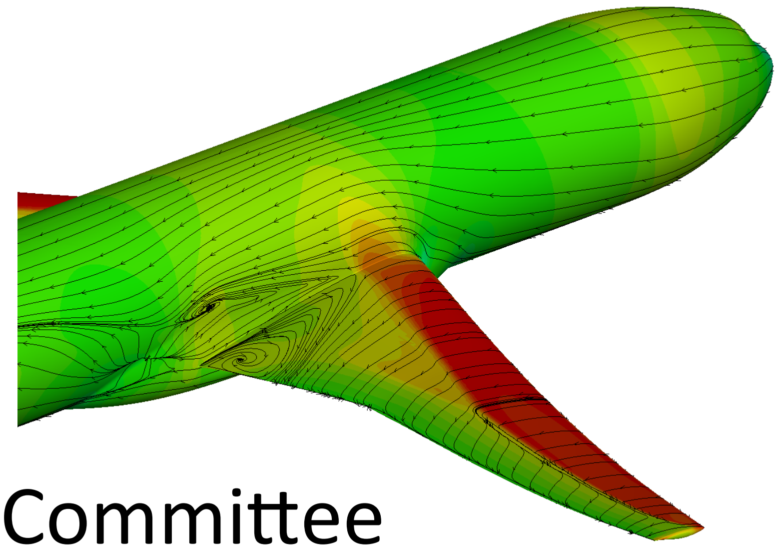
DPW 5 Summary of Participant Data



Ed Tinoco,

David Levy,

Olaf Brodersen,

and the DPW Organizing Committee

24 June 2012

Outline:

- Participant Data
- Case 1: Grid Convergence
- Case 2: Buffet Study
- Pressure Data
- Side of Body Separation
- Trailing Edge Separation
- Conclusions

Participant Data:

- **54 Data Total Data Submittals**
- **22 Teams/Organizations**
  - 10 N. America, 5 Europe, 6 Asia, 1 S. America
  - 8 Government, 5 Industry, 6 Academia, 2 Commercial, 1 Unknown
  - 1 for Case 3 only
- **Grid Types:**
  - 5 Overset (4 Teams)
  - 7 Structured Multi-block (5 Teams)
  - 25 Unstructured (13 teams)
(14 Hex, 7 Hybrid, 4 Prism)
  - 16 Custom (all types)
- **Turbulence Models:**
  - 34 SA (all types), 12 SST, 4 k-e-RT, 1 EARSM, 1 Lag-RST

5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012

AIAA Applied Aerodynamics Technical Committee

Team	ID	Name	Organization	File Name	Code	Misc Solver	Grid Type	Turbulence Model
1	A	Sclafani	Boeing (Huntington)	SclafaniT-CommonOverset-SAIa-1	OVERFLOW v2.2c	Central	Overset	SA-Ia
	B	Sclafani	Boeing (Huntington)	SclafaniT-CommonOverset-SARC-1	OVERFLOW v2.2c	Central	Overset	SA-Ia w/ RC
	C	Sclafani	Boeing (Huntington)	SclafaniT-CustomOverset-SAIa-1	OVERFLOW v2.2c	Central	Custom (Overset)	SA-Ia
	D	Sclafani	Boeing (Huntington)	SclafaniT-CustomOverset-SAIa-2	OVERFLOW v2.2c	Central / QCR	Custom (Overset)	SA-Ia
	E	Sclafani	Boeing (Huntington)	SclafaniT-CustomOverset-SARC-1	OVERFLOW v2.2c	Central	Custom (Overset)	SA-Ia w/ RC
	F	Sclafani	Boeing (Huntington)	SclafaniT-CustomOverset-SARC-2	OVERFLOW v2.2c	Central / QCR	Custom (Overset)	SA-Ia w/ RC
	G	Sclafani	Boeing (Huntington)	SclafaniT-CustomOverset-SARC-3	OVERFLOW v2.2c	Central	Custom (Overset)	SA-Ia w/ RC
	H	Sclafani	Boeing (Huntington)	SclafaniT-CustomOverset-SARC-4	OVERFLOW v2.2c	Central / QCR	Custom (Overset)	SA-Ia w/ RC
2	I	Chen	Mianyang City, China	Chen-CommonHex-SA-1	MFlow	Upwind	Hex	SA
	J	Chen	Mianyang City, China	Chen-CommonHex-SA-1	MFlow	Upwind	Hybrid	SA
3	K	GariÈpy	EcolePolytechMontreal	GariepyM-CommonPrism-SA-1	Fluent V13	Upwind	Prism	SA
	L	GariÈpy	EcolePolytechMontreal	GariepyM-Custom-SA-1	Fluent V13	Upwind	Custom (Hex)	SA
4	M	Scalabrin	Embraer	ScalabrinL-CommonHex-RT-1	CFD++	Upwind	Hex	k-e-RT
	N	Scalabrin	Embraer	ScalabrinL-CommonHex-SST-1	CFD++	Upwind	Hex	SST
	O	Scalabrin	Embraer	ScalabrinL-CommonHybrid-RT-1	CFD++	Upwind	Hybrid	k-e-RT
	P	Scalabrin	Embraer	ScalabrinL-CommonHybrid-SST-1	CFD++	Upwind	Hybrid	SST
	Q	Scalabrin	Embraer	ScalabrinL-CommonPrism-RT-1	CFD++	Upwind	Prism	k-e-RT
	R	Scalabrin	Embraer	ScalabrinL-CommonPrism-SST-1	CFD++	Upwind	Prism	SST
	S	Scalabrin	Embraer	ScalabrinL-CommonCustom-RT-1	CFD++	Upwind	Custom (Hybrid)	k-e-RT
	T	Scalabrin	Embraer	ScalabrinL-CommonCustom-SST-1	CFD++	Upwind	Custom (Hybrid)	SST
5	U	Eliasson	FOI	EliassonP-CommonHex-EARSM-1	EDGE		Hex	EARSM
	V	Eliasson	FOI	EliassonP-CommonHex-SA-1	EDGE		Hex	SA
	W	Eliasson	FOI	EliassonP-CommonHex-SST-1	EDGE		Hex	SST
6	X	Powell	Gulfstream	PowellN-CommonHybrid-SA-1	FUN3D		Hybrid	SA
7	Y	Balakrishnan	Indian Inst. Science	BalakrishnanN-CommonHex-SA-1	HiFUN	Upwind	Hex	SA
8	Z	Hashimoto	JAXA	Hashimoto-CommonHex-SA-1	FaSTAR	Upwind	Hex	SA-noft2-R
	2	Hashimoto	JAXA	Hashimoto-Custom-SA-1	FaSTAR	Upwind	Custom (Hex)	SA-noft2-R

5th CFD Drag Prediction Workshop

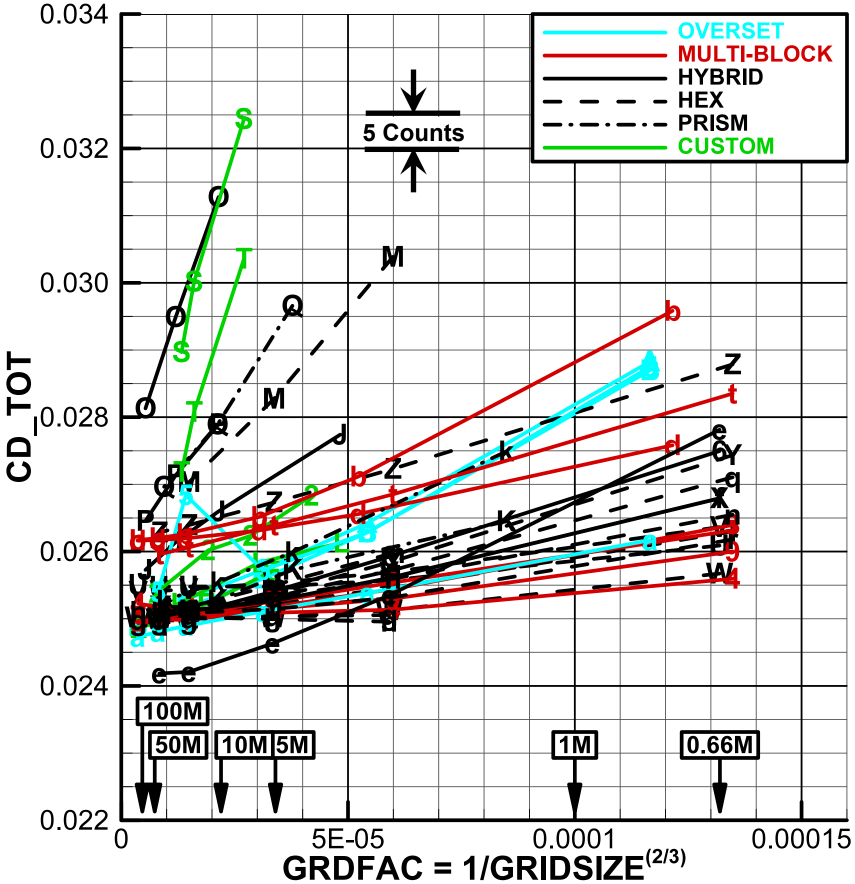
New Orleans, Louisiana – June 2012

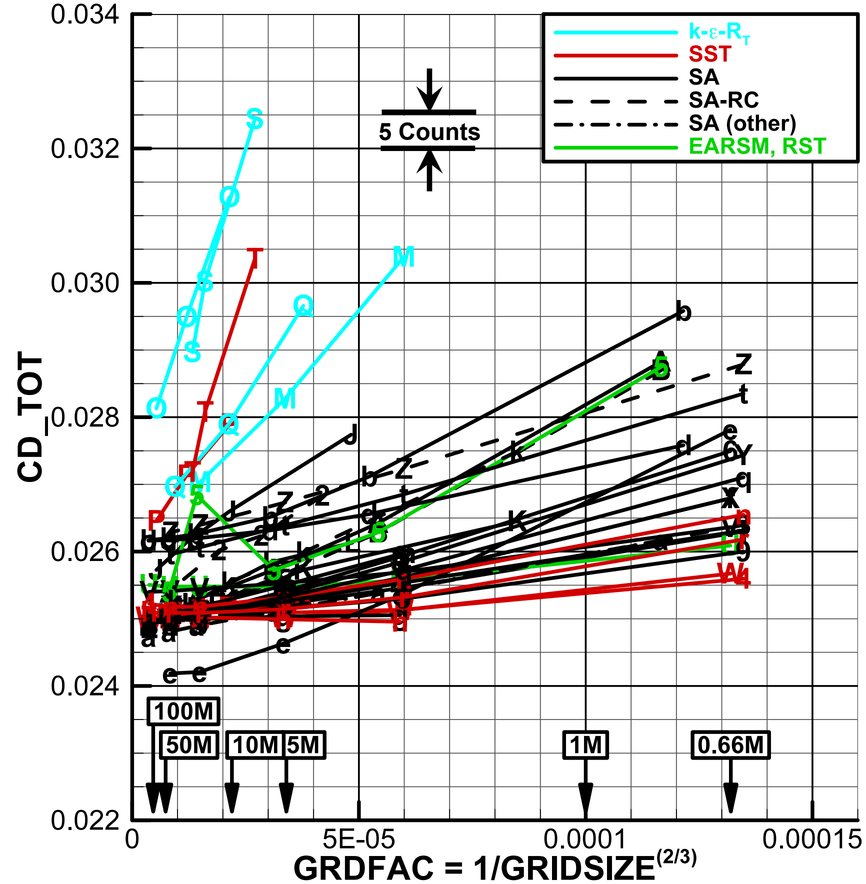
Team	ID	Name	Organization	File Name	Code	Misc Solver	Grid Type	Turbulence Model
9	3	Yamamoto	JAXA	YamamotoK-CommonMB-SA-noft2-R-1	UPACS	Upwind	Multi-block	SA-noft2-R (Crot=1)
	4	Yamamoto	JAXA	YamamotoK-CommonMB-SST-V-1	UPACS	Upwind	Multi-block	SST-V
10	5	Olson	NASA Ames	Olsen-CommonOverset-LagRST-1	overflow2.2e_LRS	Central/matrix	Overset	Lag RST
11	6	Park	NASA Langley	ParkM-CommonHybrid-SA-1	FUN3D v12.2	Upwind Roe	Hybrid	SA
	7	Park	NASA Langley	ParkM-CommonMB-SA-1	CFL3D v6.6	Upwind Roe	Multi-block	SA
12	8	Cai	NPU China	CaiJ-CommonOverset-SST-1	ExStream	Upwind	Overset	SST
13	9	Hue	ONERA	HueD_CommonMB_SA_1	elsA	Central	Multi-block	SA
14	a	Coder	Penn St. U	CoderJ-CommonOverset-SA-fv3-1	OVERFLOW 2.2c	Upwind	Overset	SA-fv3
15	b	Osusky	U. Toronto	OsuskyM-CommonMB-SA-1	Diablo	Scalar	Multi-block	SA
	d	Osusky	U. Toronto	OsuskyM-CommonMB-SA-2	Diablo	Matrix	Multi-block	SA
16	e	Levy	Cessna Aircraft Co.	LevyD-CommonHybrid-SA-1	NSU3D	Central/matrix	Hybrid	SA
	f	Levy	Cessna Aircraft Co.	LevyD-CommonHybrid-SA-2	FUN3D	Upwind Roe	Hybrid	SA
17	g	Crippa	DLR	DLR_CrippaS-CommonHex-SA-1	TAU	Matrix	Hex	SA
	h	Crippa	DLR	DLR_CrippaS-CommonHex-SST-1	TAU	Matrix	Hex	SST
18	k	Moitra	CRL_INDIA	CRL_INDIA_MoitraA	CFD++	Upwind	Prism	SA-RC
19	m	Winkler	Boeing (St. Louis)	BCFD-CommonHex-SA-1	BCFD	Upwind HLLE	Hex	SA
	n	Winkler	Boeing (St. Louis)	BCFD-CommonHex-SSTV-1	BCFD	Upwind HLLE	Hex	SST-V
	q	Winkler	Boeing (St. Louis)	BCFD-CommonHex-SA-2	BCFD	Upwind HLLE	Hex	SA
	r	Winkler	Boeing (St. Louis)	BCFD-CommonHex-SSTV-2	BCFD	Upwind HLLE	Hex	SST-V
20	t	Temmerman	NUMECA	DPW-V-NUMECA	FINE/Open	Cell Centered	Multi-block	SA
21	α	Brodersen	DLR	DLR_BrodersenO_Cust1_SA_D1	TAU	Diss 1	Custom (Hybrid)	SA
	β	Brodersen	DLR	DLR_BrodersenO_Cust1_SA_D3	TAU	Diss 3	Custom (Hybrid)	SA
	δ	Brodersen	DLR	DLR_BrodersenO_Cust2_SA_D1	TAU	Diss 1	Custom (Hyb w/ Hex-Wake)	SA
	γ	Brodersen	DLR	DLR_BrodersenO_Cust2_SA_D3	TAU	Diss 3	Custom (Hyb w/ Hex-Wake)	SA
	λ	Brodersen	DLR	DLR_BrodersenO_Cust2_SST_D1	TAU	Diss 1	Custom (Hyb w/ Hex-Wake)	Menter SST
	π	Brodersen	DLR	DLR_BrodersenO_Cust2_SST_D3	TAU	Diss 3	Custom (Hyb w/ Hex-Wake)	Menter SST

Case 1: Grid Convergence Study

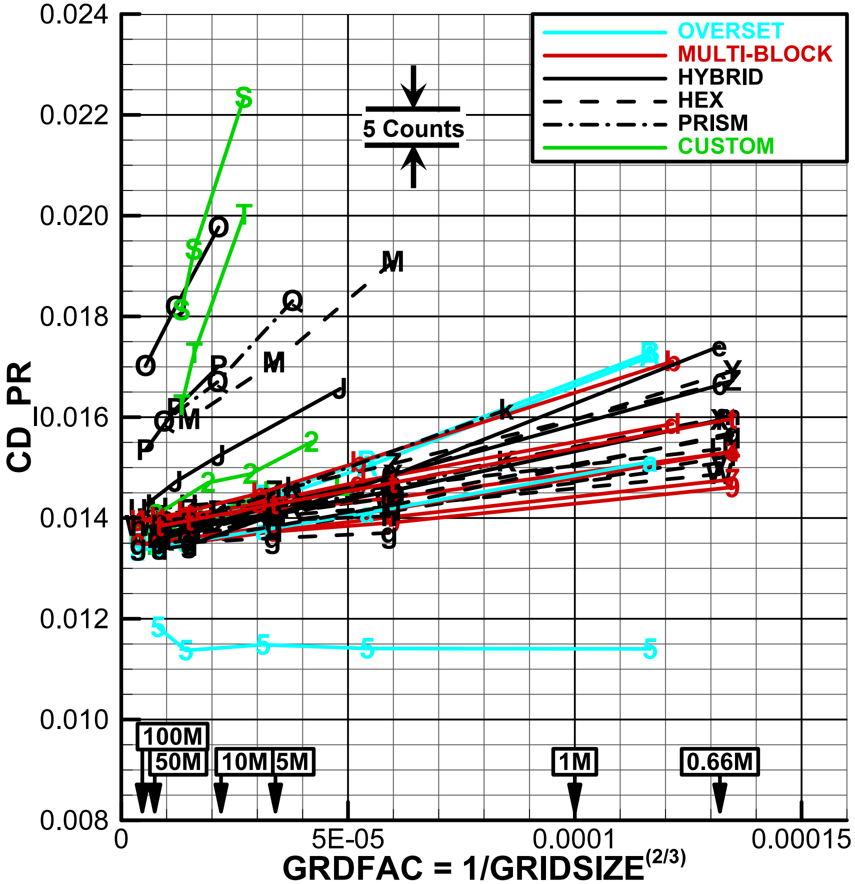
- NASA Common Research Model, Wing-Body
- Mach=0.85, C_L=0.500±0.001
- Grid Resolution Level:
  - 1) Tiny 2) Coarse 3) Medium,
  - 4) Fine 5) Extra-Fine 6) Super-Fine
- Chord Reynolds Number: 5×10^6

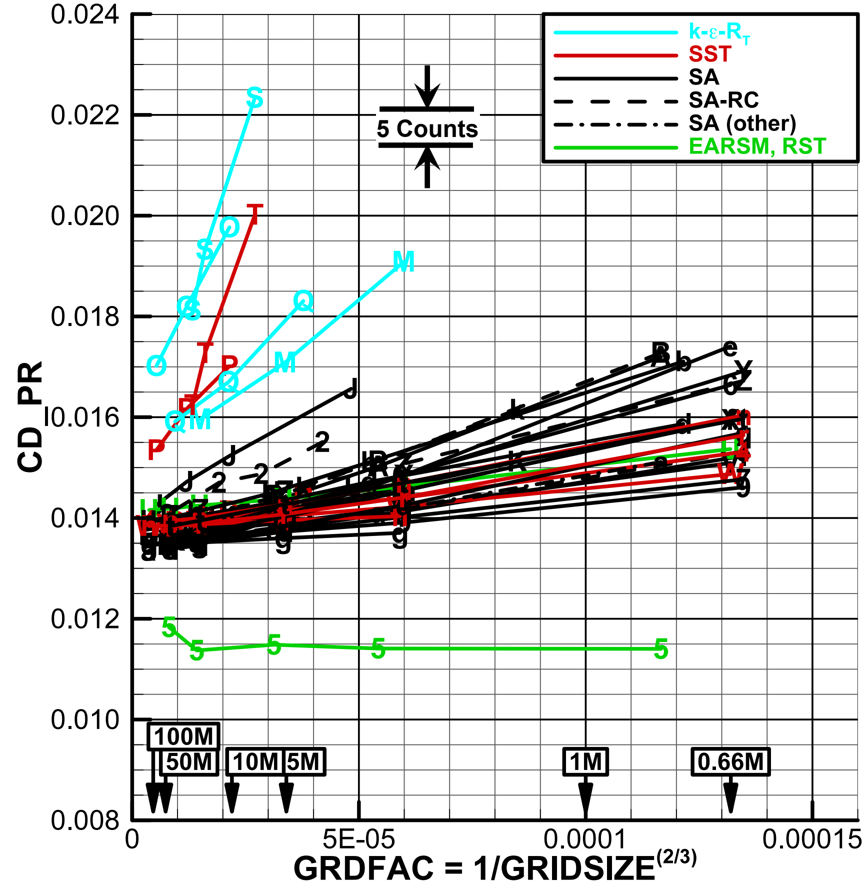
Case 1: CD_TOT - All Solutions by Grid Type and Turbulence Model



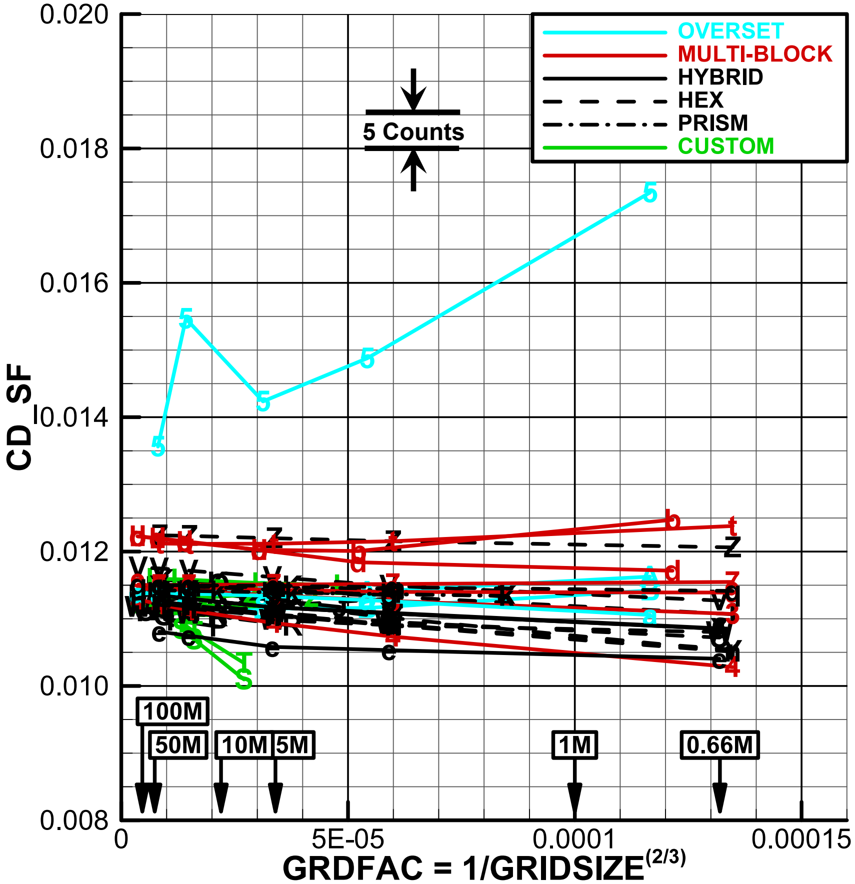


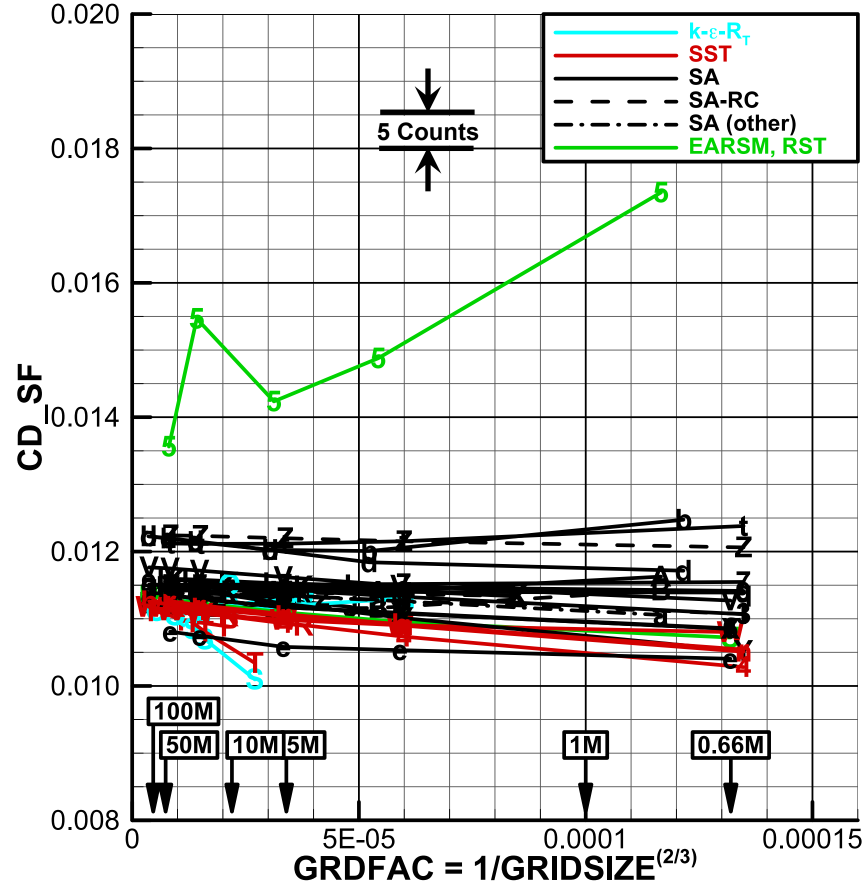
Case 1: CD_PR - All Solutions by Grid Type and Turbulence Model



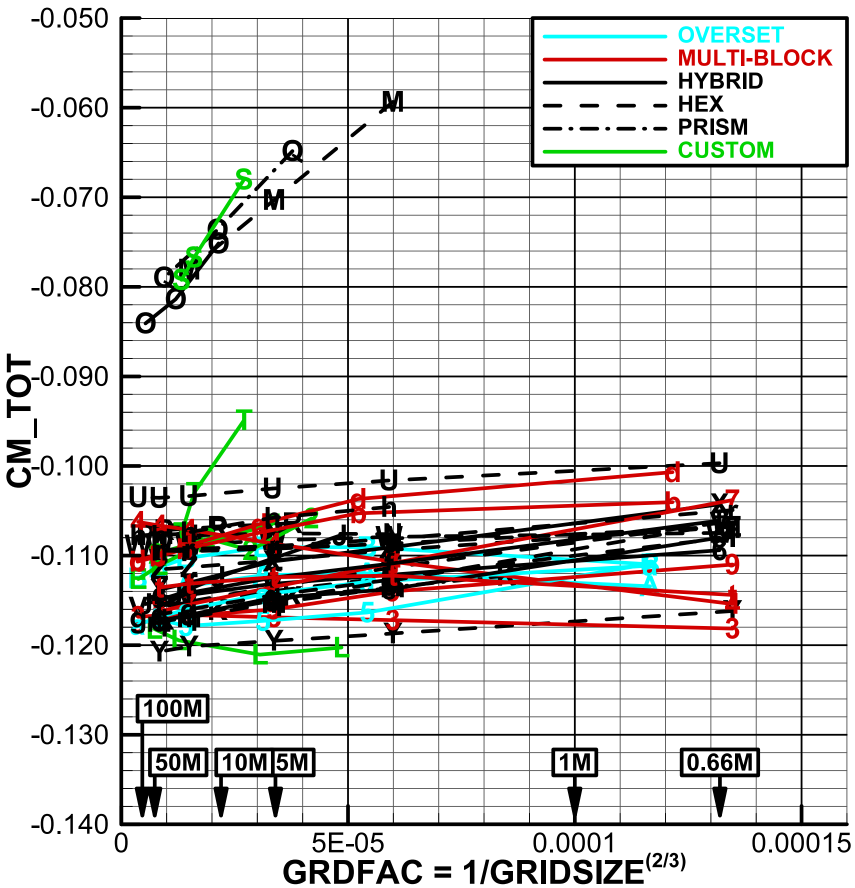


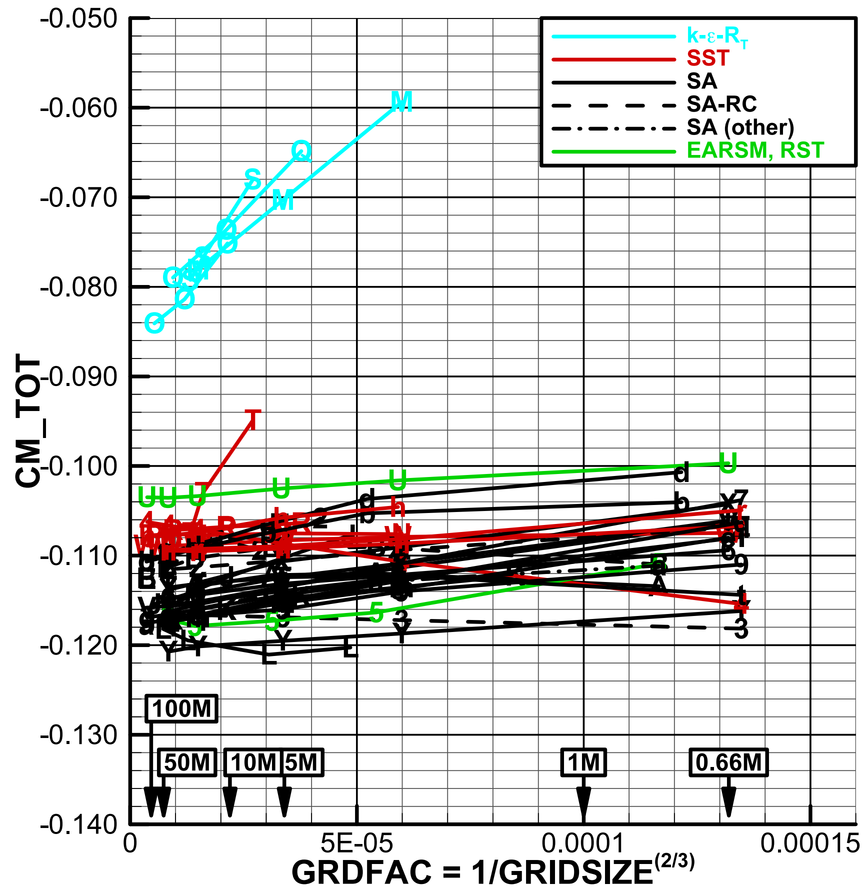
Case 1: CD_SF - All Solutions by Grid Type and Turbulence Model



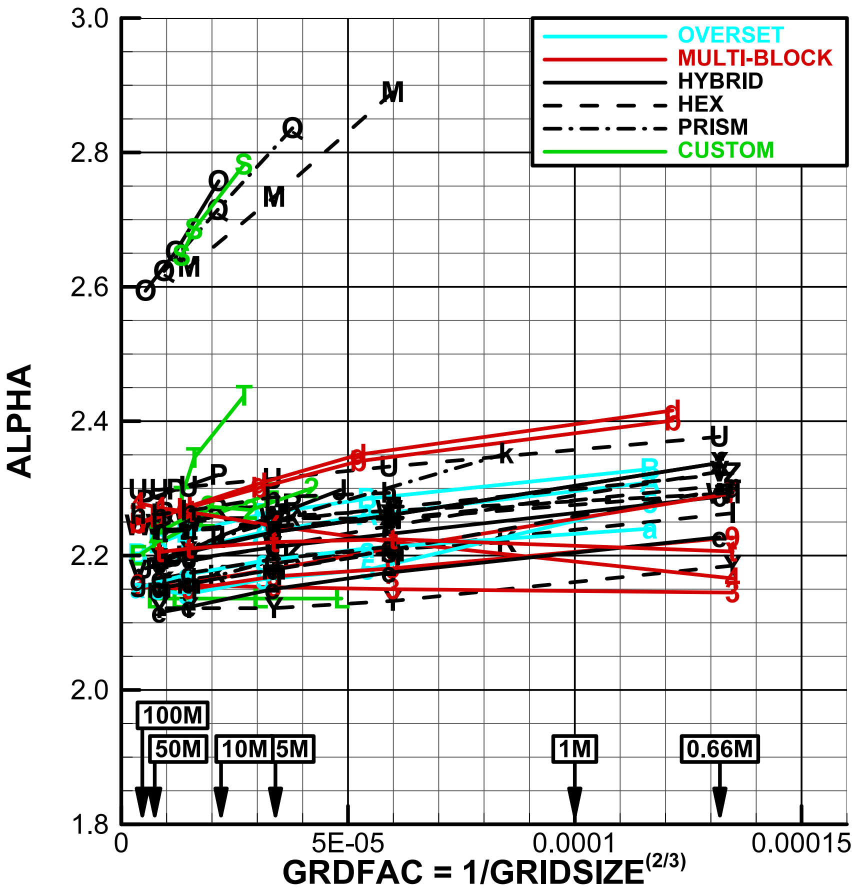


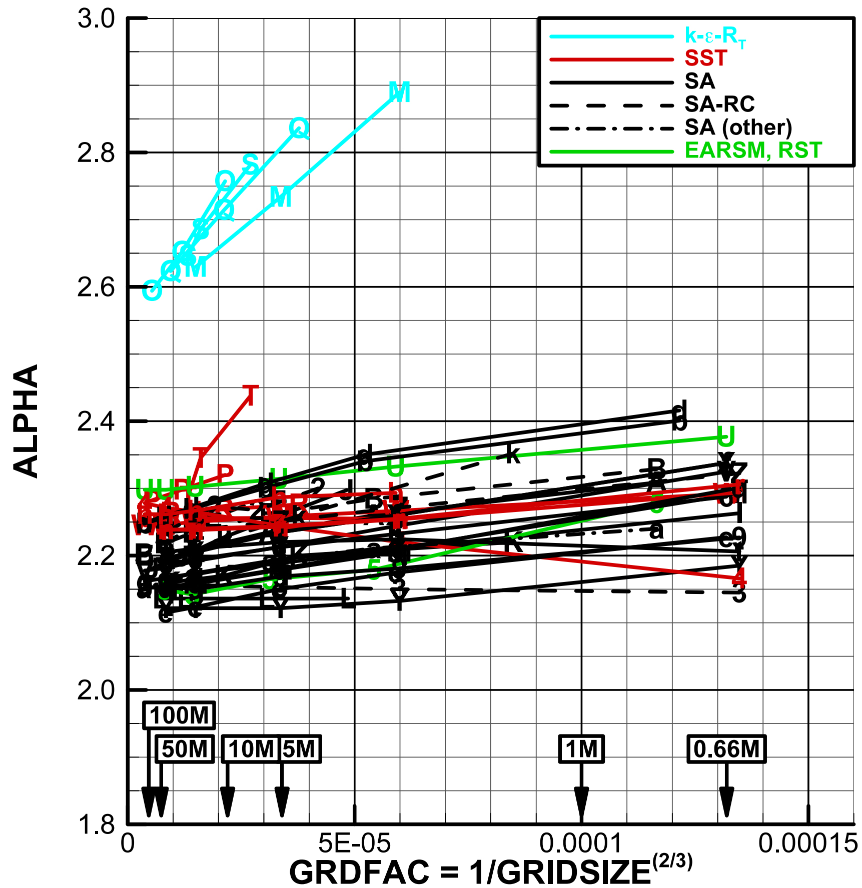
Case 1: CM_TOT - All Solutions by Grid Type and Turbulence Model



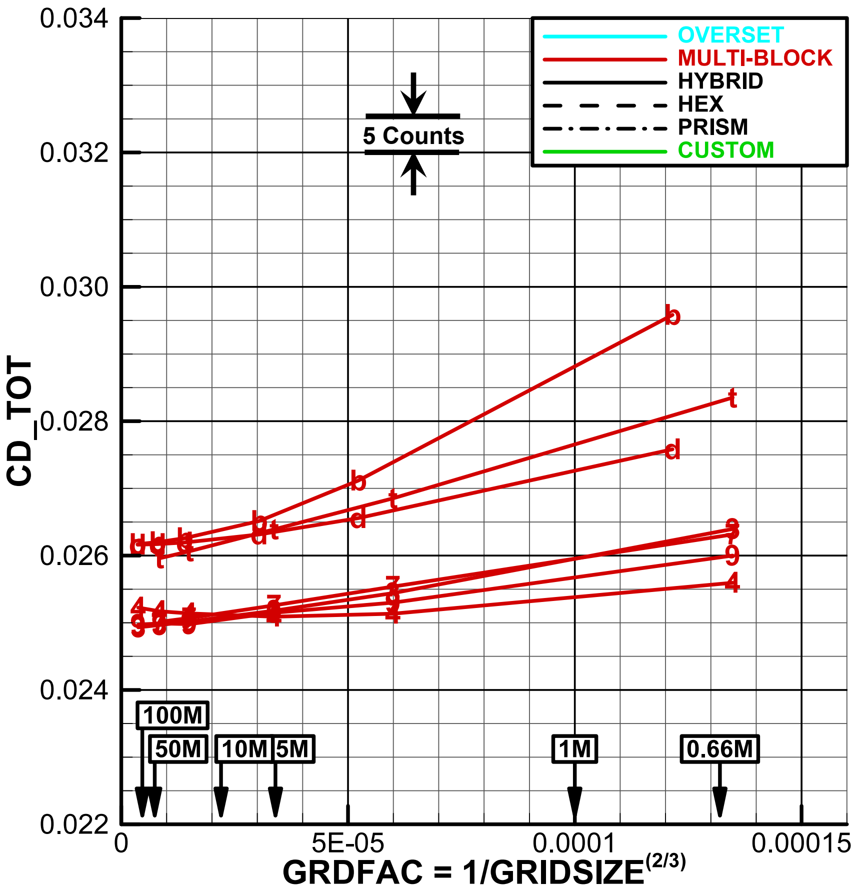


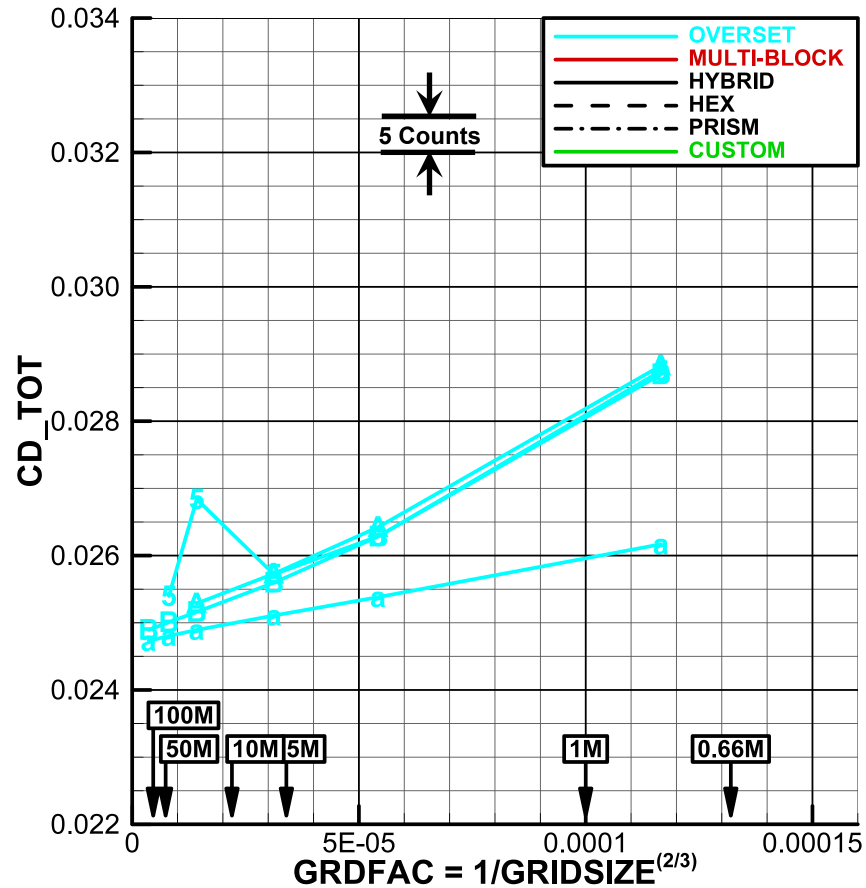
Case 1: ALPHA - All Solutions by Grid Type



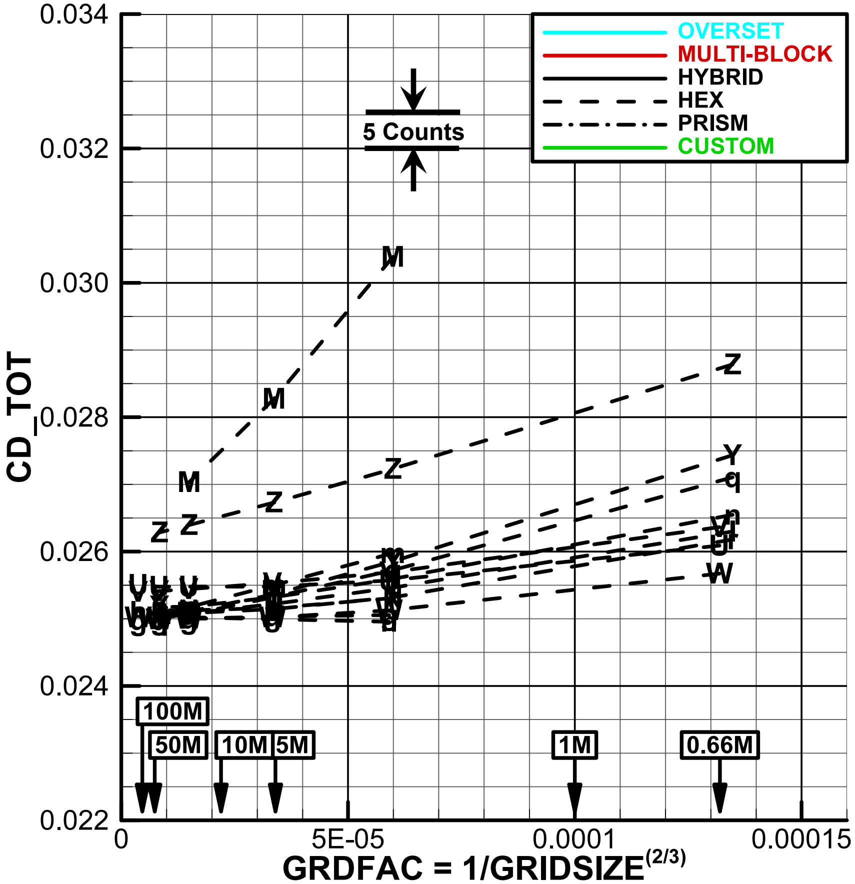


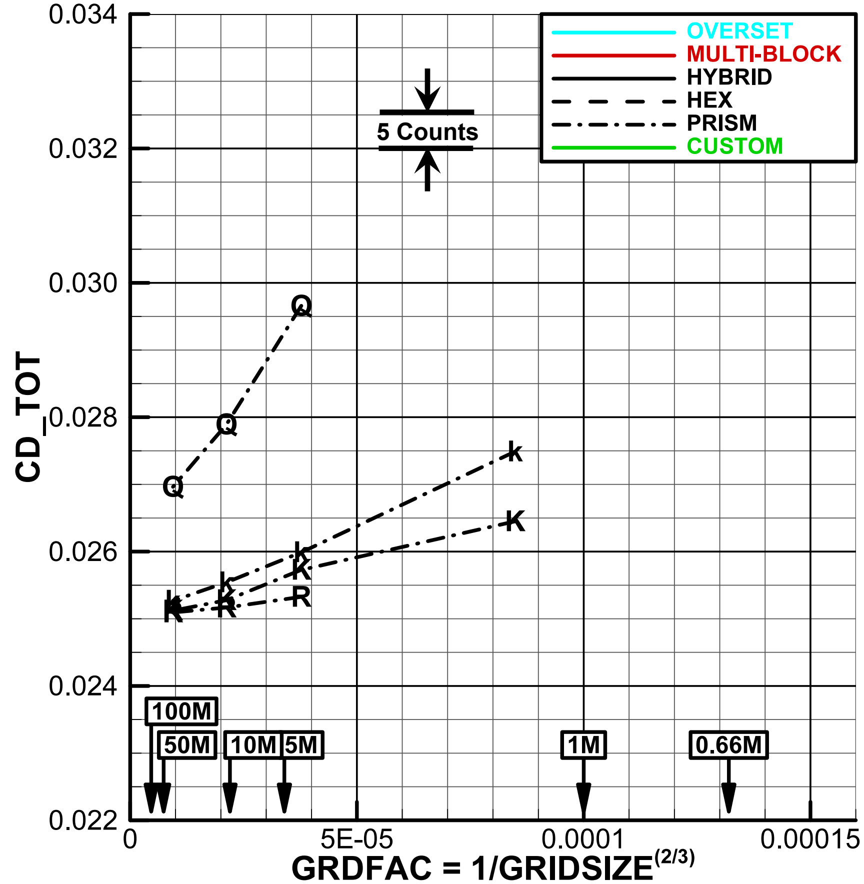
Case 1: CD_TOT – Multi-block and Overset Grids



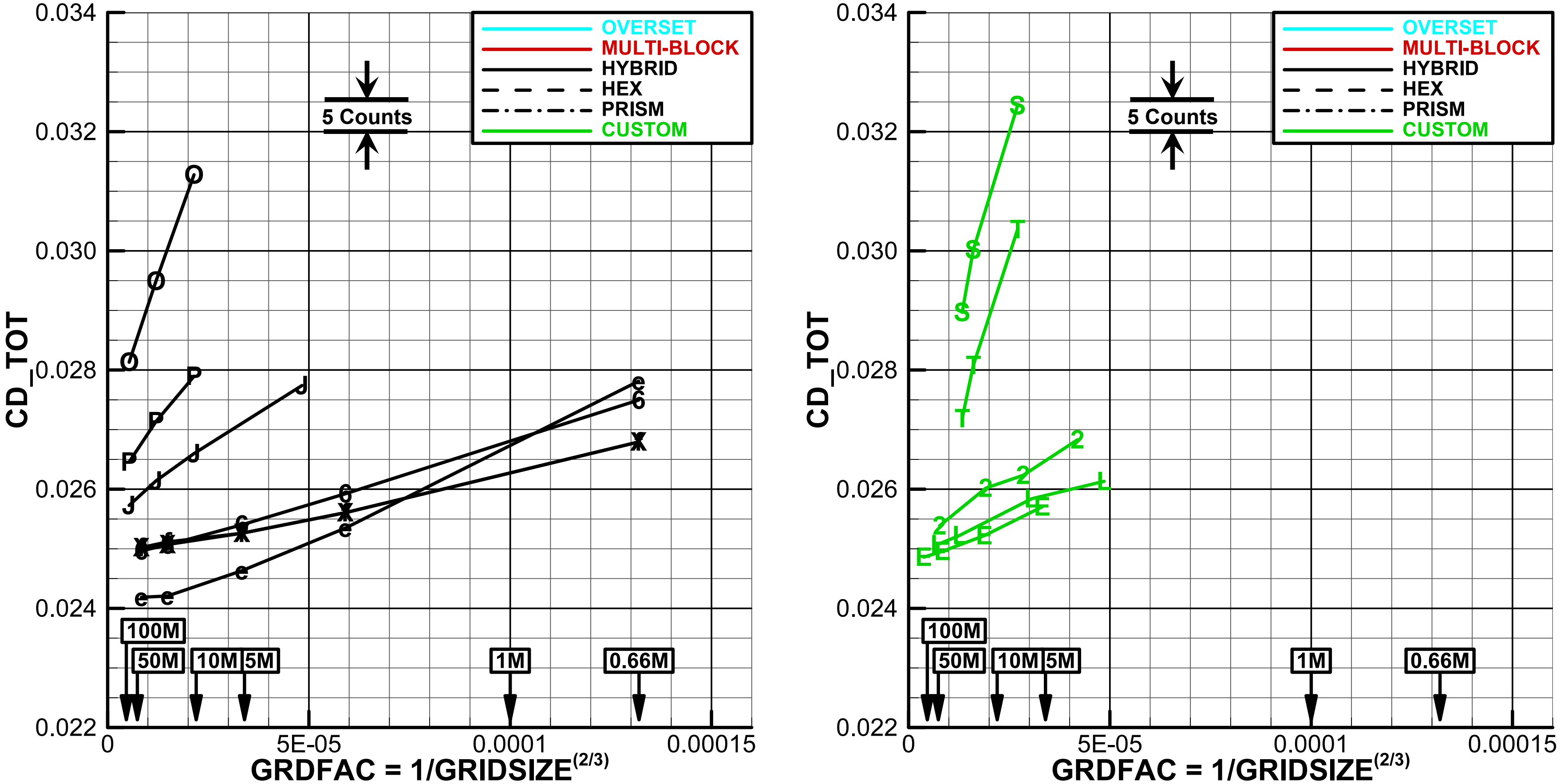


Case 1: CD_TOT – Unstructured Hexahedral and Prismatic Grids

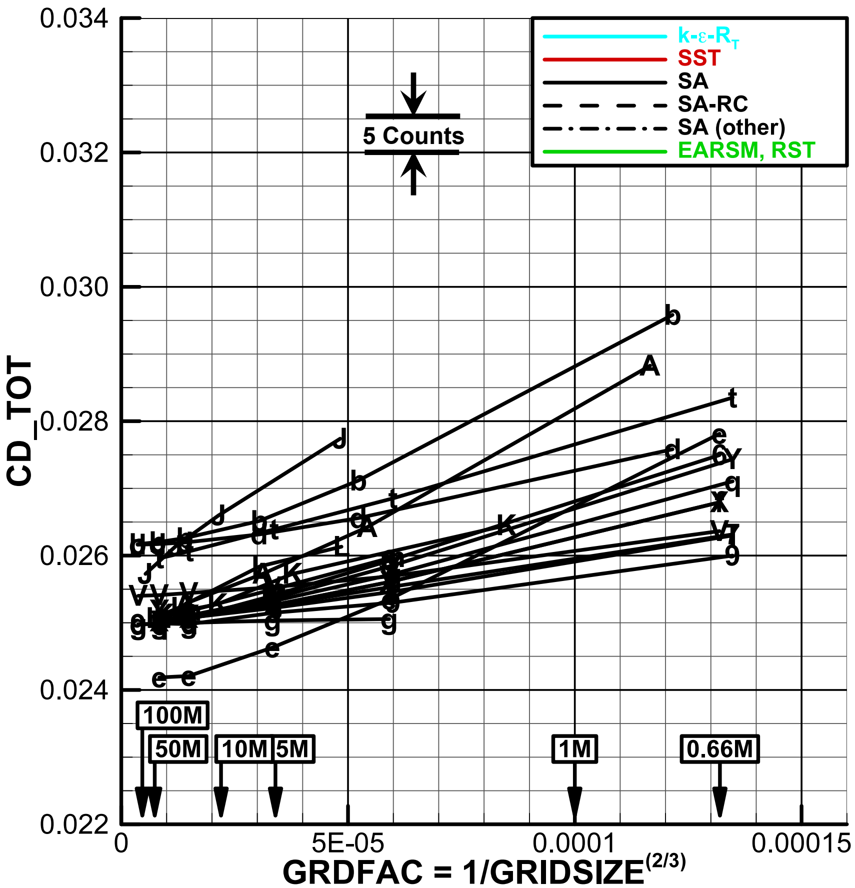


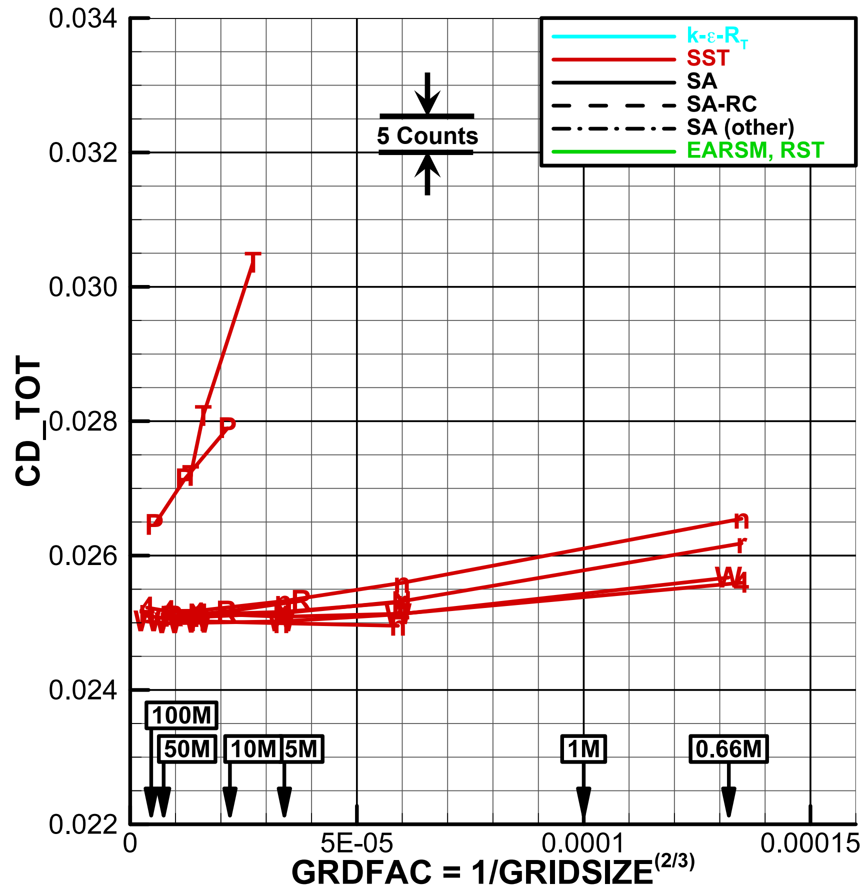


Case 1: CD_TOT – Unstructured Hybrid and all Custom Grids

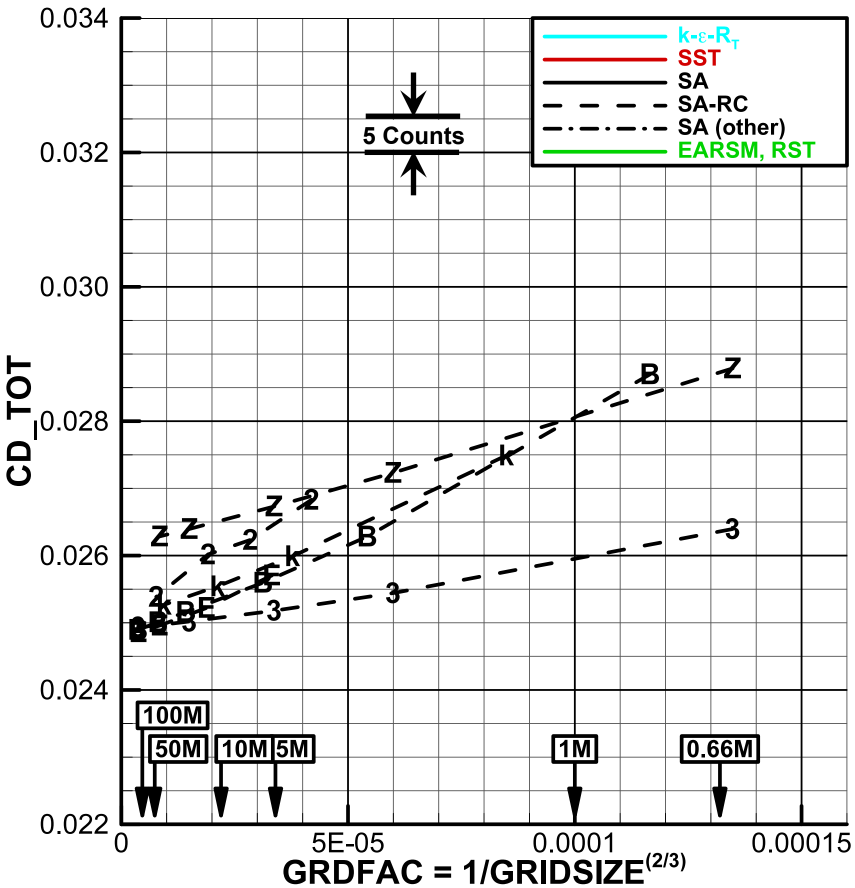


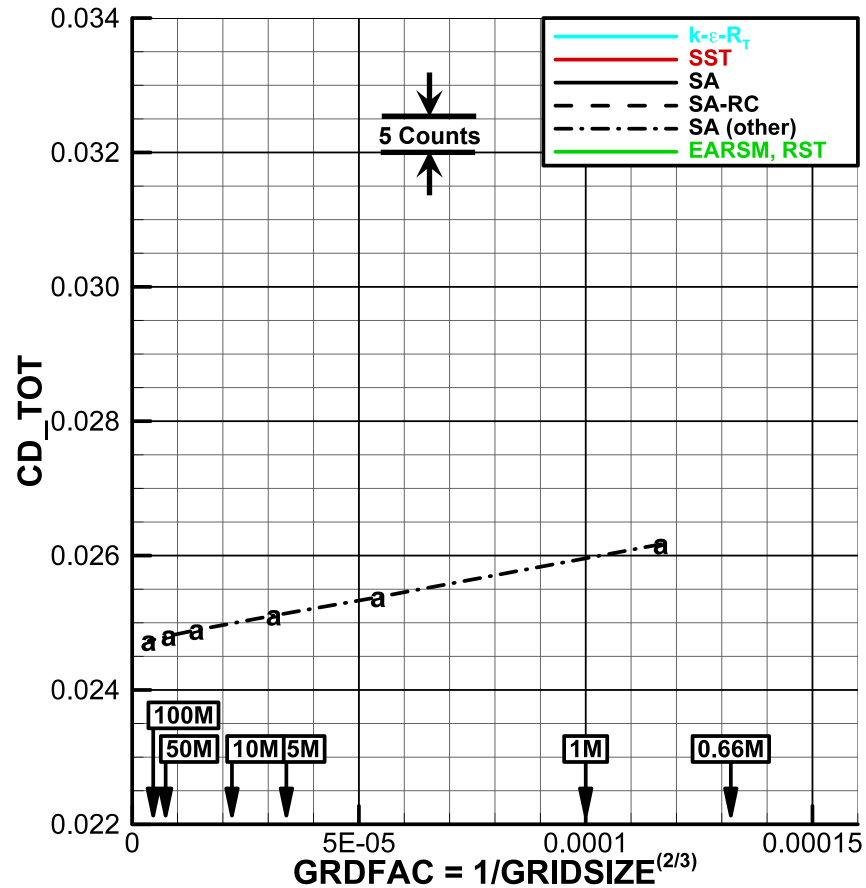
Case 1: CD_TOT – Spalart Allmaras and Shear Stress Transport Turb. Models



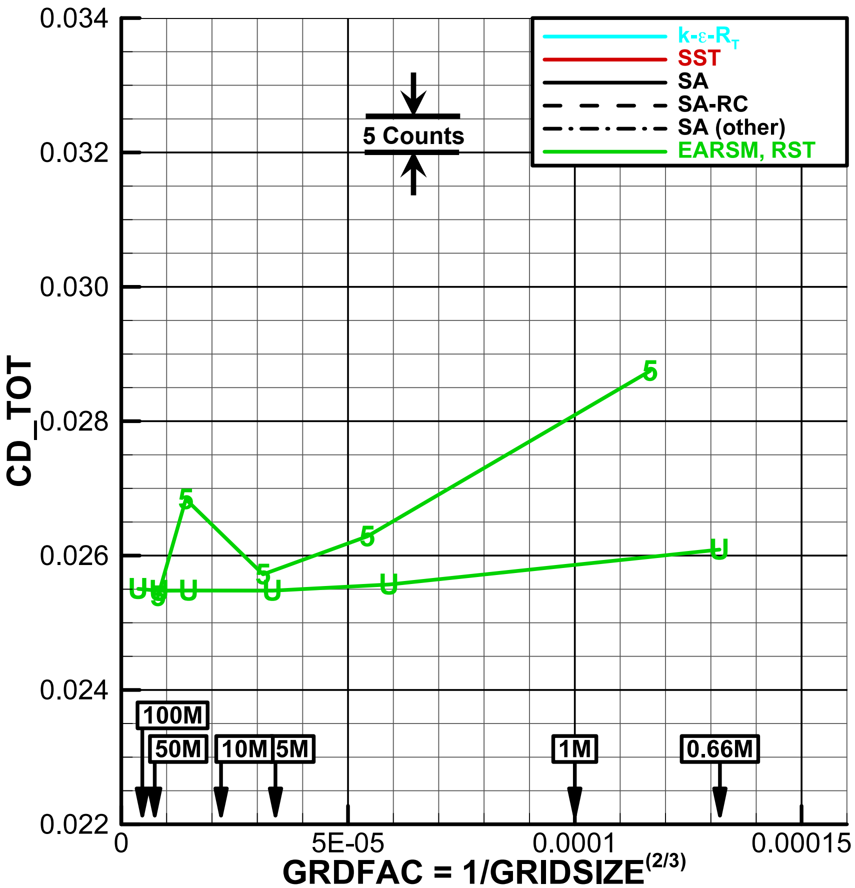


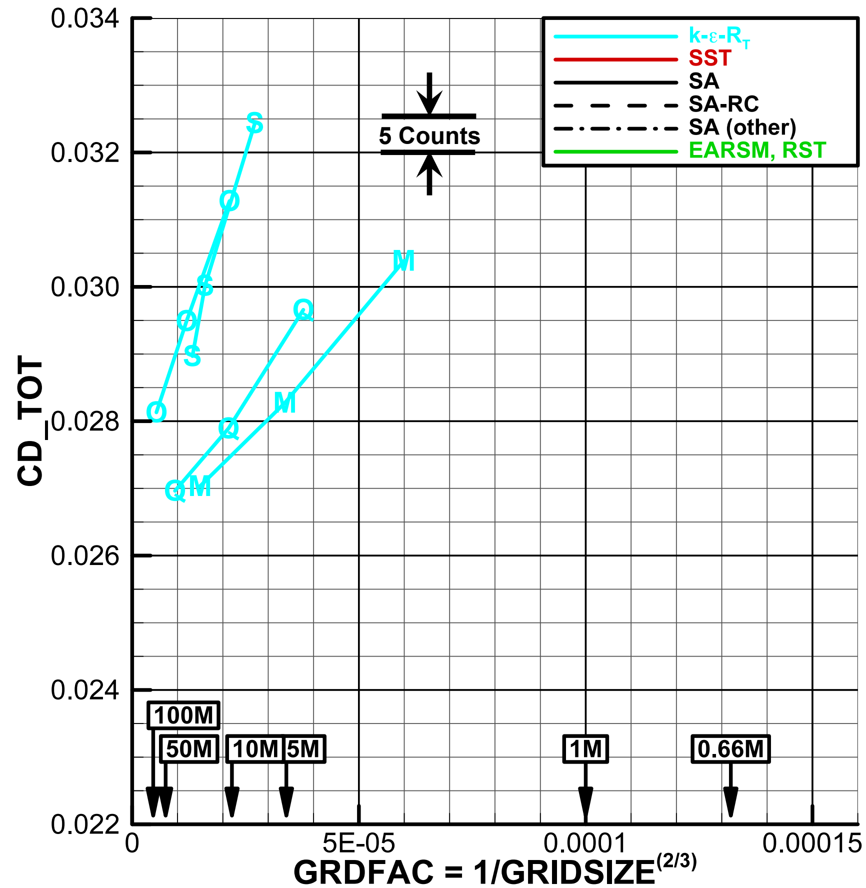
Case 1: CD_TOT – SA w/ Rotation Correction and SA other Turb. Models





Case 1: CD_TOT – k-ε-RT and EARSM,RST Turbulence Models



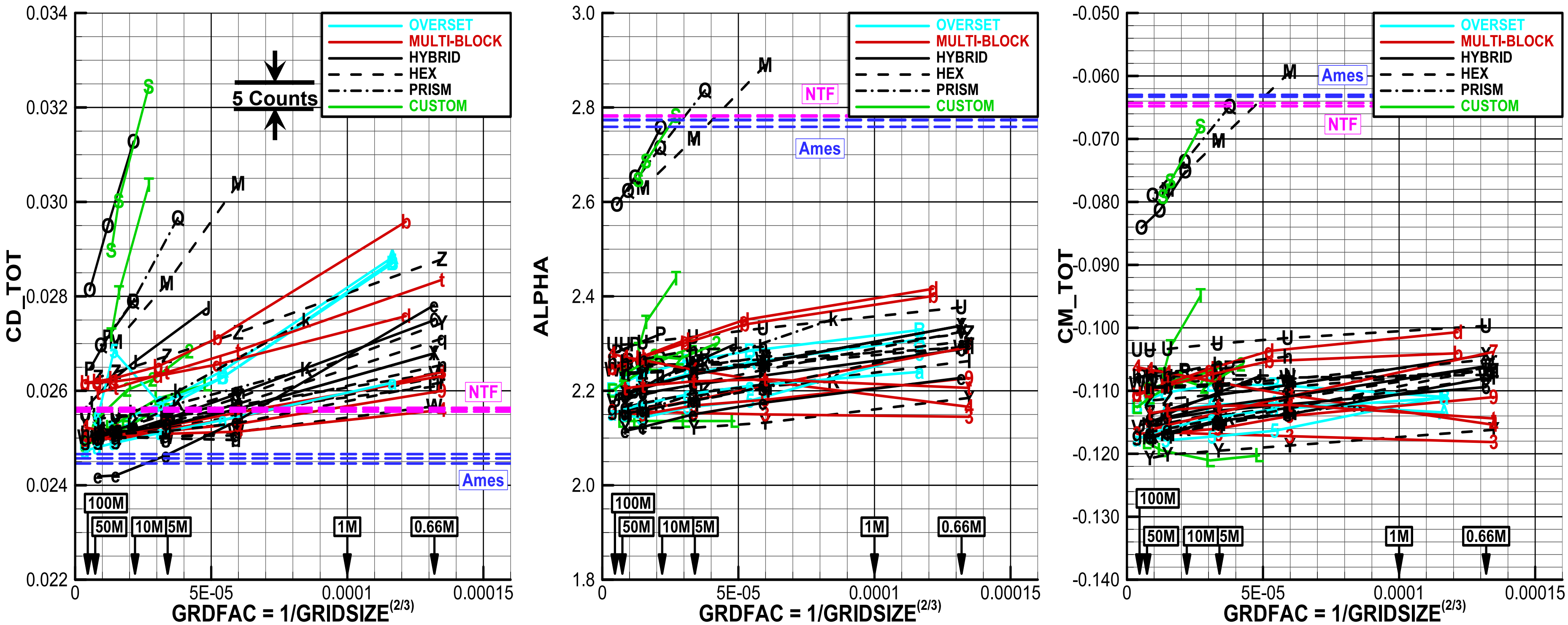


Should we Compare to Wind Tunnel?

Wind Tunnel	CFD
Walls	Free Air
Support System (Sting)	Free Air
Laminar/Turbulent (Tripped)	“Fully” Turbulent (usually)
Aeroelastic Deformation	Rigid 1g Shape
Measurement Uncertainty	Numerical Uncertainty & Error
Corrections for known effects	No Corrections

- Wind Tunnel and CFD measure/compute different things!
- Data are included for reference only!

Case 1: CD_TOT, ALPHA, and CM_TOT with Wind Tunnel Results

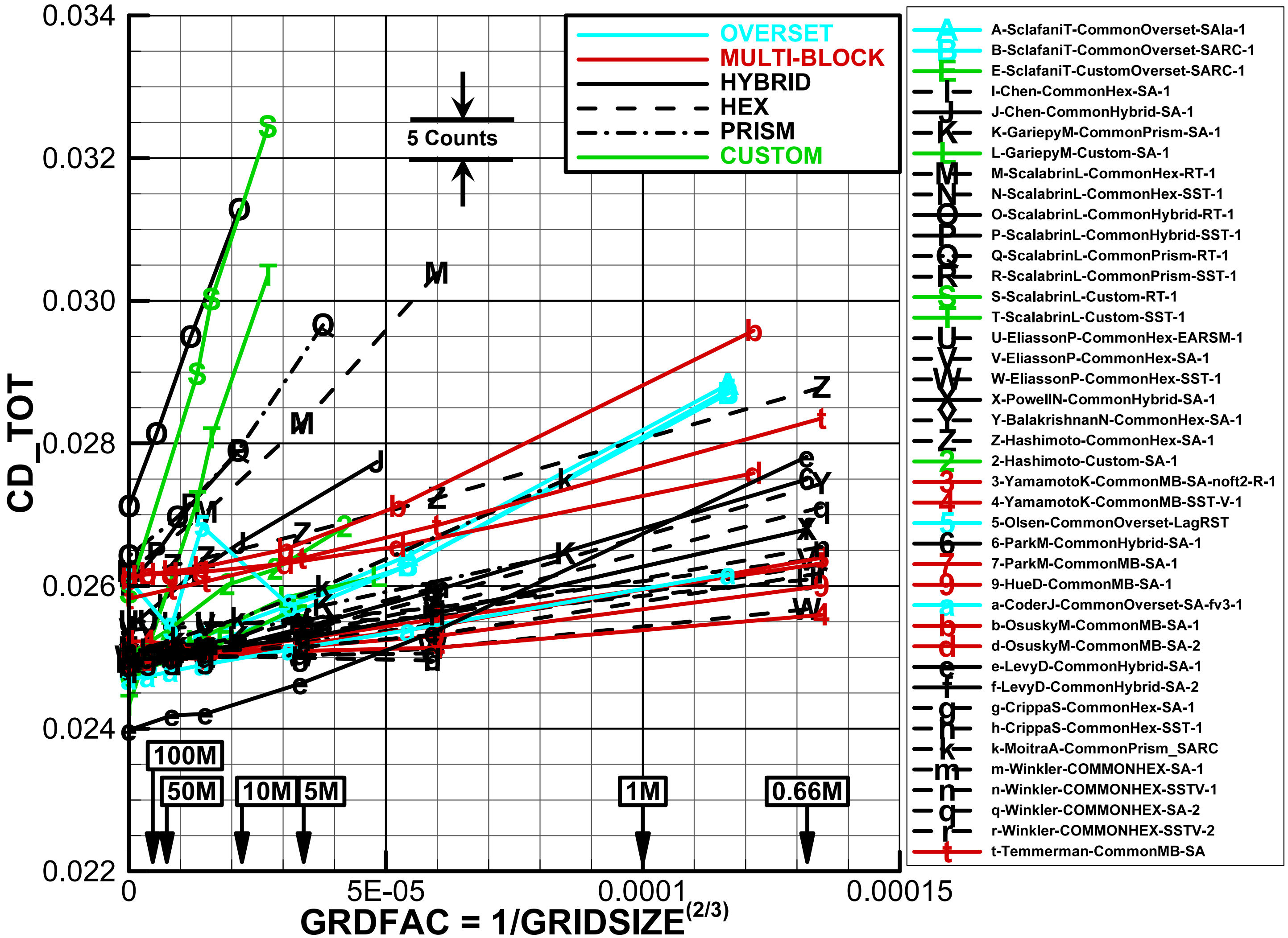


Wind Tunnel Results shown for Reference Only

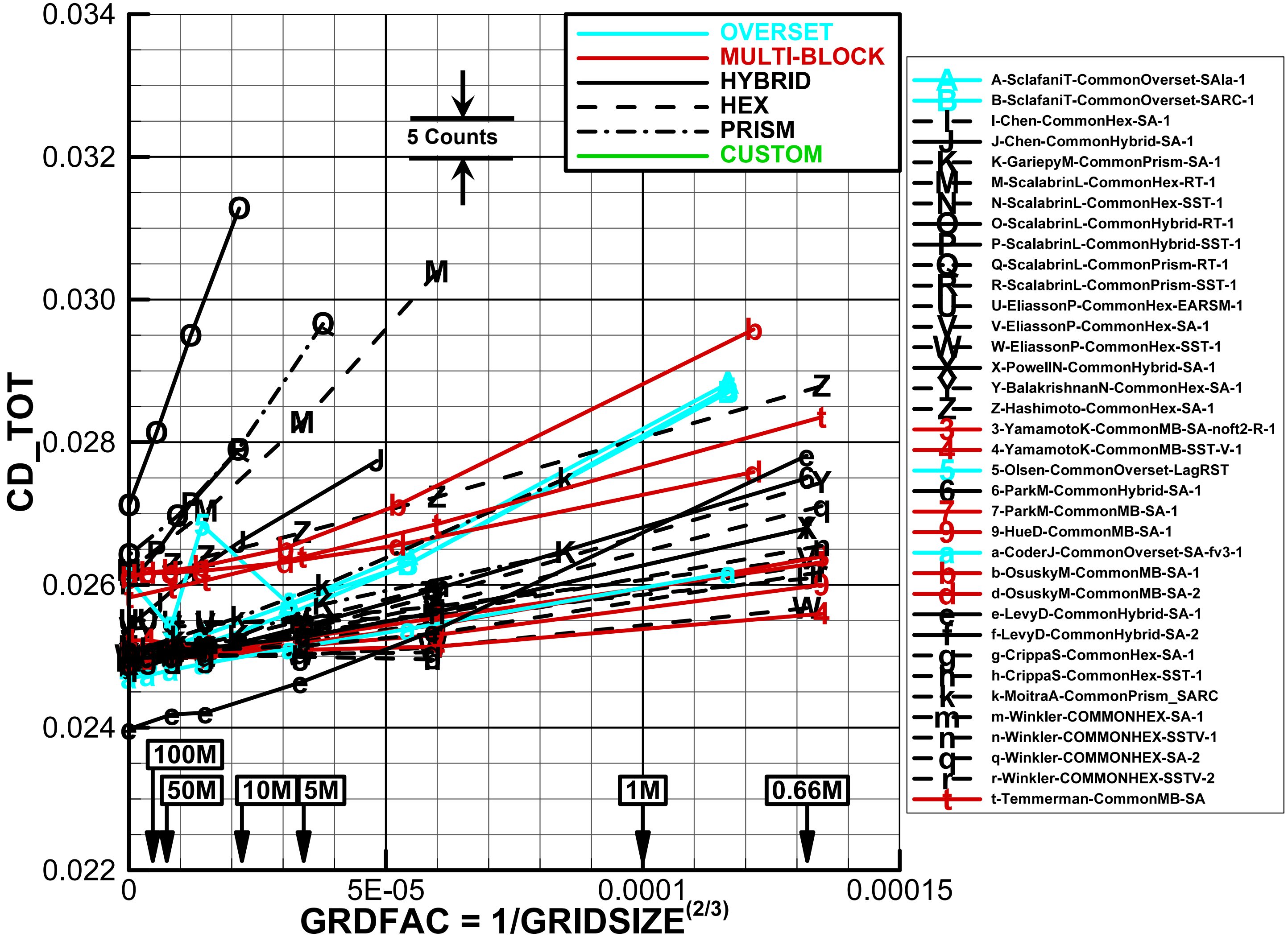
Richardson Extrapolation:

- Standard 2nd order least squares fit (Excel)
- For 2nd order codes, should be linear vs.
  Grid_Factor = $N^{-2/3}$
- Y-intercept estimates theoretical infinite resolution (continuum) result

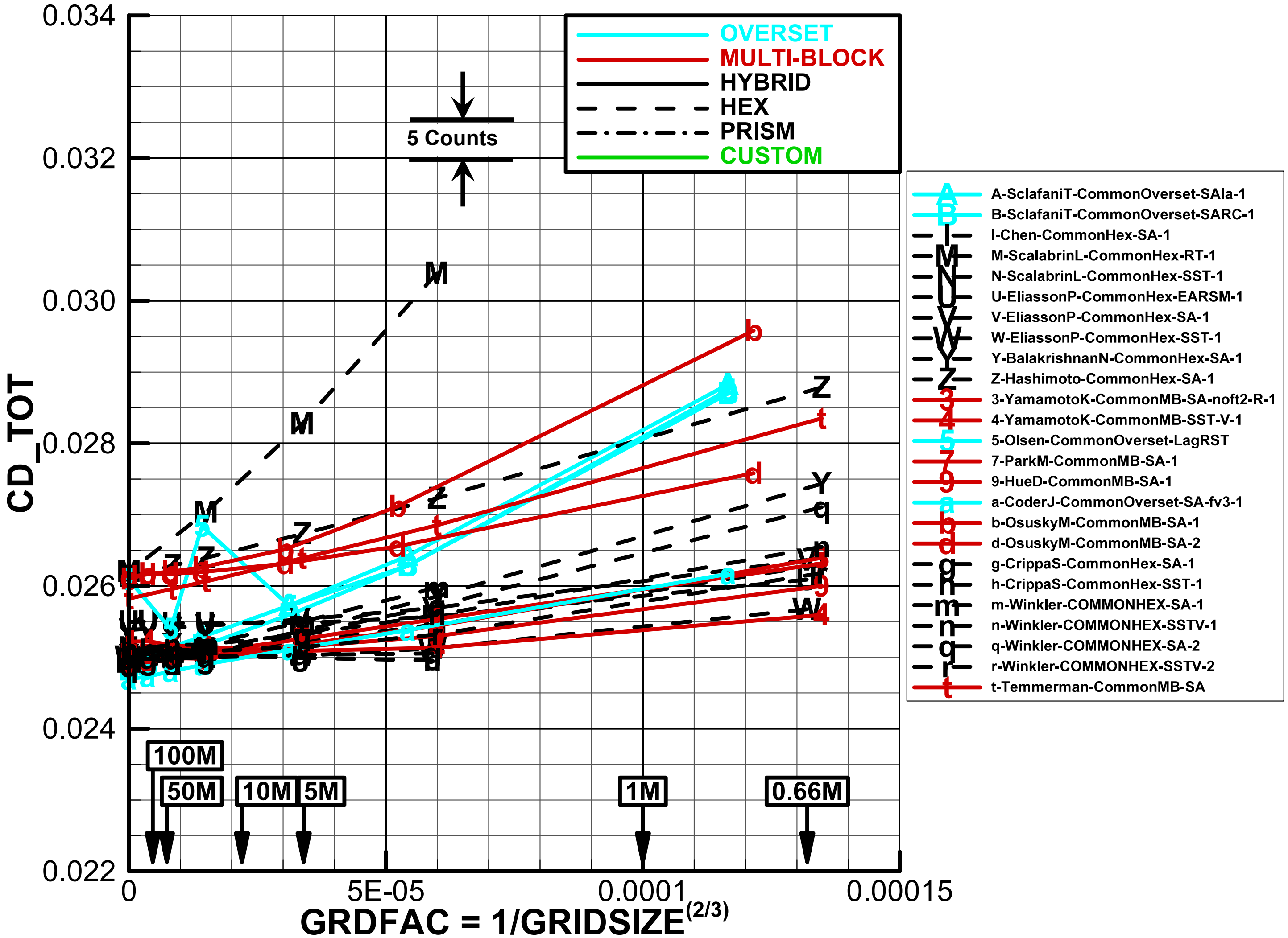
Case 1: Extrapolated CD_TOT by Grid Type



Case 1: Extrapolated CD_TOT by Grid Type (Common Grids Only)



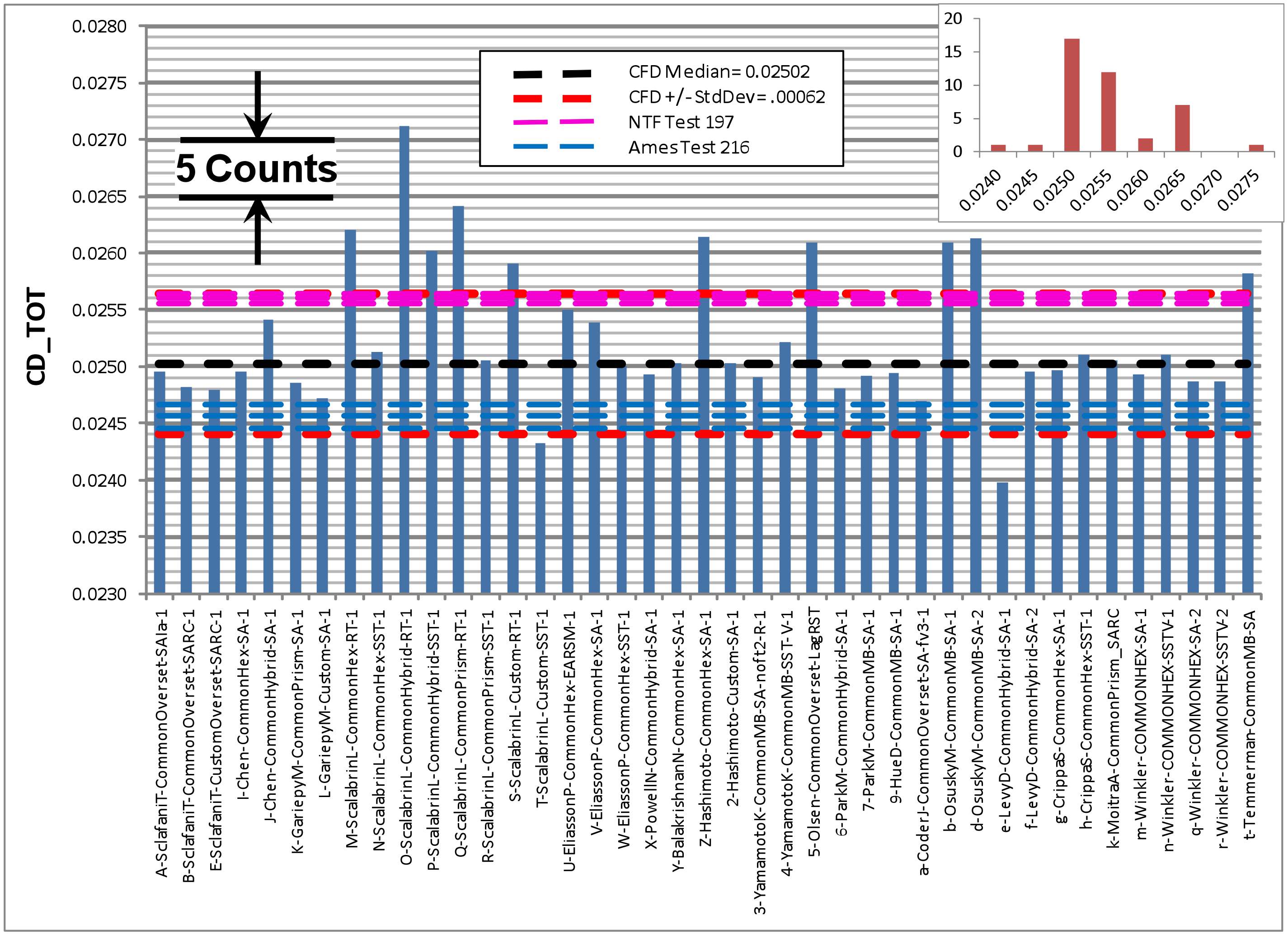
Case 1: Extrapolated CD_TOT by Grid Type (Common Hex Grids Only)



Conclusions from Richardson Extrapolation:

- Most results are monotonically decreasing
- Some are nonlinear
  - Convergence issues
  - Possible flow-feature changes (SOB or TE Separation)
- No clear break-outs with grid type or turbulence model (except for some outliers)
- Scatter is reduced somewhat for Common Grids
  - Scatter still large for coarser grids
  - Best for Hex-based, including Structured, Overset, and Unstructured

Case 1: Extrapolated CD_TOT Statistics



Conclusions from Case 1 Results:

- Still a lot of scatter!
  - Less than DPW4 (was σ=8.1 for tail on). Are we getting better?
- No clear break-outs with grid type or turbulence model
  - Some Turb. Models are outliers
  - Trends are still hard to isolate due to small sample sizes
- Agreement with experiment on CD_TOT is better than for ALPHA and CM_TOT
  - Wing aeroelastic effects are likely part of this
  - Spread in CD_TOT is similar between wind tunnel and CFD scatter
- Scatter is reduced somewhat for Common Grids
  - Statistics did not change significantly
  - Best for Hex-based, including Structured, Overset, and Unstructured
  - Discretization and Turbulence Modeling is still a major contributor

Case 2 Buffet Study:

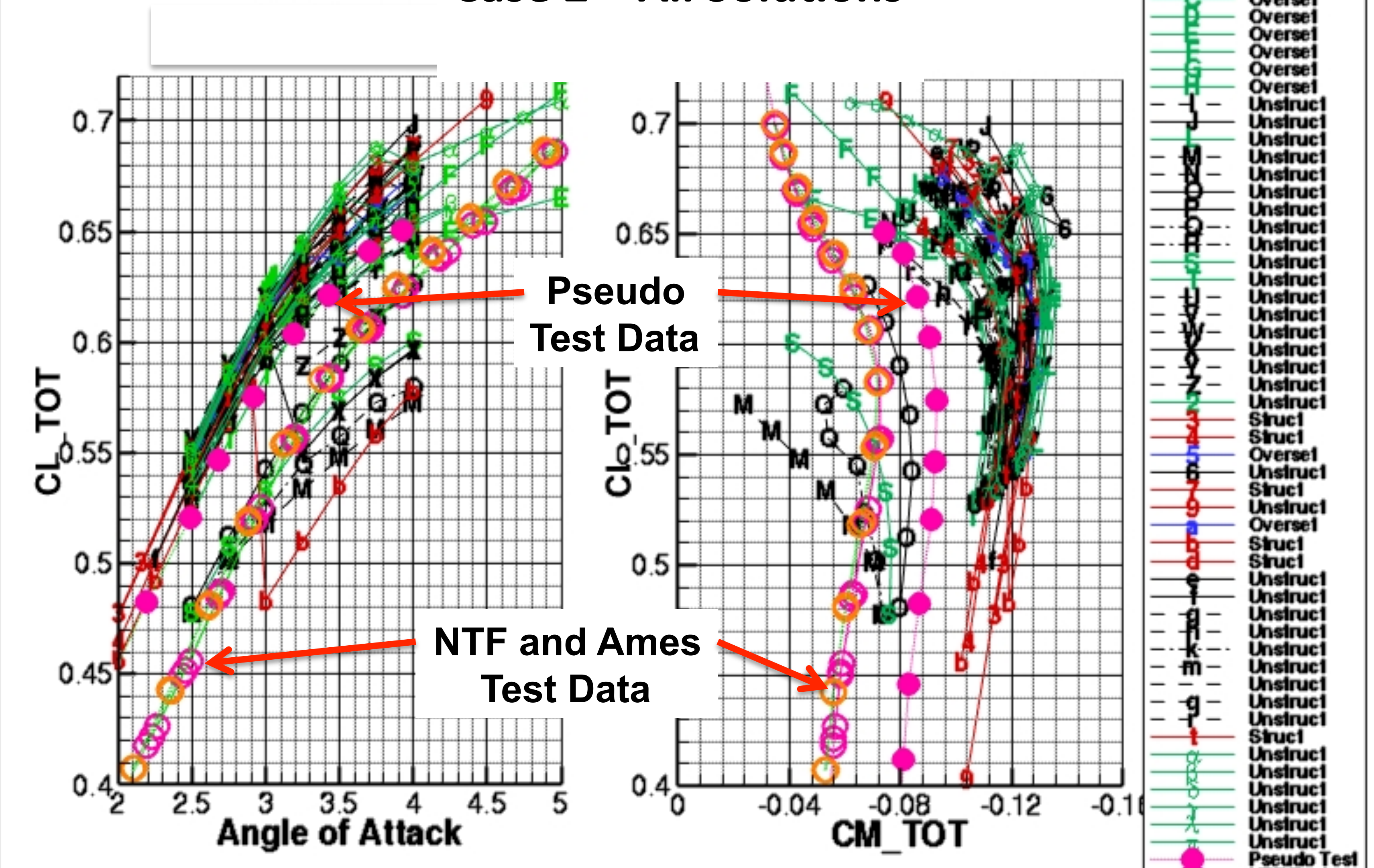
- NASA Common Research Model, Wing-Body
- Mach=0.85:
  - α=2.50°, 2.75 °, 3.00 °, 3.25 °, 3.50 °, 3.75 °, 4.00 °
- Grid Resolution Level:
  - 3) Medium,
- Chord Reynolds Number: $5x10^6$

AIAA Applied Aerodynamics Technical Committee

5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012

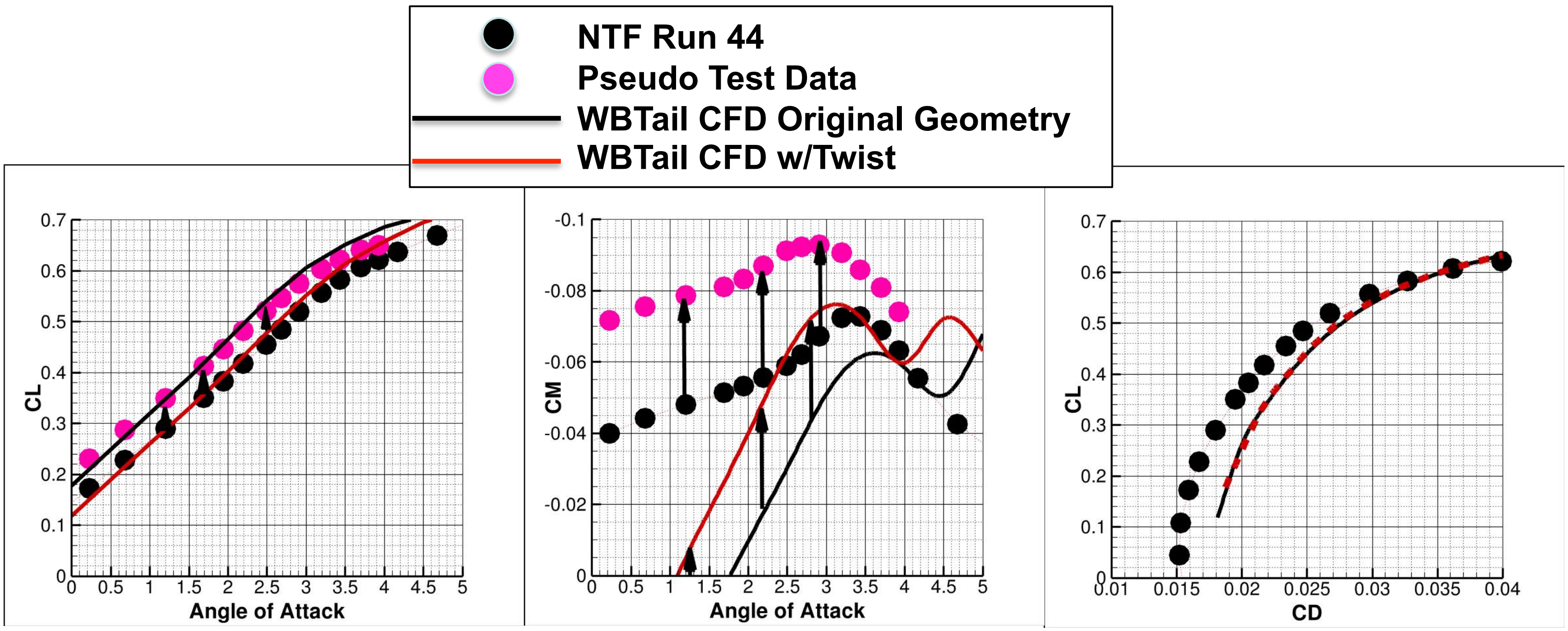
Case 2 – All Solutions



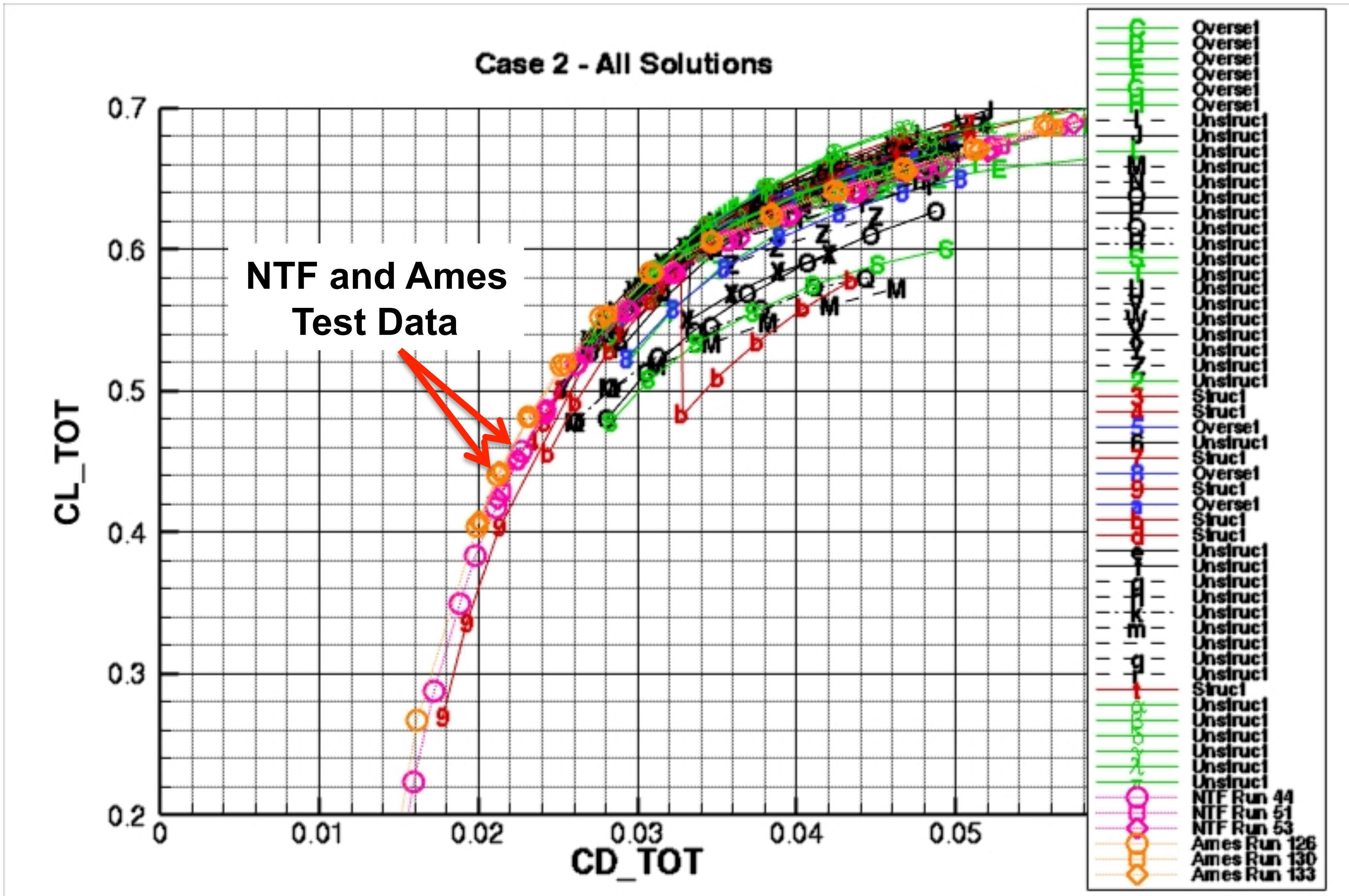
Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209

CREATION OF “PSEUDO TEST DATA”

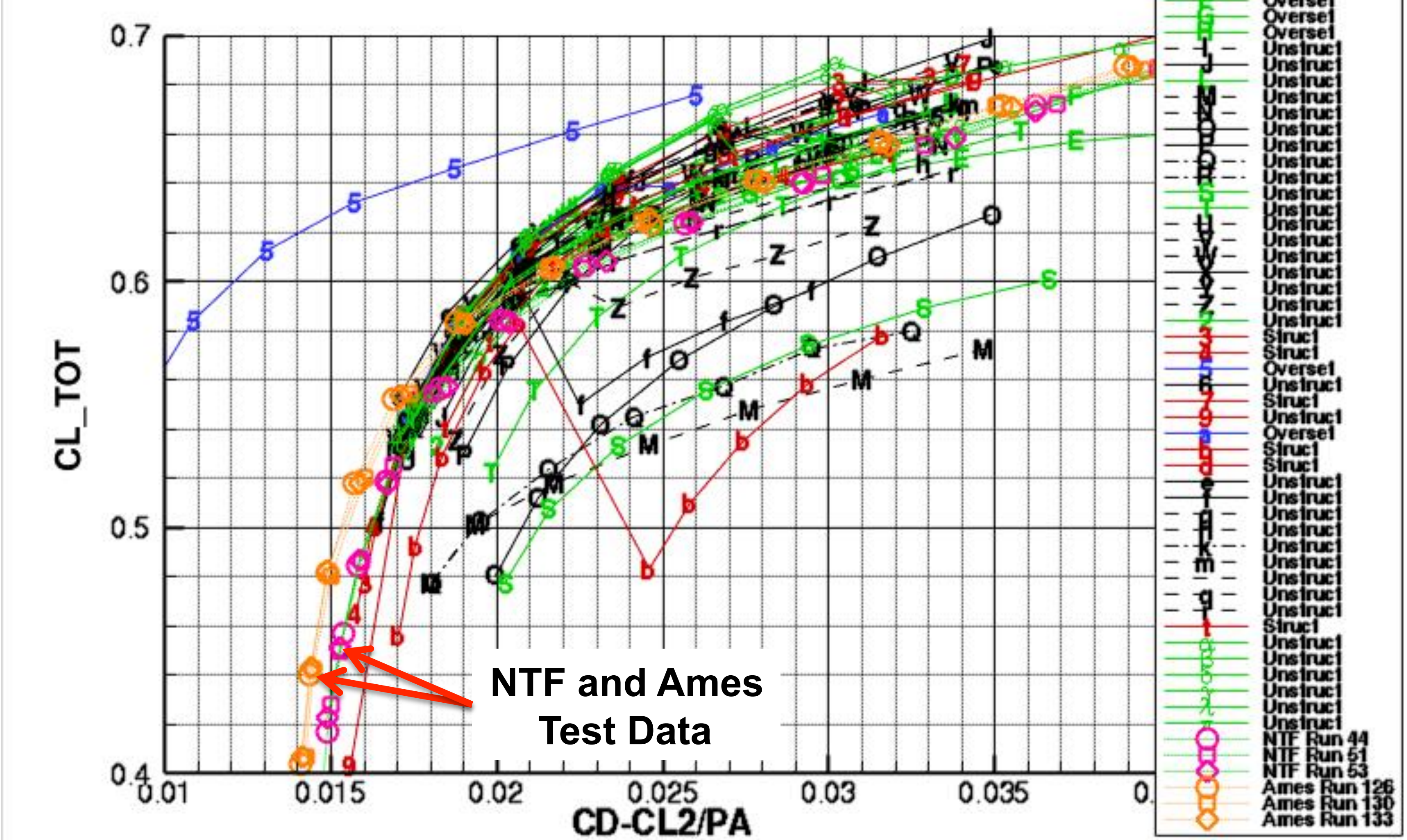
- The CRM geometry used for DPW5 was that of the wind tunnel model definition
- AIAA-2012-3209 details recent CFD analyses to account for the wing aeroelastic twist at Mach=0.85, CL=0.50, and for additional wind tunnel mounting system effects.
- “Pseudo Test Data” were created from the NTF data and CFD analyses to reflect what the test data might look like for the wing without the “CL=0.50 aeroelastic” twist.



- No corrections were applied to drag data


Case 2 - All Solutions
NTF and Ames Test Data
CL_TOT
CD_TOT
0.7
0.6
0.5
0.4
0.3
0.2
0
0.01
0.02
0.03
0.04
0.05
NTF Run 44
NTF Run 51
NTF Run 53
Ames Run 126
Ames Run 130
Ames Run 133

Case 2 – All Solutions

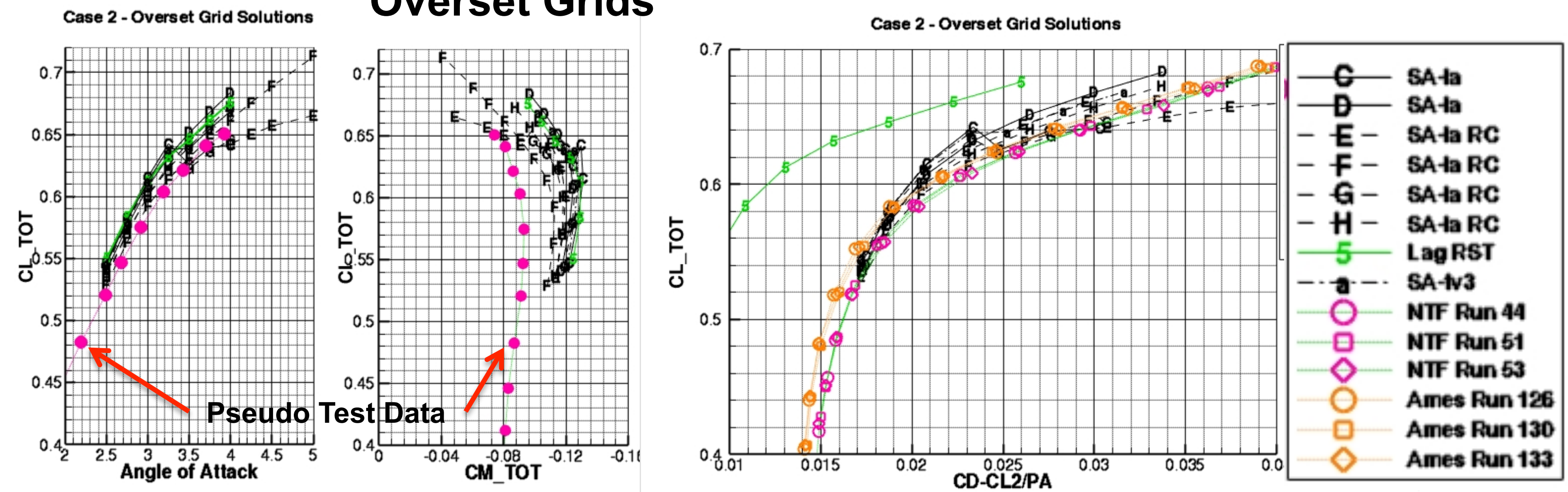


Applied Aerodynamics Technical Committee

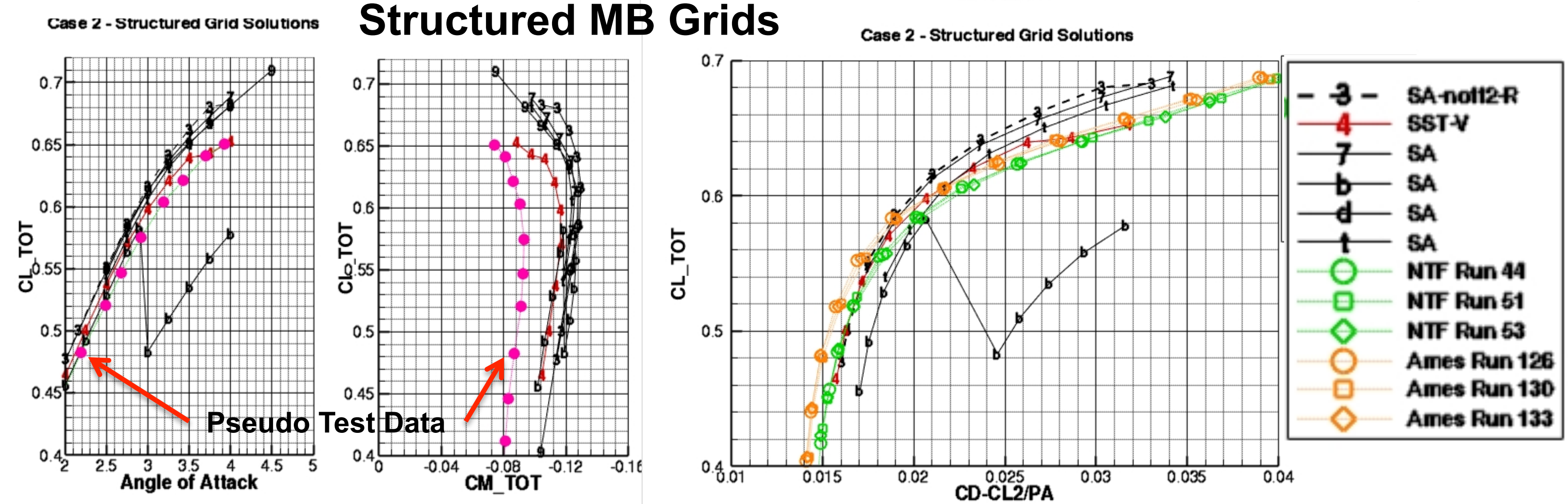
5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012

Overset Grids



Structured MB Grids

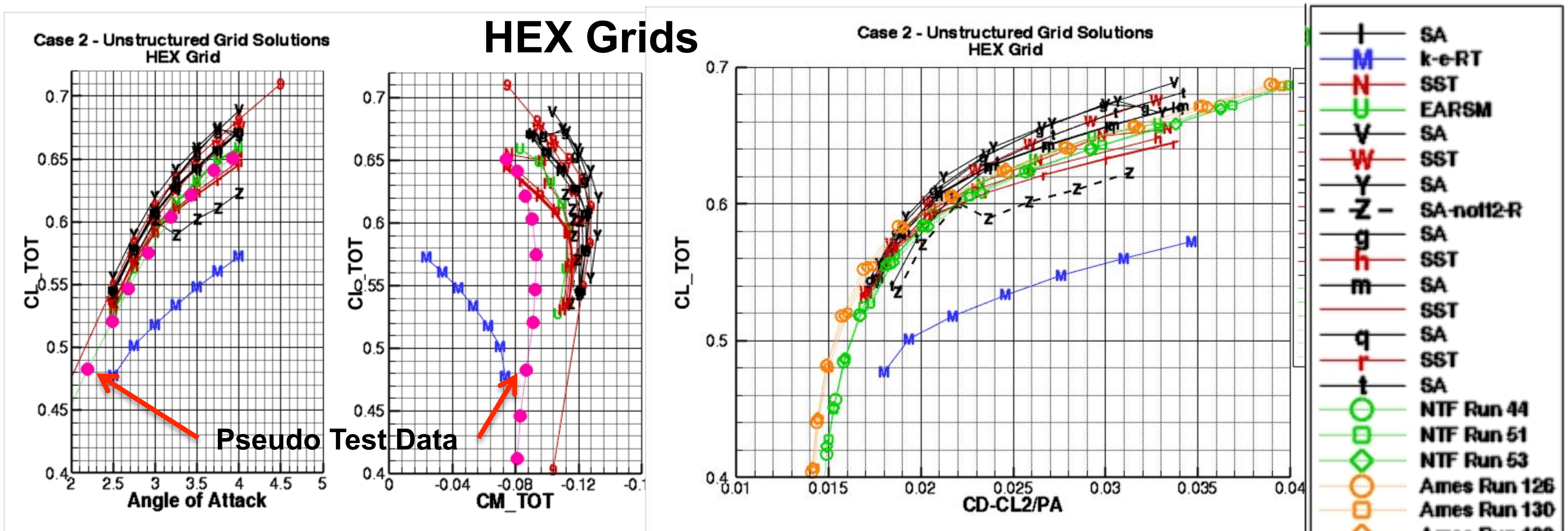


Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209

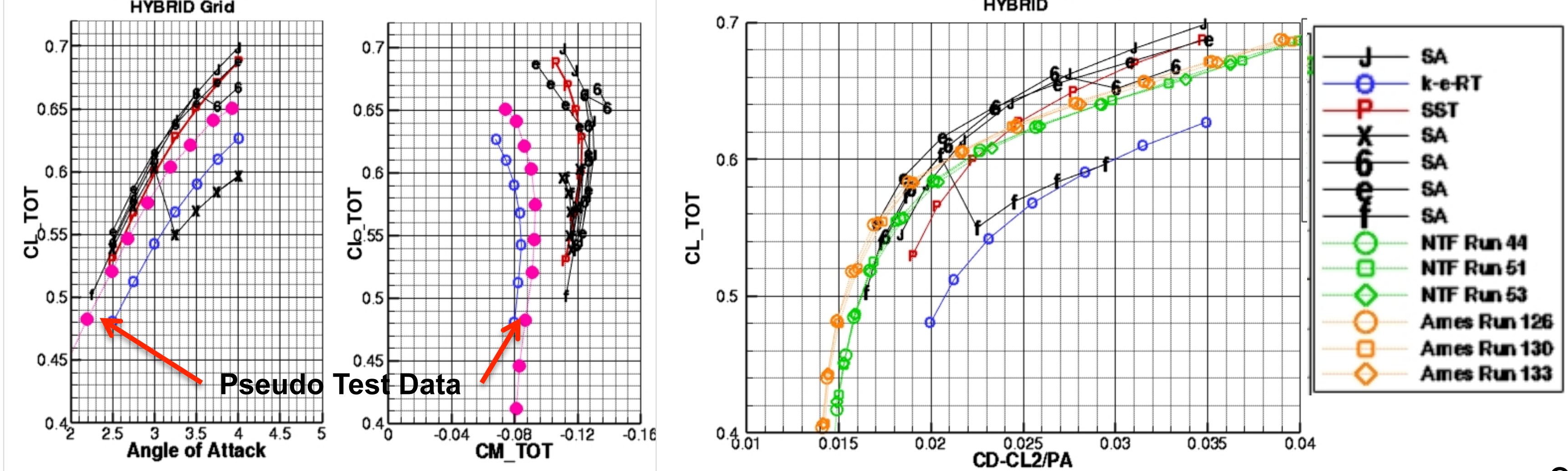
5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012

HEX Grids



HYBRID Grids

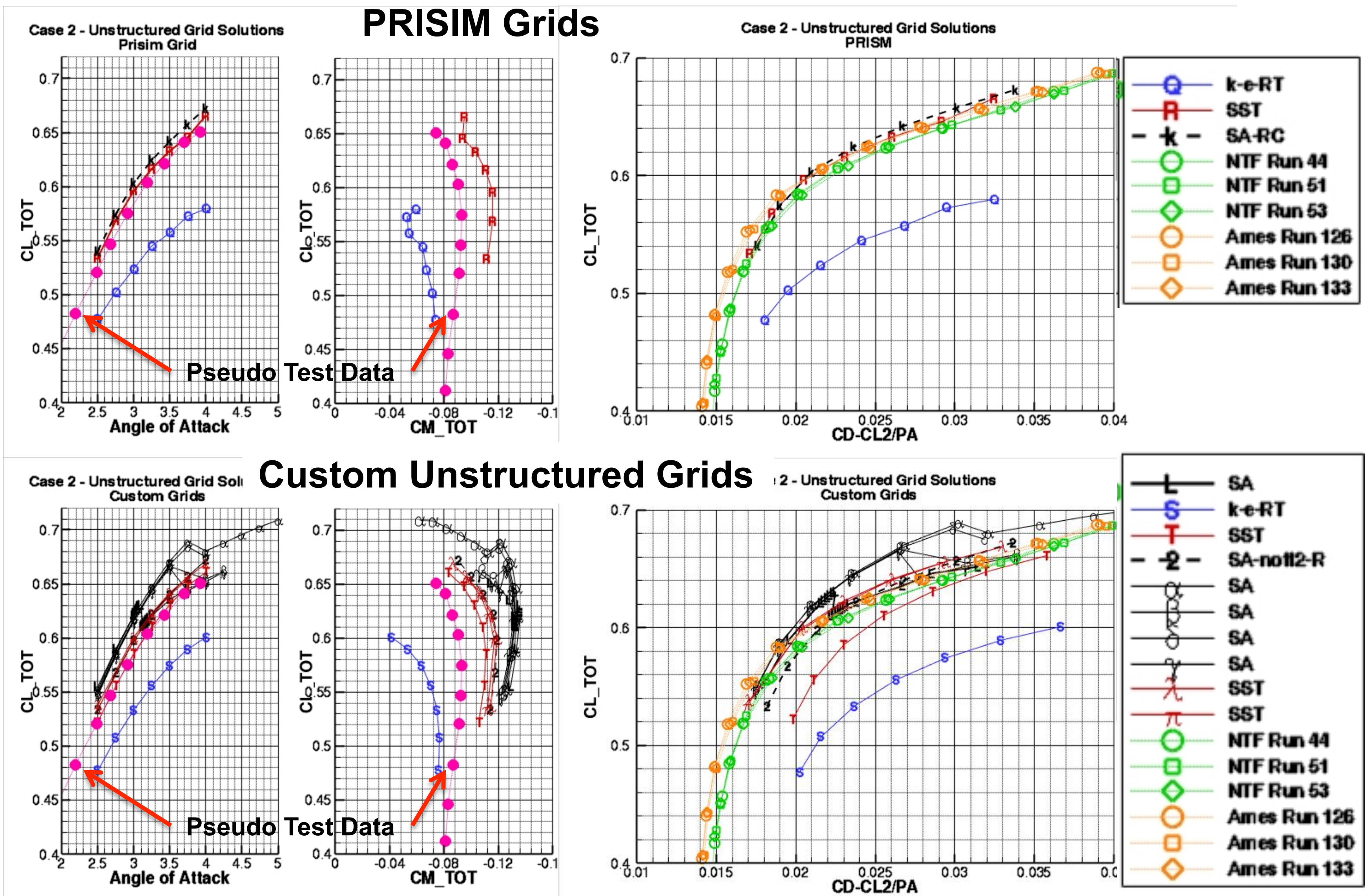


Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209

Applied Aerodynamics Technical Committee

5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012



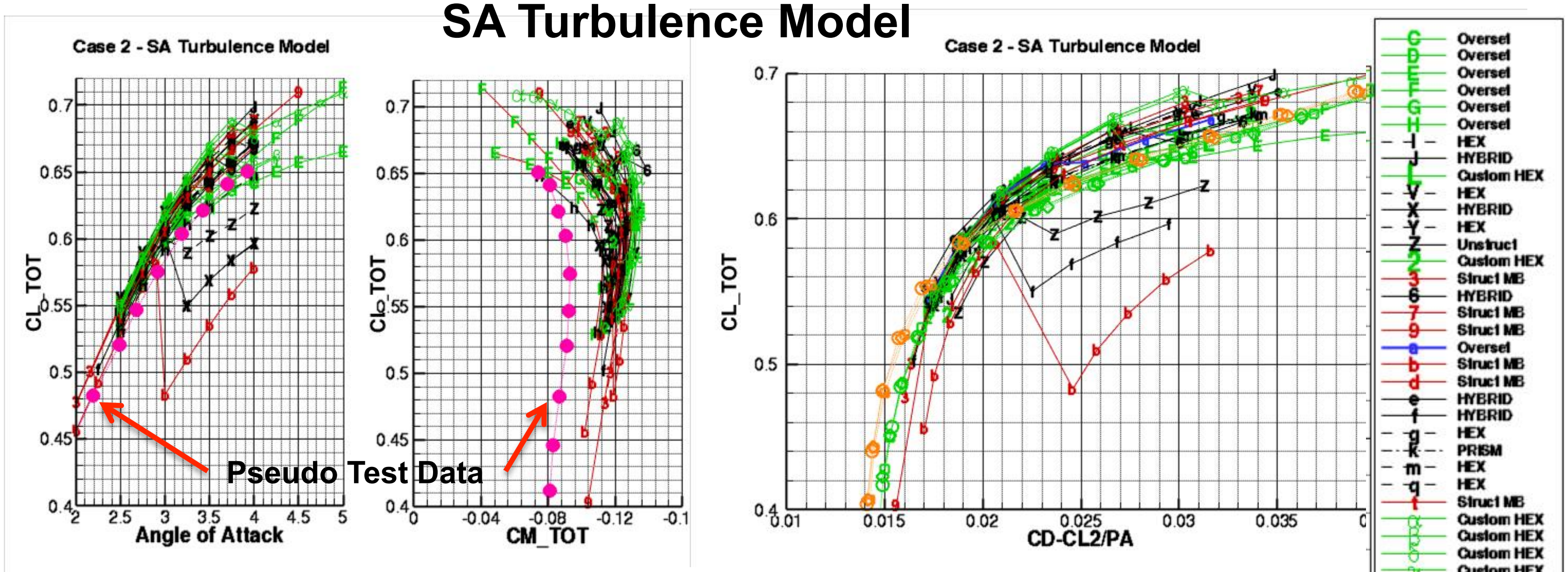
Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209

Applied Aerodynamics Technical Committee

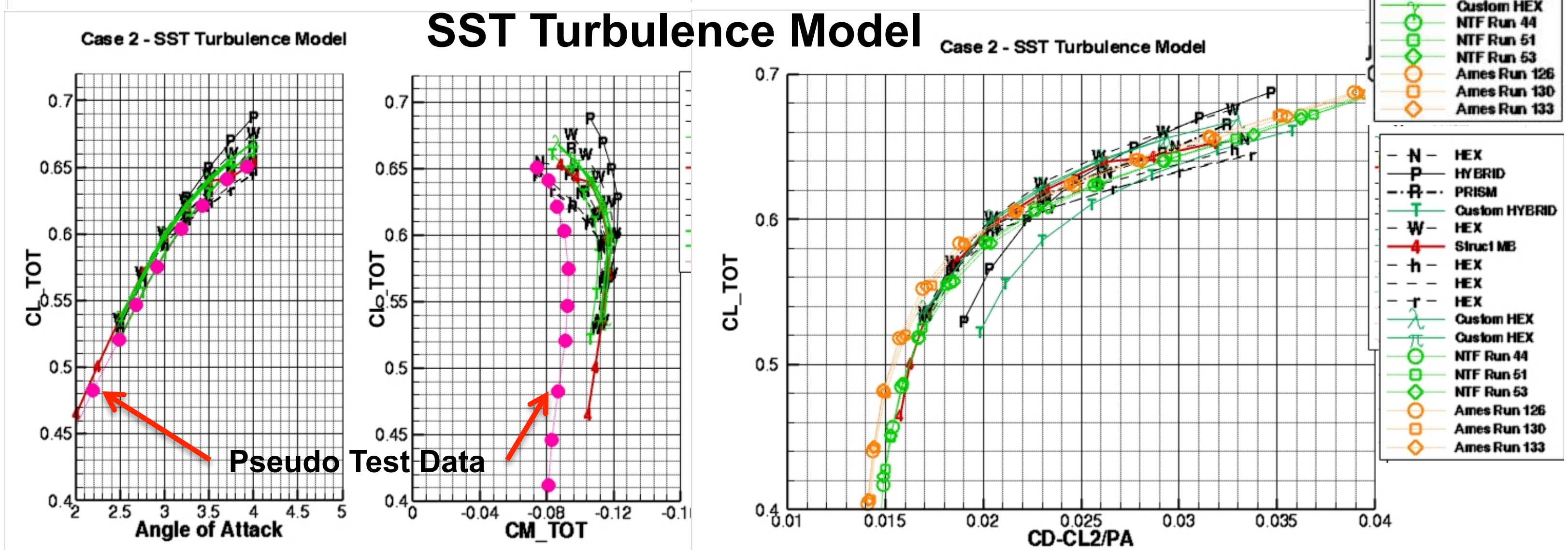
5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012

SA Turbulence Model

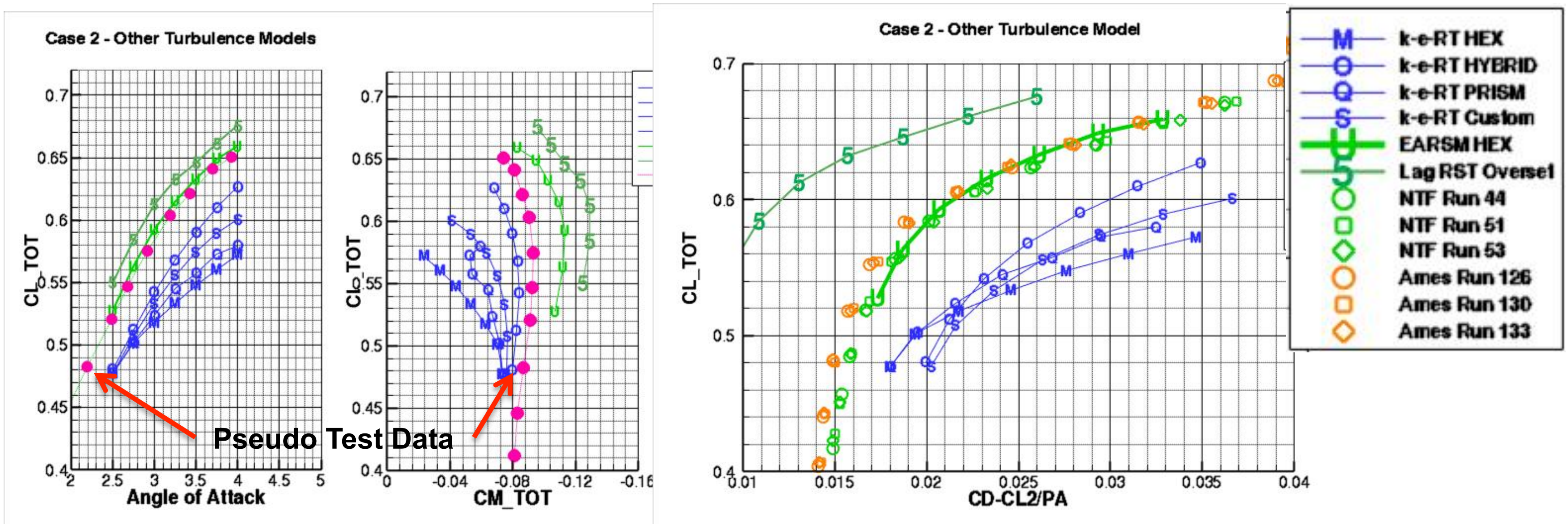


SST Turbulence Model

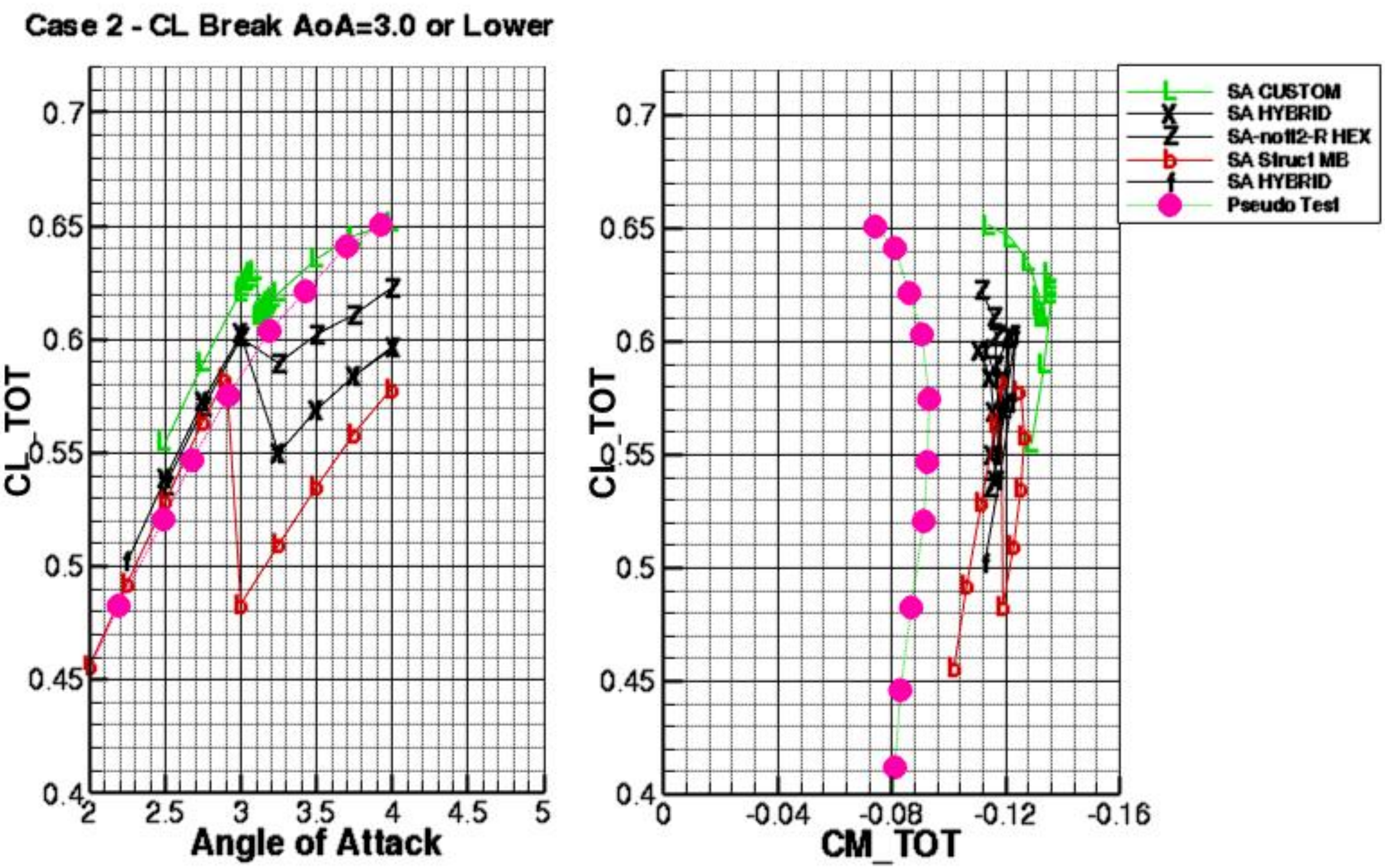


Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209

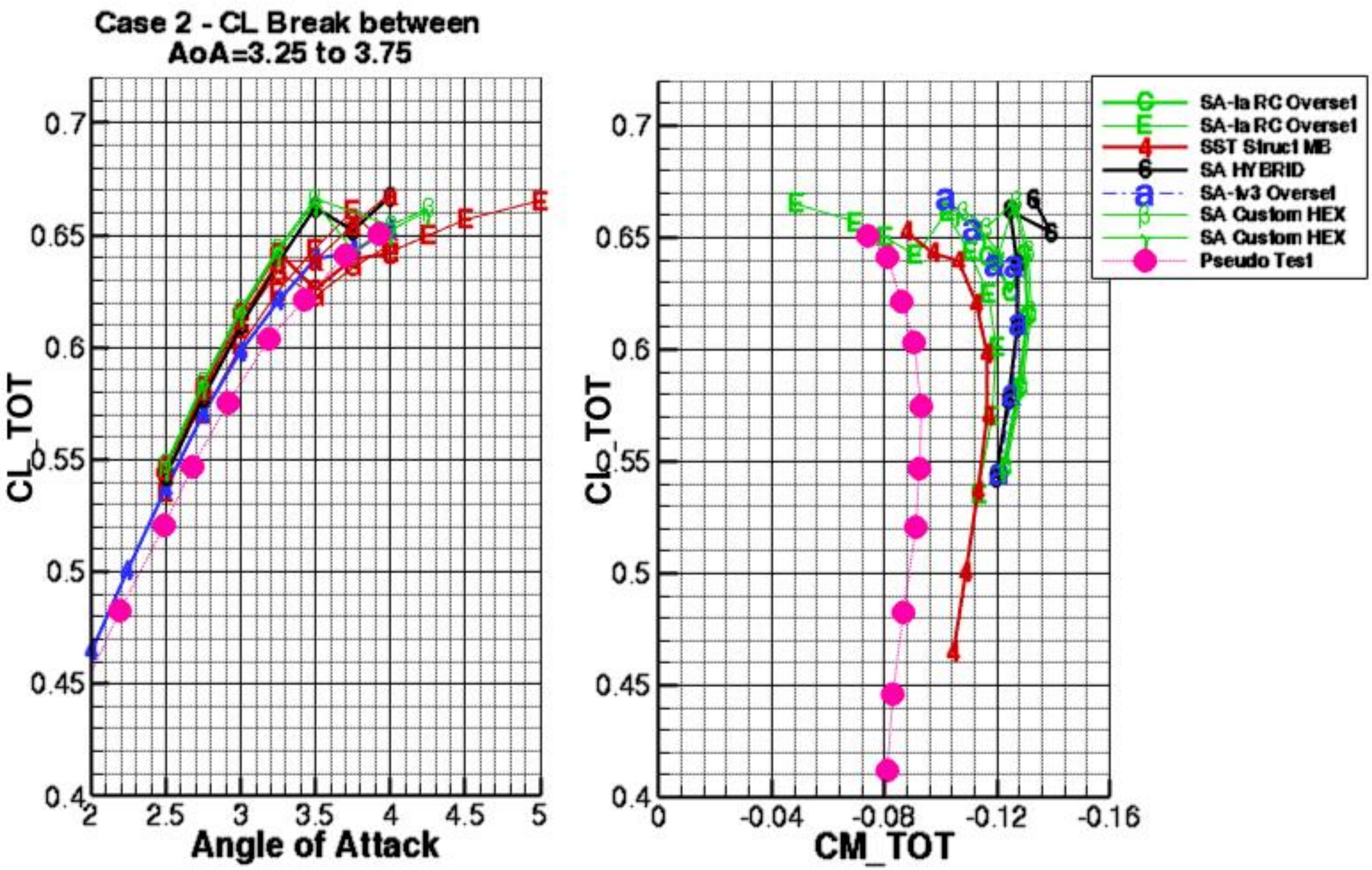
Other Turbulence Models



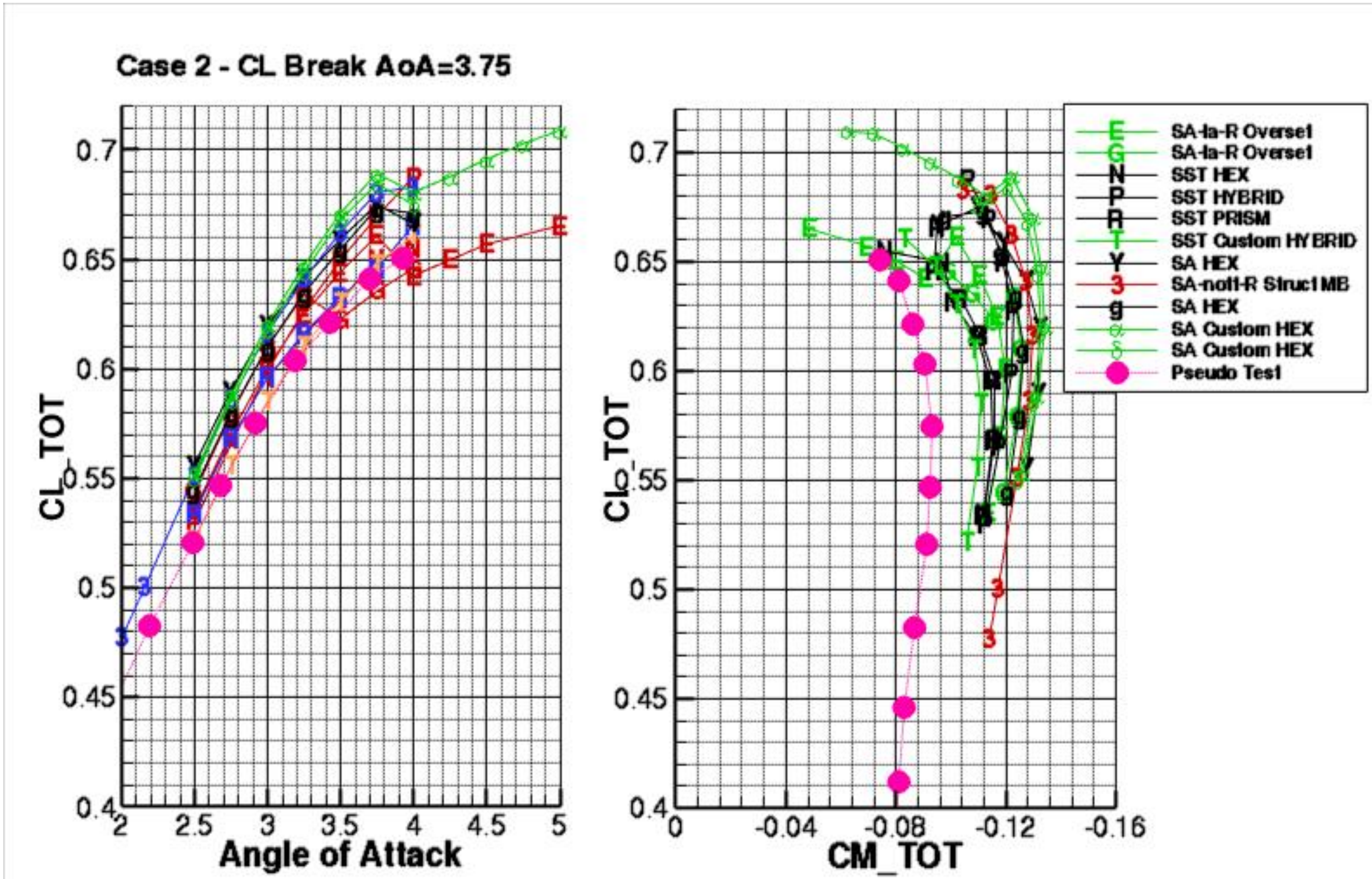
Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209



Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209



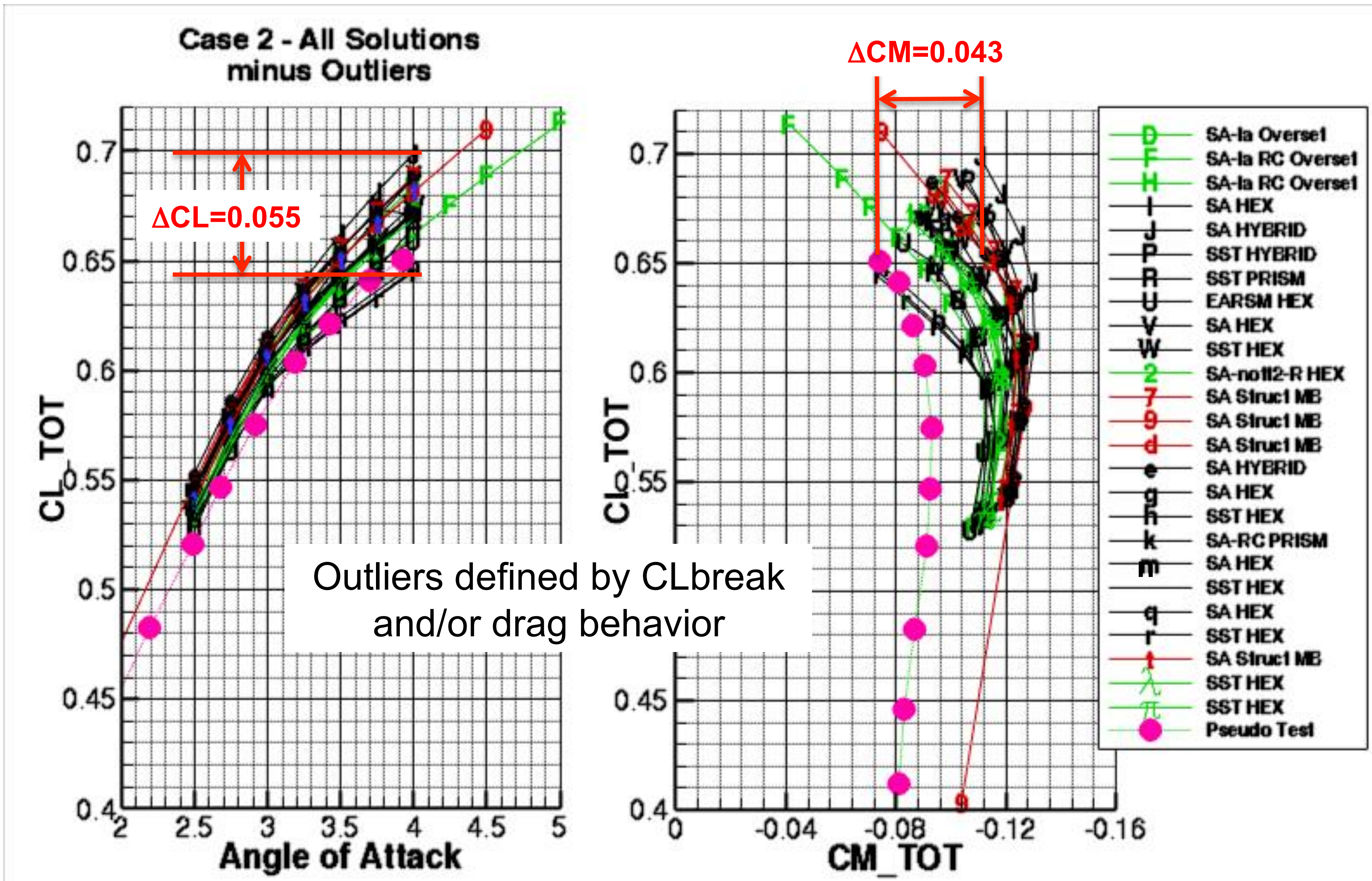
Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209



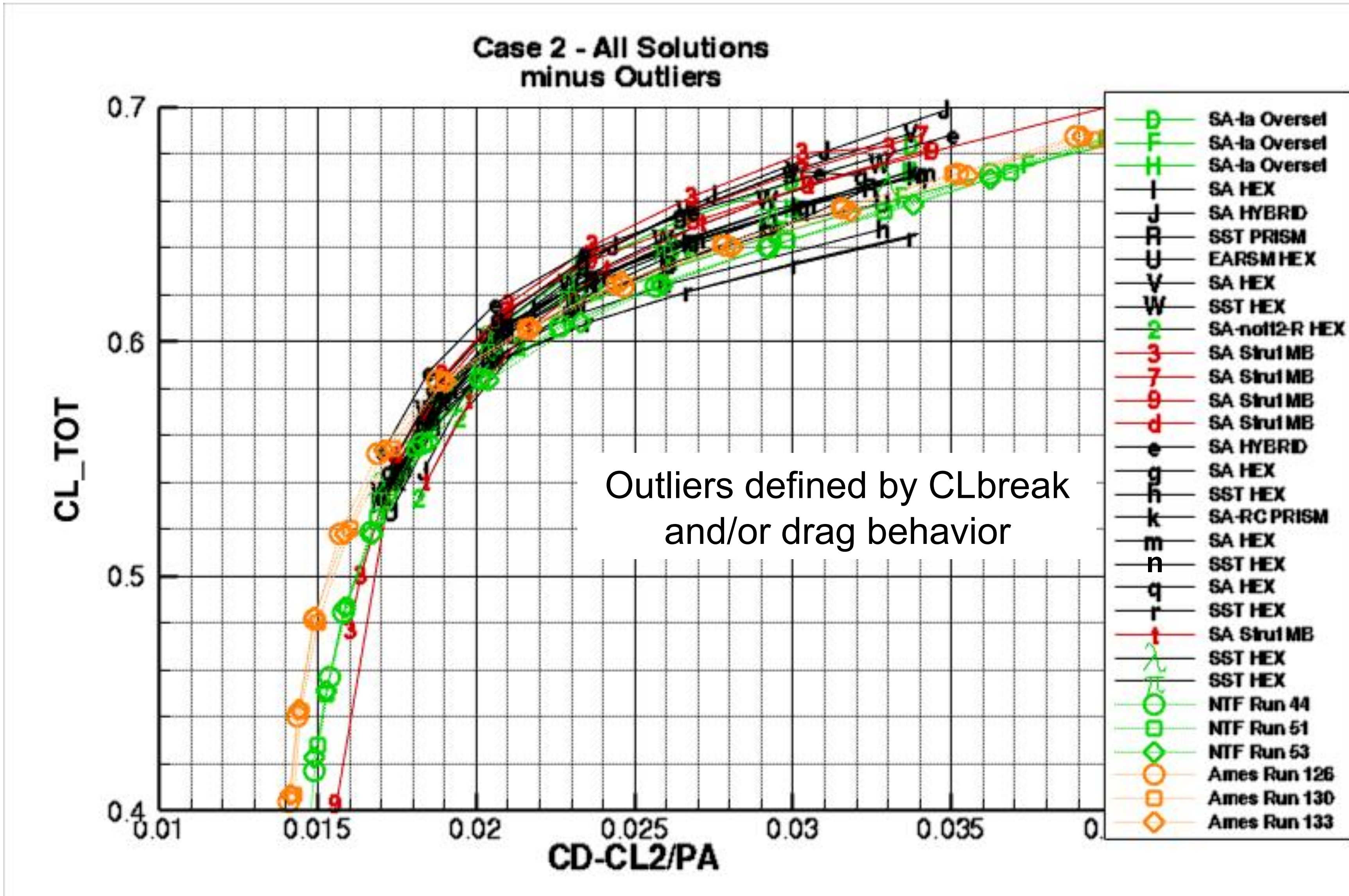
Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209

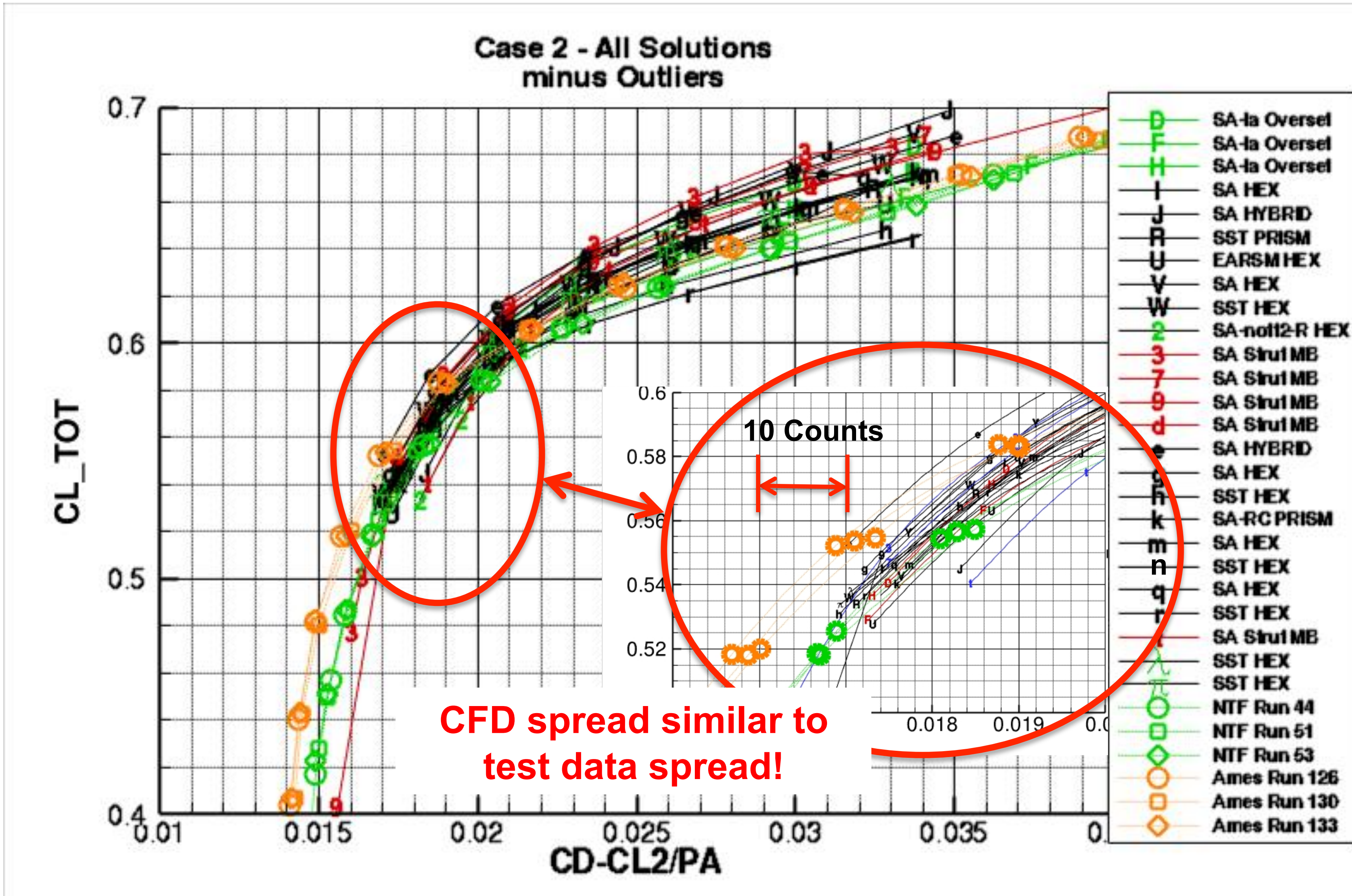
5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012



Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209

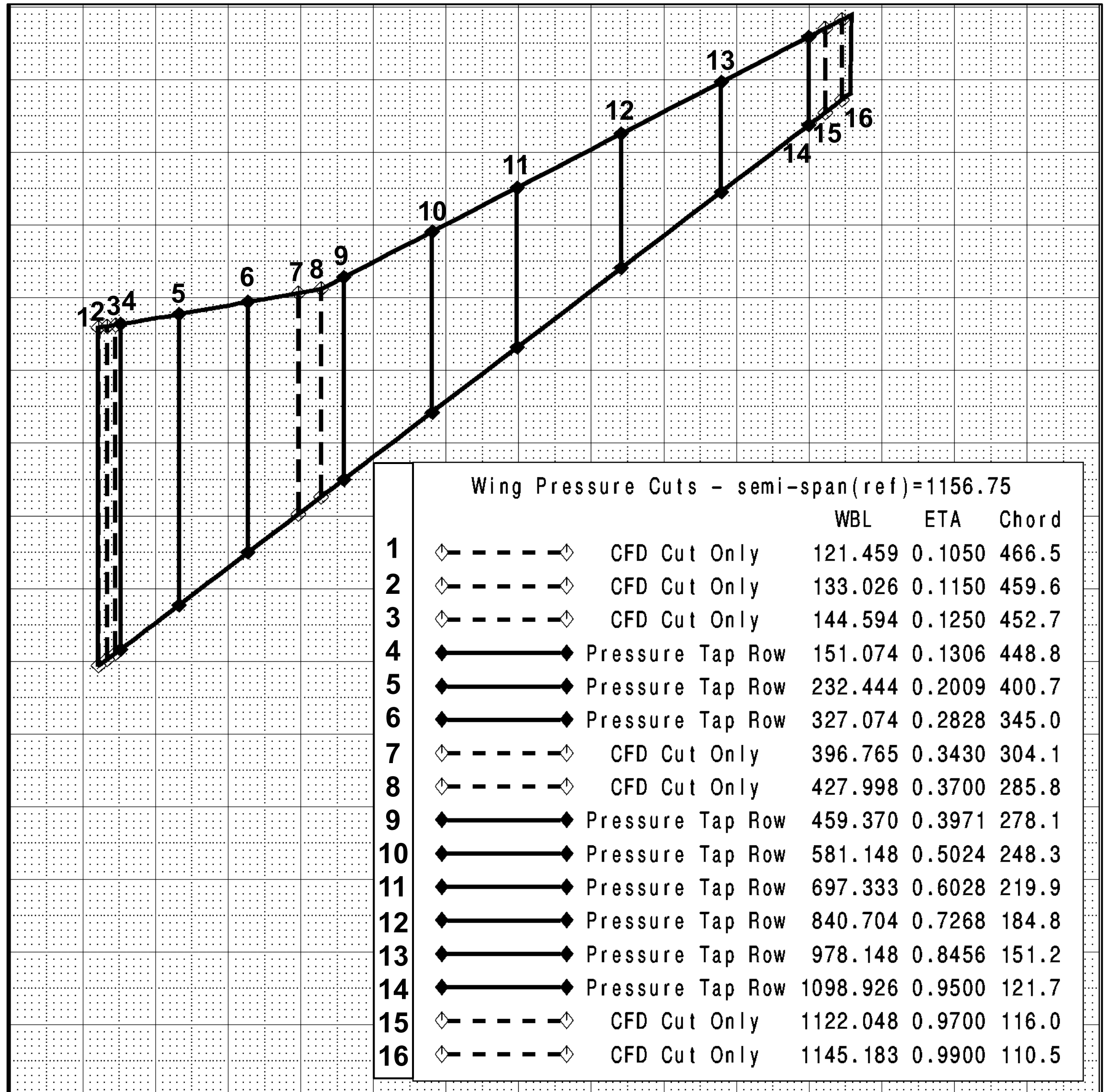

Case 2 - All Solutions
minus Outliers
CL_TOT
CD-CL2/PA
0.7
0.6
0.5
0.4
0.01
0.015
0.02
0.025
0.03
0.035
Outliers defined by CLbreak
and/or drag behavior
SA-la Overset
SA-la Overset
SA-la Overset
SA HEX
SA HYBRID
SST PRISM
EARSM HEX
SA HEX
SST HEX
SA-noft2-R HEX
SA Stru1 MB
SA Stru1 MB
SA Stru1 MB
SA Stru1 MB
SA HYBRID
SA HEX
SST HEX
SA-RC PRISM
SA HEX
SST HEX
SA HEX
SST HEX
SA Stru1 MB
SST HEX
SST HEX
NTF Run 44
NTF Run 51
NTF Run 53
Ames Run 126
Ames Run 130
Ames Run 133


Case 2 - All Solutions minus Outliers
CL_TOT
CD-CL2/PA
0.7
0.6
0.5
0.4
0.01
0.015
0.02
0.025
0.03
0.035
10 Counts
0.58
0.56
0.54
0.52
0.018
0.019
CFD spread similar to test data spread!
SA-la Overset
SA-la Overset
SA-la Overset
SA HEX
SA HYBRID
SST PRISM
EARSM HEX
SA HEX
SST HEX
SA-noft2-R HEX
SA Stru1 MB
SA Stru1 MB
SA Stru1 MB
SA Stru1 MB
SA HYBRID
SA HEX
SST HEX
SA-RC PRISM
SA HEX
SST HEX
SA HEX
SST HEX
SA Stru1 MB
SST HEX
SST HEX
NTF Run 44
NTF Run 51
NTF Run 53
Ames Run 126
Ames Run 130
Ames Run 133

Case 2 - Concluding Remarks

- No clear break-outs with grid type or turbulence model (except for some outliers)
- In general, the k-e-RT and Lag RST results tend outside the norm of the other solutions.
- For all solutions minus outliers
  - Relatively tight forces and moment at α=2.5°
  - Significant force and moment spread at α=4.0° ΔCL=0.055, ΔCM=0.043
- CM predicted too negative – is it CFD, test, geometry, etc.?
- Steady aeroelastic effects are significant
  - Must be included in CFD to better assess accuracy
- Wing section characteristics (section CL, CM) needed to better assess CFD
- High angles of attack characterized by significant shock induced separation
  - How steady is the real flow at these conditions? Need dynamic test data?
  - If there is a significant amount of flow unsteadiness at high angles of attack is RANS adequate or do we need URANS or DES?

Pressure Data



Wing Pressure Cuts - semi-span(ref)=1156.75

		WBL	ETA	Chord
1	CFD Cut Only	121.459	0.1050	466.5
2	CFD Cut Only	133.026	0.1150	459.6
3	CFD Cut Only	144.594	0.1250	452.7
4	Pressure Tap Row	151.074	0.1306	448.8
5	Pressure Tap Row	232.444	0.2009	400.7
6	Pressure Tap Row	327.074	0.2828	345.0
7	CFD Cut Only	396.765	0.3430	304.1
8	CFD Cut Only	427.998	0.3700	285.8
9	Pressure Tap Row	459.370	0.3971	278.1
10	Pressure Tap Row	581.148	0.5024	248.3
11	Pressure Tap Row	697.333	0.6028	219.9
12	Pressure Tap Row	840.704	0.7268	184.8
13	Pressure Tap Row	978.148	0.8456	151.2
14	Pressure Tap Row	1098.926	0.9500	121.7
15	CFD Cut Only	1122.048	0.9700	116.0
16	CFD Cut Only	1145.183	0.9900	110.5

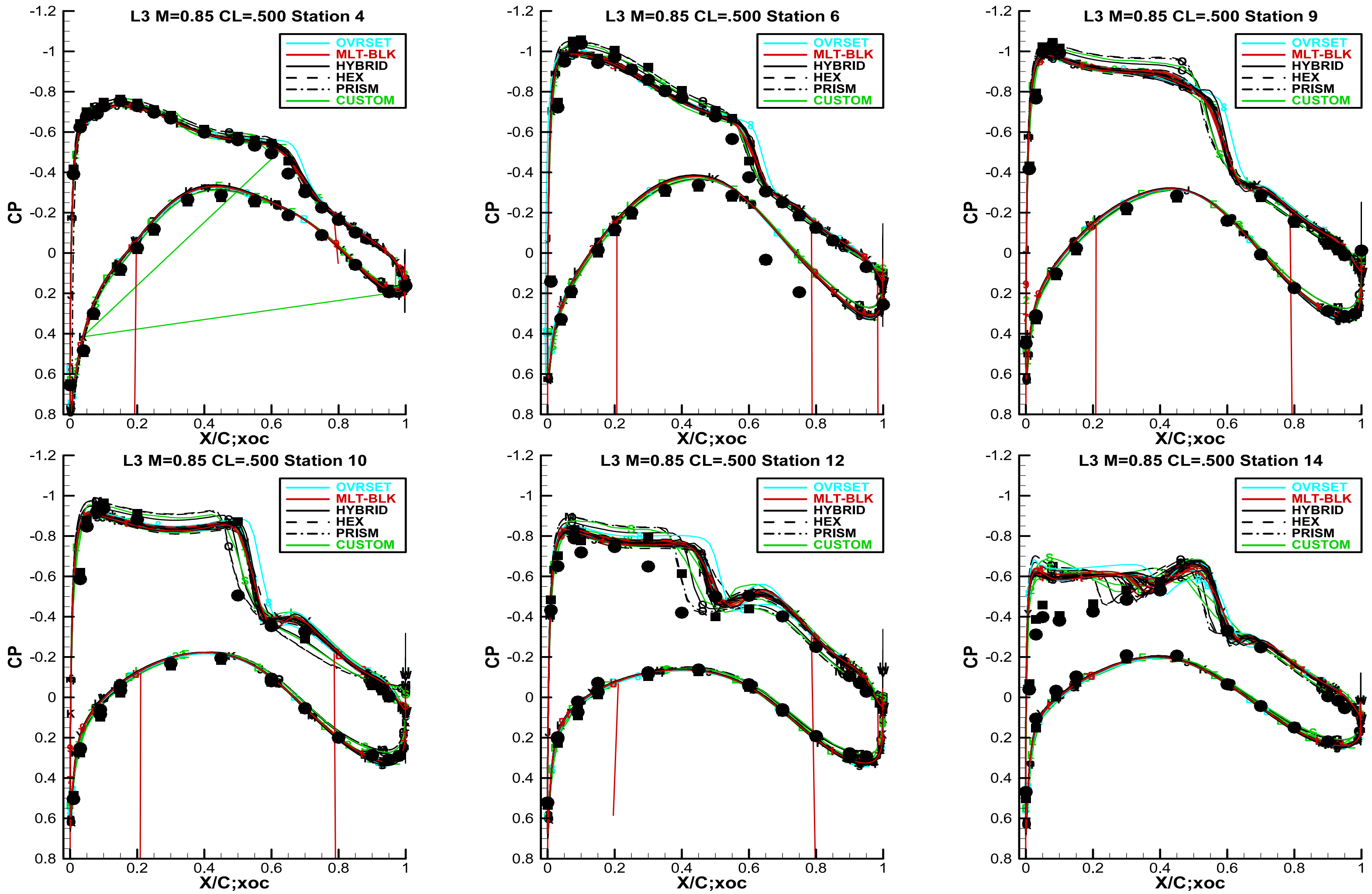
AIAA Applied Aerodynamics Technical Committee

5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012

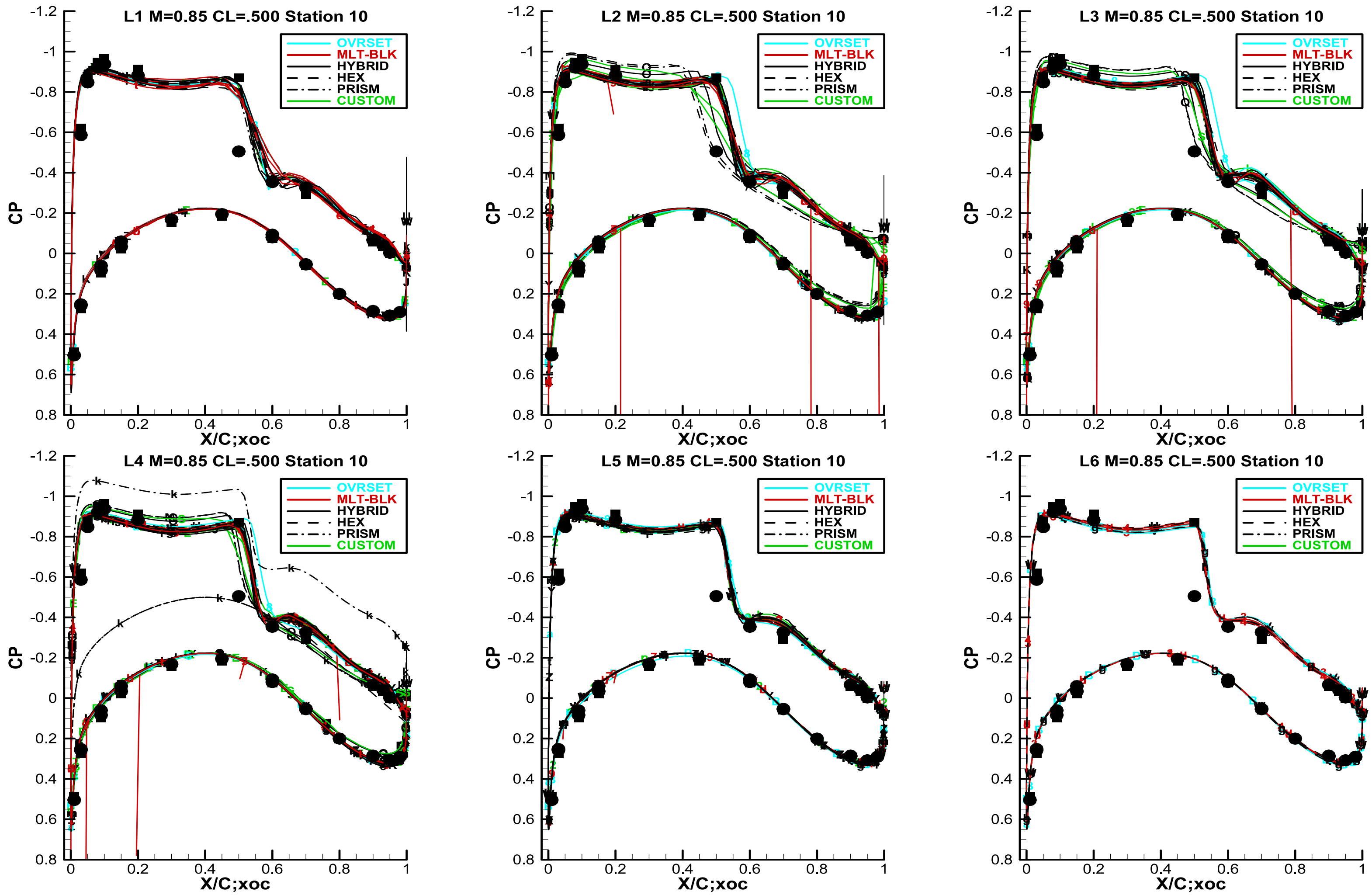
Case 1: Level 3 Grid, M=0.85, C_L=.50
Spanwise Variation

NTF Test 197 Run 44:
● α=2.68°, CL=0.485
■ α=2.91 °, CL=0.519



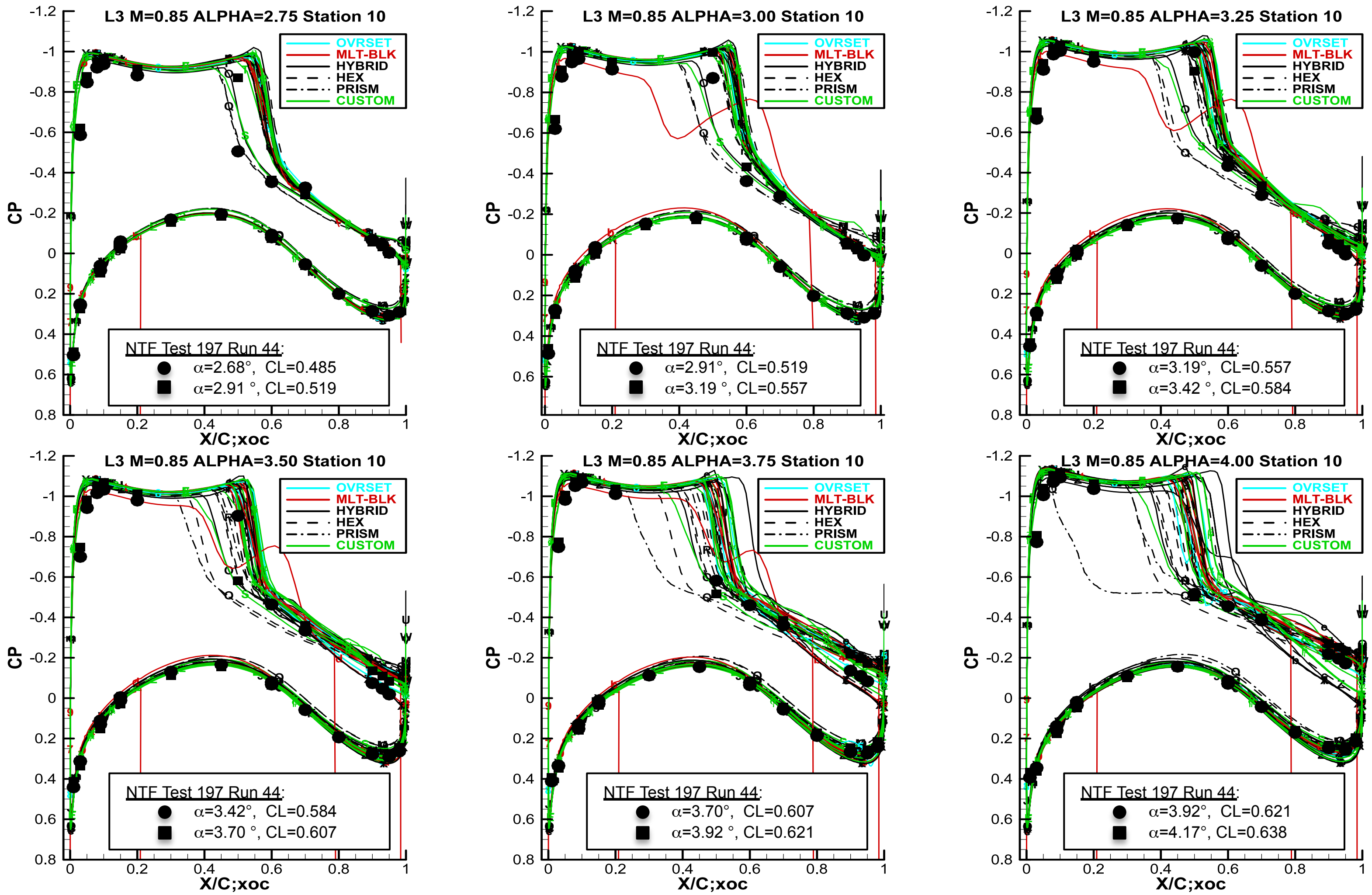
Case 1: Grid Refinement Study, M=0.85, C_L=.50
Station 10, η=.502

NTF Test 197 Run 44:
● α=2.68°, CL=0.485
■ α=2.91 °, CL=0.519



Case 2: Buffet Study, Level 3 Grids, M=0.85

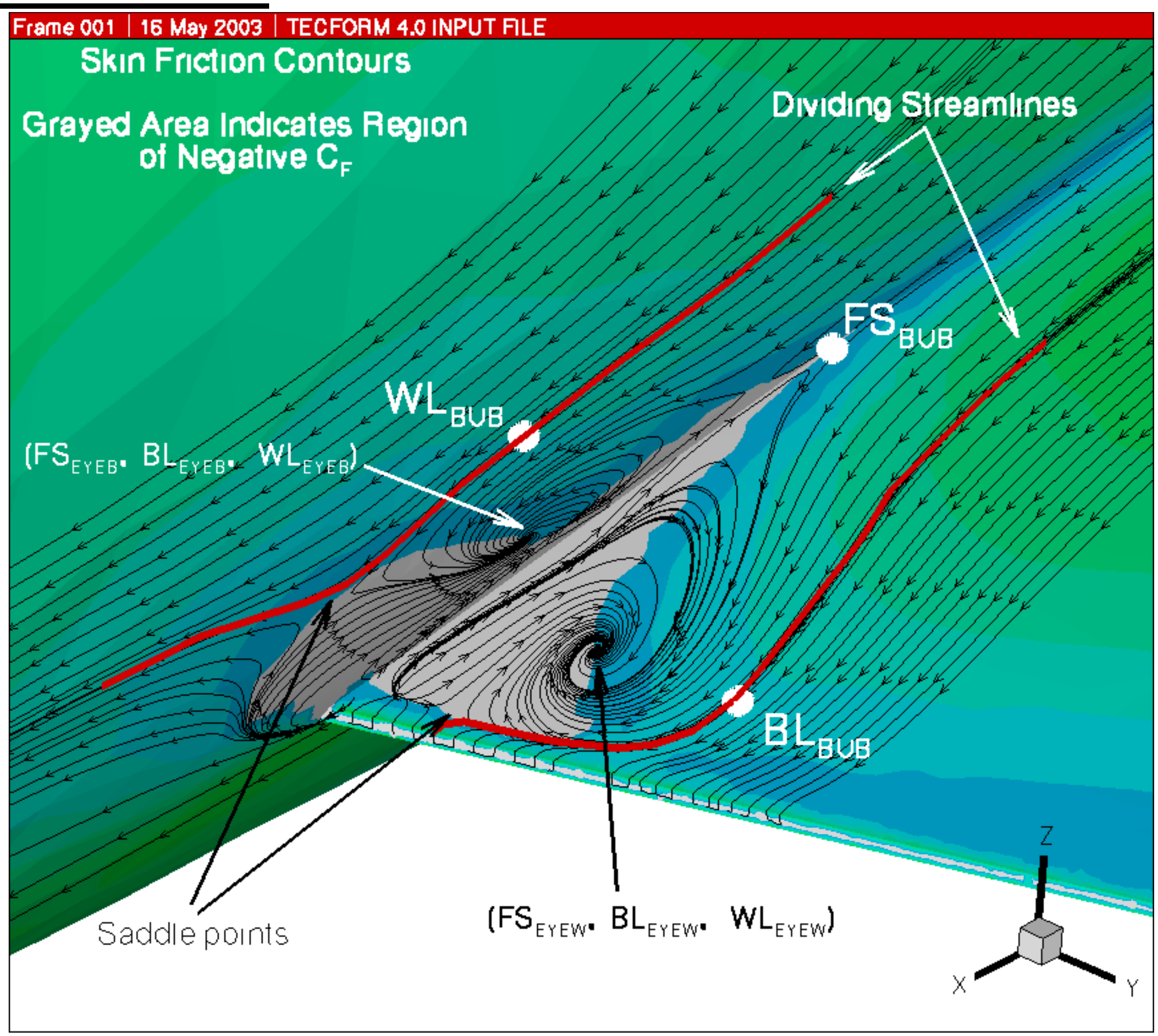
Station 10, η=.502



Conclusions from Pressure Data:

- Agreement with experiment deteriorates at outboard stations, likely due to aeroelastic effects
- Variations with grid level hard to discern due to reduced number of data sets
- Variation at high alphas due to separation effects on shock location
- No clear break-out with grid type (Turbulence model affects not examined yet)

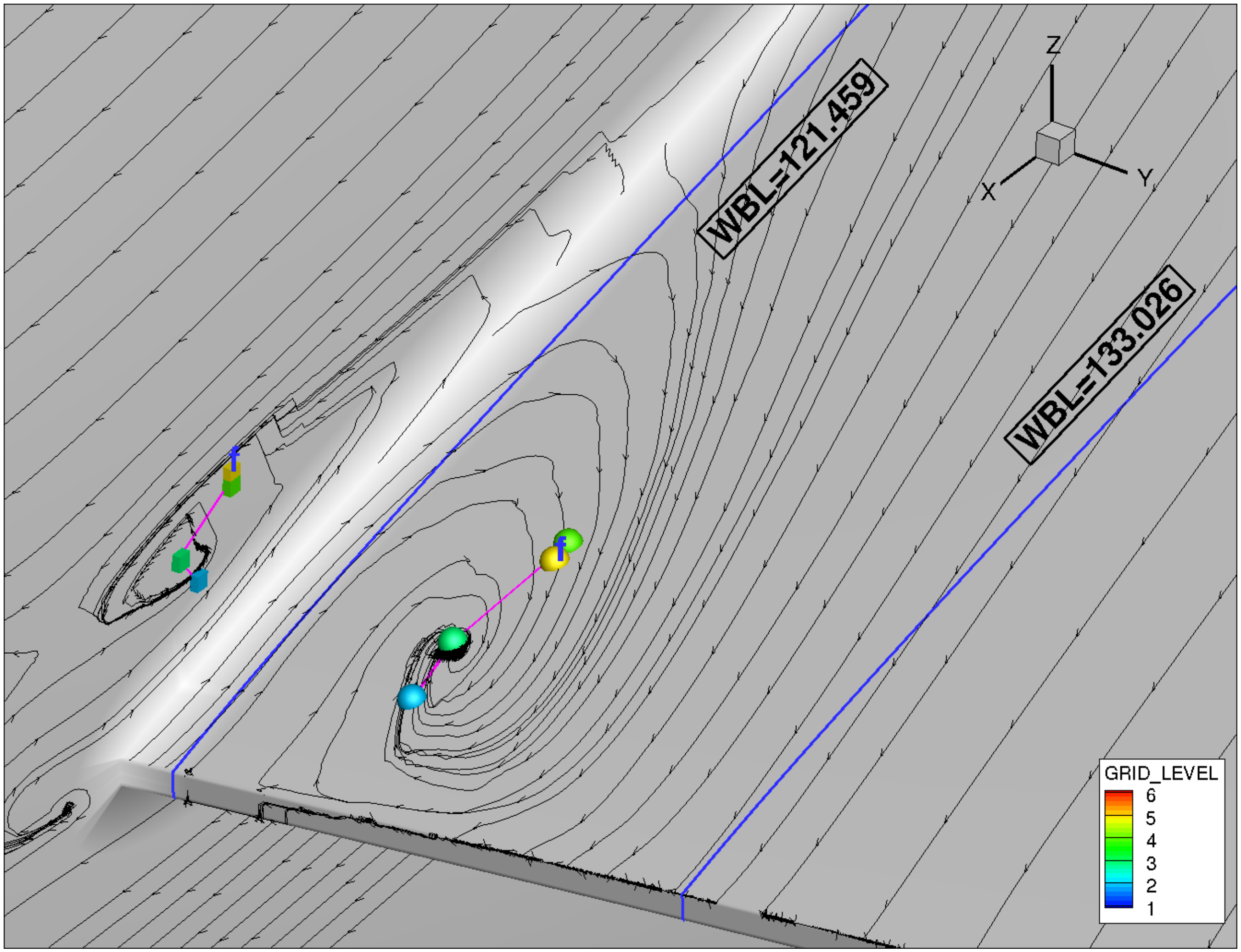
Separation Bubble



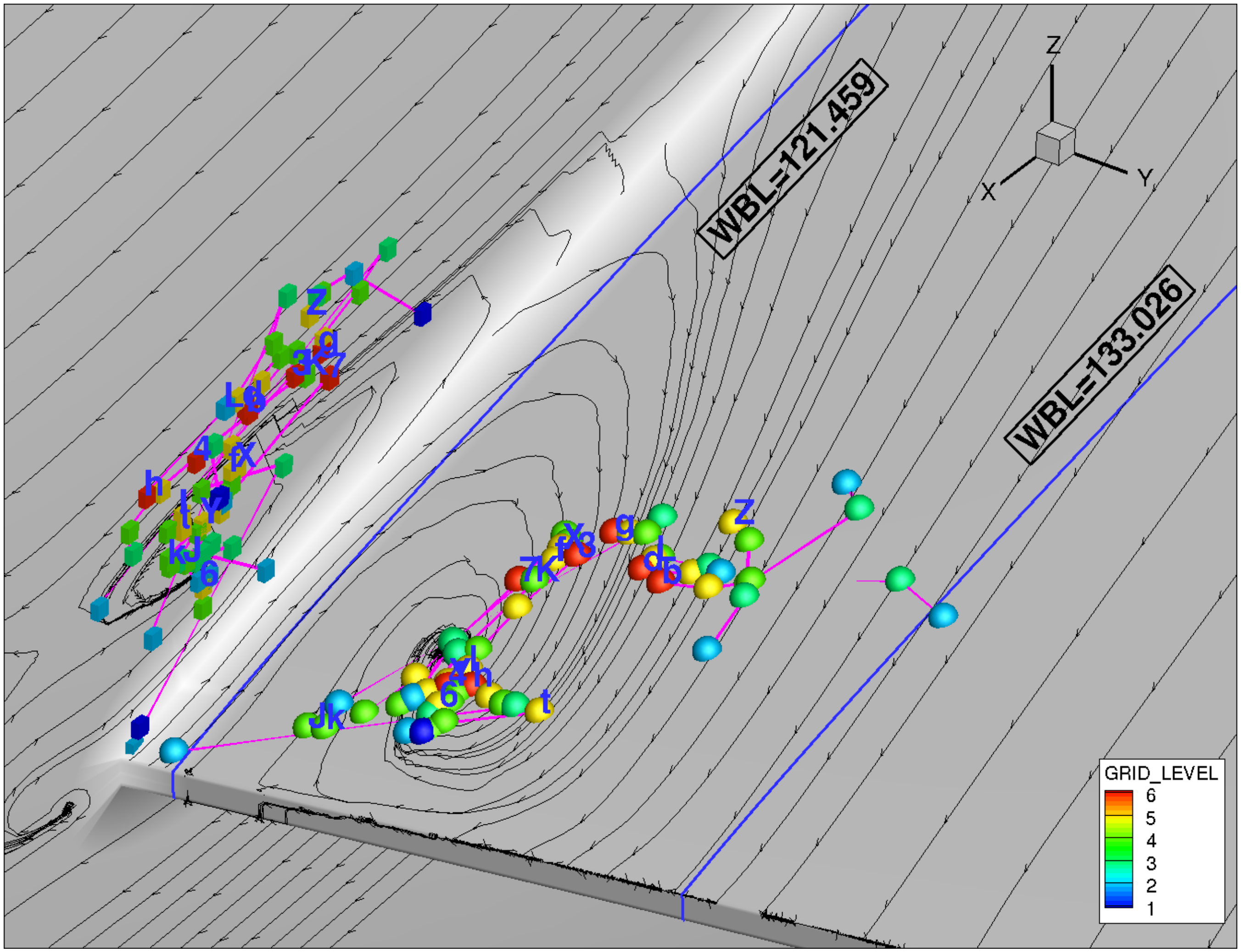
Side of Body Separation Bubble

1. Reported some level of SOB Separation:
   I, J, K, L, X, Y, Z, 3, 4, 5, 6, 7, 9,
   b, d, f, g, h, k, t, α, β, δ, γ, λ, π
2. Reported no SOB Separation (SOB File Provided):
   U, V, W, 2, e, m, n, q, r
3. No Report (No SOB File Provided):
   A, B, C, D, E, F, G, H, M, N, O, P, Q, R, S, T, 8, a

Example Grid Refinement: with Dataset "f" only



Grid Refinement: All Data

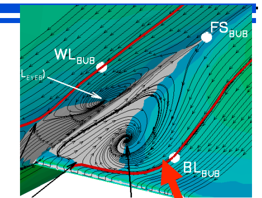


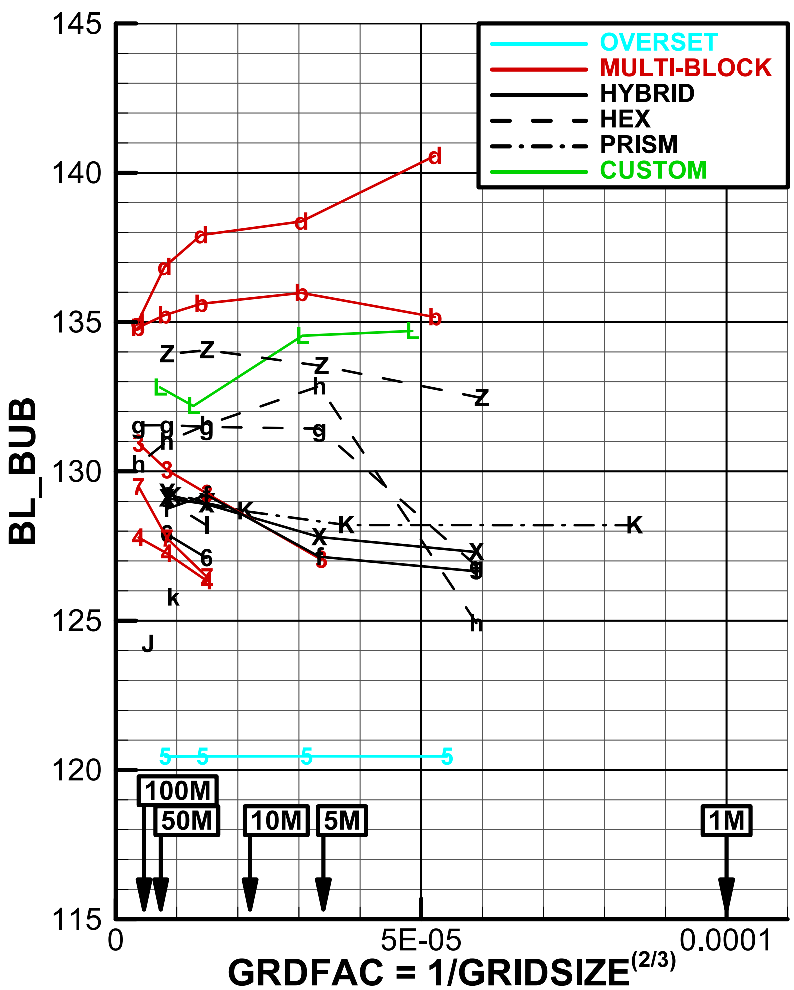
Applied Aerodynamics Technical Committee

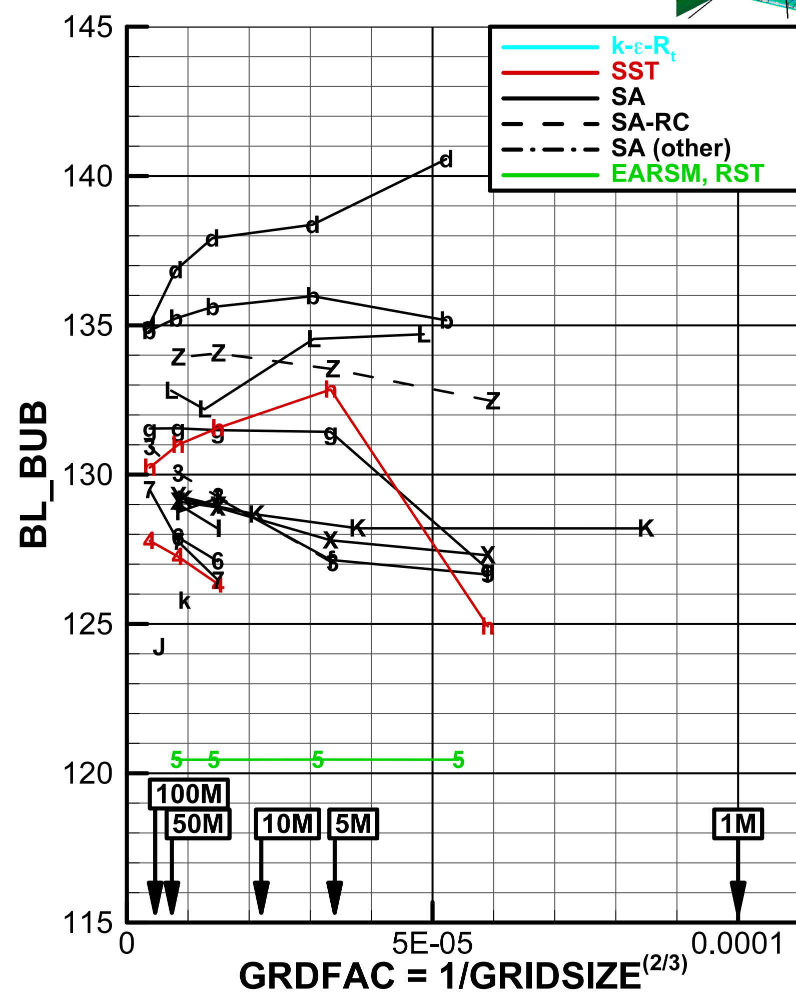
5th CFD Drag Prediction Workshop

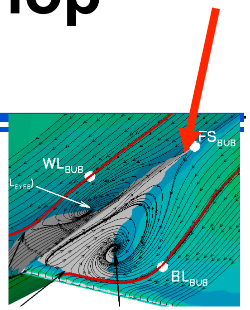
New Orleans, Louisiana – June 2012

Bubble Width (Wing): Case 1 By Grid Type and Turbulence Model

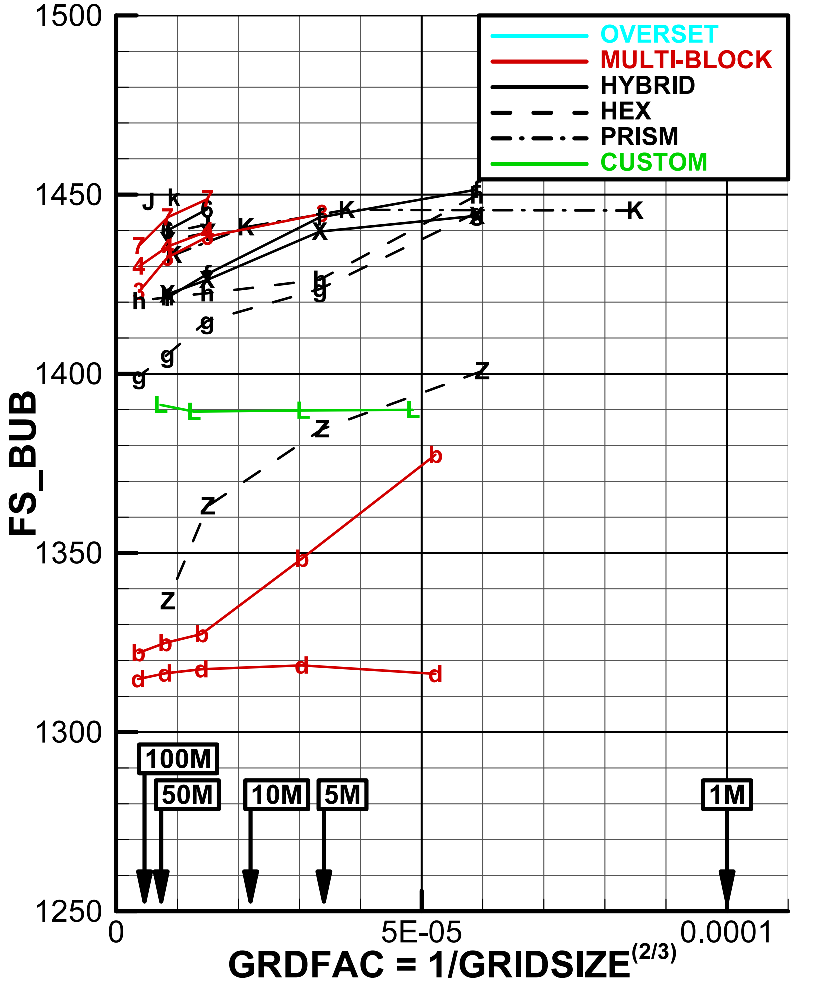


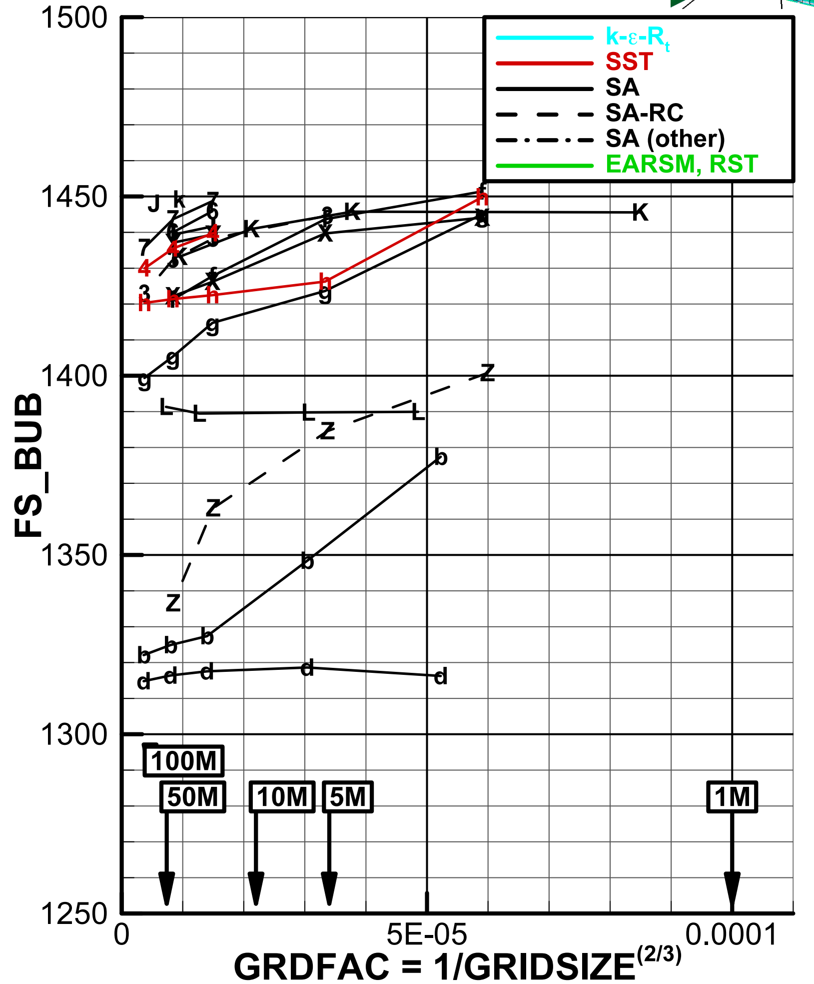


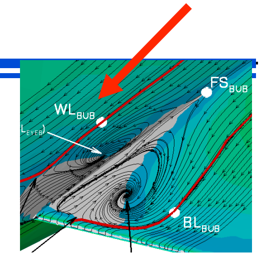




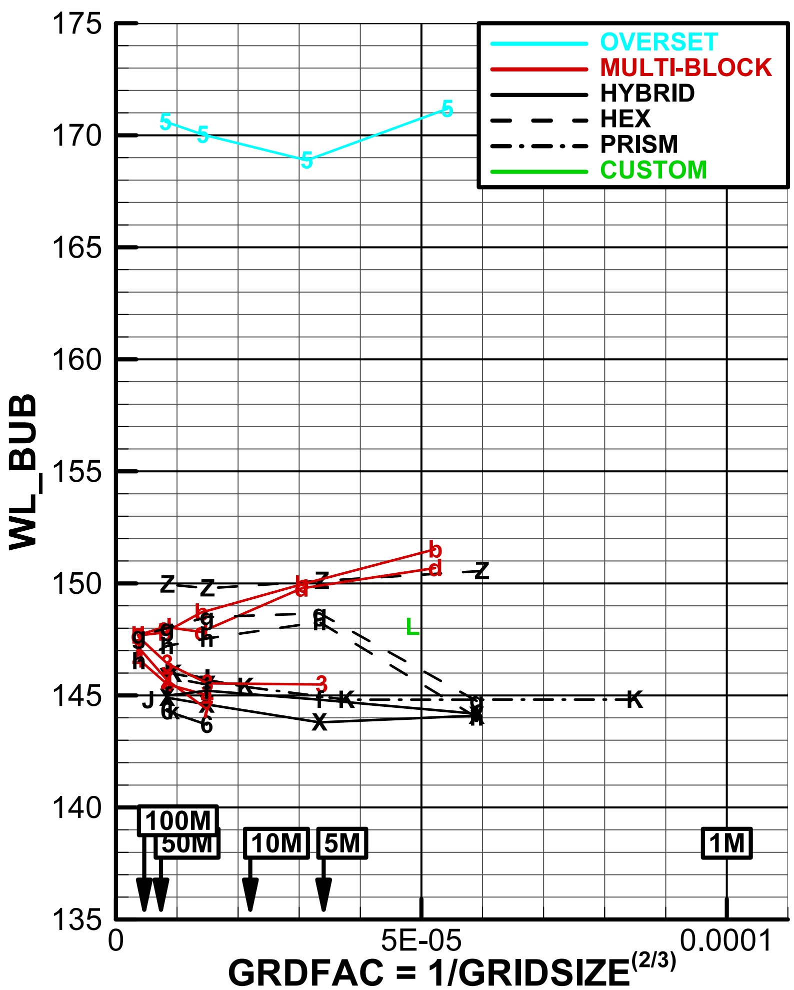
Bubble Leading Edge: Case 1 By Grid Type and Turbulence Model

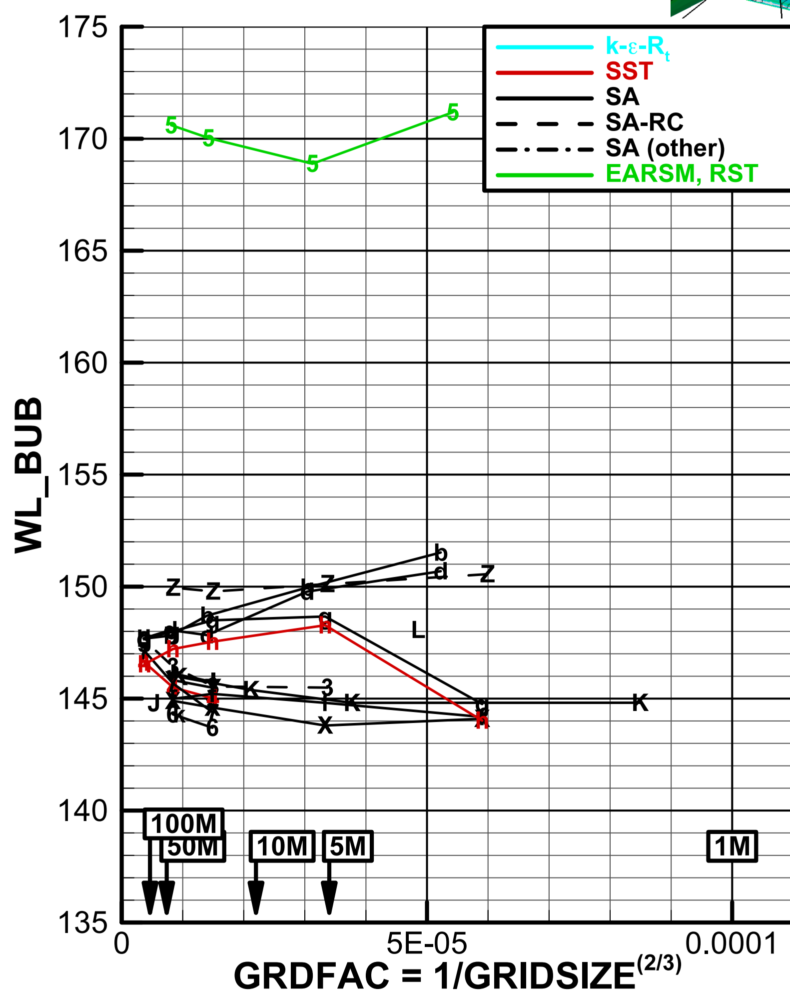




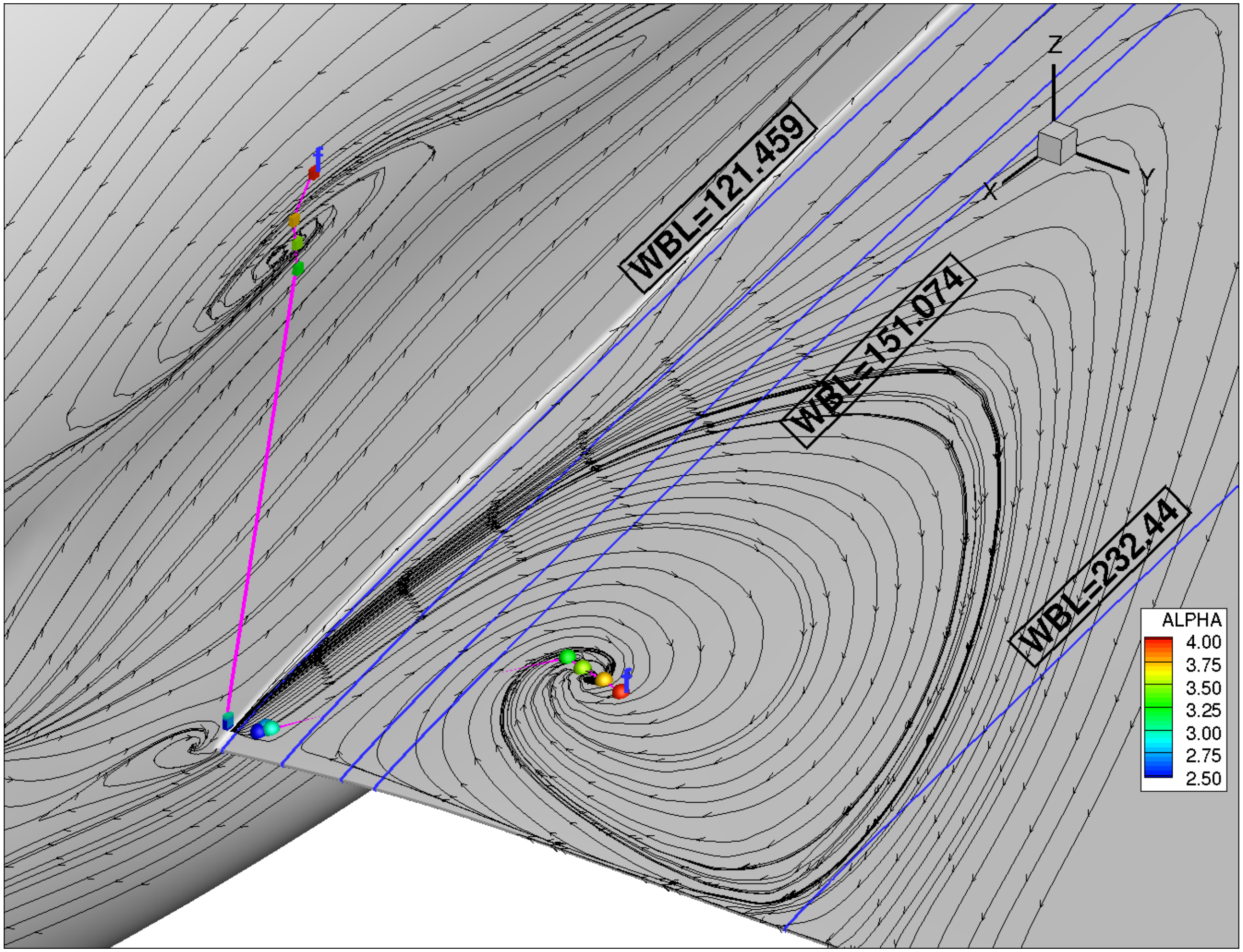


Bubble Height (Fuselage): Case 1 By Grid Type and Turbulence Model

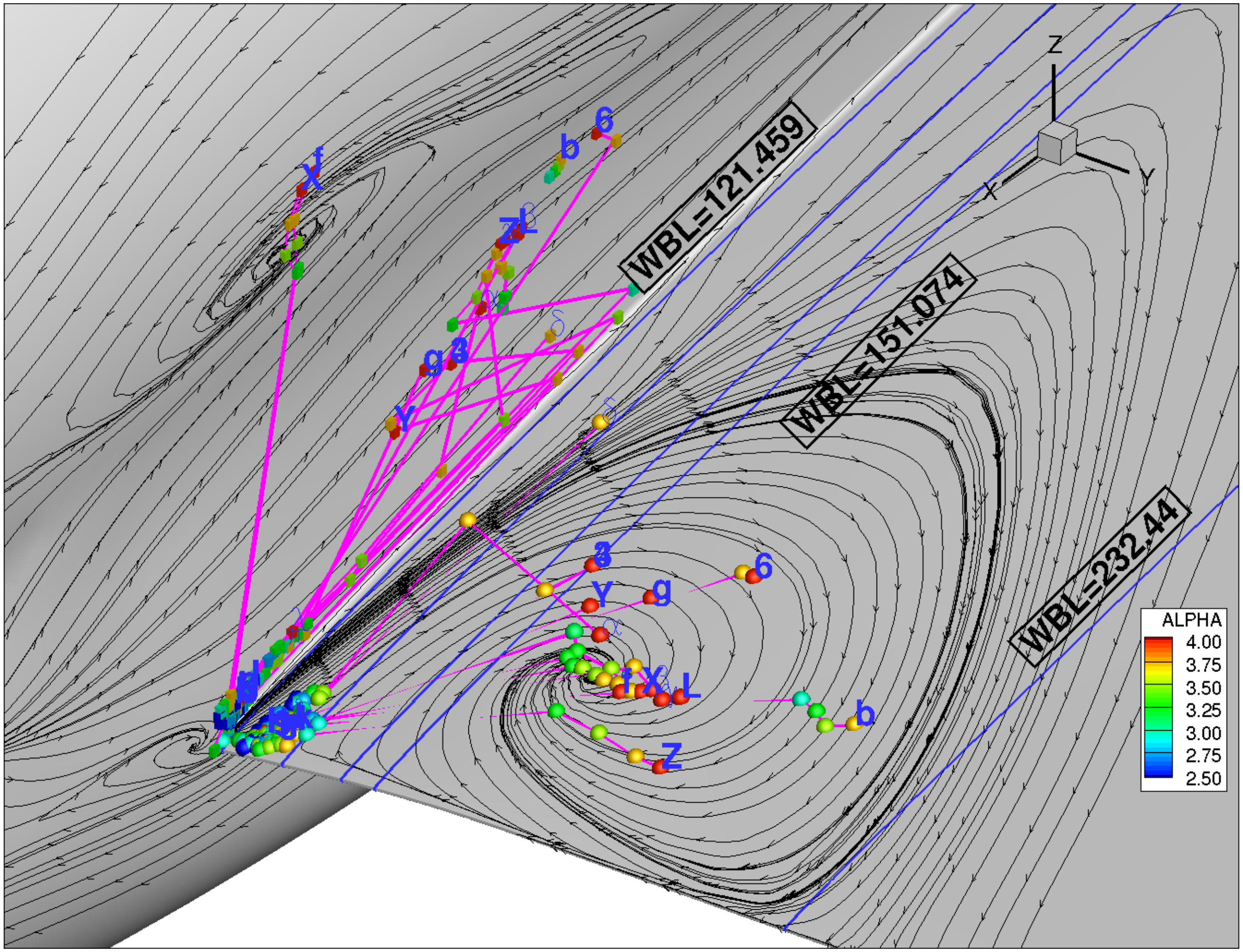


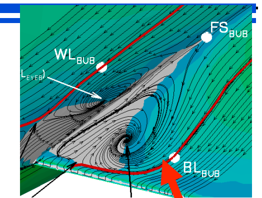


Example Alpha Sweep: with Dataset "f" only

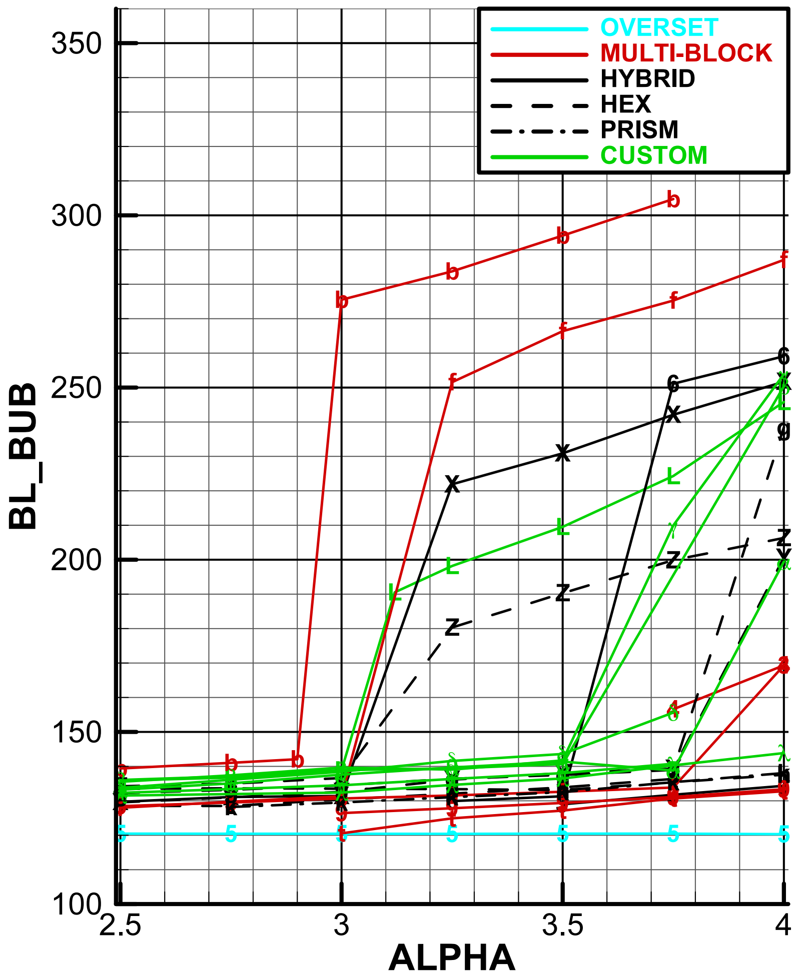


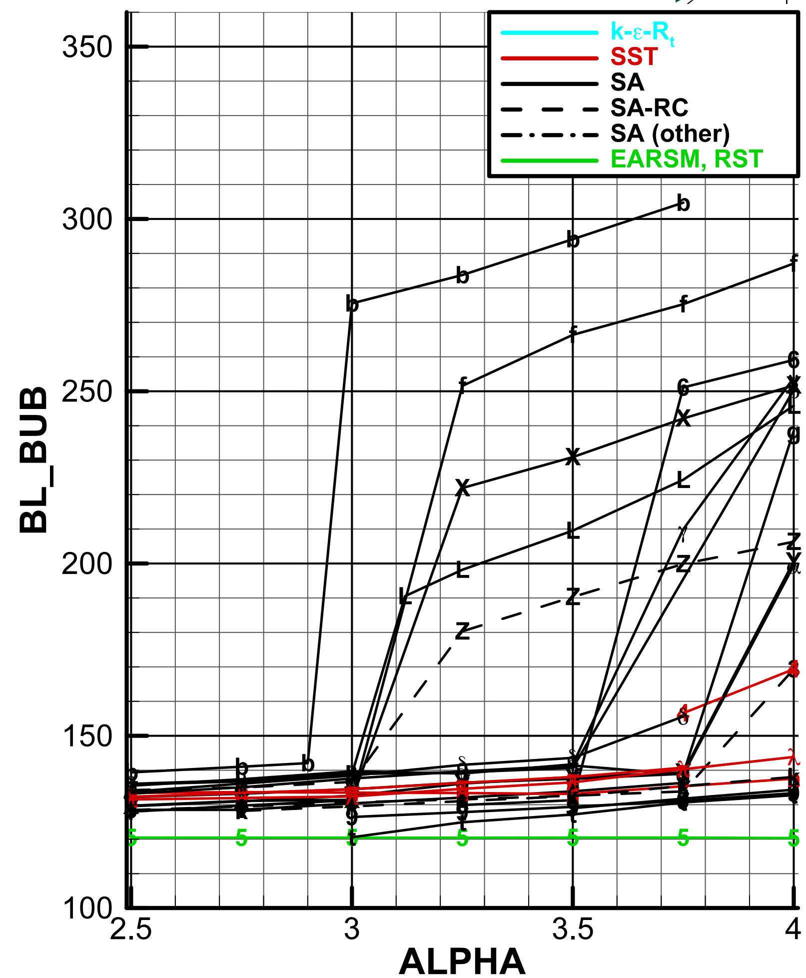
Alpha Sweep: All Data



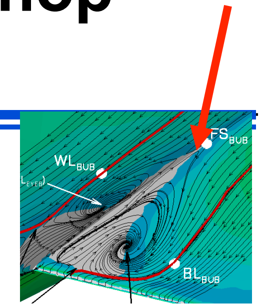


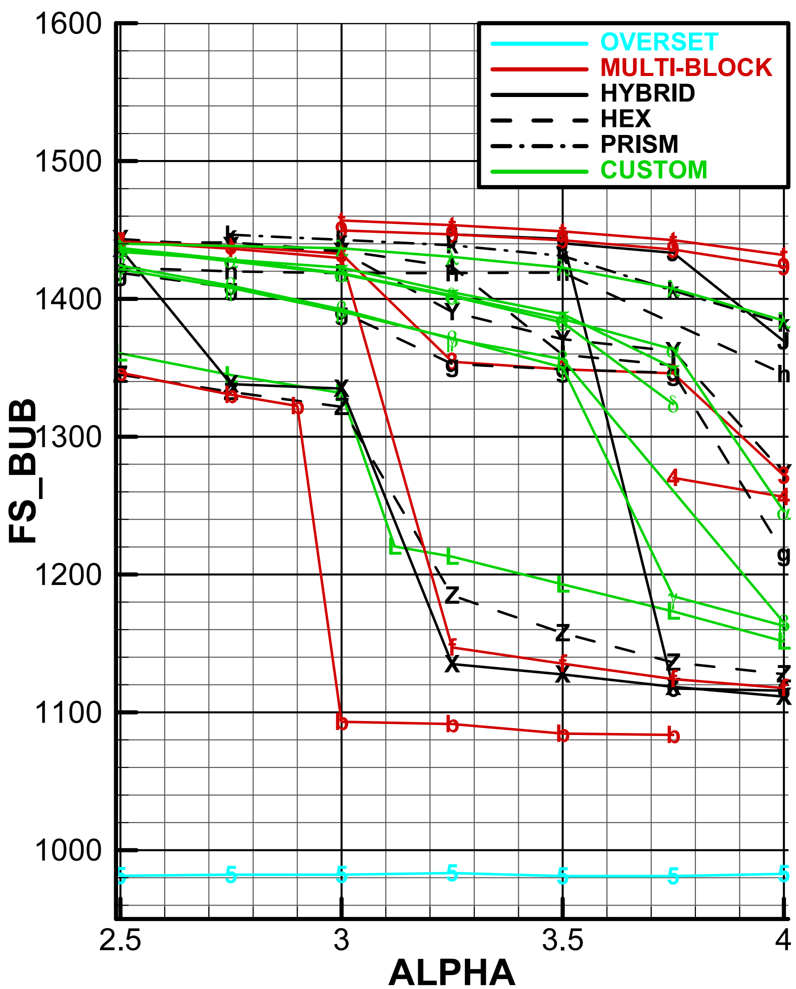
Bubble Width (Wing): Case 2 By Grid Type and Turbulence Model

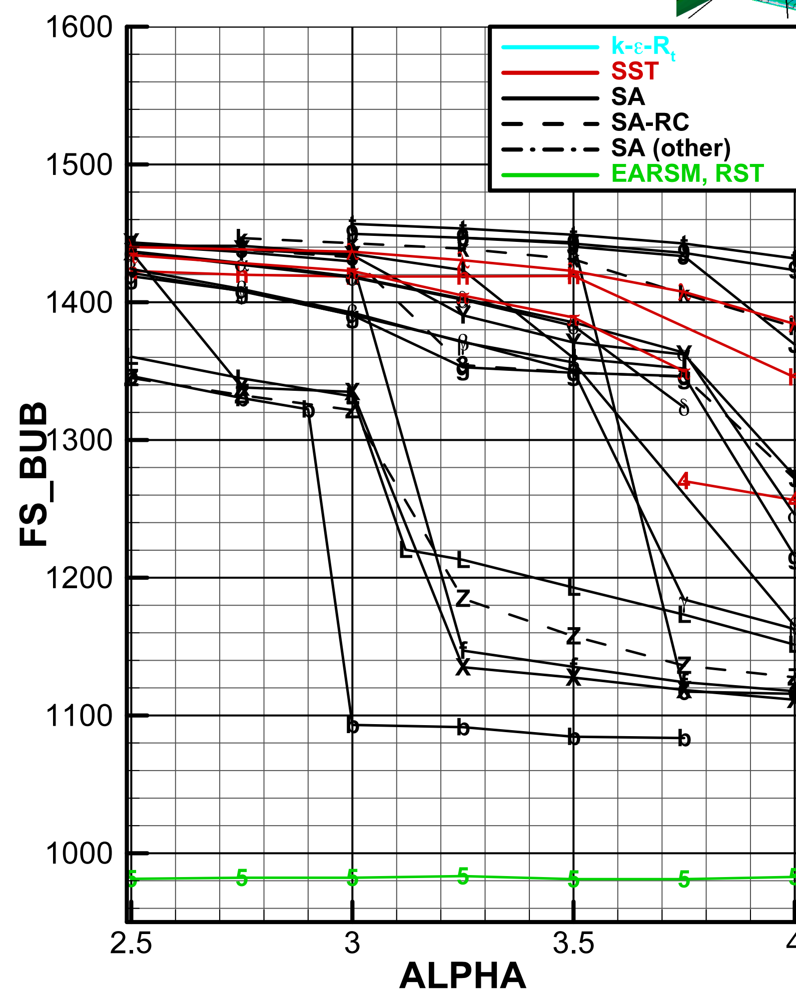


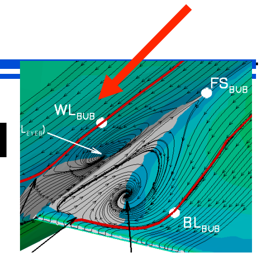


Bubble Leading Edge: Case 2 By Grid Type and Turbulence Model

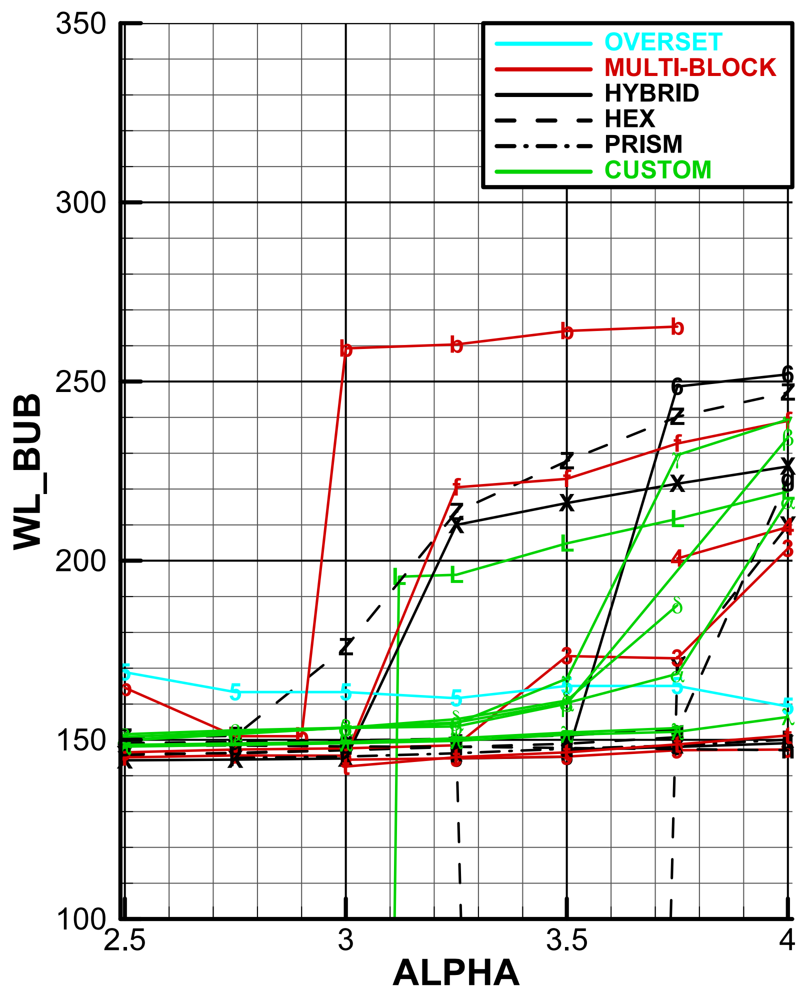


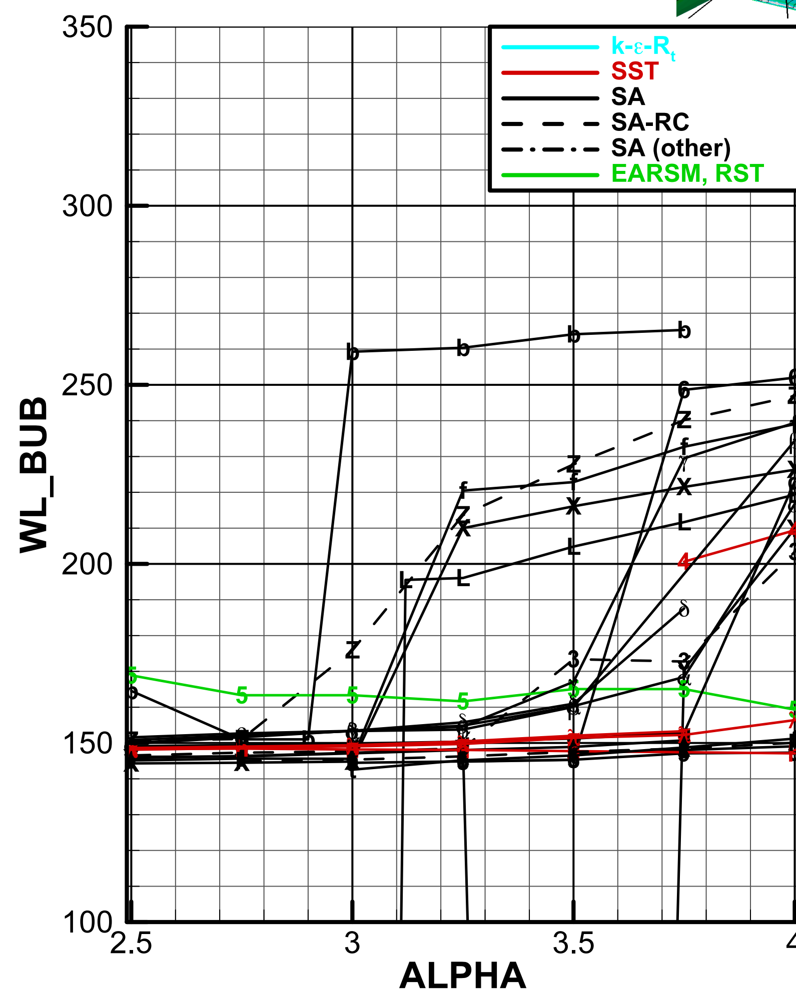






Bubble Height (Fuselage): Case 2 By Grid Type and Turbulence Model



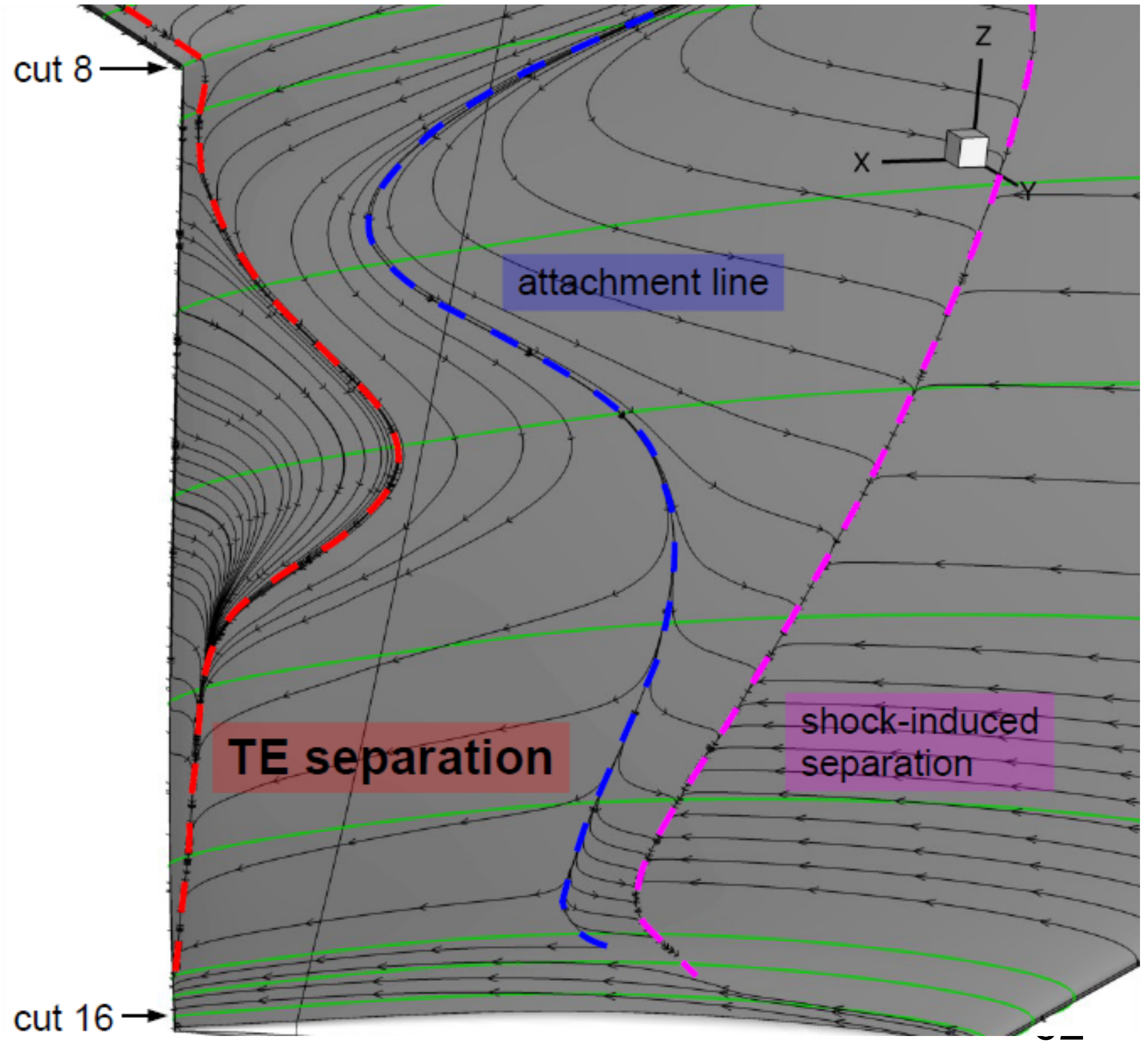


Conclusions from Separation Bubble:

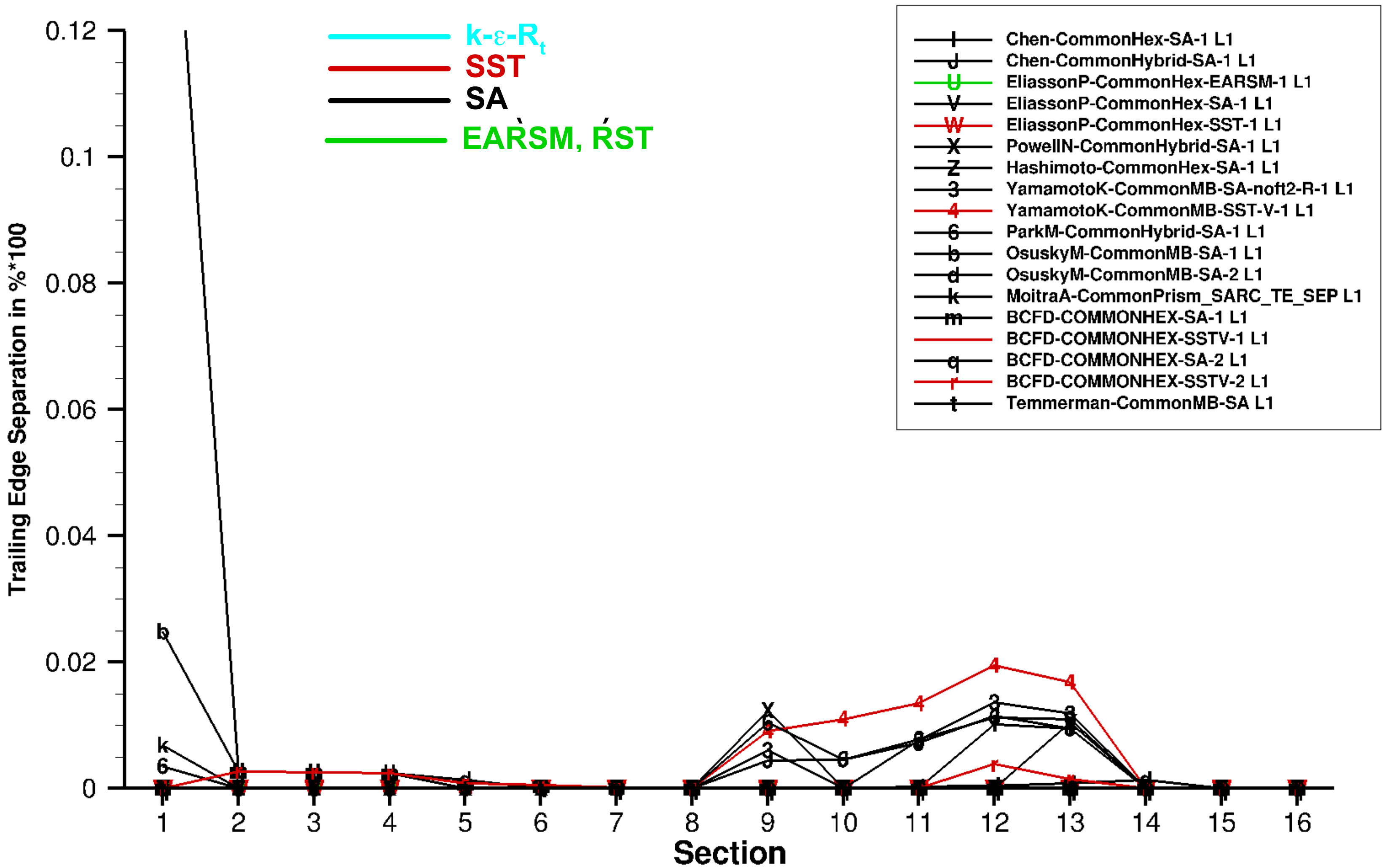
- Variation with grid level fairly consistent (note that coarse level grids do not have proper resolution)
- Some data sets show dramatic increase in bubble size at higher alpha
  - Mostly for Spalart-Allmaras results

Trailing Edge Separation:

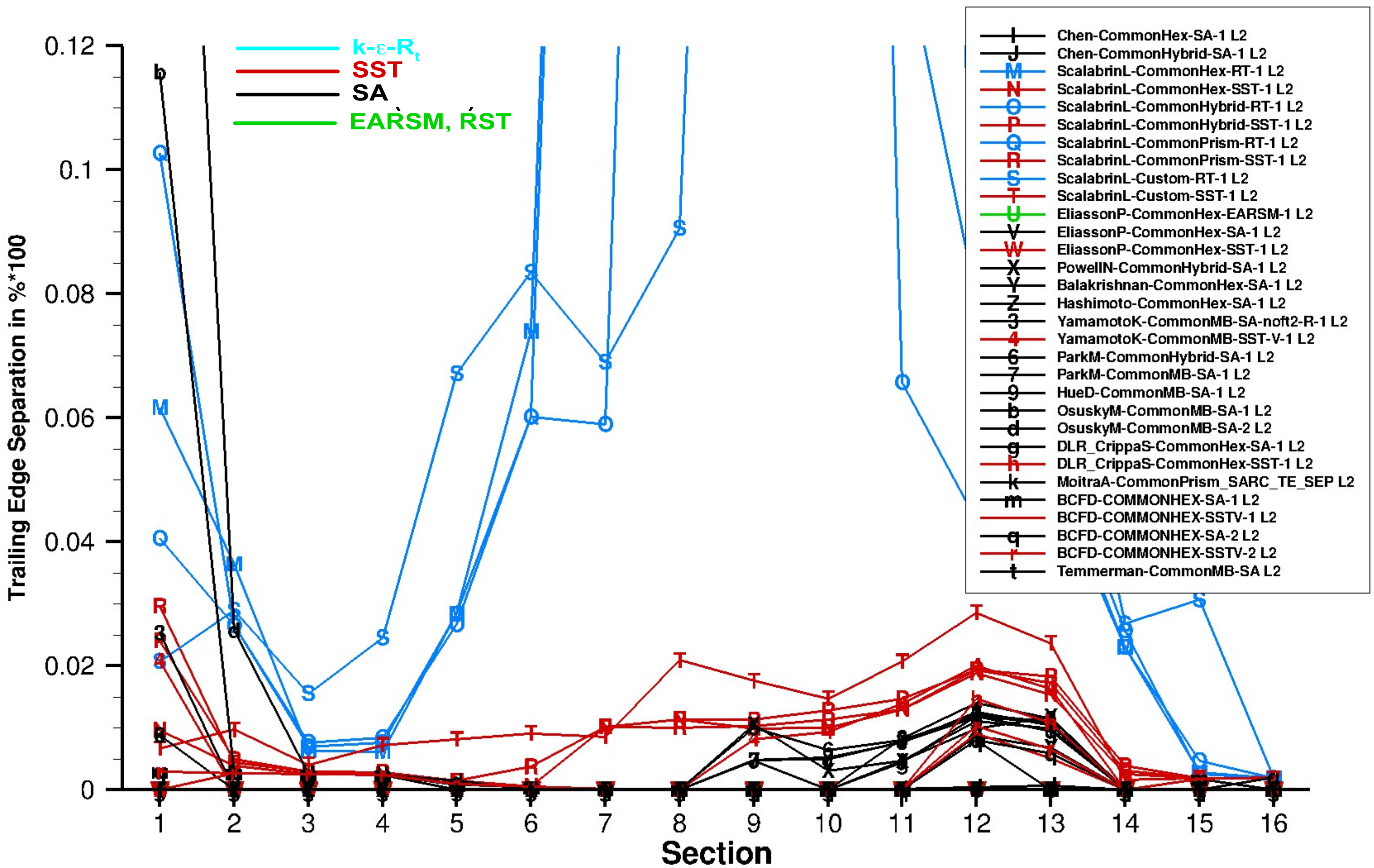
- DPW-4: C_f normal to TE < 0 as criteria
- For higher α more difficult to define & detect



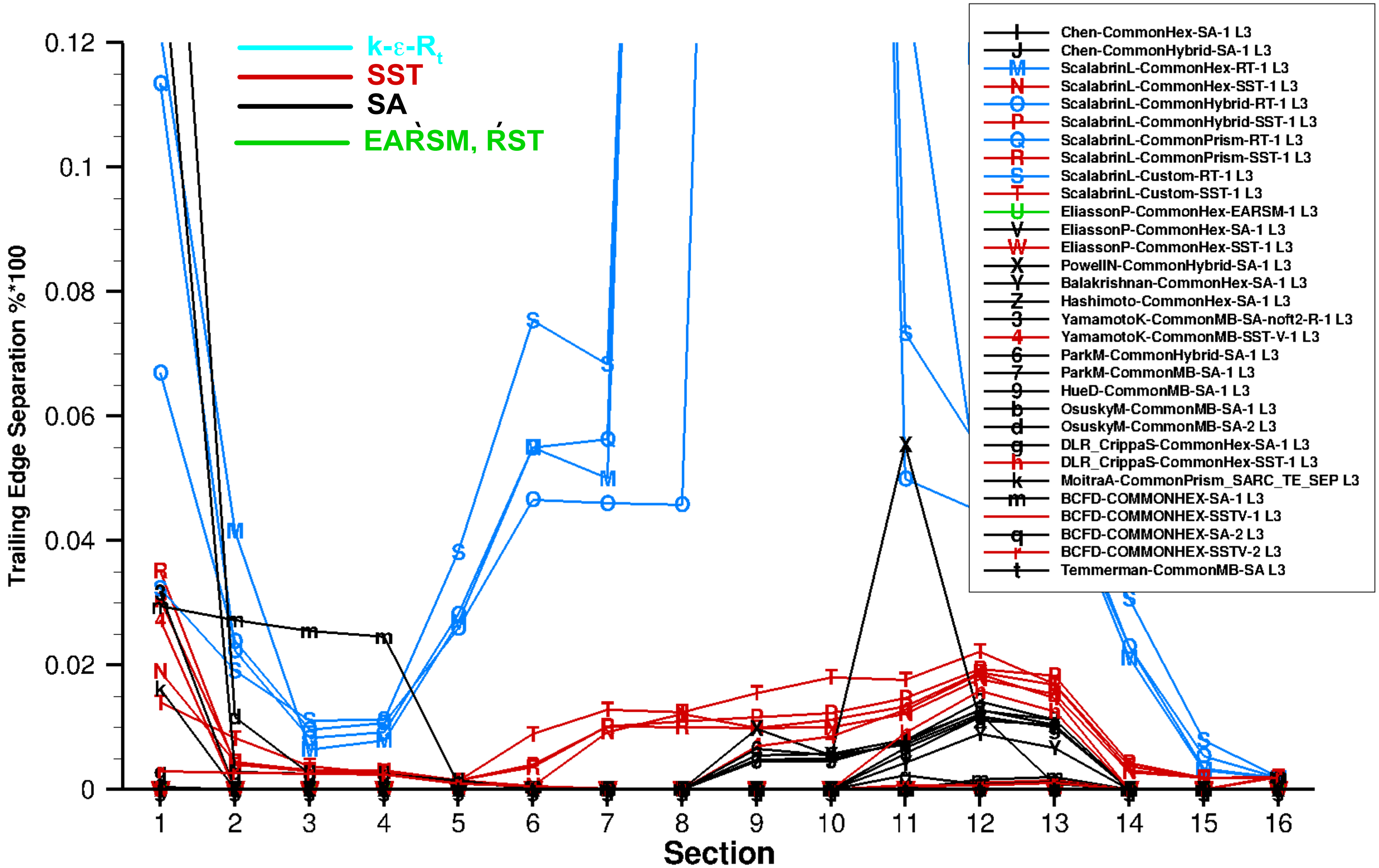
Case 1: Trailing Edge Separation, Level 1



Case 1: Trailing Edge Separation, Level 2



Case 1: Trailing Edge Separation, Level 3

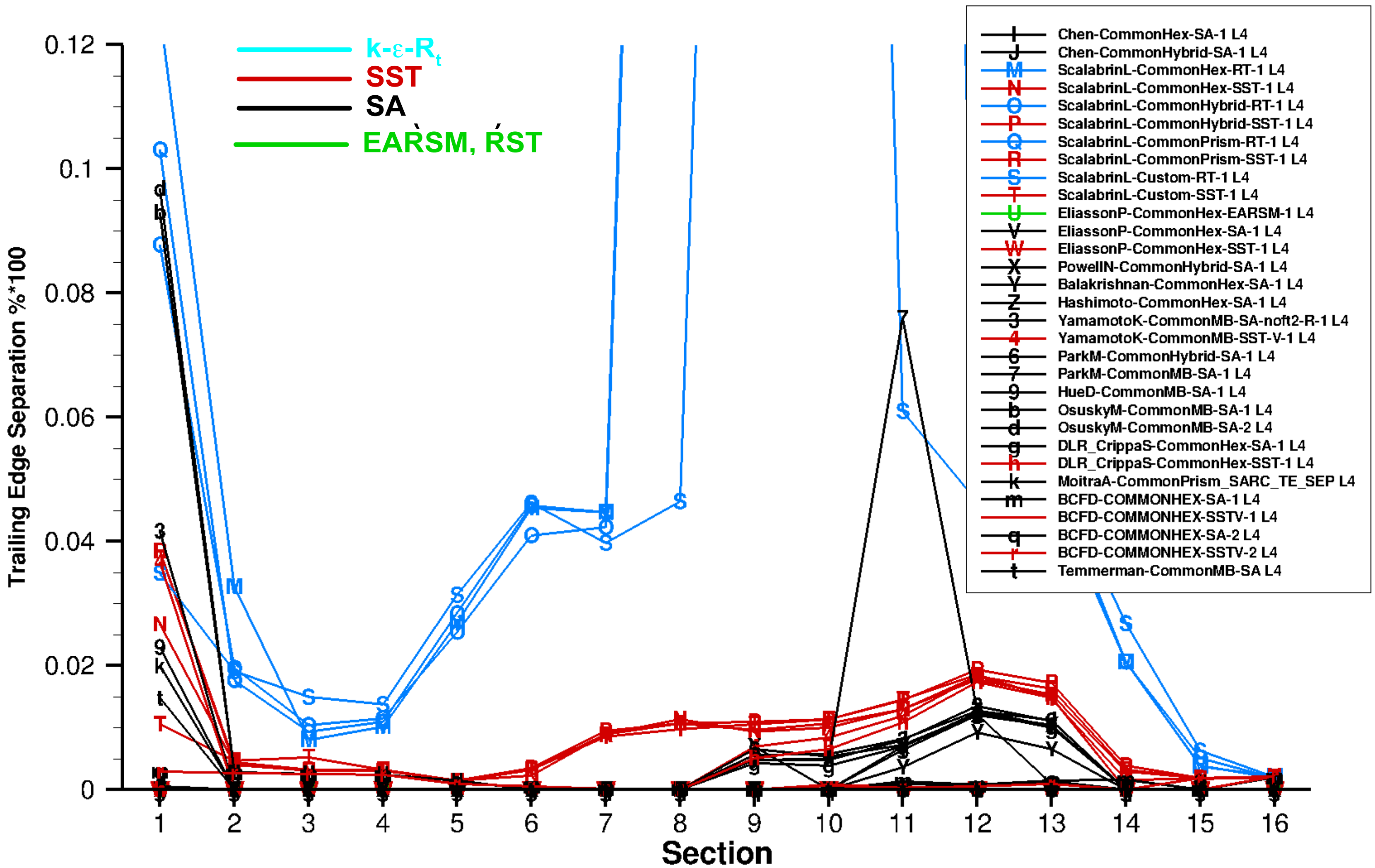


5th CFD Drag Prediction Workshop

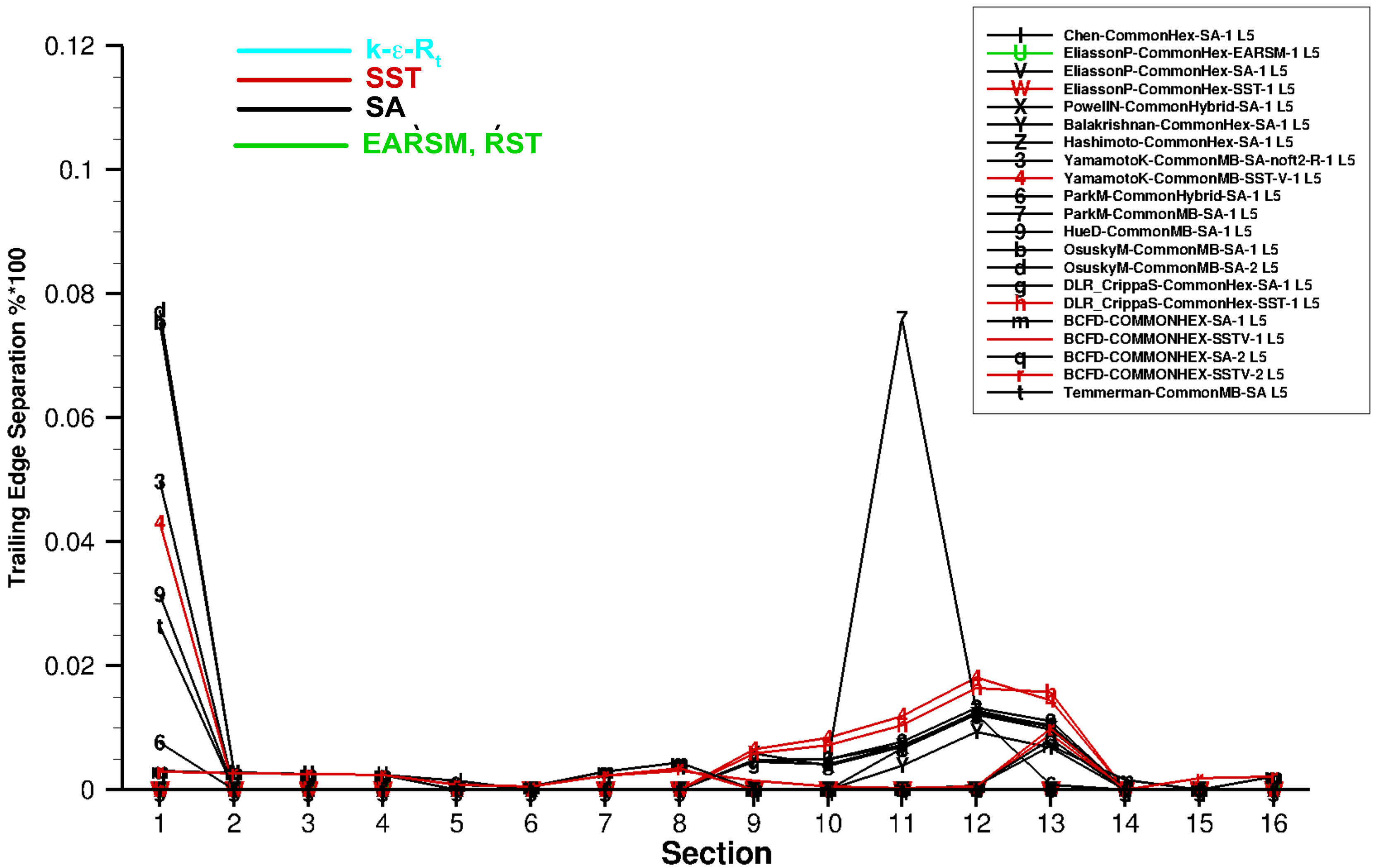
New Orleans, Louisiana – June 2012

Applied Aerodynamics Technical Committee

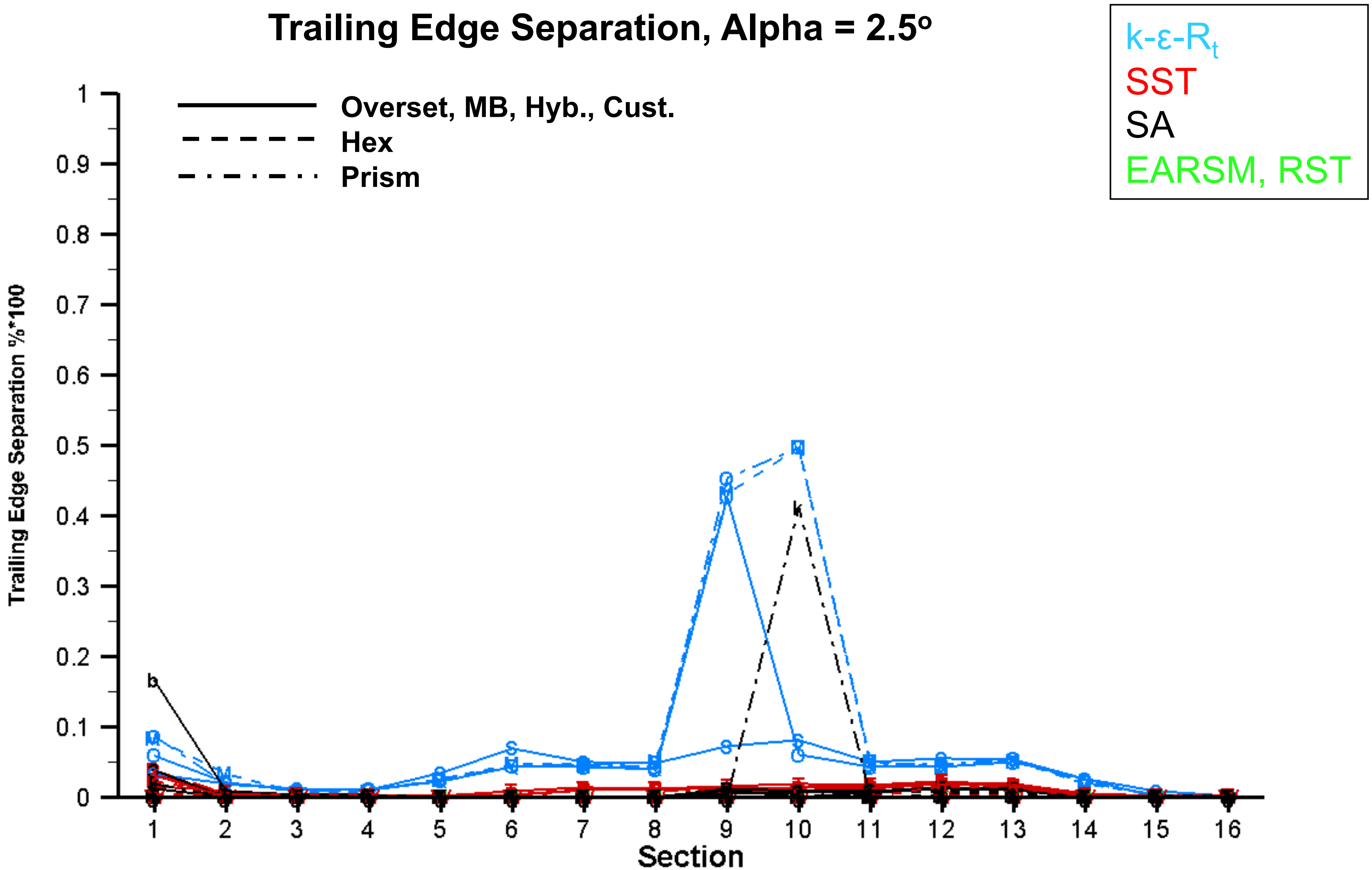
Case 1: Trailing Edge Separation, Level 4



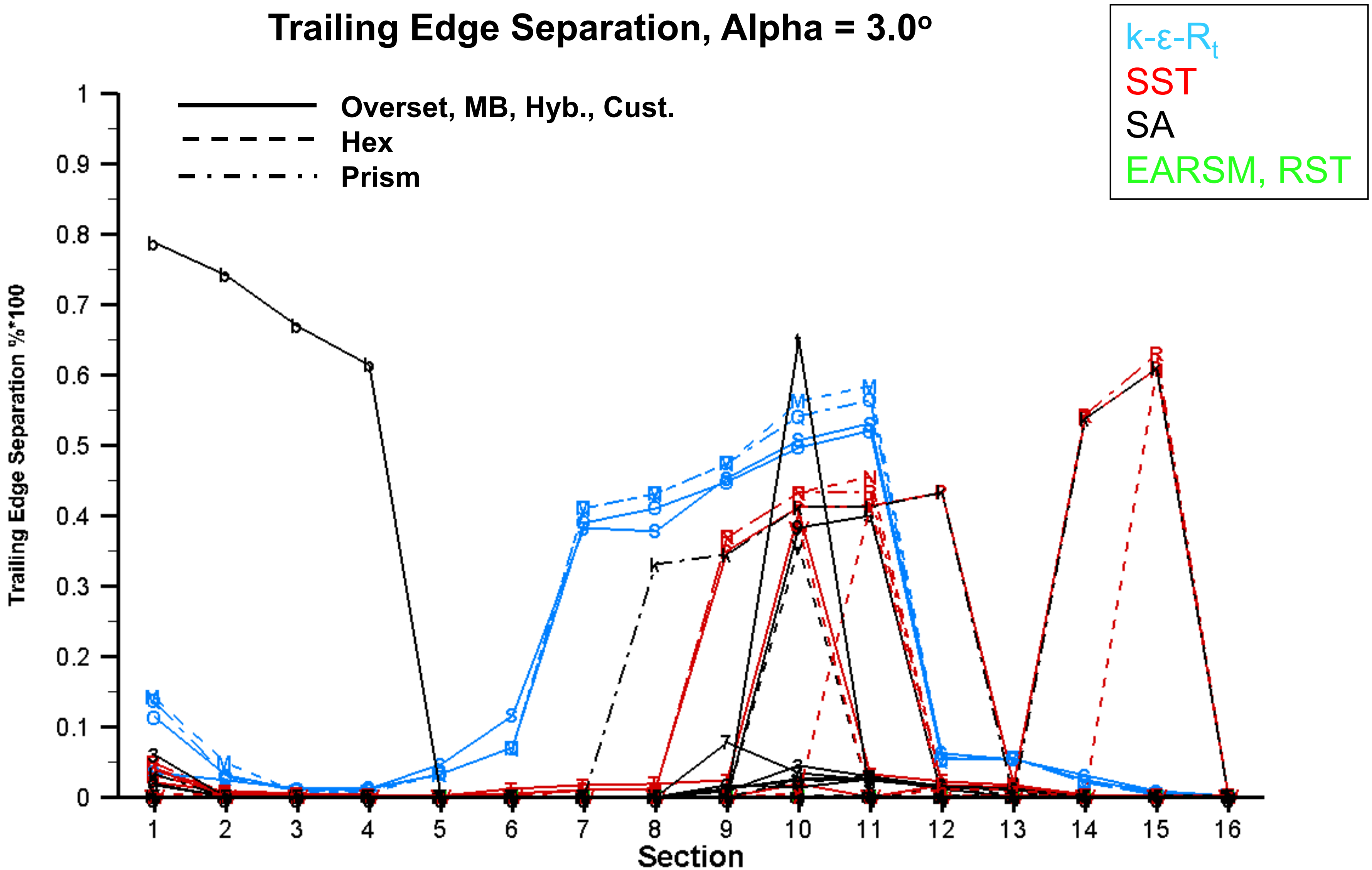
Case 1: Trailing Edge Separation, Level 5



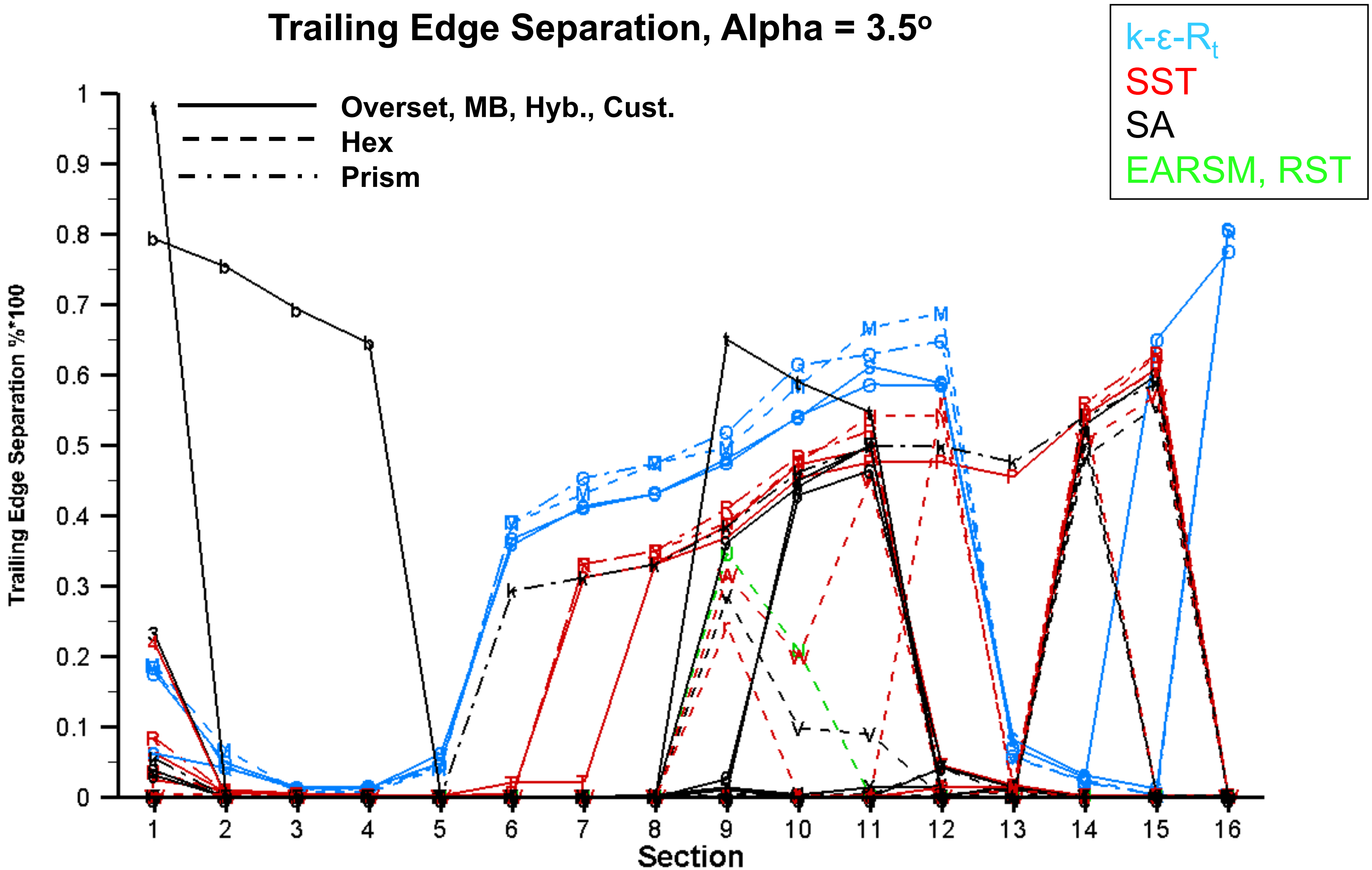
Trailing Edge Separation, Alpha = 2.5°



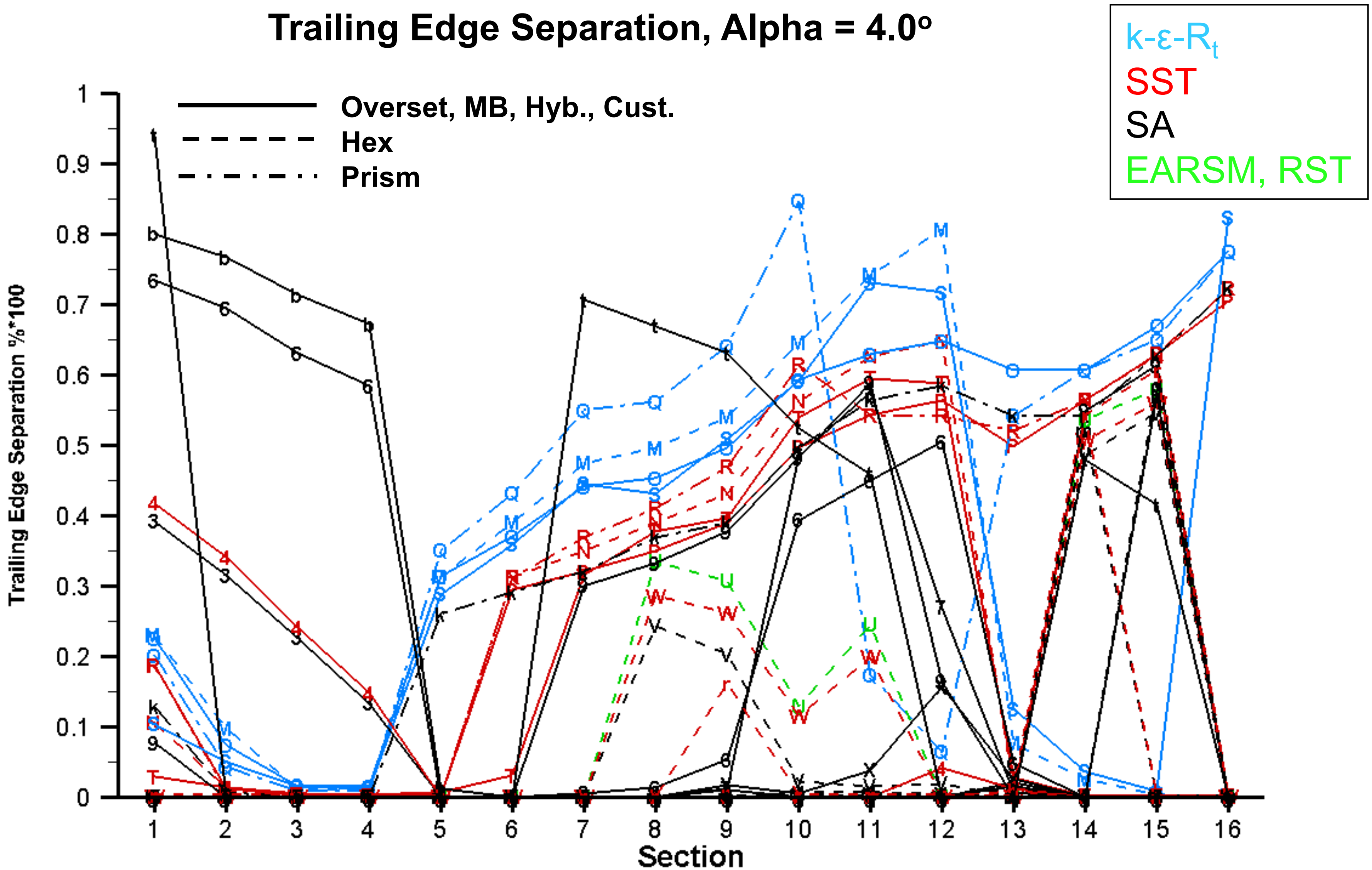
Trailing Edge Separation, Alpha = 3.0°



Trailing Edge Separation, Alpha = 3.5°



Trailing Edge Separation, Alpha = 4.0°



Conclusions from Trailing Edge Separation:

- Case 1:
  - SA, SST show similar small TE sep ≤ 2% between sections 8, …, 14
  - Slightly larger for SST on coarse, medium grids
- Case 2:
  - Trend to extend towards sections 5 & 16 for $\alpha \geq 2.5^{o}$
  - No clear conclusion
- Overall check necessary whether same TE sep identification procedure has been applied

General Conclusions:

- Very successful workshop. **Thank You!**
  - 54 data submittals, many with parametric variations in grid type and/or turbulence model
- Still more variation than desired
  - Some improvement from DPW4: We are getting better
  - Mixed results from common grid study. Discretization and turbulence modeling are still a factor
- Drag comparisons to wind tunnel generally favorable
  - Variations similar between WT and CFD
  - ALPHA and CM_TOT offsets
  - Aeroelasticity

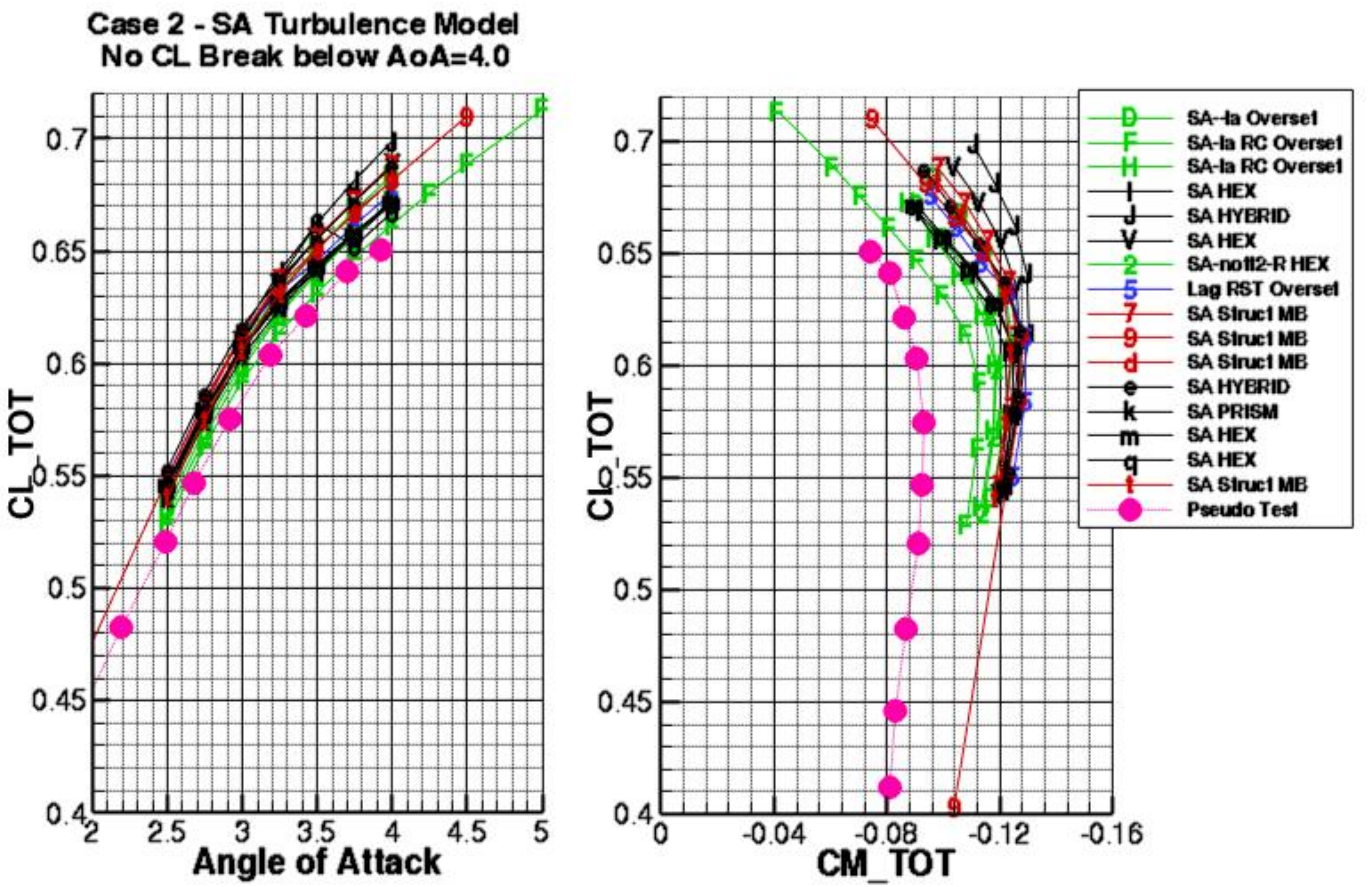
General Conclusions (Cont'd):

- Force/Moment predictions better at α=2.5°
  - Less separation
  - Bigger spread at α=4.0°
- Pressures consistent with Force/Moments
  - Correlation outboard supports aeroelastic effects
  - Wide variation in α for shock separation
- Large variations in separation prediction
  - SOB Separation
  - TE Separation and Buffet onset alpha
  - Is RANS good enough? Is flow steady?

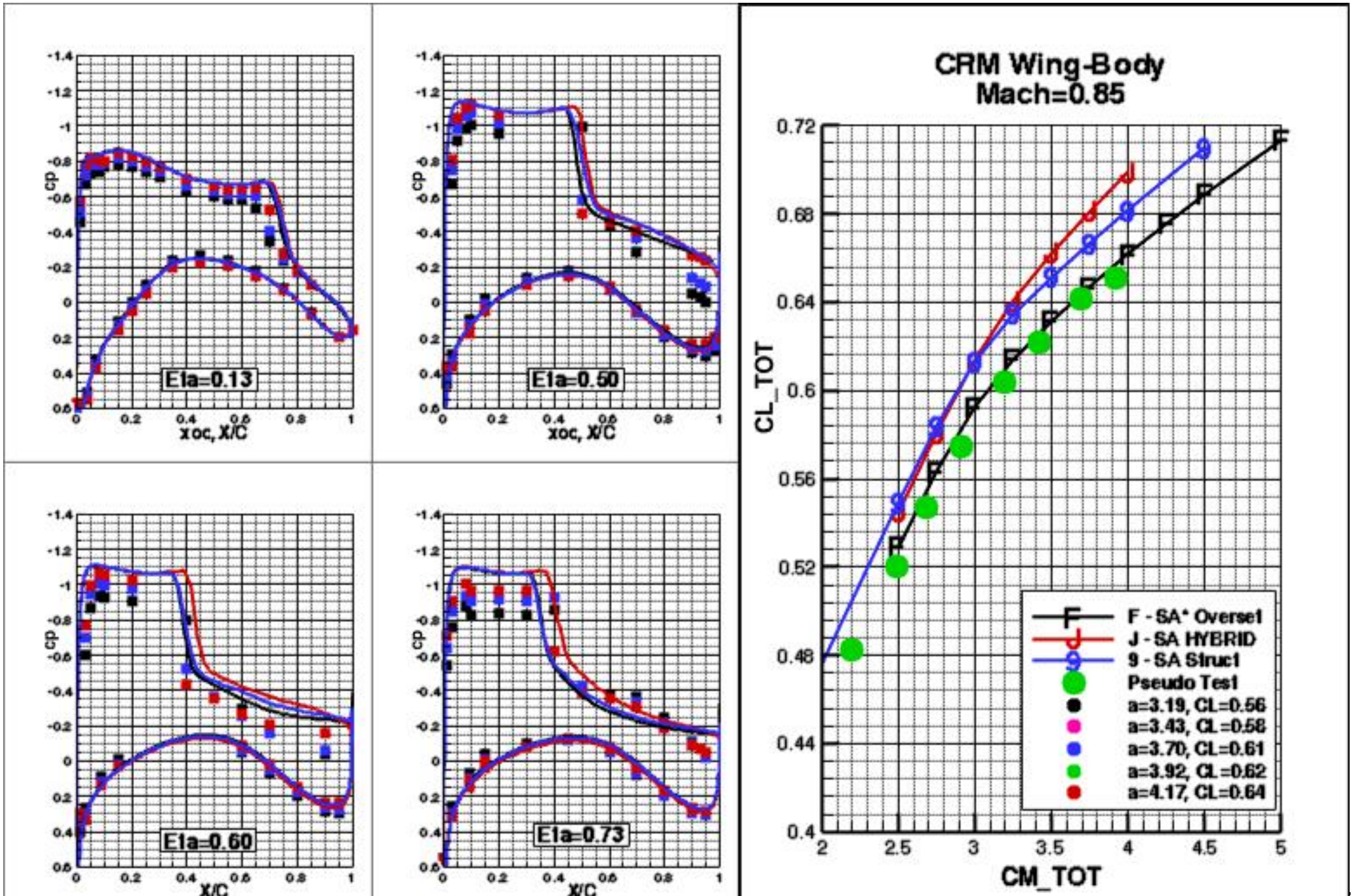
Further Study:

- Check SOB/TE separation with wind tunnel data
  - Is flow visualization data available?
- Include static aeroelastics in CFD
  - Needed to match wind tunnel data
- Include boundary layer transition model
  - Forced/Free
- Unsteady RANS?
  - Will only help if flow is unsteady
- LES/DES?
  - DES only helps for off-body separation
  - LES (beyond current SOA?)

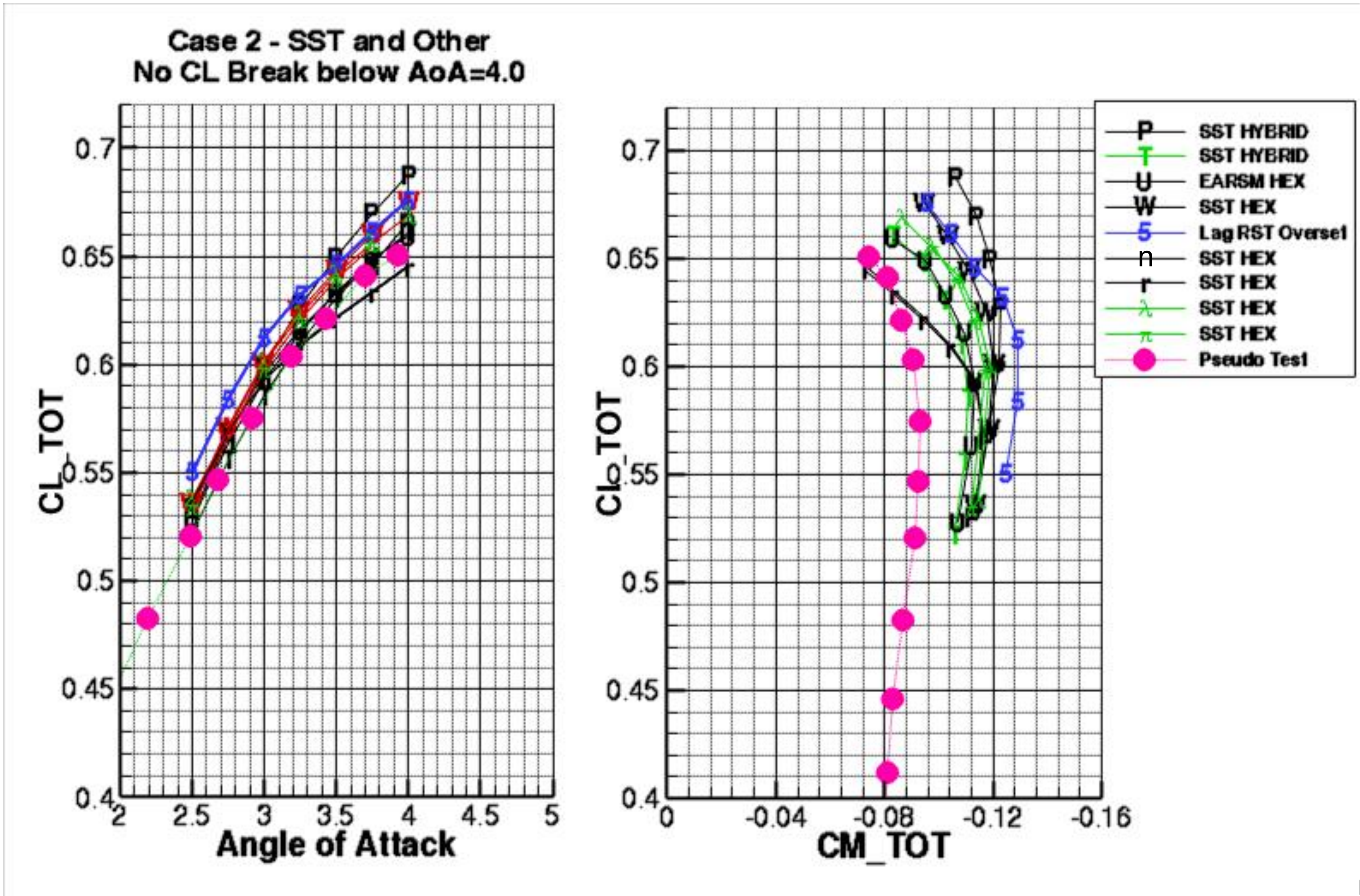
Backup



Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209



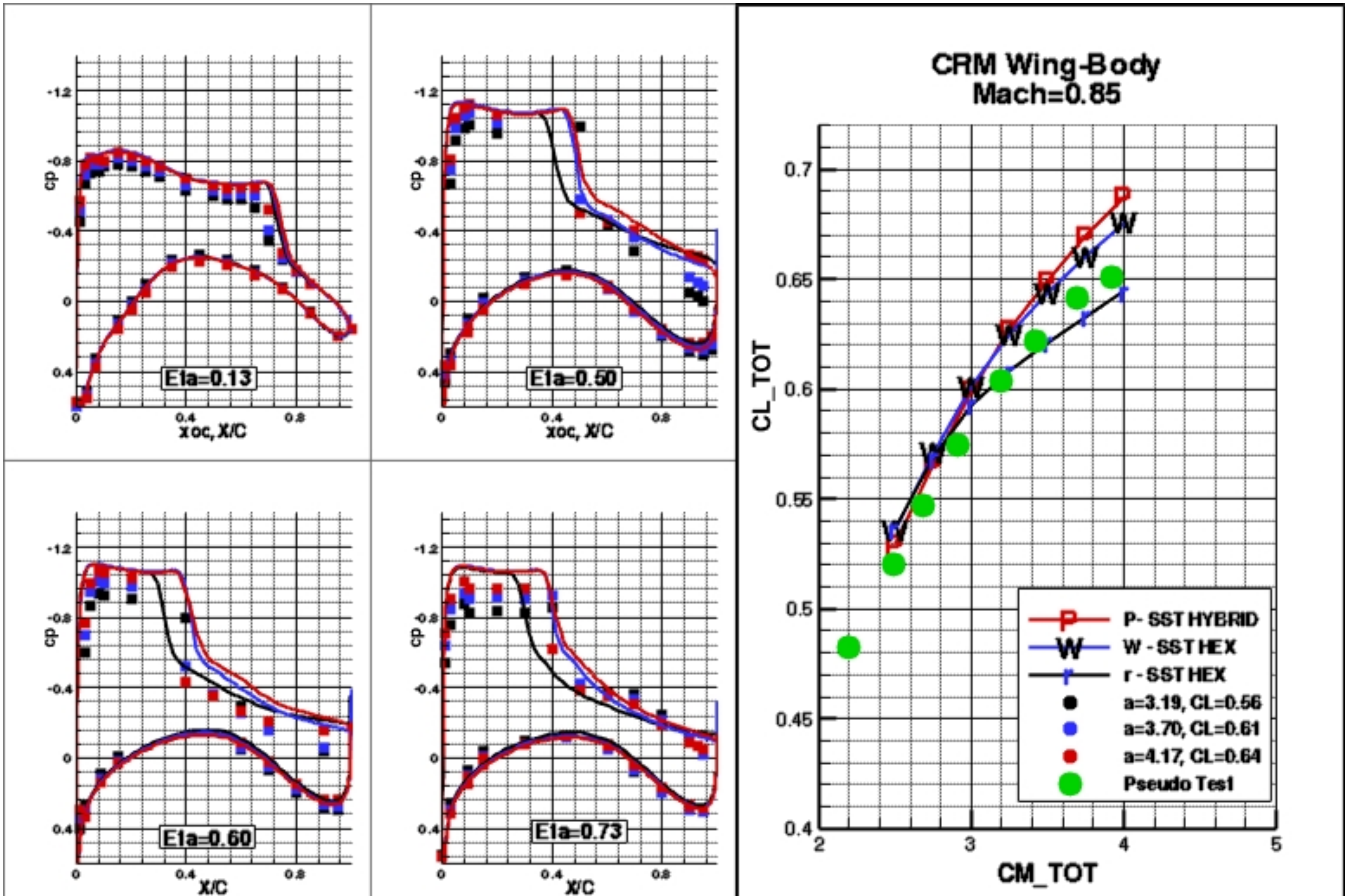
Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209


Case 2 - SST and Other
No CL Break below AoA=4.0
CL_TOT
Angle of Attack
CM_TOT
SST HYBRID
SST HYBRID
EARSM HEX
SST HEX
Lag RST Overset
SST HEX
SST HEX
SST HEX
SST HEX
Pseudo Test

Applied Aerodynamics Technical Committee

5th CFD Drag Prediction Workshop

New Orleans, Louisiana – June 2012



Pseudo Test data based on NTF test data modified by results from AIAA-2012-3209