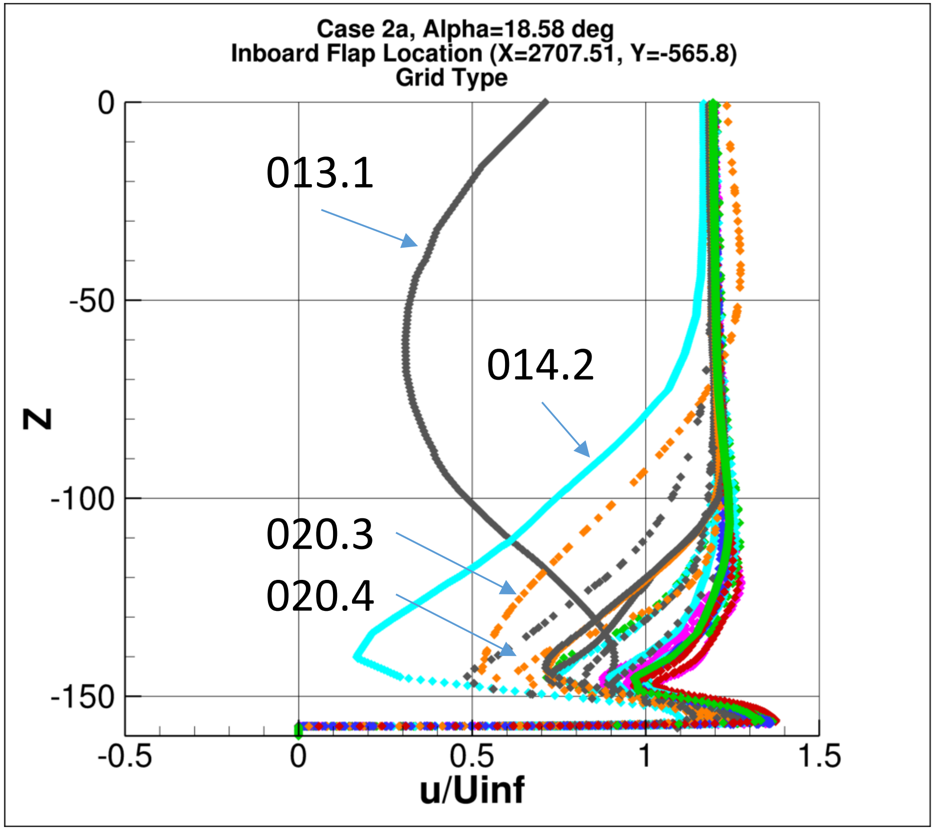

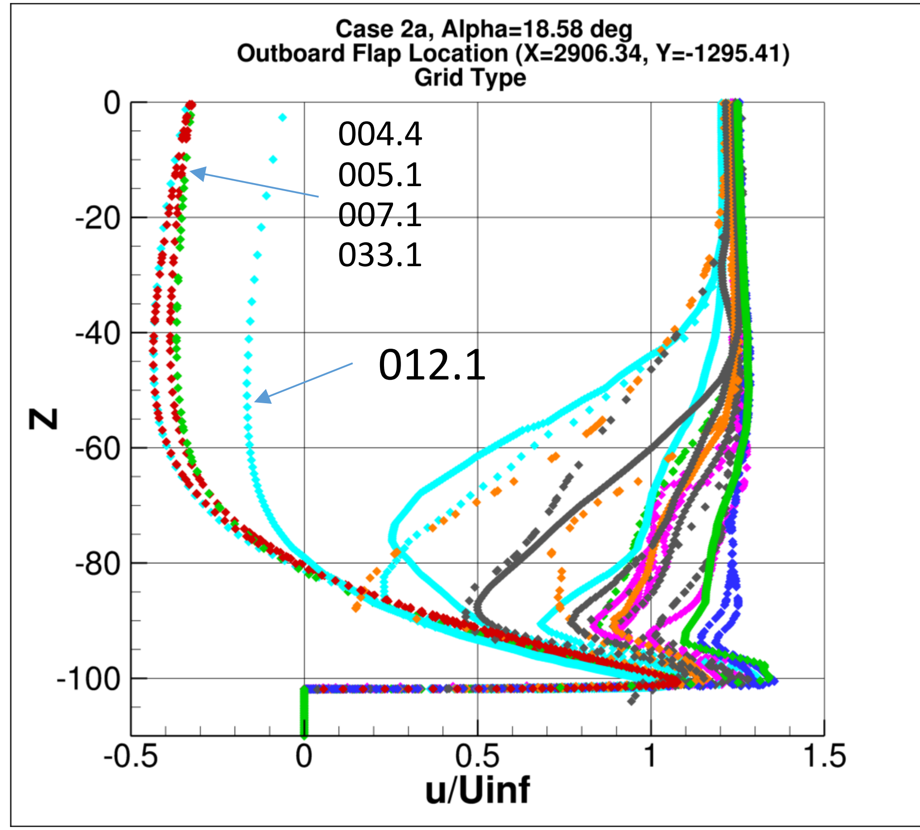

- Generally, no clear difference by grid type at inboard station. 013.1 appears to miss capturing confluent BL.
- Larger variation in results at outboard station. Several results consistently show large wake deficit.

StrOverset_ChimeraGridTools
UnstrMixed_DLR_SOLAR
UnstrTet_VGRID
UnstrMixed_VGRID
UnstrMixed_JAXA
UnstrMixed_ANSA
Participant

Comparison of Velocity Profiles

Case2a – Inboard, Outboard Locations (by Turbulence Model)

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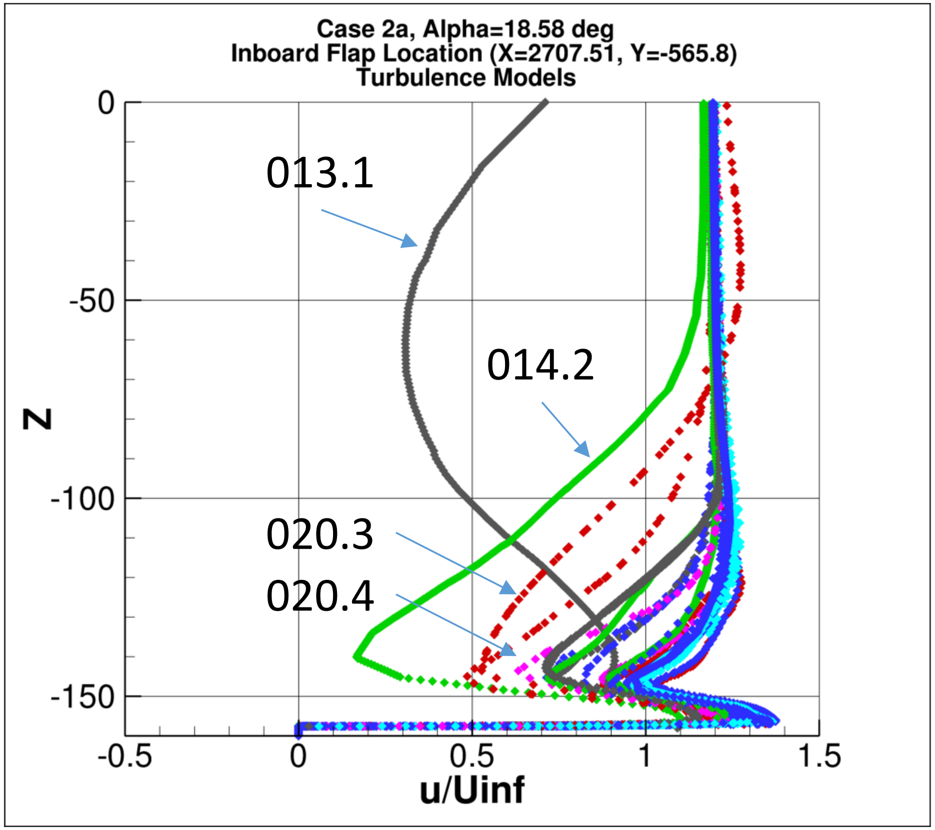

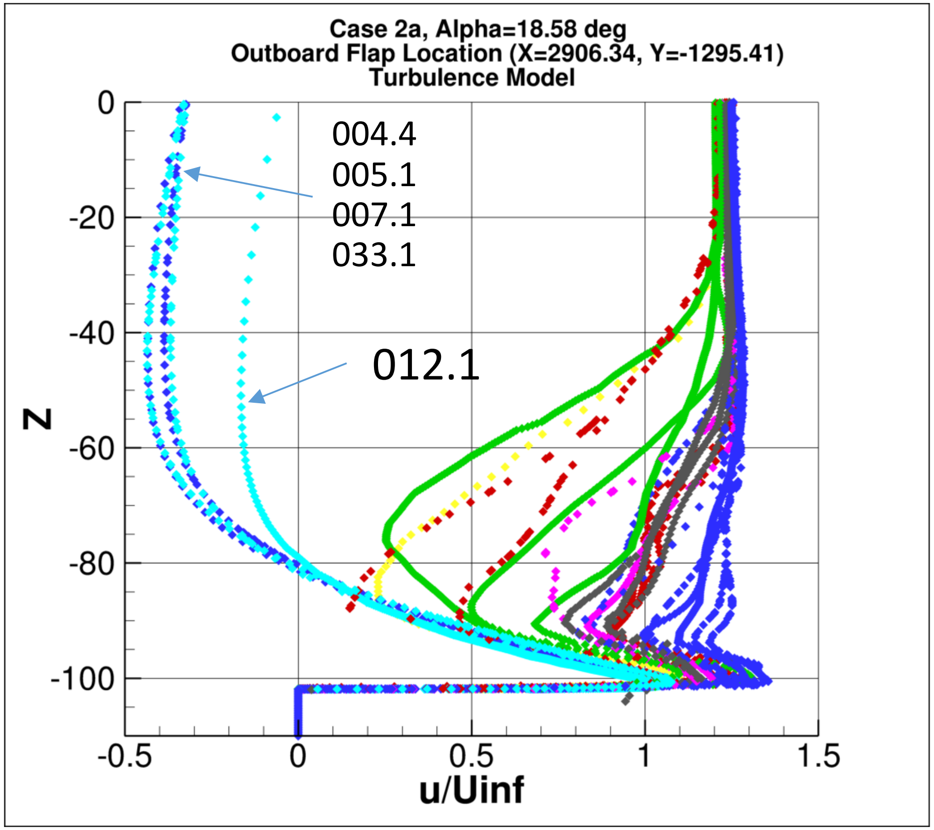

- Generally, no clear difference by turbulence model at inboard station.
- Might larger variation in results at outboard station. SA with QCR only appears to consistently show large wake deficit

SST, SST-SAS, SST-GAMMA
SA, SA-neg, SA-noft2, SA-AFT
SA-noft2-R, SARC
SA-QCR, SA-QCR2000
SA-RC-QCR
Other

Comparison of Velocity Profiles

Case2a, Case2c – Inboard Location (All Simulations)

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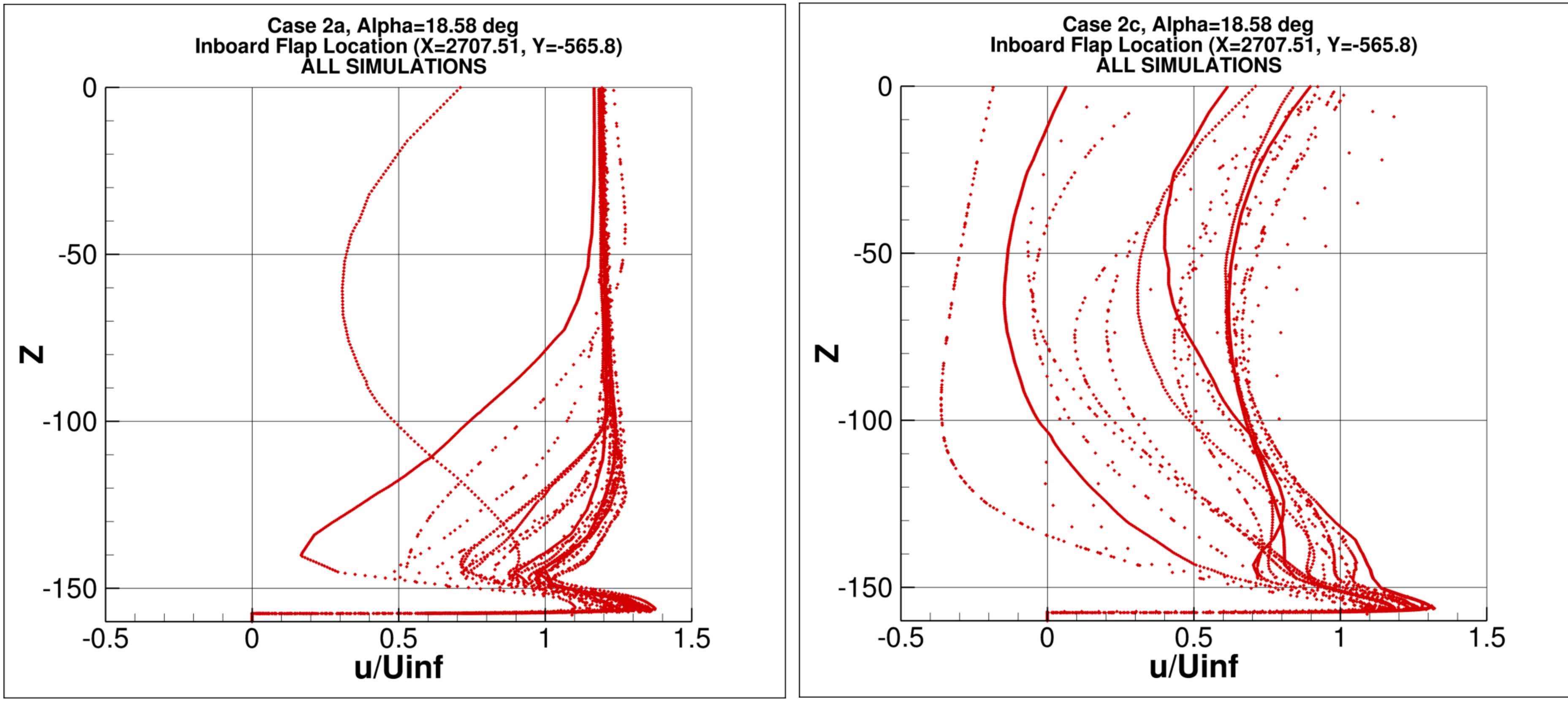

- Much more scatter in velocity profiles at inboard flap location with presence of the nacelle/pylon

Back-Up

Comparison of Idealized Profile Drag Results – All Simulations Case2a (No Nacelle/Pylon) and Case2c (Nacelle/Pylon)

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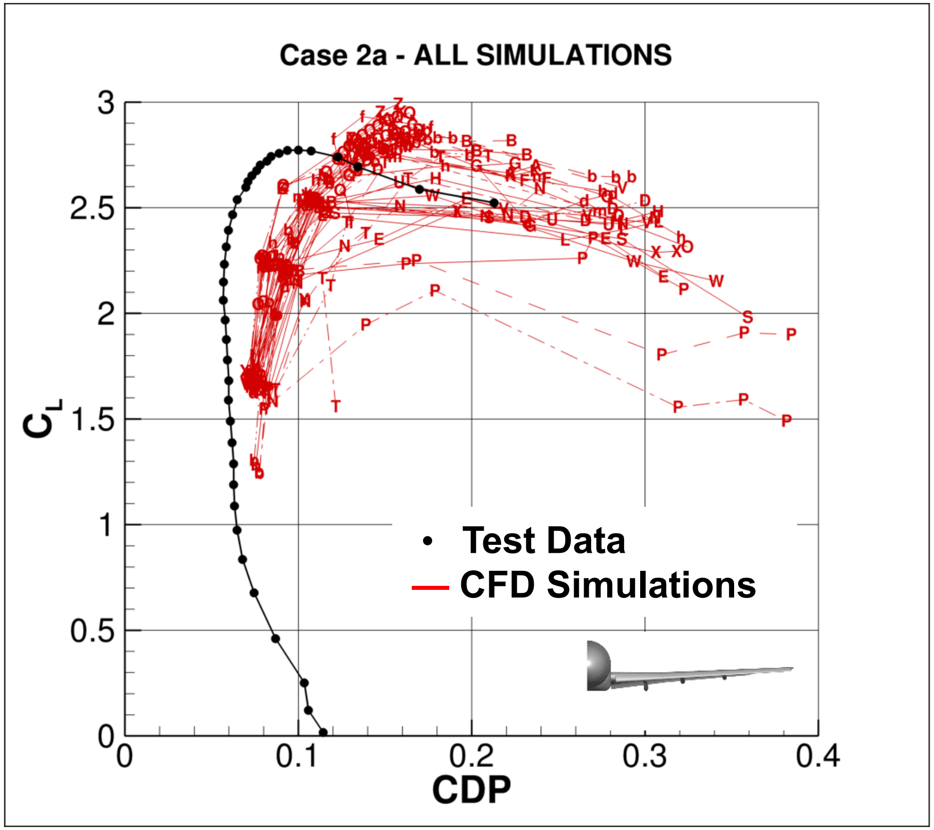

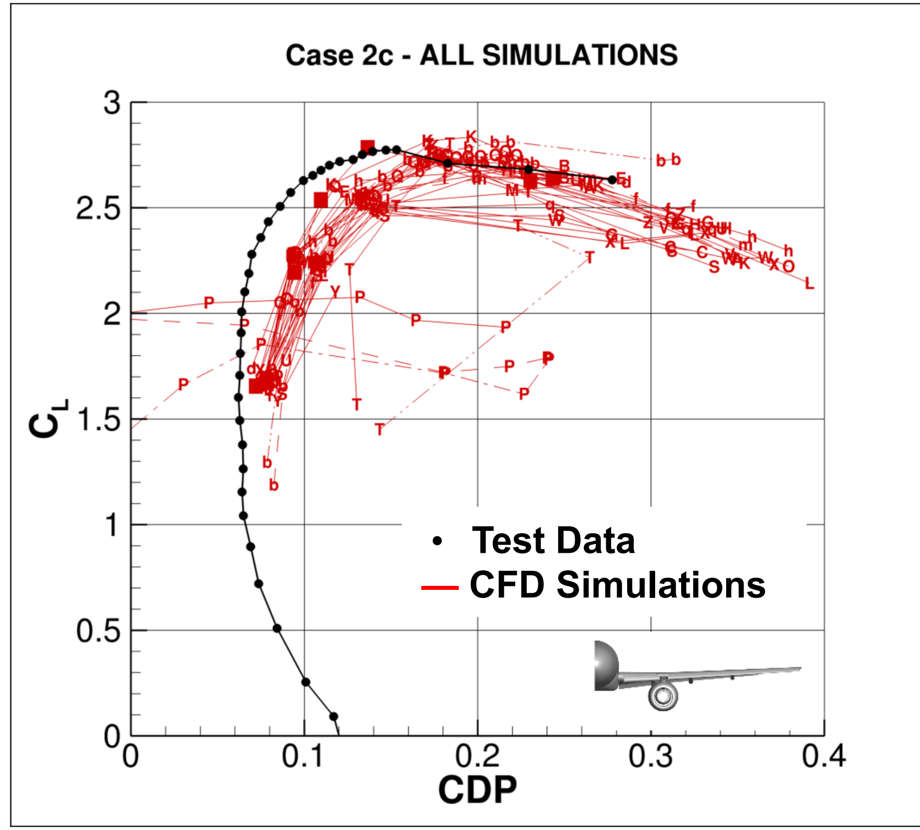

- All simulations predict higher total drag relative to test data at all angles-of-attack.
- Most solutions appear to better predict drag at CLmax for Case2c than for Case2a
- Datasets P and T are clear outliers for Case2c

Comparison of Lift Curve by Grid Type

Unstructured-Mixed (Case2a)

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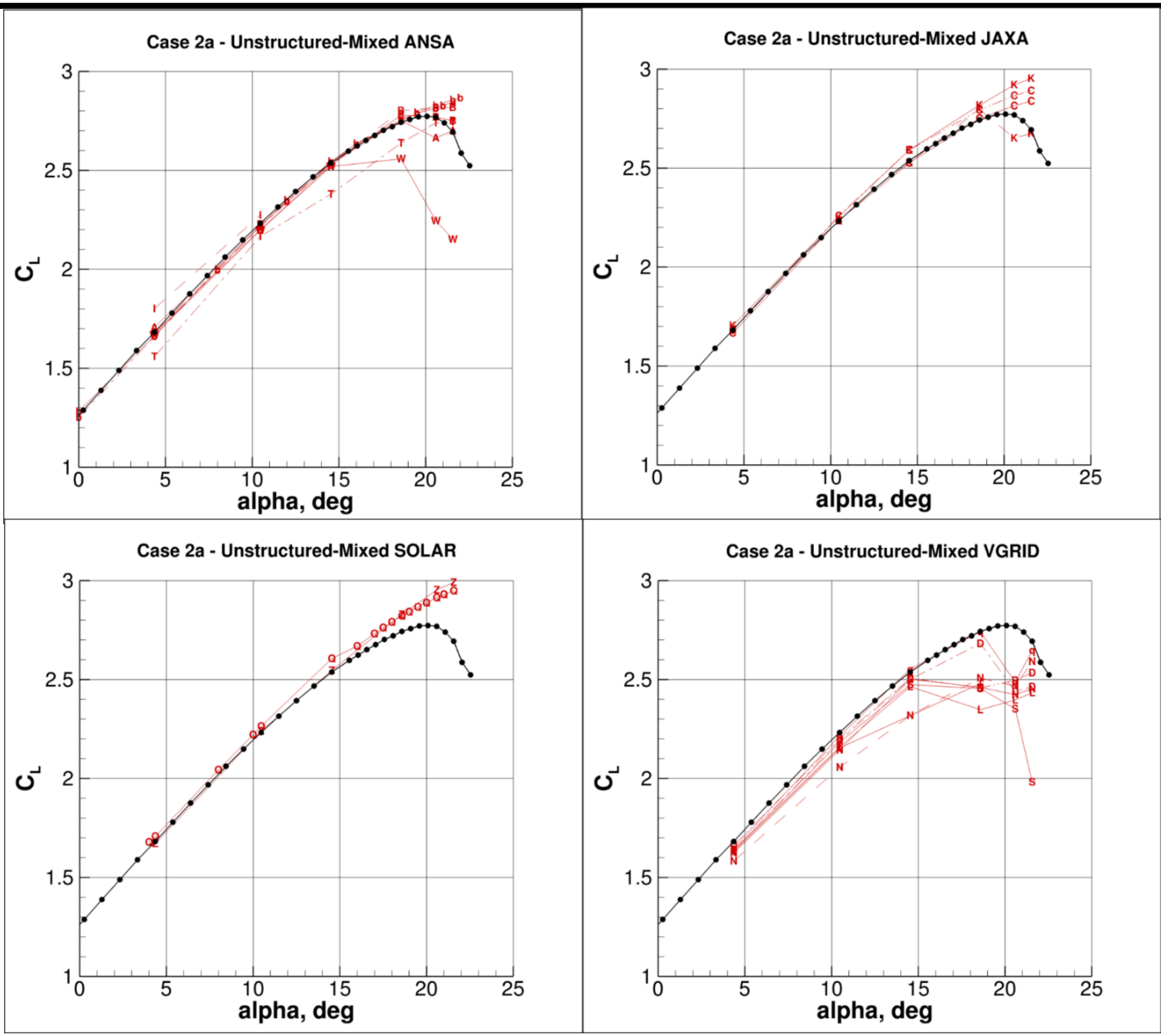
- In general, solutions using the same grid system tend to show similar results, regardless of flow solver
- VGRID results appear to be consistently low in lift, and show more scatter near CLmax



Comparison of Lift Curve by Grid Type
VGRID (Case2a)

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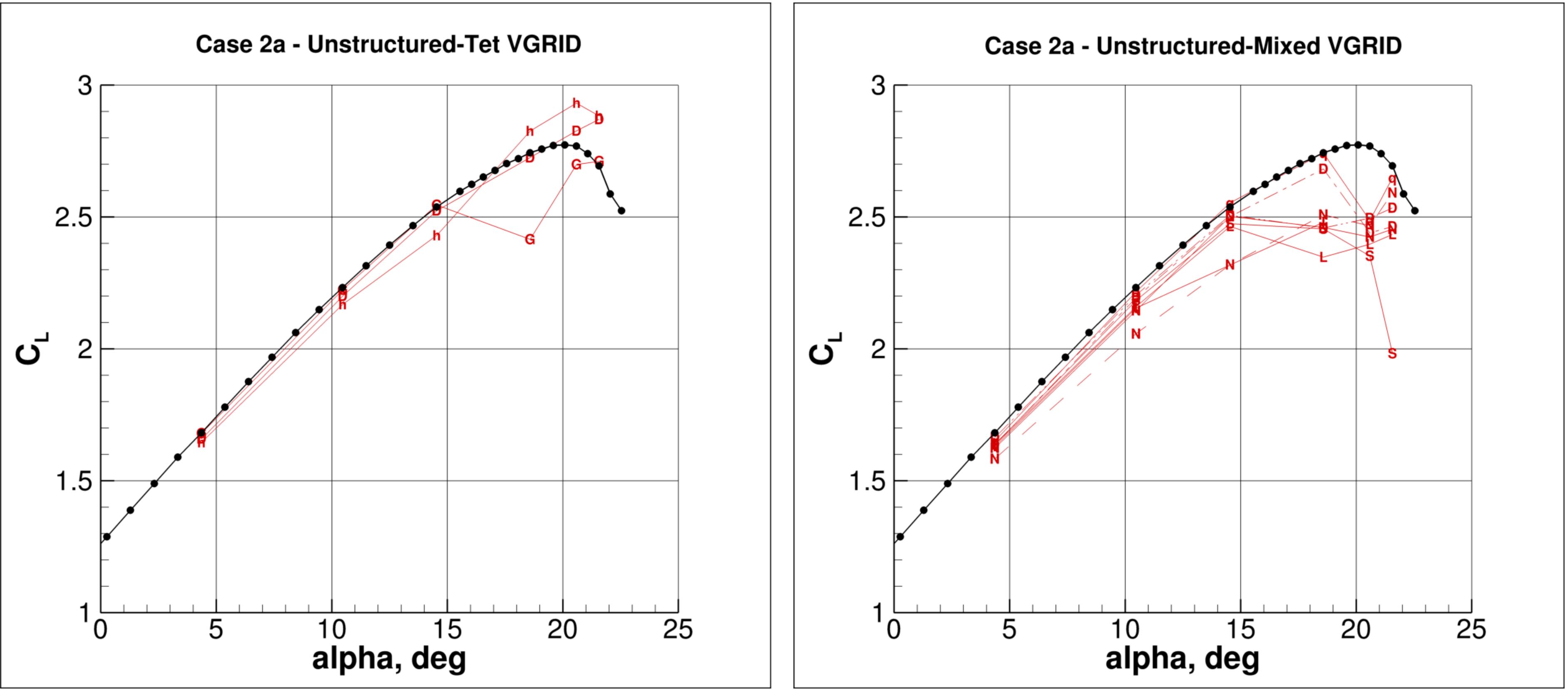

- Simulation results using the mesh generated by VGRID appear to be consistently low in lift, and show significant scatter near CLmax
- No significant difference see between type of unstructured grid discretization used.

Comparison of Lift Curve by Grid Type

Overset and Participant Grids (Case2a)

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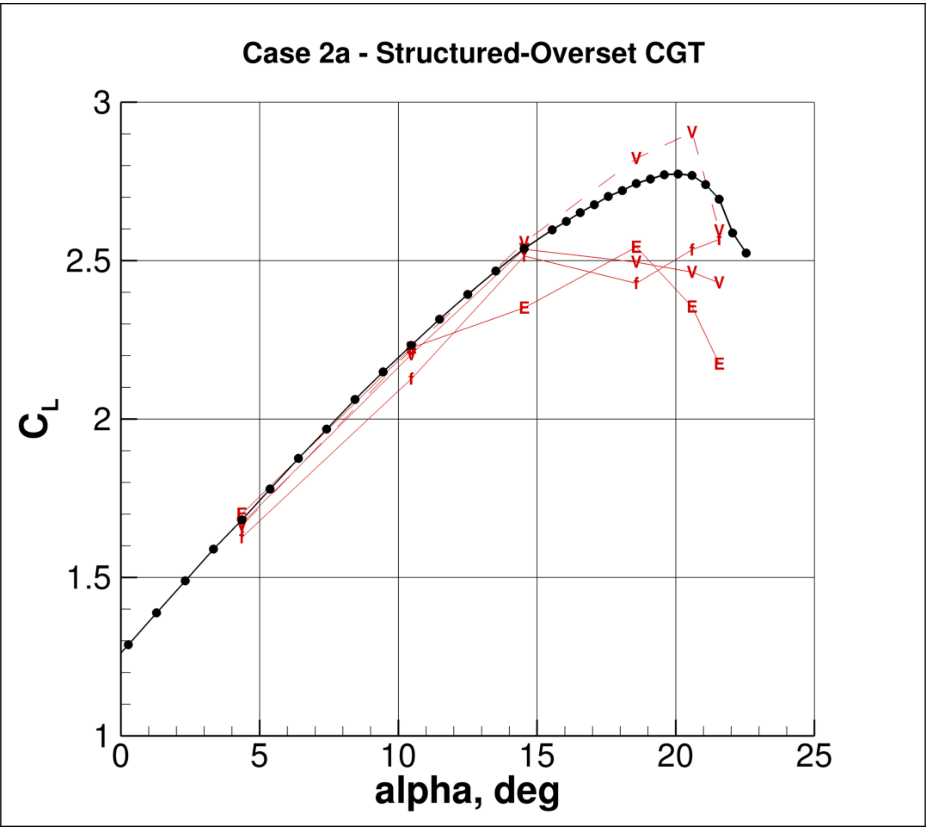
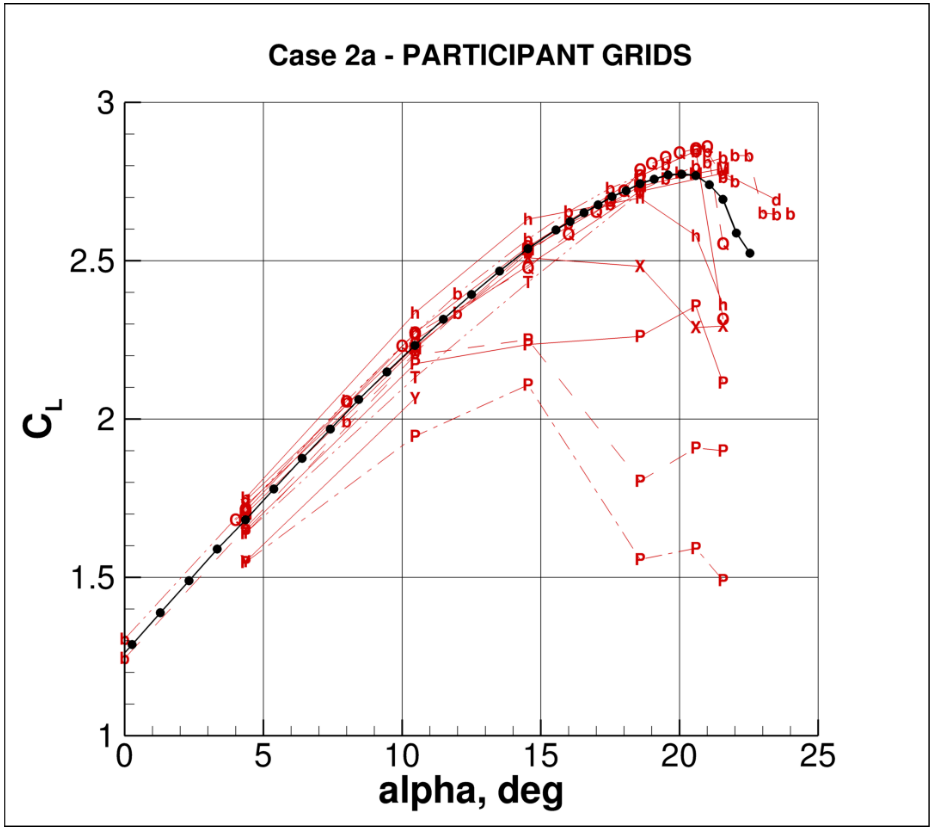
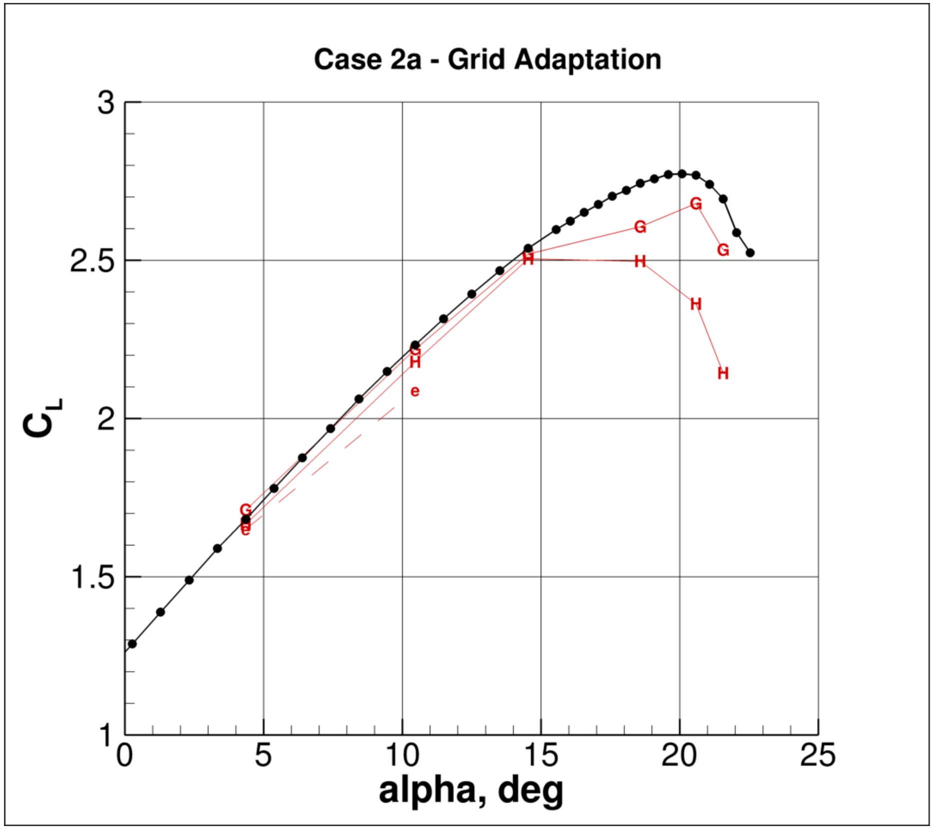




- Overset grid results do not correlate to one another. Some results correlate well with test data.
- Some simulations using participant grids show very good correlation with test data.

Comparison of Lift Curve by Grid Type

Grid Adaptation (Case2a)



- CFD simulations using grid adaptation generally match with test data in the linear portion of the lift curve, but do no better than as fixed grid simulations at CL_{max}

Comparison of Velocity Profiles

Case2a – Inboard, Outboard Locations (All Simulations)

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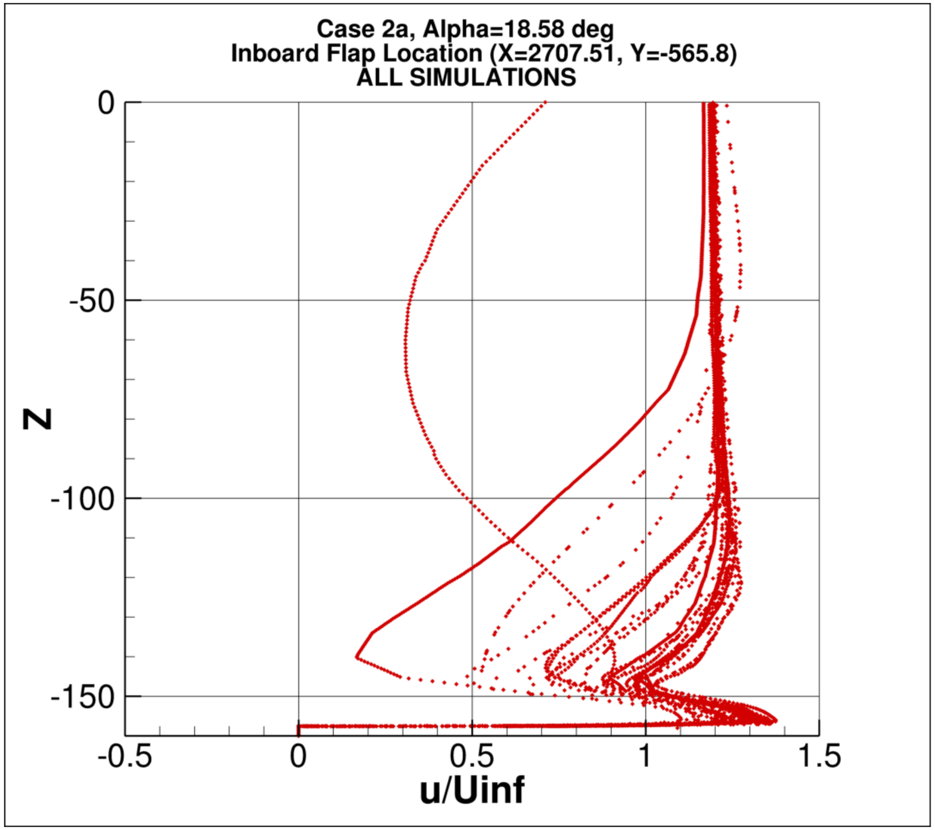
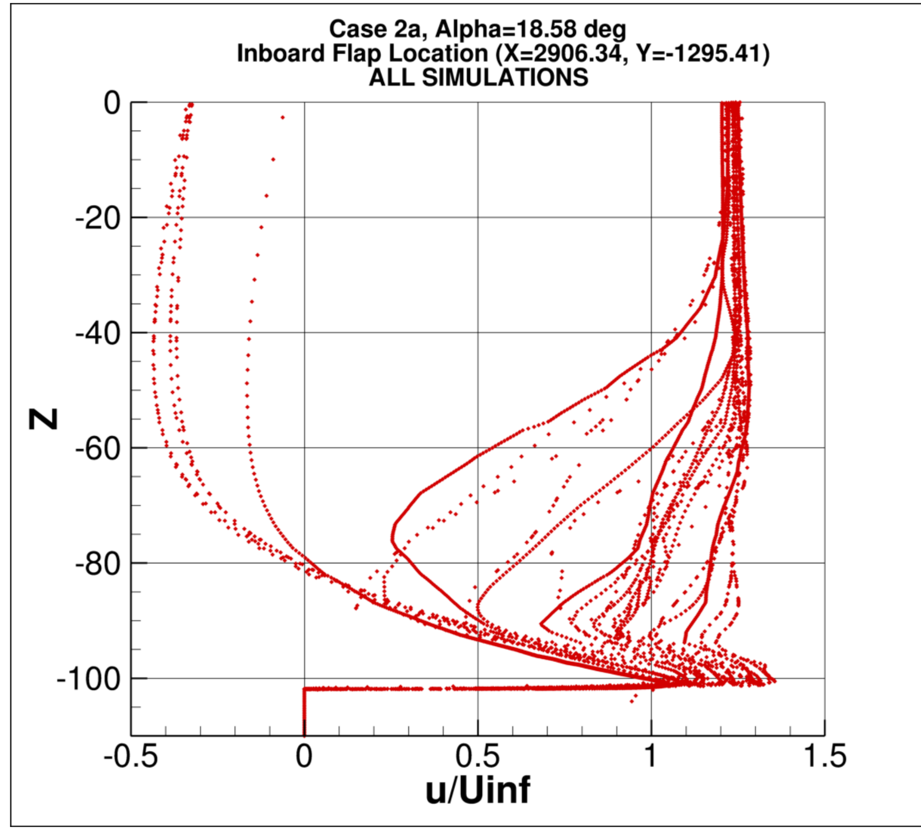
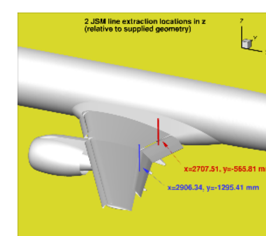




- Most simulations capture wake confluence (and many correlate well) at the inboard flap location
- Much more scatter in the results at the outboard flap location



Comparison of Lift Curve by Turbulence Model

Advanced Models (Case2a) near CLmax

- Simulations using the Wilcox k-omega appear to provide the best correlation with test data. However, the lift curve for fully turbulent (tripped) flow generally provides higher lift than transitional flow. These results show the opposite trend.
- Lattice-Boltzmann simulations show overall good agreement with test data for lift, but the agreement with test data would likely worsen if flow was tripped in the WT.