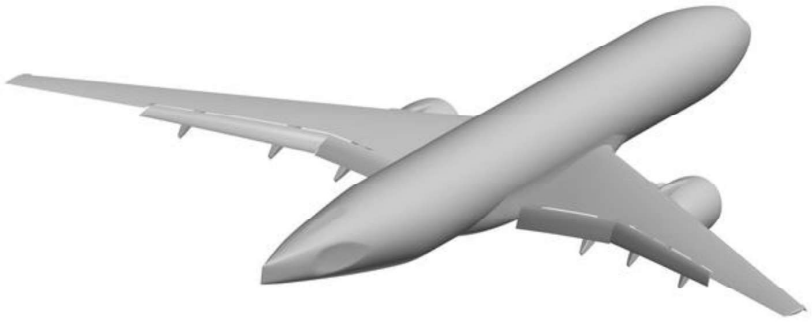
The 54th Fluid Dynamics Conference/ The 40th Aerospace Numerical Simulation Symposium
29th June 2022

APC-8の集計結果

Summary of Eighth Aerodynamics Prediction Challenge (APC-8)

橋本 敦 (JAXA)
Hashimoto Atsushi(JAXA)



Statistics of submitted data

- Organizations and number of submitted data(total 21 data)
  - National research institutes : JAXA(9)
  - Aerospace industry: KHI(8)
  - Vender: Hexagon(1)
  - University: Univ. of Tokyo(3)
- Grid
  - HLPW4 grid generated by MEGG3D: 7
  - HLPW4 gird generated by Pointwise: 2
  - HLPW4 grid generated by ANSA: 2
  - Custom grid: 7
  - TMR提供格子(FAMILY1): 3
- Code
  - Unstructured solver(19)
  - Unstructured Cartesian solver(3)
- Turbulence model
  - SA(21)
- Initial condition
  - Cold start(17) : Calculation from the uniform flow solution
  - Warm start(4) : Calculation from the low angle of attack solution

This document is provided by JAXA.

Participants of Case 1

ID	Name	Organization	Code	Grid (generated by)	Description of the grid	Turbulence Model	Initial Condition
A1	Zauner Markus	JAXA	FaSTAR (Unstructured solver)	HLPW4(MEGG3D)		SA-noft2	Cold start
A2						SA-noft2-R-QCR2000	
A3						SA-noft2	Warm start
A4						SA-noft2-R-QCR2000	
B1	山内優果	KHI	Cflow (Unstructured solver)	HLPW4(MEGG3D)		SA-neg	Uniform flow
B2				HLPW4(Pointwise)	Pointwise grid(1.3.C)		
B3				HLPW4(ANSA)	ANSA(101.C)		
B4				Custom	Orthogonal octree + Body-Fitted layer grid	SA-neg	
B5						SA-R-QCR	
C1	古谷龍太郎	JAXA	TAS (Unstructured solver)	HLPW4(MEGG3D)		SA-noft2-R(Crot=1)	Uniform flow
C2							Low angle of attack
D1	中島吉隆	Hexagon	scFLOW (Unstructured solver)	Custom	Polyhedral mesh generated by scFLOW	SA-neg	Uniform flow
E1	船田雅也	Univ. of Tokyo	UTCart (Unstructured Cartesian solver)	Custom	Hierarchical orthogonal grid(100M)	SA-noft2 +Wall function	Uniform flow
E2					Hierarchical orthogonal grid(200M)		
E3					Hierarchical orthogonal grid(400M)		

3

Participants of Cases 3 and 4

Case 3

ID	Name	Organization	Code	Grid (generated by)	Description of the grid	Turbulence Model	Initial Condition
B6	山内優果	KHI	Cflow (Unstructured solver)	HLPW4(ANSA)	ANSA(101_43/40.C)	SA-neg	Uniform flow
B7				Custom	Orthogonal octree + Body-Fitted layer grid		
C3	古谷龍太郎	JAXA	TAS (Unstructured solver)	HLPW4(Pointwise)	Pointwise-Smoothed grid(2.2-Pointwise-Unstr-PrismTet-V2_43/40)	SA-noft2-R(Crot=1)	Low angle of attack

Case 4

ID	Name	Organization	Code	Grid	Description of the grid	Turbulence Model	Initial Condition
B8	山内優果	KHI	Cflow (Unstructured solver)	TMR提供格子 (FAMILY1)		SA-neg	Uniform flow
C4	古谷龍太郎	JAXA	TAS (Unstructured solver)	TMR提供格子 (FAMILY1)		SA-noft2-R(Crot=1)	Uniform flow
C5						SA	

4

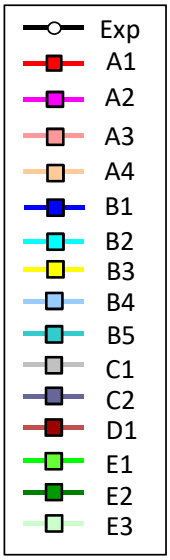
This document is provided by JAXA.

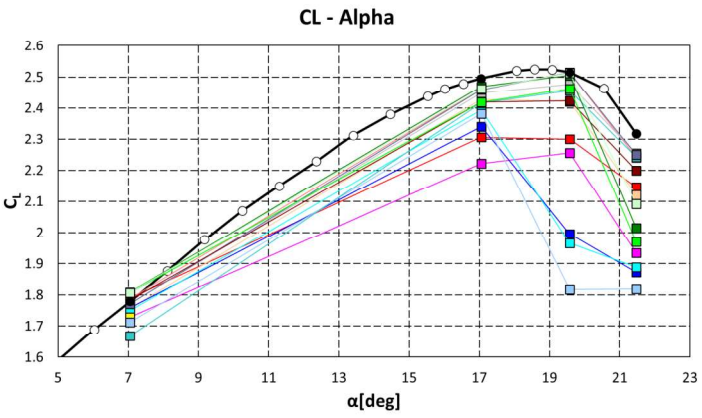
Case 1 : Steady computation

- Conditions
  - 3D CRM-HL flap angle : 40°/37°(inboard/outboard)
  - M = 0.2, Re = 5.49 x 10^6 (C_{ref} = 275.8inches), T_{ref} = 521°R
  - AoA = 7.05, 17.05, 19.57, 21.47deg

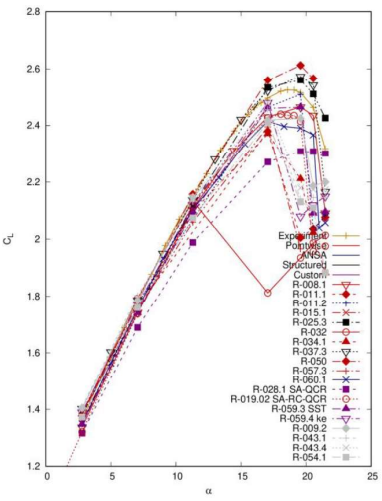
5

CL-Alpha, Case 1





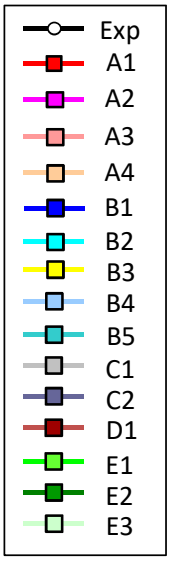
HLPW4
All Best-Practice Results
(03_GMGW3_HLPW4_RANS.pdf, p.17)

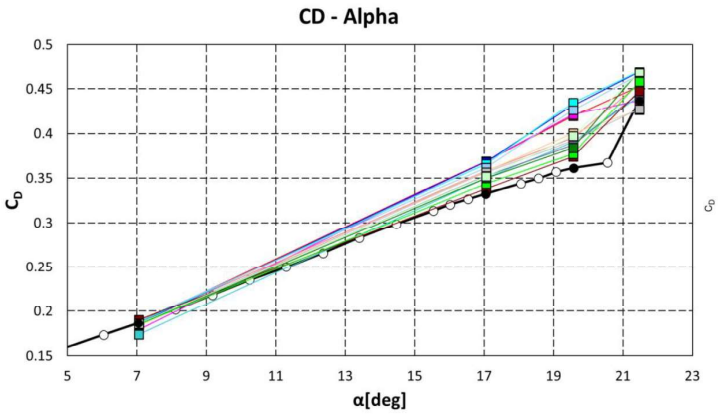


6

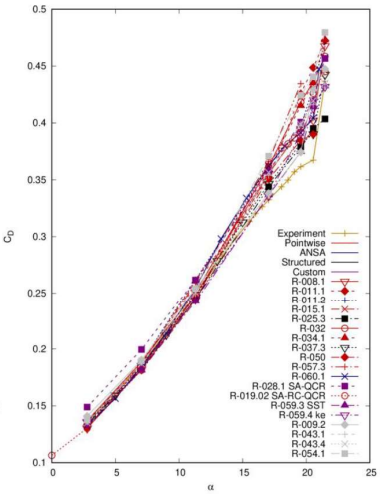
This document is provided by JAXA.

CD-Alpha, Case 1



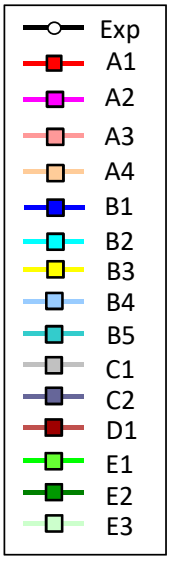


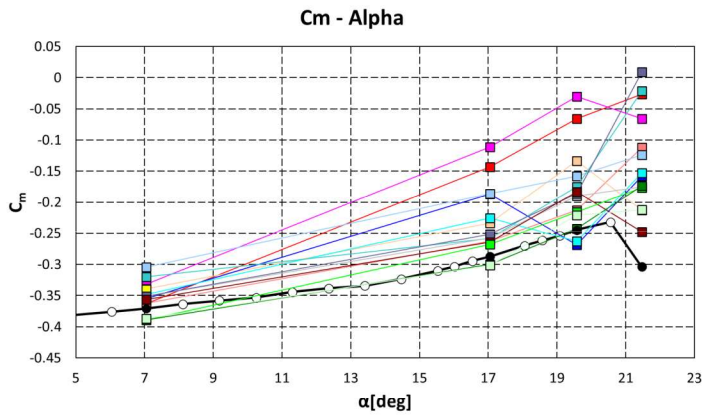
HLPW4
All Best-Practice Results
（03_GMGW3_HLPW4_RANS.pdf, p.17）



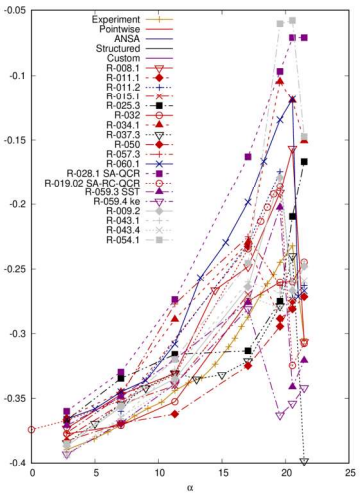
7

Cm-Alpha, Case 1





HLPW4
All Best-Practice Results
（03_GMGW3_HLPW4_RANS.pdf, p.17）

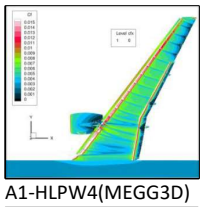


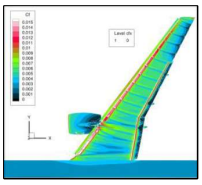
8

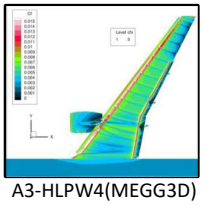
This document is provided by JAXA.

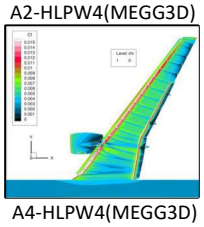
Surface Cf Contours（Case 1, 7.05deg, Viewpoint 1）

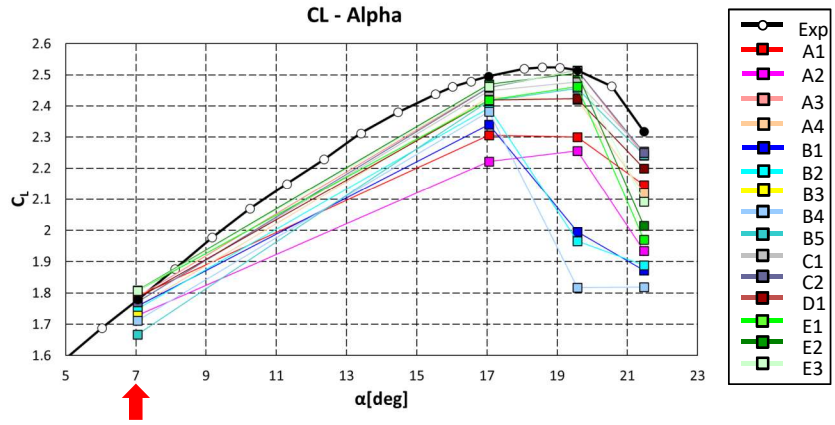
ID-Grid(generated by)

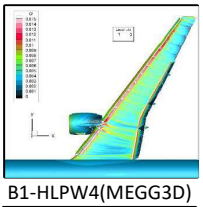

A1-HLPW4(MEGG3D)

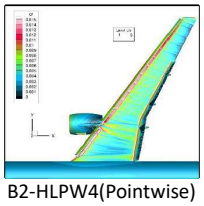

A2-HLPW4(MEGG3D)

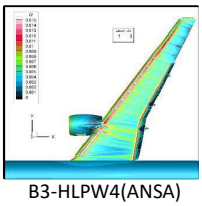

A3-HLPW4(MEGG3D)

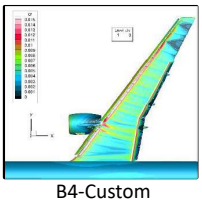

A4-HLPW4(MEGG3D)

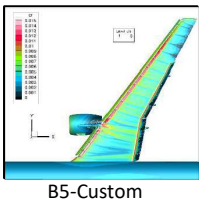


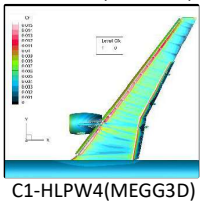

B1-HLPW4(MEGG3D)

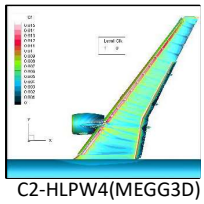

B2-HLPW4(Pointwise)

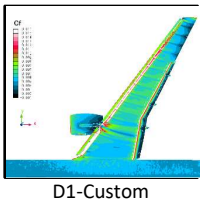

B3-HLPW4(ANSA)

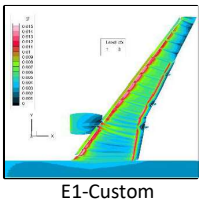

B4-Custom

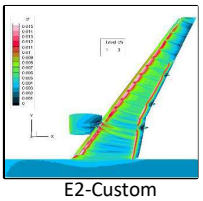

B5-Custom

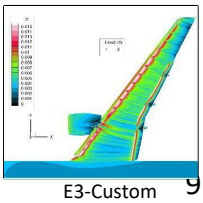

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

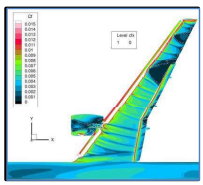

E2-Custom

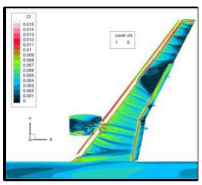

E3-Custom

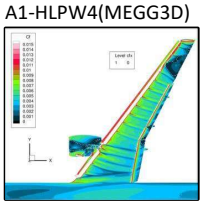
9

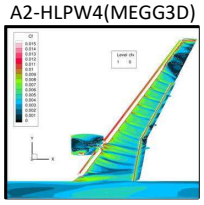
Surface Cf Contours（Case 1, 17.05deg, Viewpoint 1）

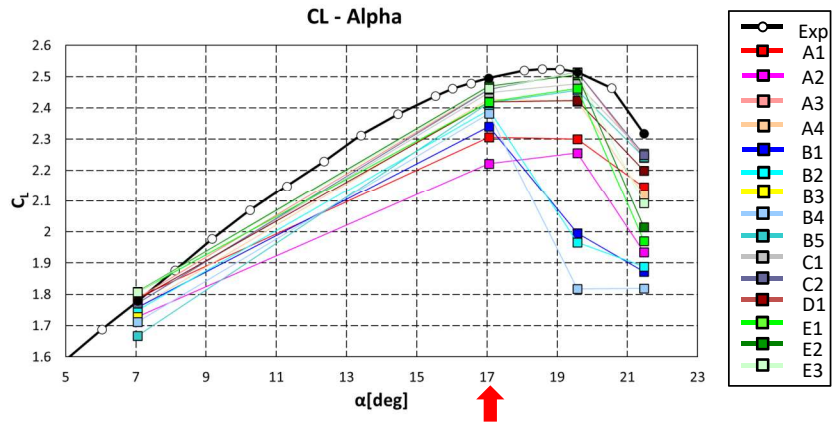
ID-Grid(generated by)

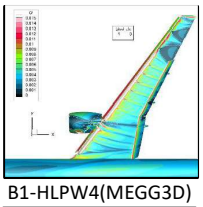

A1-HLPW4(MEGG3D)

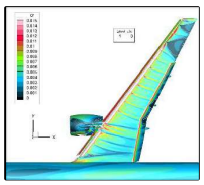

A2-HLPW4(MEGG3D)

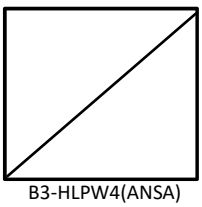

A3-HLPW4(MEGG3D)

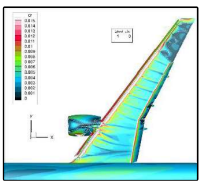

A4-HLPW4(MEGG3D)

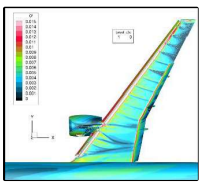


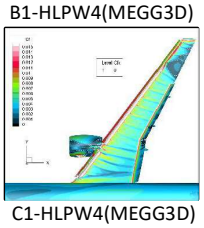

B1-HLPW4(MEGG3D)

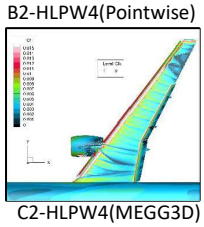

B2-HLPW4(Pointwise)

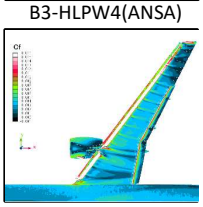

B3-HLPW4(ANSA)

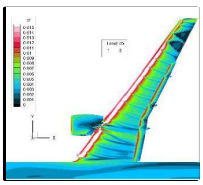

B4-Custom

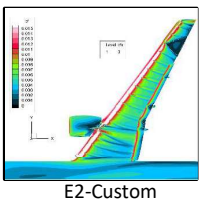

B5-Custom

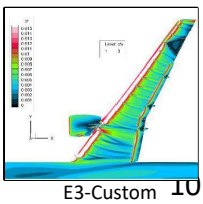

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

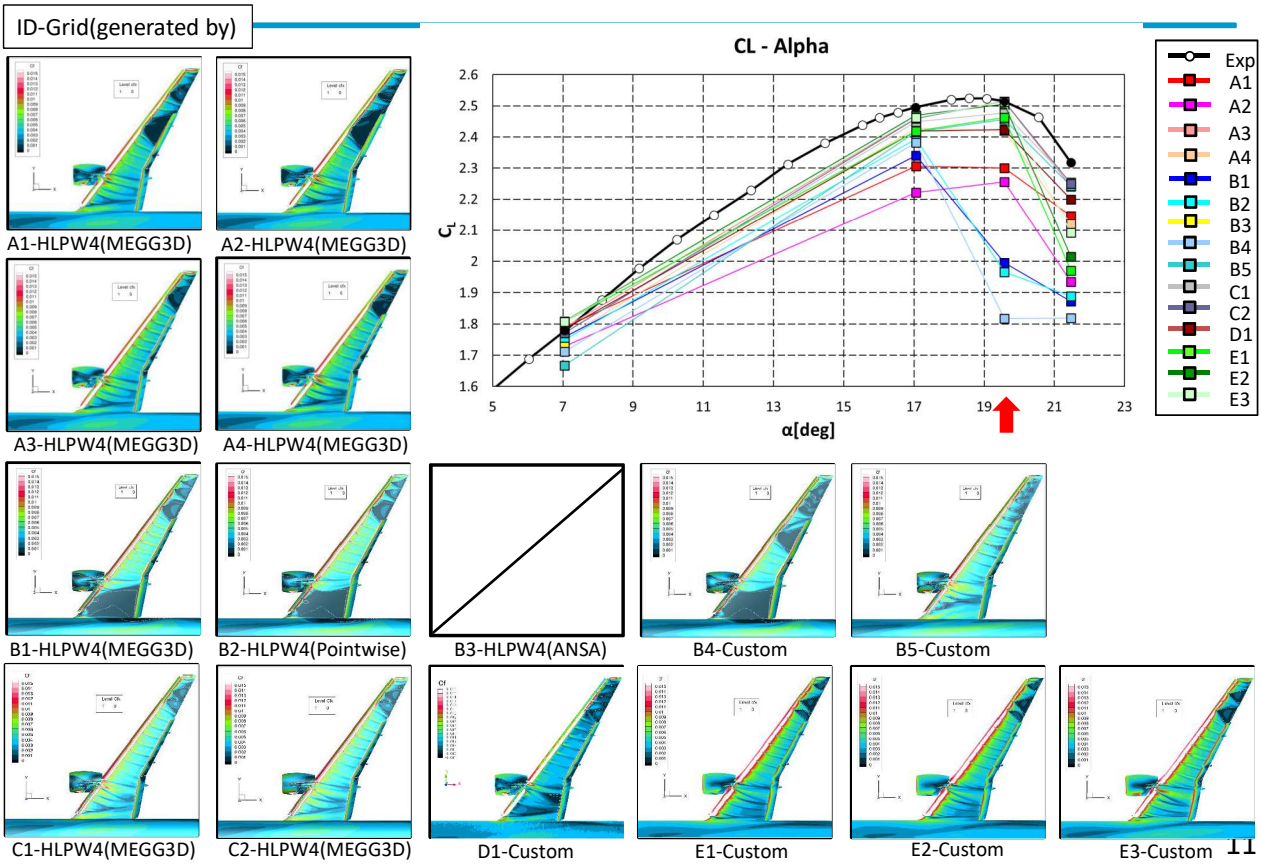

E2-Custom


E3-Custom

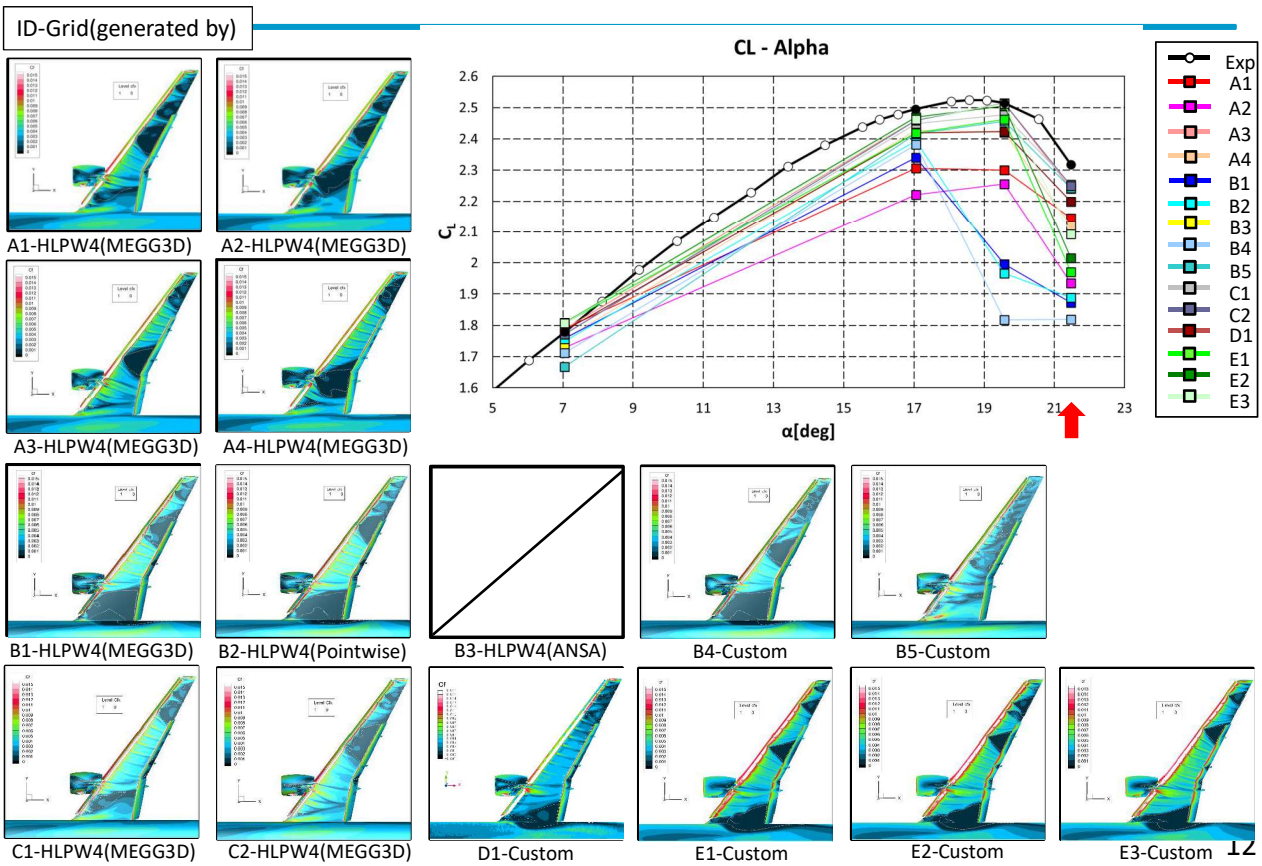
10

This document is provided by JAXA.

Surface Cf Contours（Case 1, 19.57deg, Viewpoint 1）



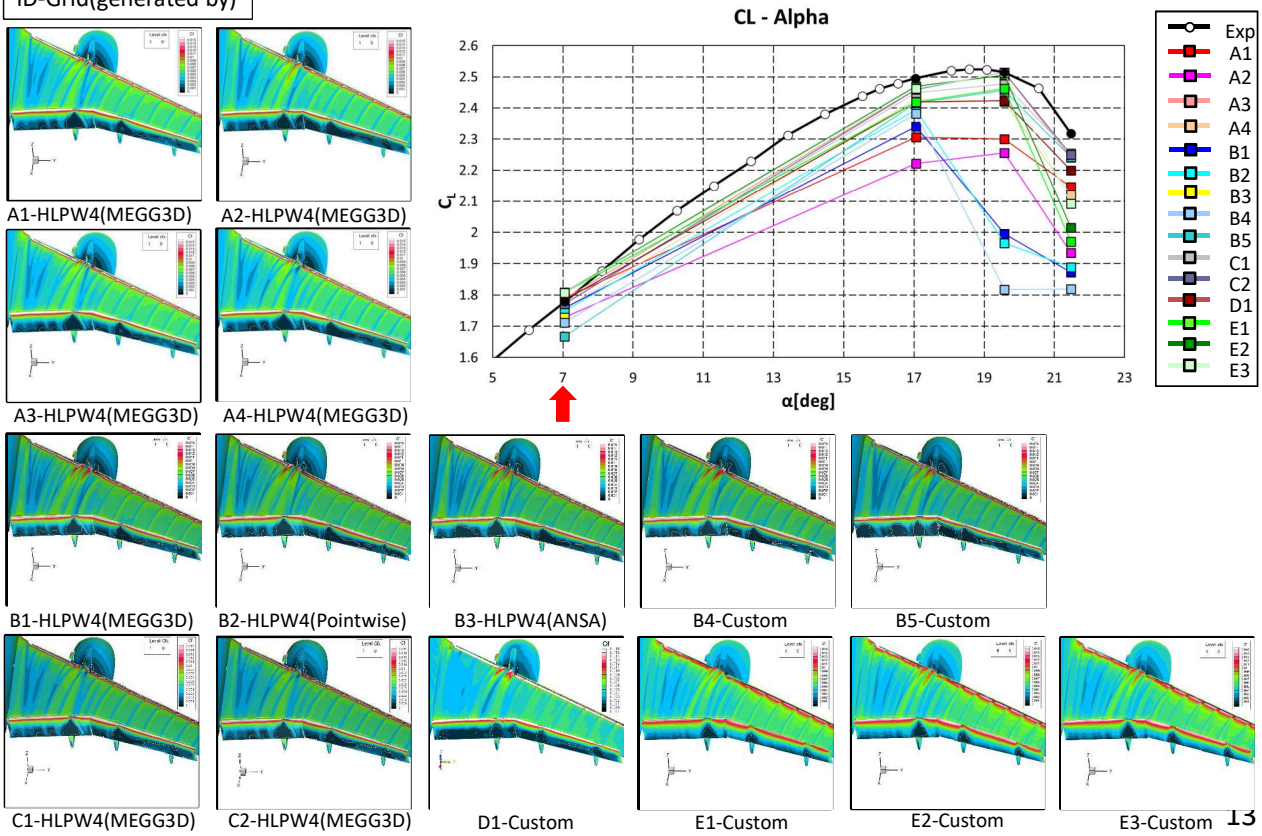
Surface Cf Contours（Case 1, 21.47deg, Viewpoint 1）



This document is provided by JAXA.

Surface Cf Contours（Case 1, 7.05deg, Viewpoint 2）

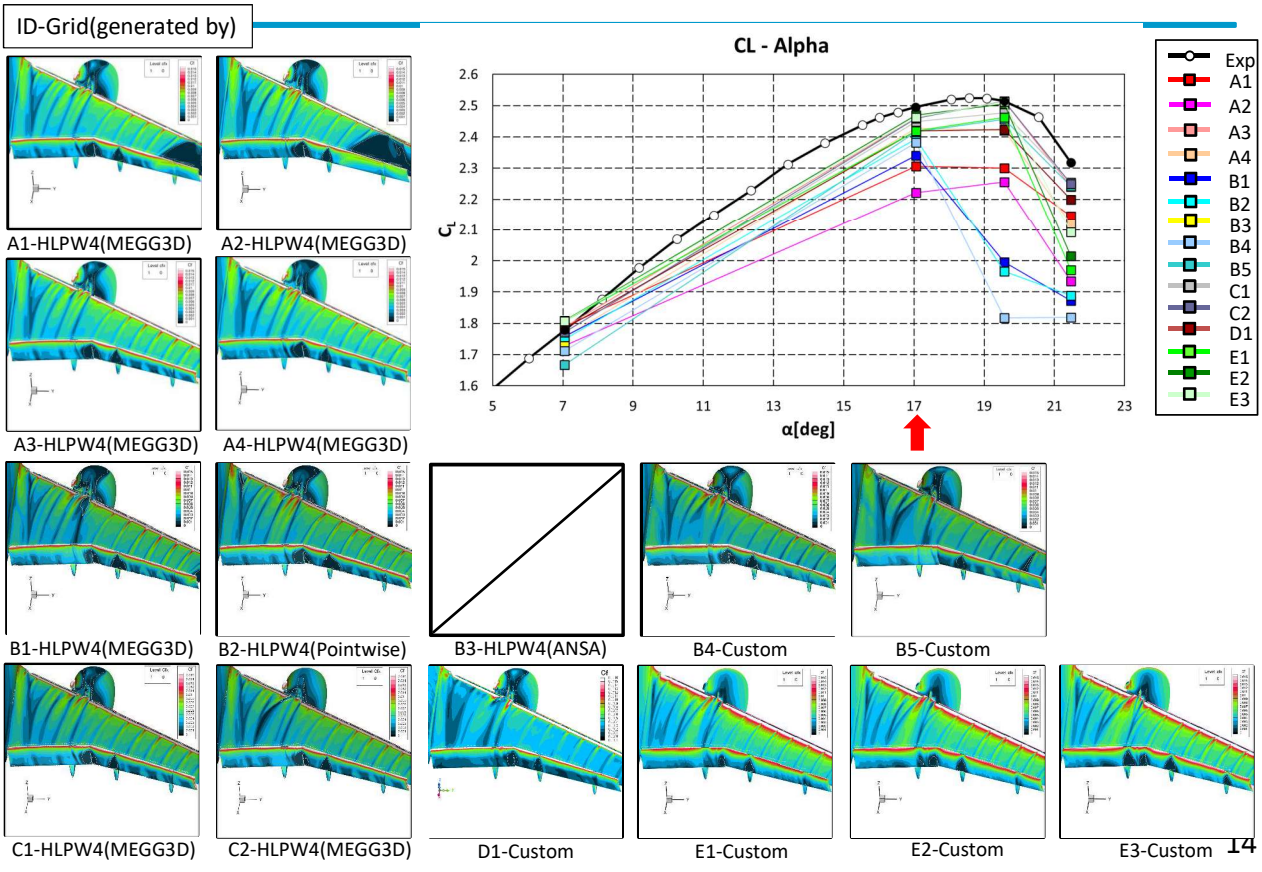
ID-Grid(generated by)



13

Surface Cf Contours（Case 1, 17.05deg, Viewpoint 2）

ID-Grid(generated by)

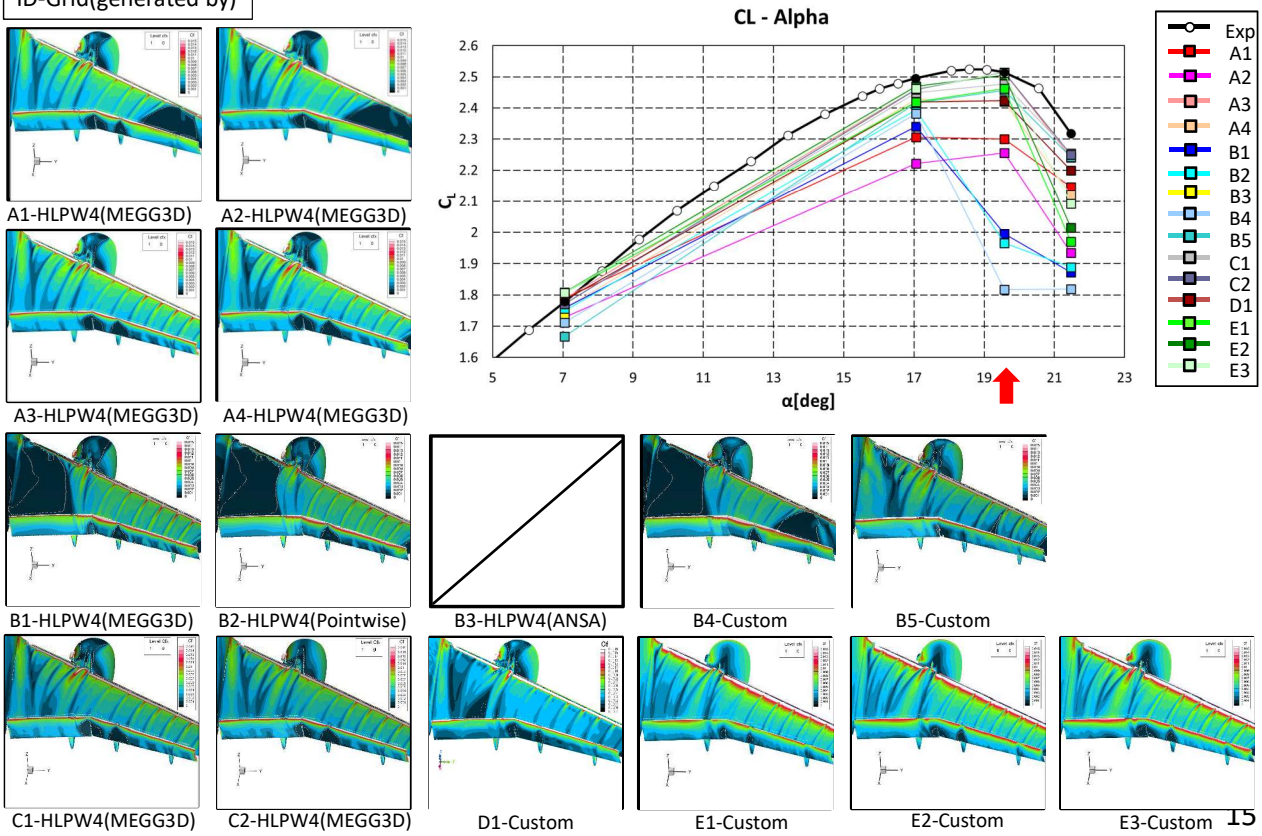


14

This document is provided by JAXA.

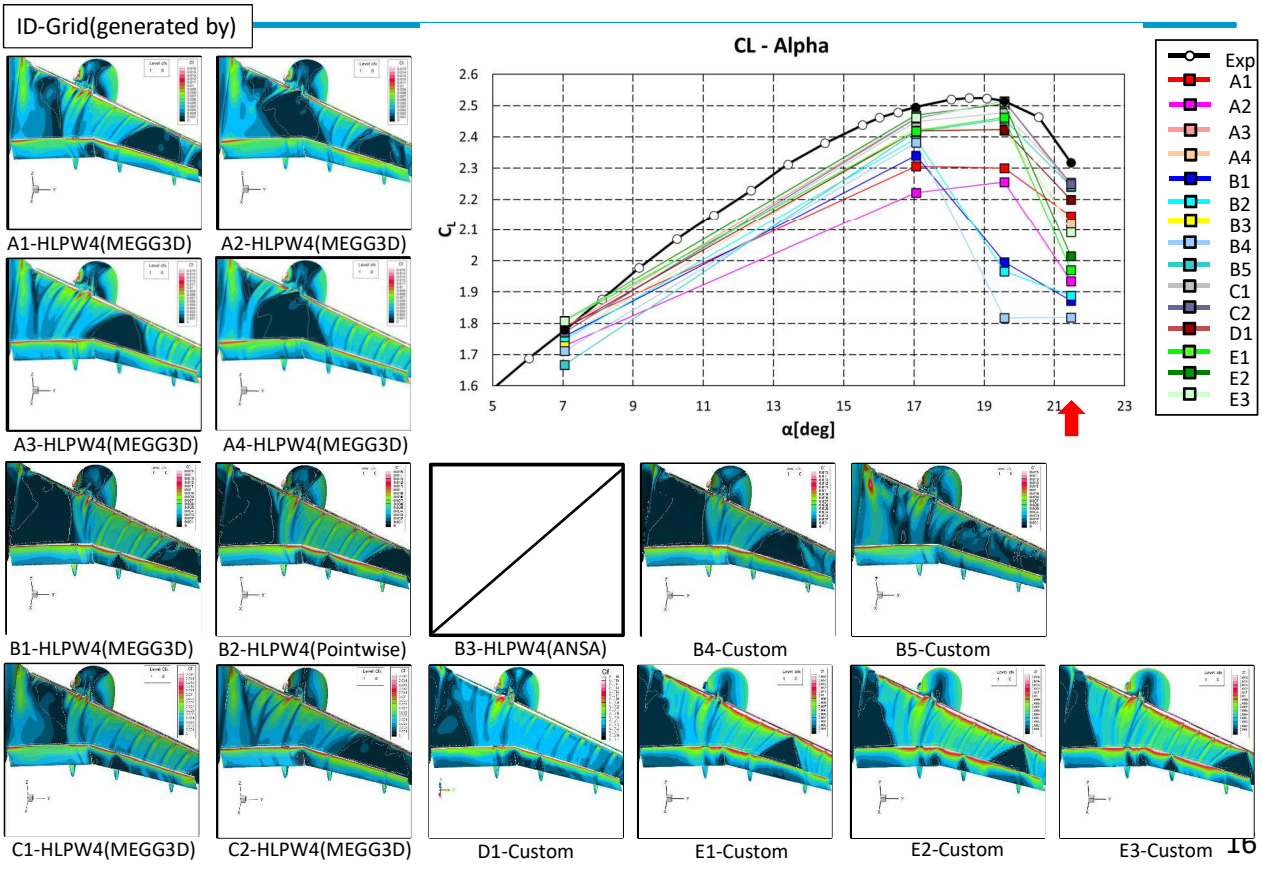
Surface Cf Contours（Case 1, 19.57deg, Viewpoint 2）

ID-Grid(generated by)



Surface Cf Contours（Case 1, 21.47deg, Viewpoint 2）

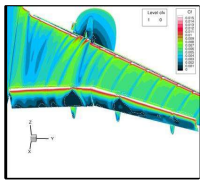
ID-Grid(generated by)

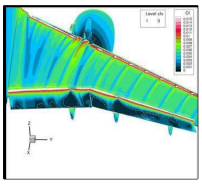


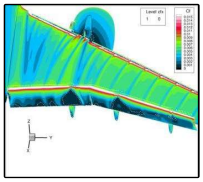
This document is provided by JAXA.

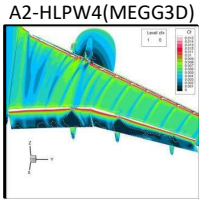
Surface Cf Contours（Case 1, 7.05deg, Viewpoint 2）

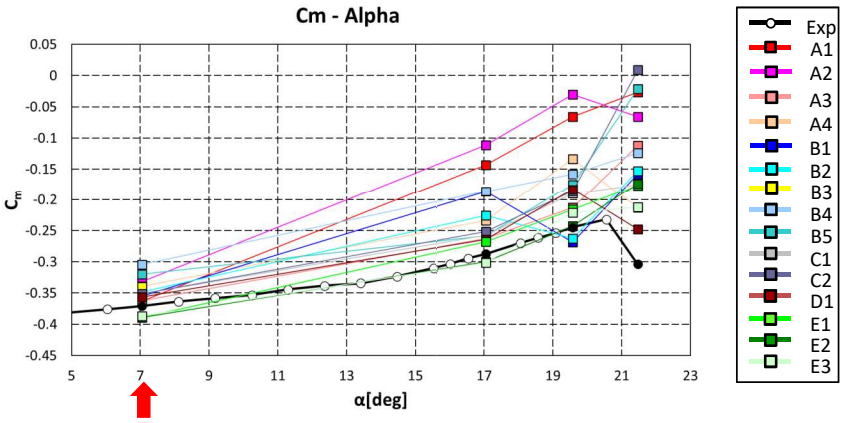
ID-Grid(generated by)

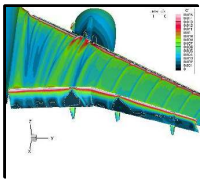

A1-HLPW4(MEGG3D)

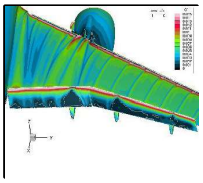

A2-HLPW4(MEGG3D)

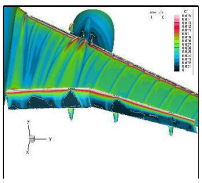

A3-HLPW4(MEGG3D)

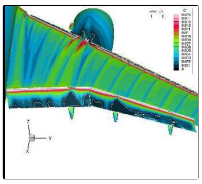

A4-HLPW4(MEGG3D)

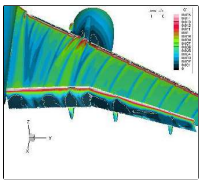


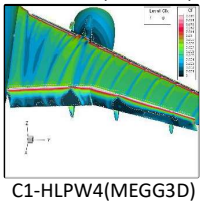

B1-HLPW4(MEGG3D)

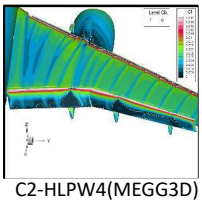

B2-HLPW4(Pointwise)

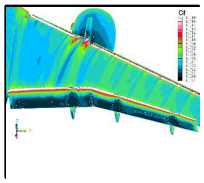

B3-HLPW4(ANSA)

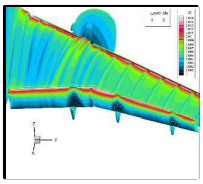

B4-Custom

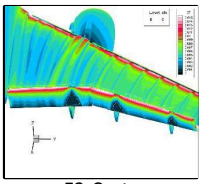

B5-Custom

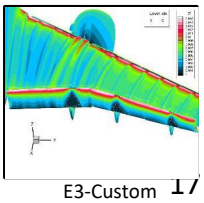

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

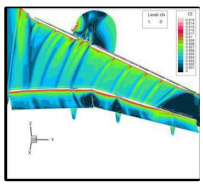

E2-Custom

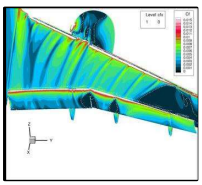

E3-Custom

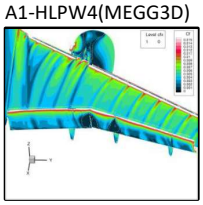
17

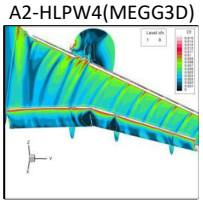
Surface Cf Contours（Case 1, 17.05deg, Viewpoint 2）

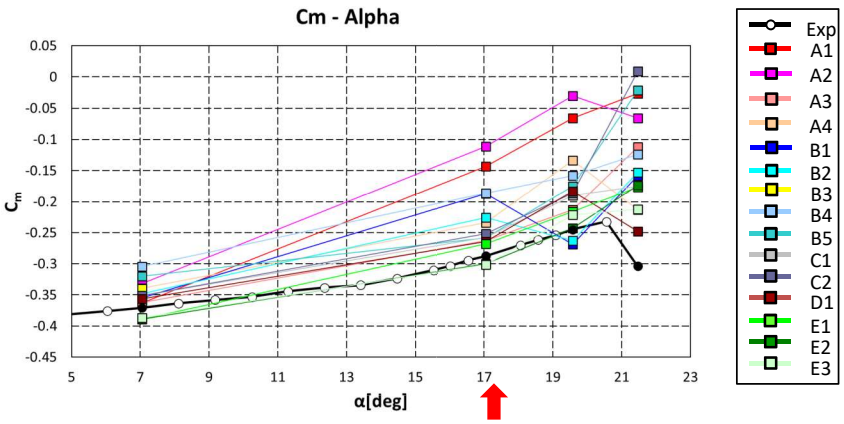
ID-Grid(generated by)

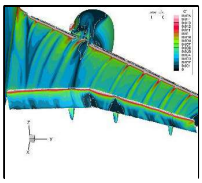

A1-HLPW4(MEGG3D)

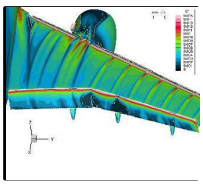

A2-HLPW4(MEGG3D)

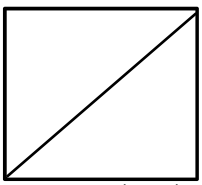

A3-HLPW4(MEGG3D)

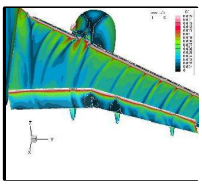

A4-HLPW4(MEGG3D)

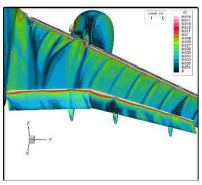


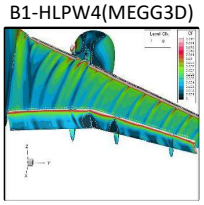

B1-HLPW4(MEGG3D)

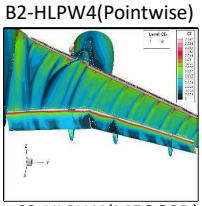

B2-HLPW4(Pointwise)

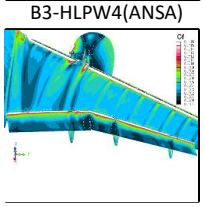

B3-HLPW4(ANSA)

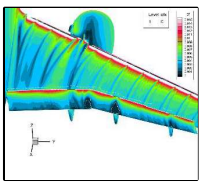

B4-Custom

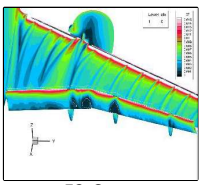

B5-Custom

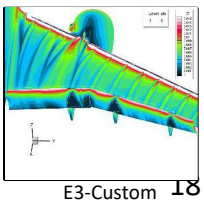

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom


E2-Custom

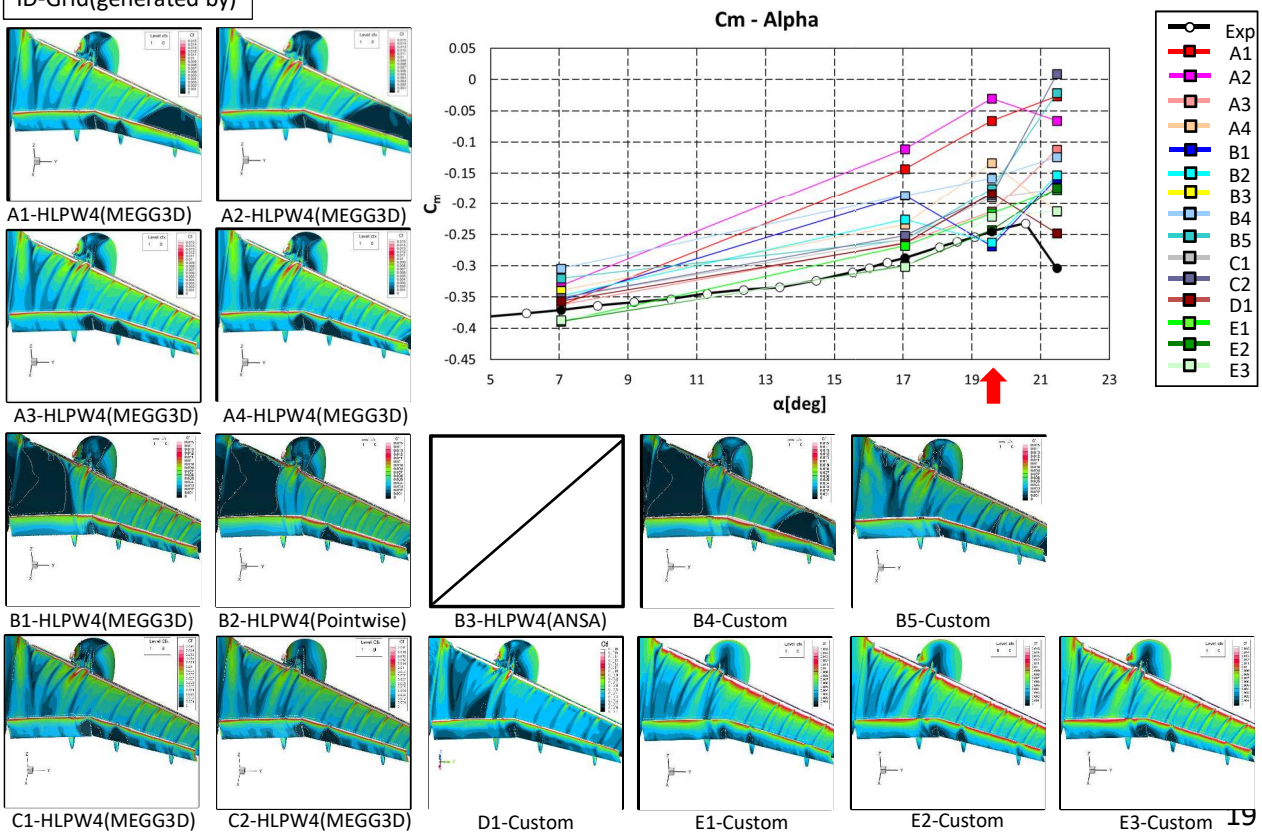

E3-Custom

18

This document is provided by JAXA.

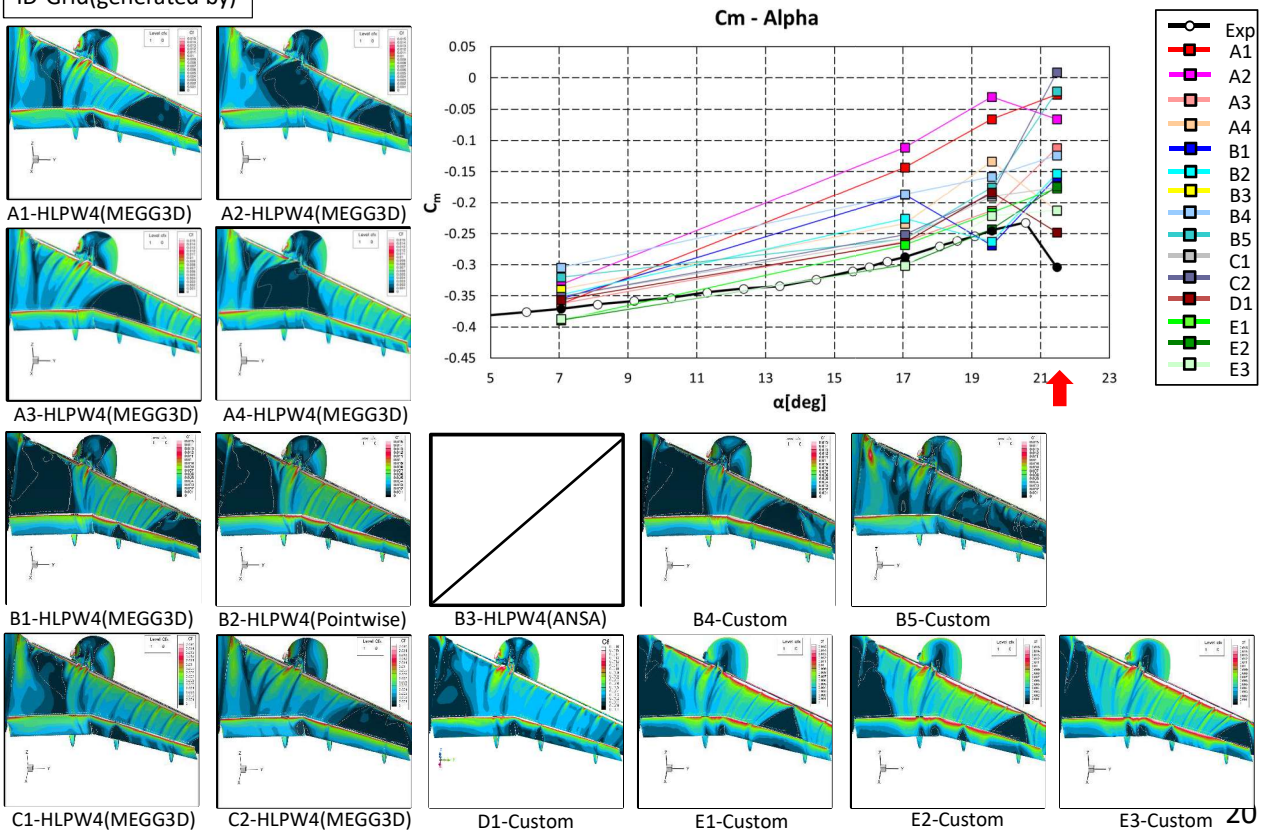
Surface Cf Contours（Case 1, 19.57deg, Viewpoint 2）

ID-Grid(generated by)



Surface Cf Contours（Case 1, 21.47deg, Viewpoint 2）

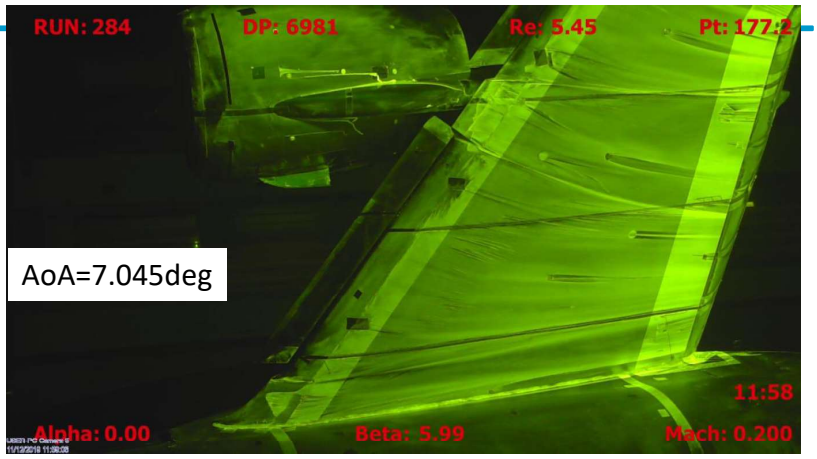
ID-Grid(generated by)

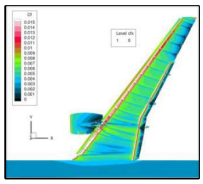


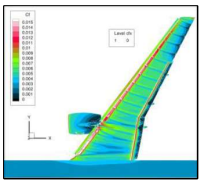
This document is provided by JAXA.

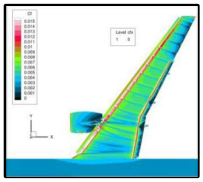
Surface Cf Contours (Case 1, 7.05deg, Viewpoint 1)

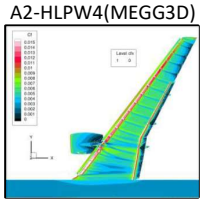
ID-Grid(generated by)

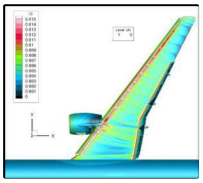


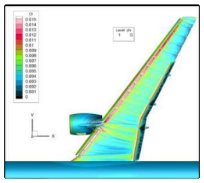

A1-HLPW4(MEGG3D)

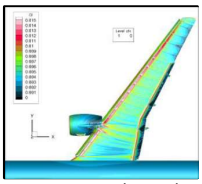

A2-HLPW4(MEGG3D)

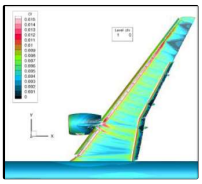

A3-HLPW4(MEGG3D)

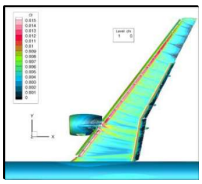

A4-HLPW4(MEGG3D)

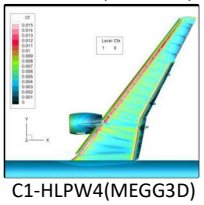

B1-HLPW4(MEGG3D)

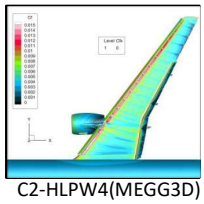

B2-HLPW4(Pointwise)

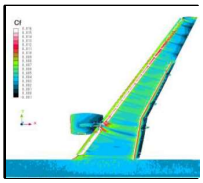

B3-HLPW4(ANSA)

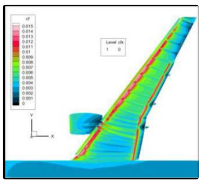

B4-Custom

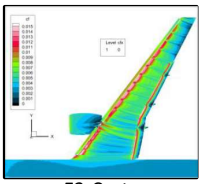

B5-Custom

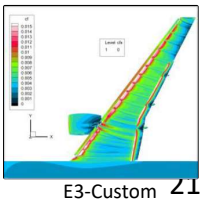

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom

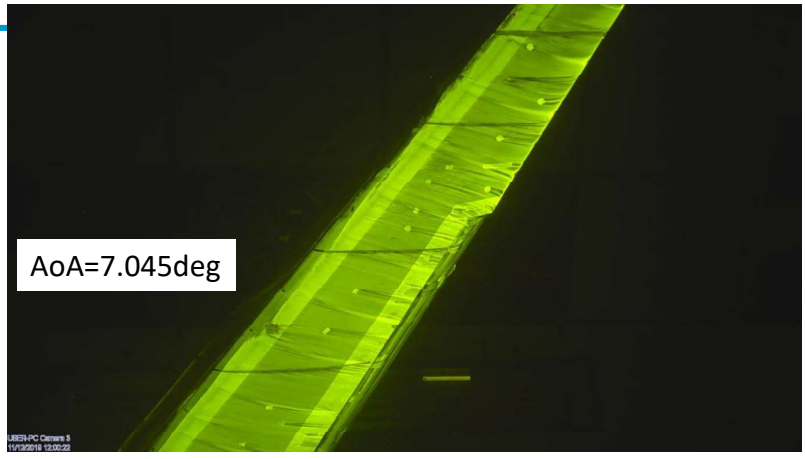

E1-Custom

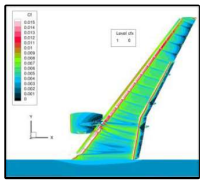

E2-Custom

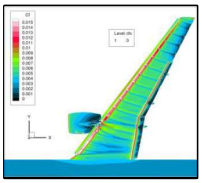

E3-Custom

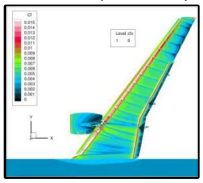
Surface Cf Contours (Case 1, 7.05deg, Viewpoint 1)

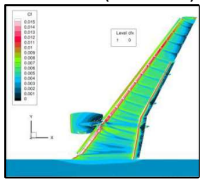
ID-Grid(generated by)

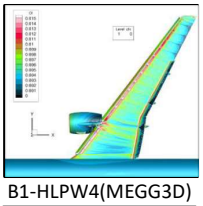


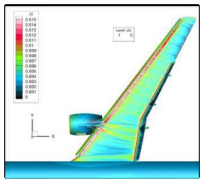

A1-HLPW4(MEGG3D)

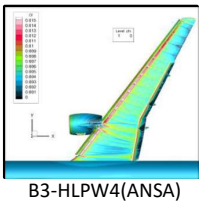

A2-HLPW4(MEGG3D)

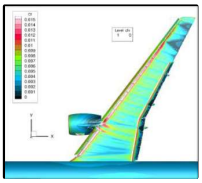

A3-HLPW4(MEGG3D)

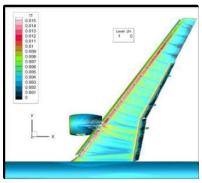

A4-HLPW4(MEGG3D)

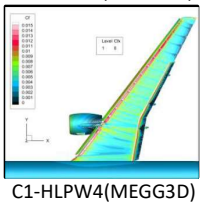

B1-HLPW4(MEGG3D)

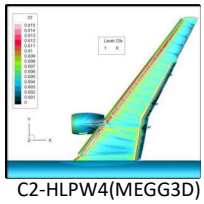

B2-HLPW4(Pointwise)

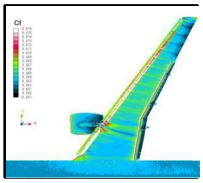

B3-HLPW4(ANSA)

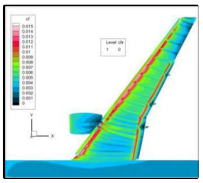

B4-Custom

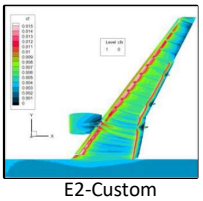

B5-Custom

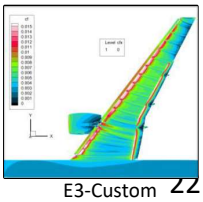

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

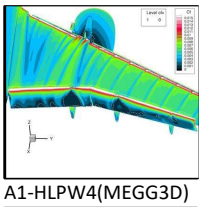

E2-Custom

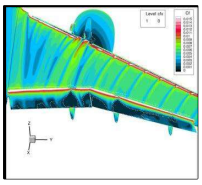

E3-Custom

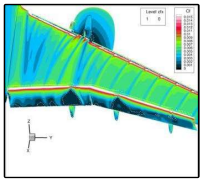
This document is provided by JAXA.

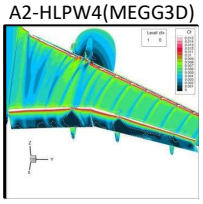
Surface Cf Contours（Case 1, 7.05deg, Viewpoint 2）

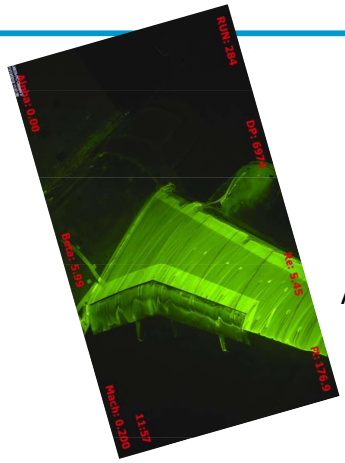
ID-Grid(generated by)


A1-HLPW4(MEGG3D)

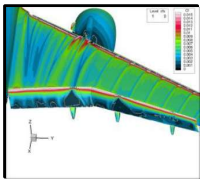

A2-HLPW4(MEGG3D)

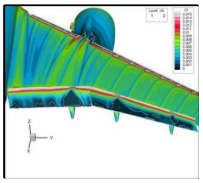

A3-HLPW4(MEGG3D)

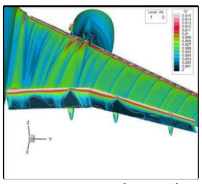

A4-HLPW4(MEGG3D)

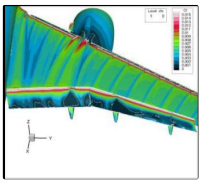


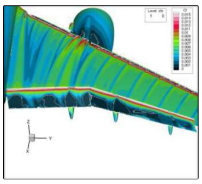
AoA=7.045deg

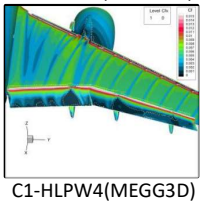

B1-HLPW4(MEGG3D)

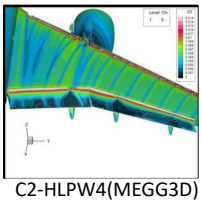

B2-HLPW4(Pointwise)

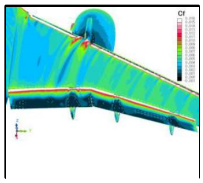

B3-HLPW4(ANSA)

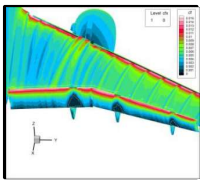

B4-Custom

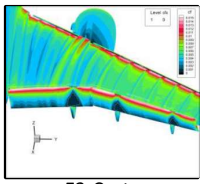

B5-Custom

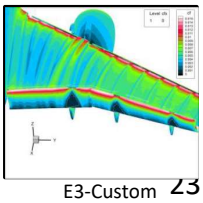

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom

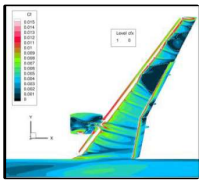

E1-Custom

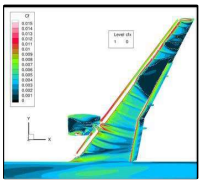

E2-Custom

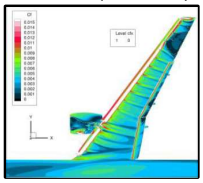

E3-Custom

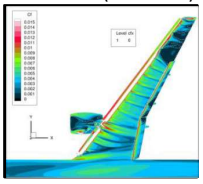
Surface Cf Contours（Case 1, 19.57deg, Viewpoint 1）

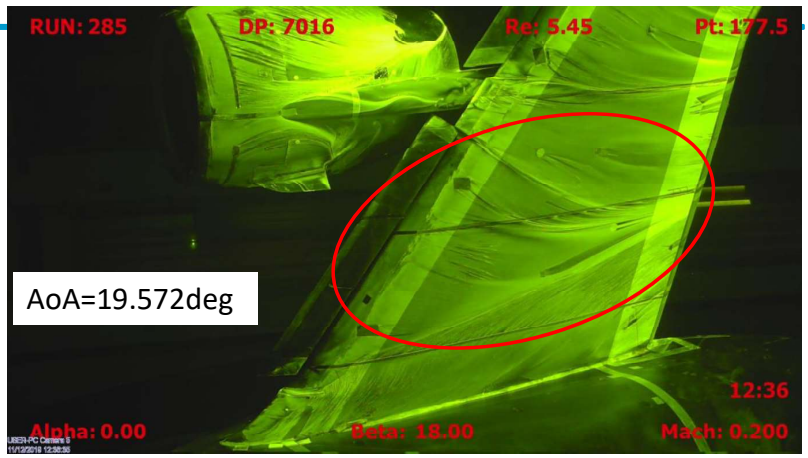
ID-Grid(generated by)

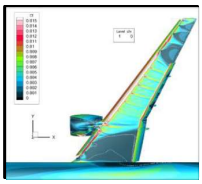

A1-HLPW4(MEGG3D)

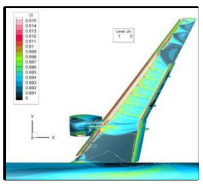

A2-HLPW4(MEGG3D)

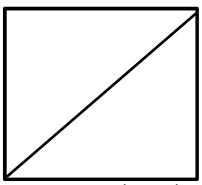

A3-HLPW4(MEGG3D)

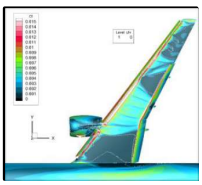

A4-HLPW4(MEGG3D)

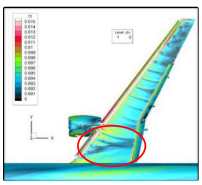


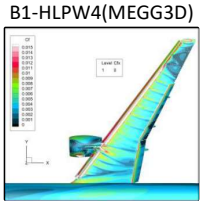

B1-HLPW4(MEGG3D)

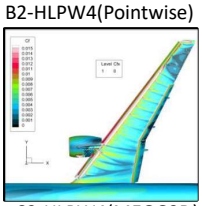

B2-HLPW4(Pointwise)

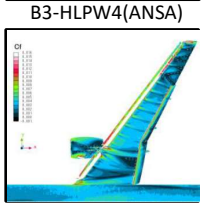

B3-HLPW4(ANSA)

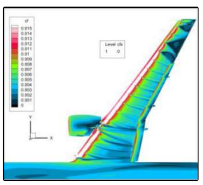

B4-Custom

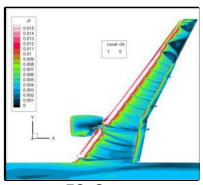

B5-Custom

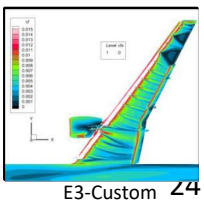

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

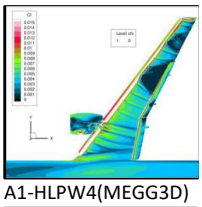

E2-Custom

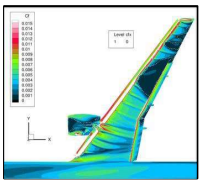

E3-Custom

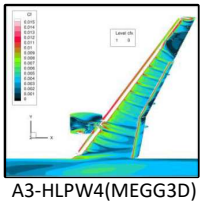
This document is provided by JAXA.

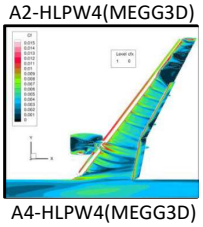
Surface Cf Contours (Case 1, 19.57deg, Viewpoint 1)

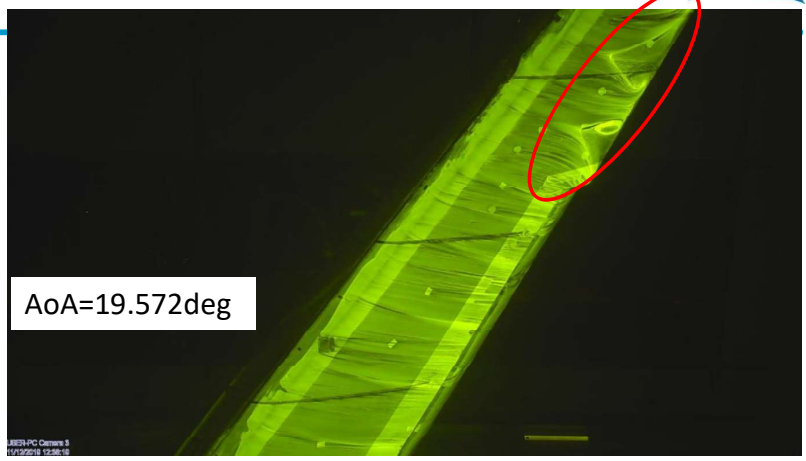
ID-Grid(generated by)

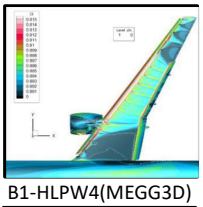

A1-HLPW4(MEGG3D)

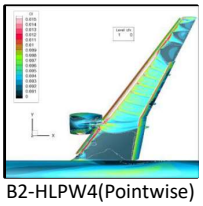

A2-HLPW4(MEGG3D)

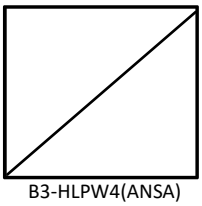

A3-HLPW4(MEGG3D)

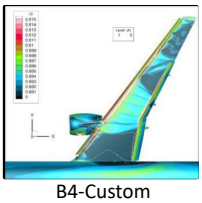

A4-HLPW4(MEGG3D)

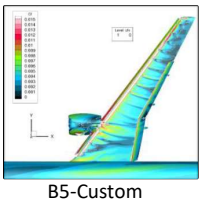


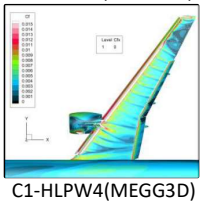

B1-HLPW4(MEGG3D)

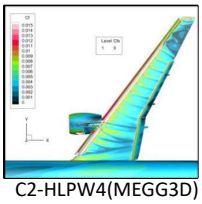

B2-HLPW4(Pointwise)

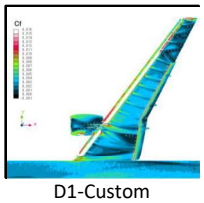

B3-HLPW4(ANSA)

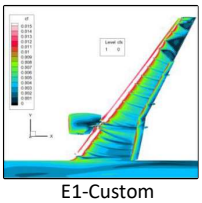

B4-Custom

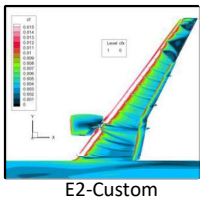

B5-Custom

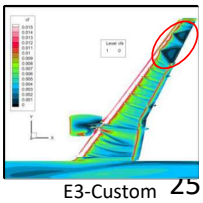

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

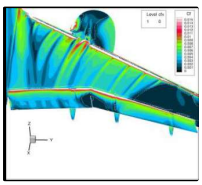

E2-Custom

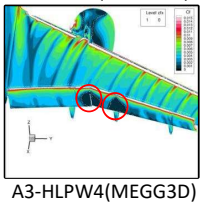

E3-Custom

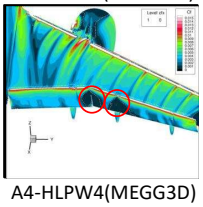
Surface Cf Contours (Case 1, 19.57deg, Viewpoint 2)

ID-Grid(generated by)

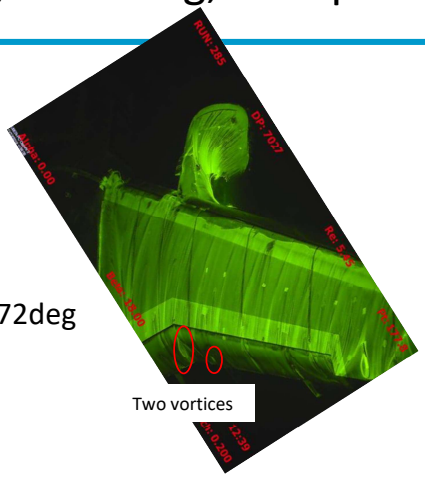
A1-HLPW4(MEGG3D)

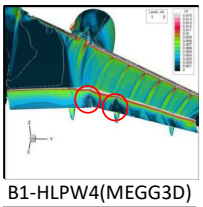

A2-HLPW4(MEGG3D)

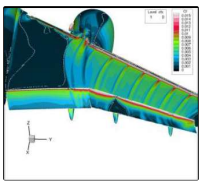

A3-HLPW4(MEGG3D)

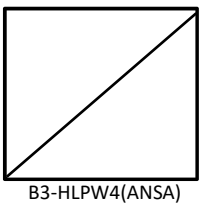

A4-HLPW4(MEGG3D)

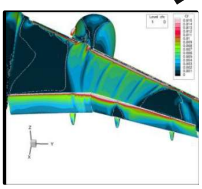
AoA=19.572deg

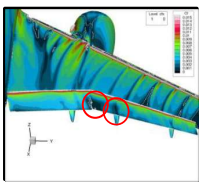


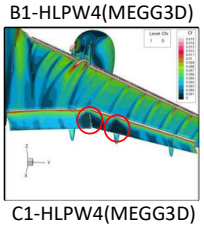

B1-HLPW4(MEGG3D)

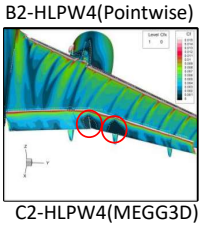

B2-HLPW4(Pointwise)

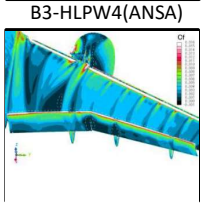

B3-HLPW4(ANSA)

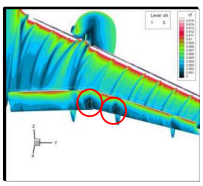

B4-Custom

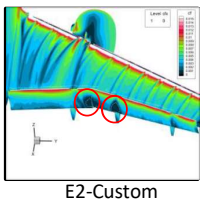

B5-Custom

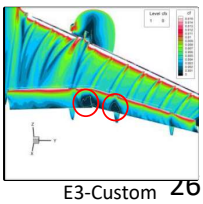

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

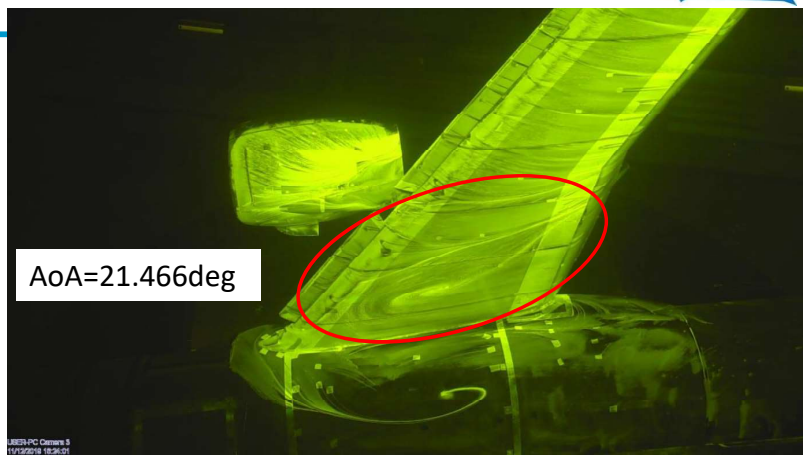

E2-Custom

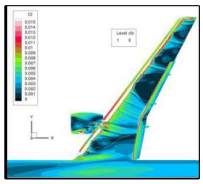

E3-Custom

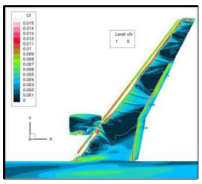
This document is provided by JAXA.

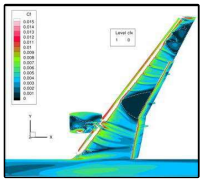
Surface Cf Contours（Case 1, 21.47deg, Viewpoint 1）

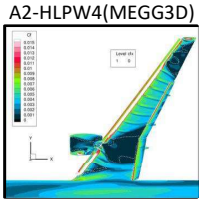
ID-Grid(generated by)

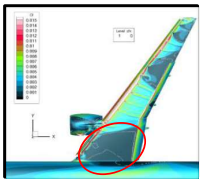


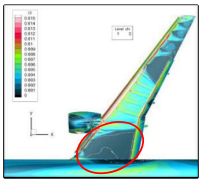

A1-HLPW4(MEGG3D)

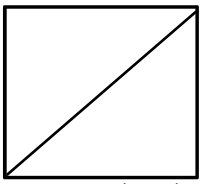

A2-HLPW4(MEGG3D)

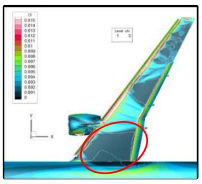

A3-HLPW4(MEGG3D)

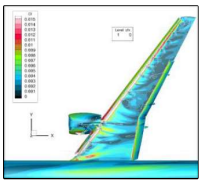

A4-HLPW4(MEGG3D)

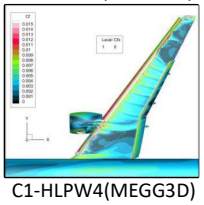

B1-HLPW4(MEGG3D)

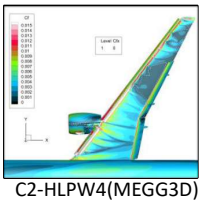

B2-HLPW4(Pointwise)

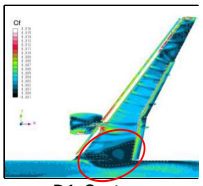

B3-HLPW4(ANSA)

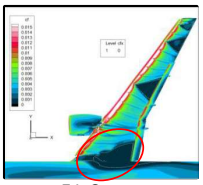

B4-Custom

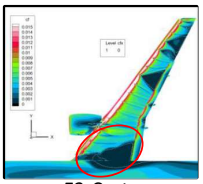

B5-Custom

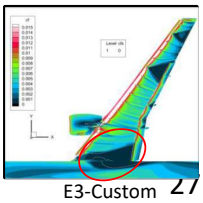

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom

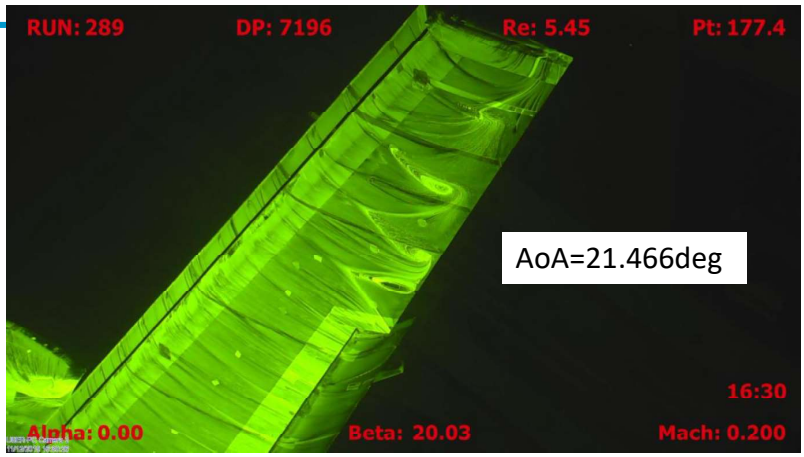

E1-Custom

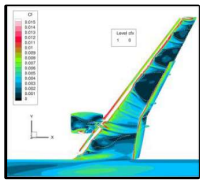

E2-Custom

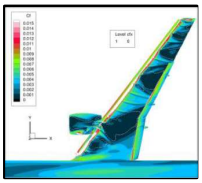

E3-Custom

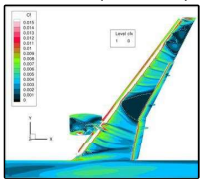
Surface Cf Contours（Case 1, 21.47deg, Viewpoint 1）

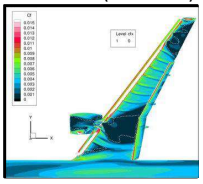
ID-Grid(generated by)

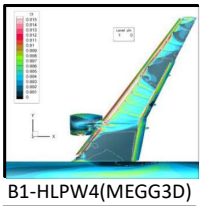


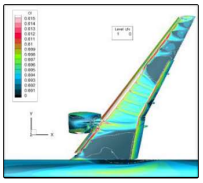

A1-HLPW4(MEGG3D)

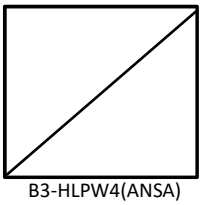

A2-HLPW4(MEGG3D)

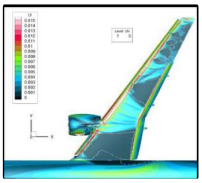

A3-HLPW4(MEGG3D)

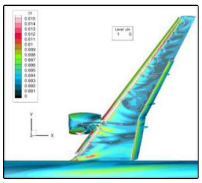

A4-HLPW4(MEGG3D)

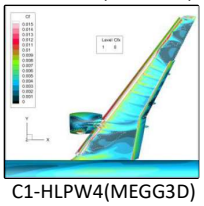

B1-HLPW4(MEGG3D)

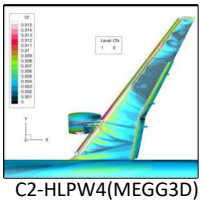

B2-HLPW4(Pointwise)

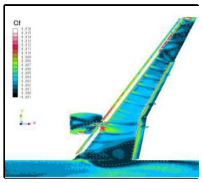

B3-HLPW4(ANSA)

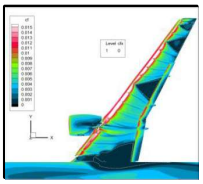

B4-Custom

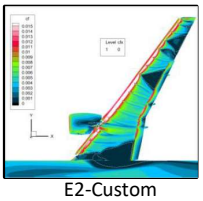

B5-Custom

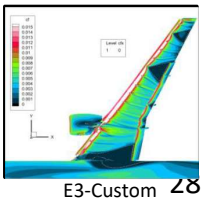

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom


E1-Custom

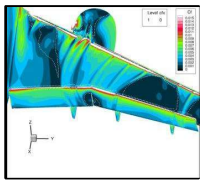

E2-Custom

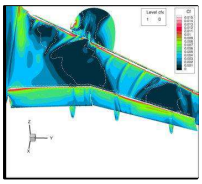

E3-Custom

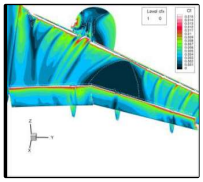
This document is provided by JAXA.

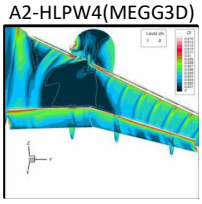
Surface Cf Contours（Case 1, 21.47deg, Viewpoint 2）

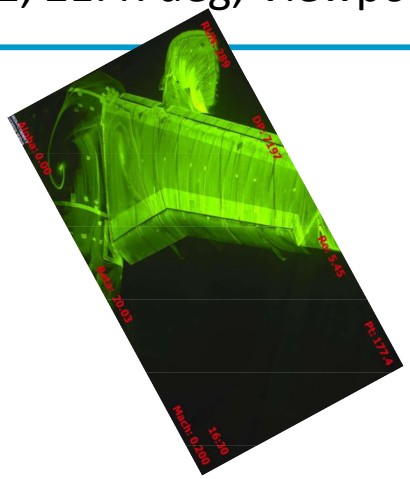
ID-Grid(generated by)


A1-HLPW4(MEGG3D)

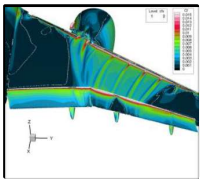

A2-HLPW4(MEGG3D)

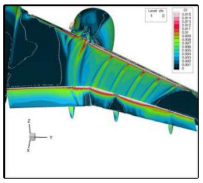

A3-HLPW4(MEGG3D)

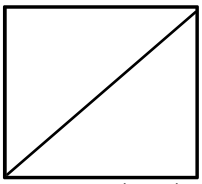

A4-HLPW4(MEGG3D)

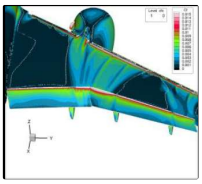


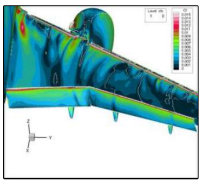
AoA=21.466deg

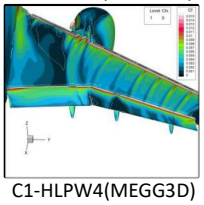

B1-HLPW4(MEGG3D)

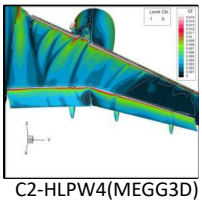

B2-HLPW4(Pointwise)

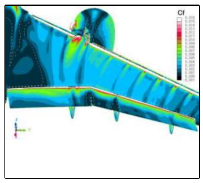

B3-HLPW4(ANSA)

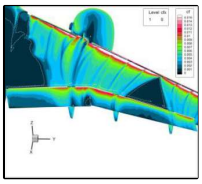

B4-Custom

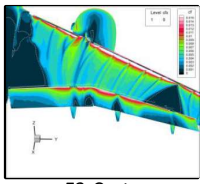

B5-Custom

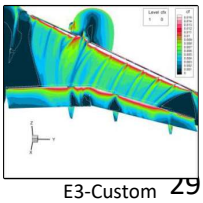

C1-HLPW4(MEGG3D)


C2-HLPW4(MEGG3D)


D1-Custom

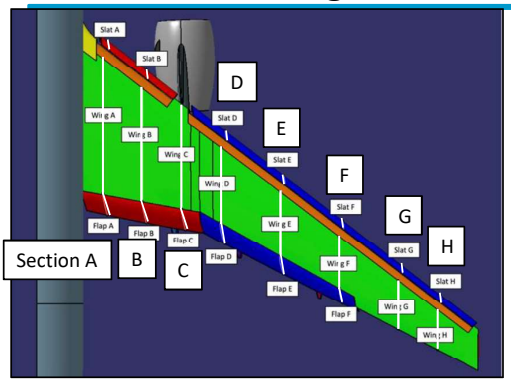

E1-Custom


E2-Custom

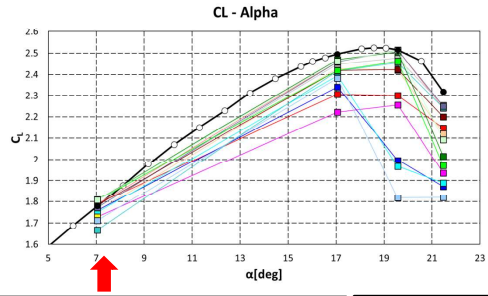

E3-Custom

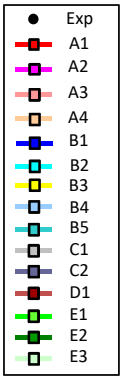
29

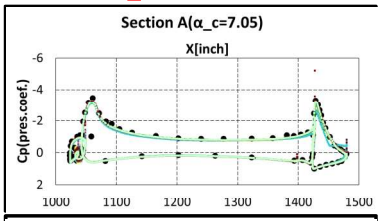
Surface Cp distribution （Case 1, 7.05deg）

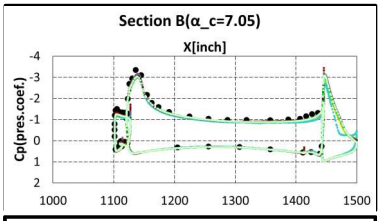


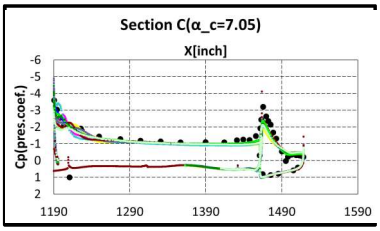
https://hiliftpw.larc.nasa.gov/Workshop4/DataForm.html

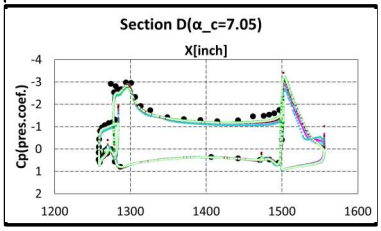


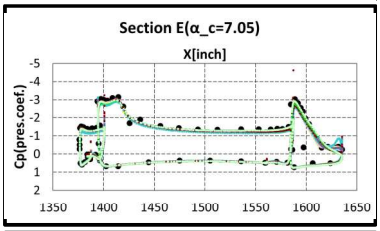


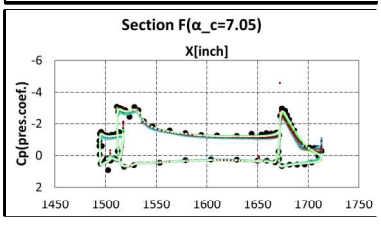


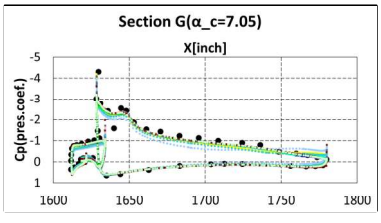


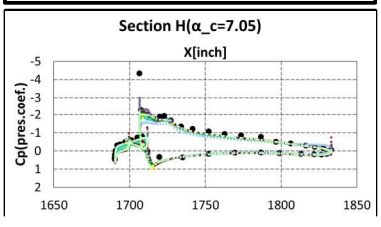






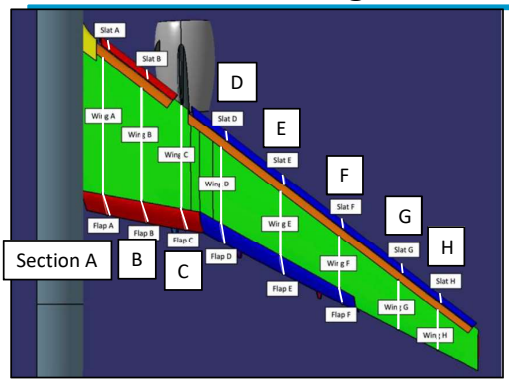




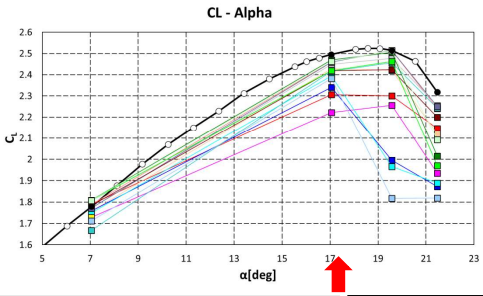


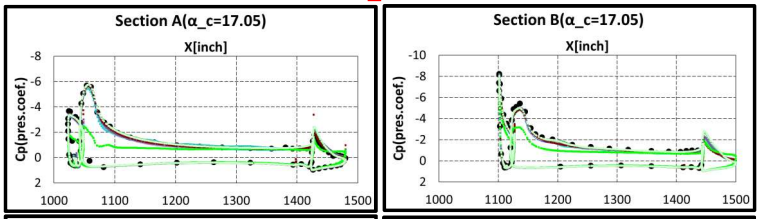
This document is provided by JAXA.

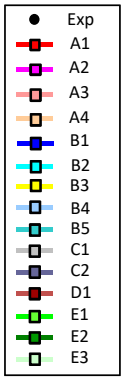
Surface Cp distribution （Case 1, 17.05deg）

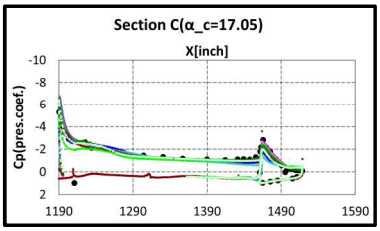


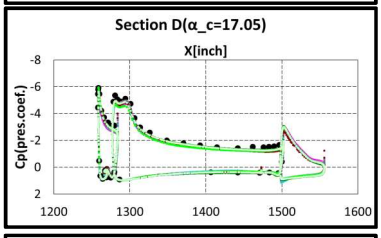
https://hiliftpw.larc.nasa.gov/Workshop4/DataForm.html

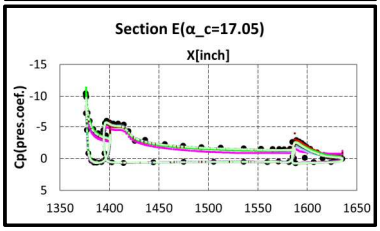


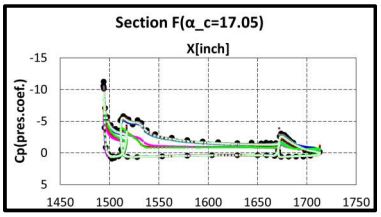


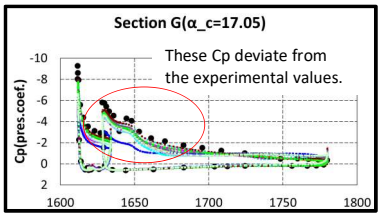


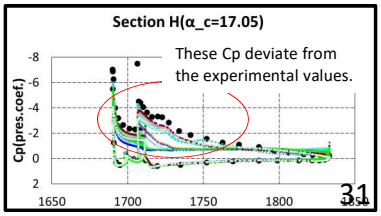




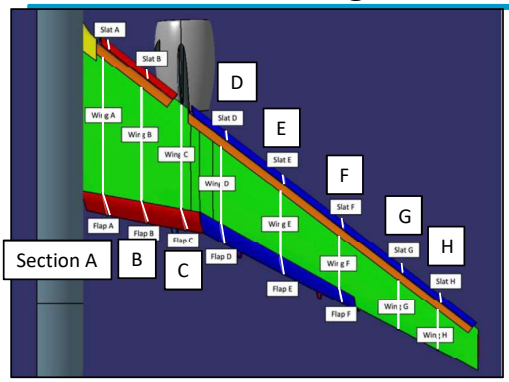




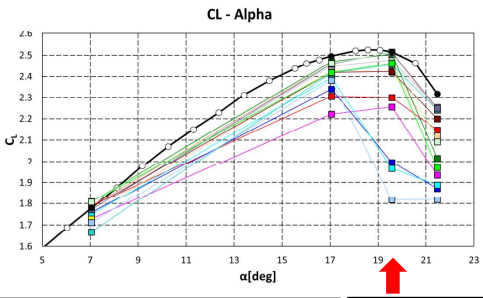


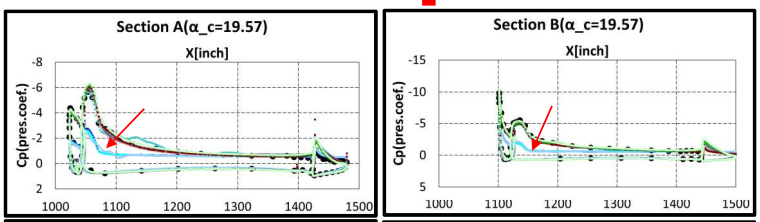


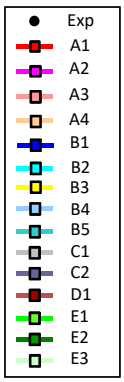
Surface Cp distribution （Case 1, 19.57deg）

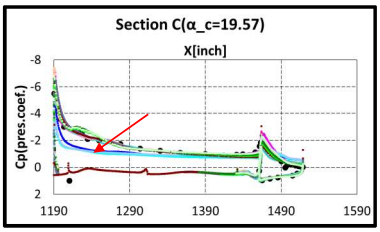


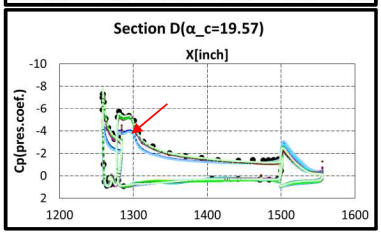
https://hiliftpw.larc.nasa.gov/Workshop4/DataForm.html

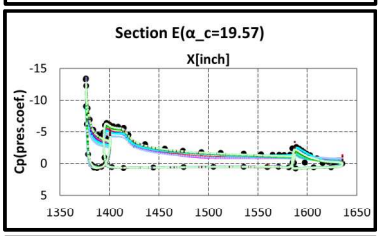


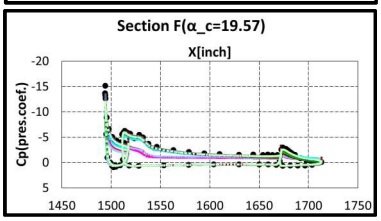


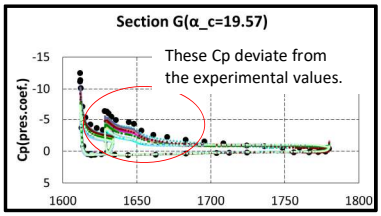


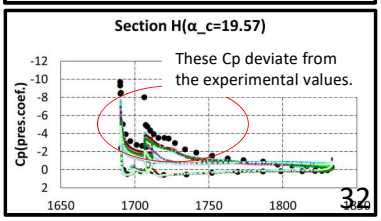






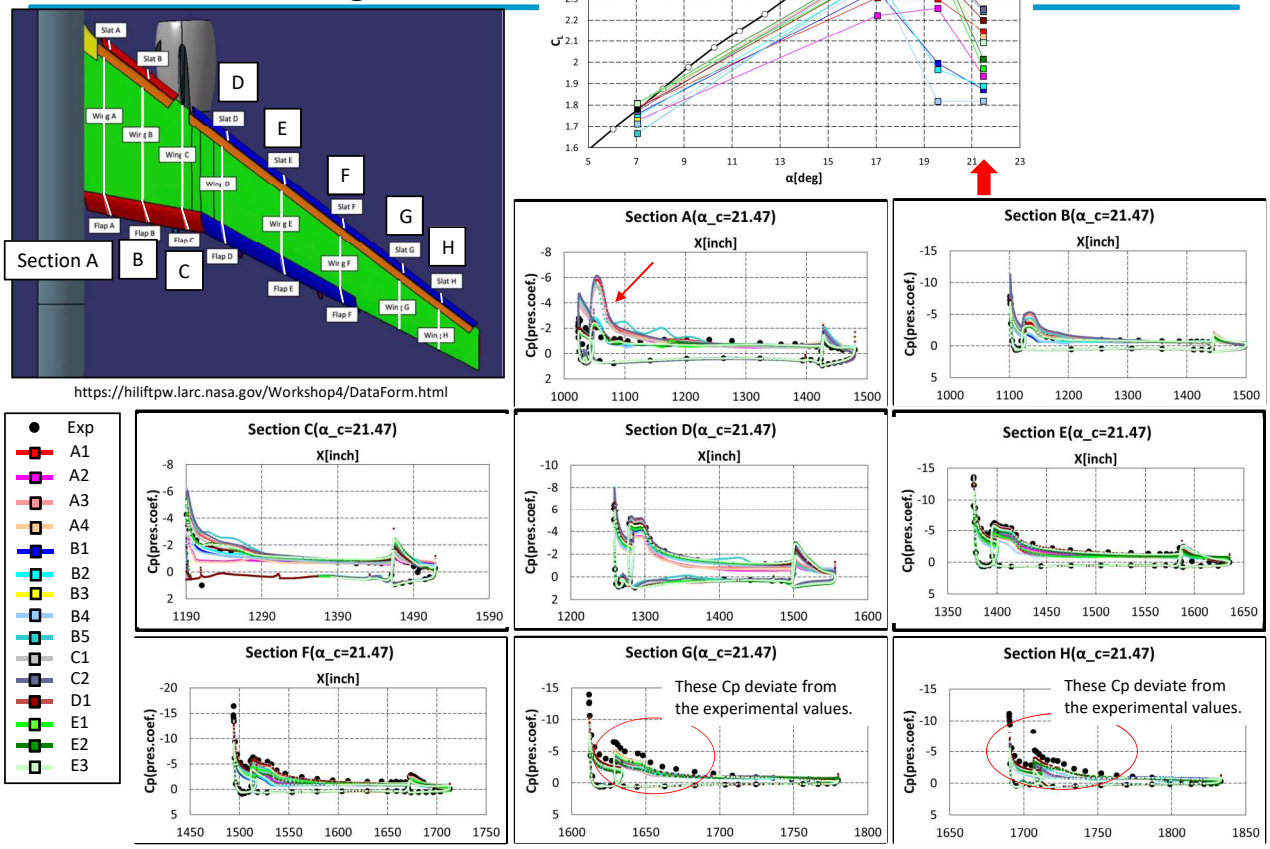






This document is provided by JAXA.

Surface Cp distribution (Case 1, 21.47deg)

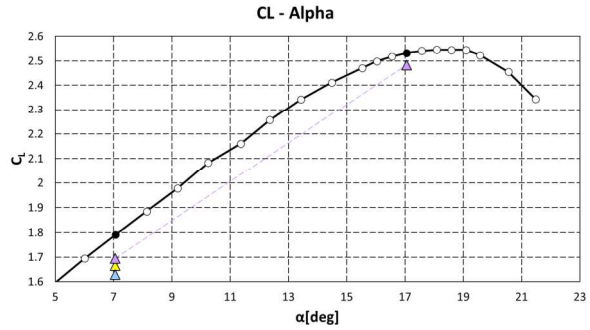


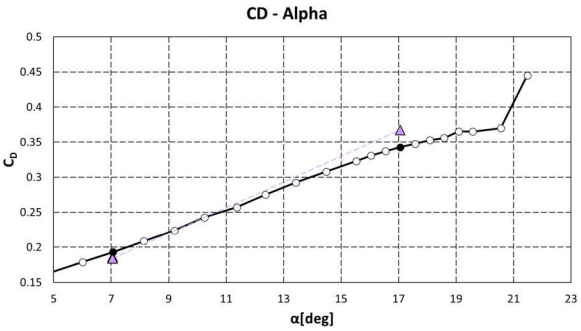
Case 3 : Steady computation

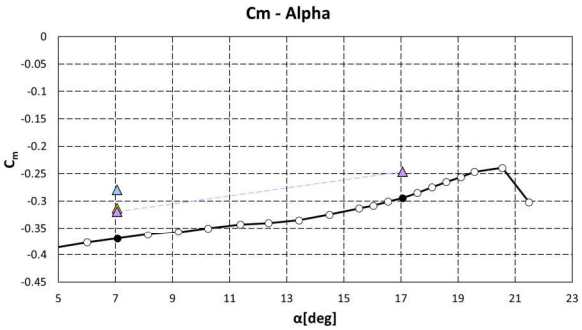
- Conditions
  - 3D CRM-HL flap angle : 43°/40°(inboard/outboard)
  - M = 0.2, Re = 5.49 x 10^6 (C_{ref} = 275.8inches), T_{ref} = 521°R
  - AoA = 7.05, 17.05deg

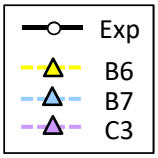
This document is provided by JAXA.

CL, CD, and Cm - Alpha, Case 3



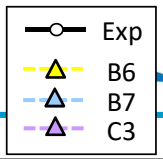


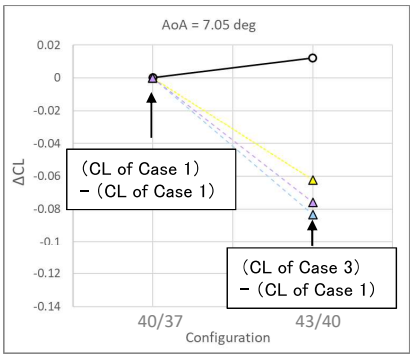


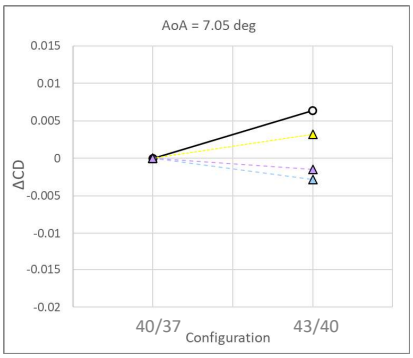


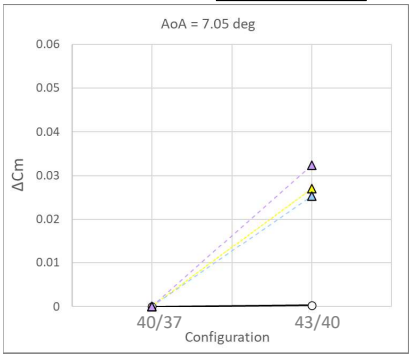
35

Lift, Drag, and Moment Increments

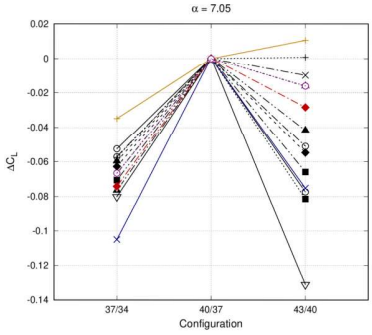


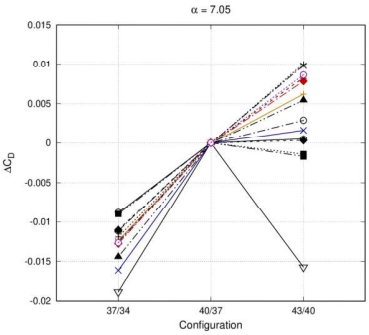


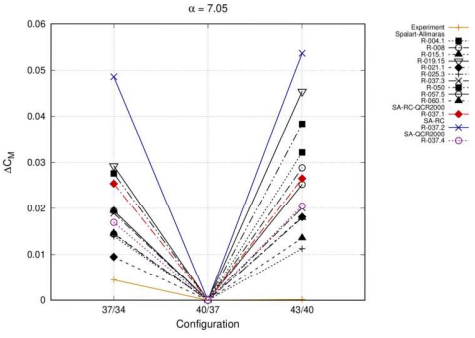




HLPW4（03_GMGW3_HLPW4_RANS.pdf,p.13 - 15）







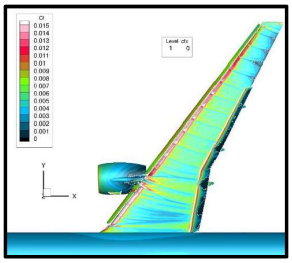
36

This document is provided by JAXA.

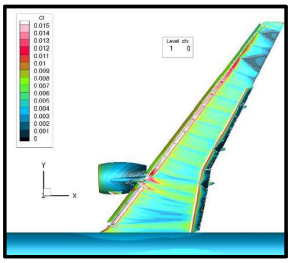
Surface Cf Contours (Case 3, 7.05deg)

ID-Grid(generated by)

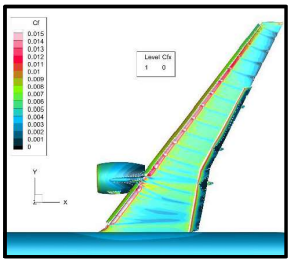
40°/37°
(inboard/outboard)



B3-HLWP4(ANSA)

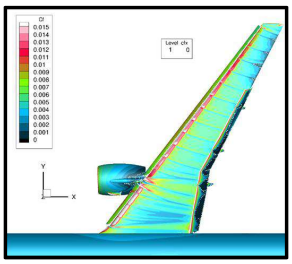


B4-Custom

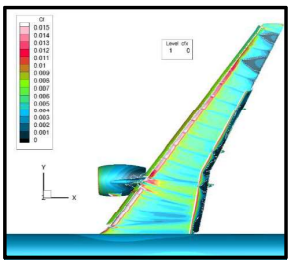


C2-HLWP4(MEGG3D)

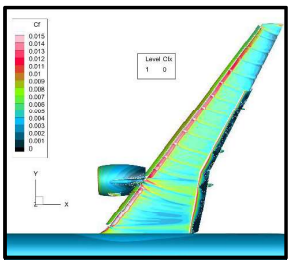
43°/40°
(inboard/outboard)



B6-HLWP4(ANSA)



B7-Custom



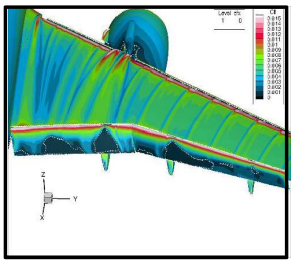
C3-HLWP4(Pointwise)

37

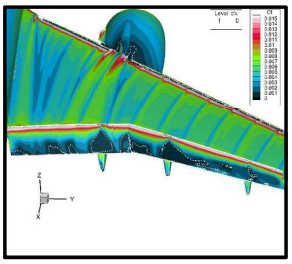
Surface Cf Contours (Case 3, 7.05deg)

ID-Grid(generated by)

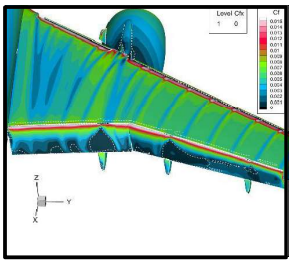
40°/37°
(inboard/outboard)



B3-HLWP4(ANSA)

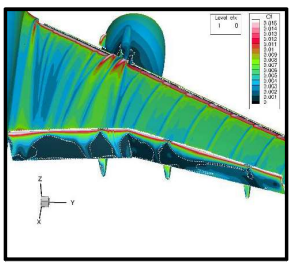


B4-Custom

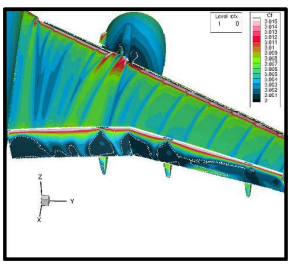


C2-HLWP4(MEGG3D)

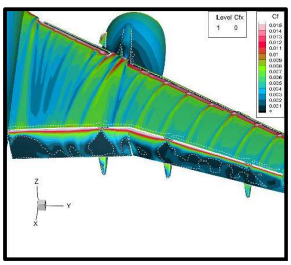
43°/40°
(inboard/outboard)



B6-HLWP4(ANSA)



B7-Custom



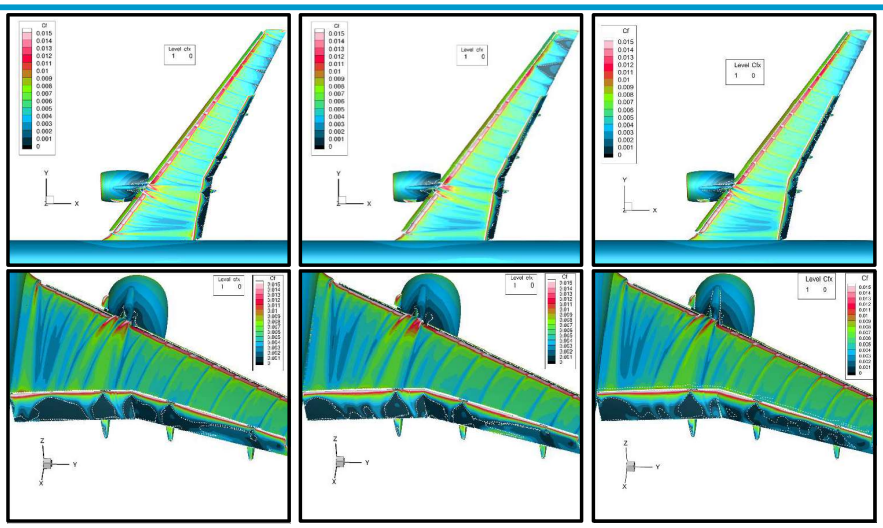
C3-HLWP4(Pointwise)

38

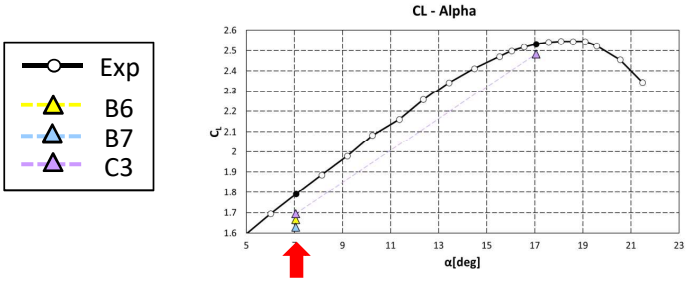
This document is provided by JAXA.

Surface Cf Contours（Case 3, 7.05deg）

ID-Grid(generated by)



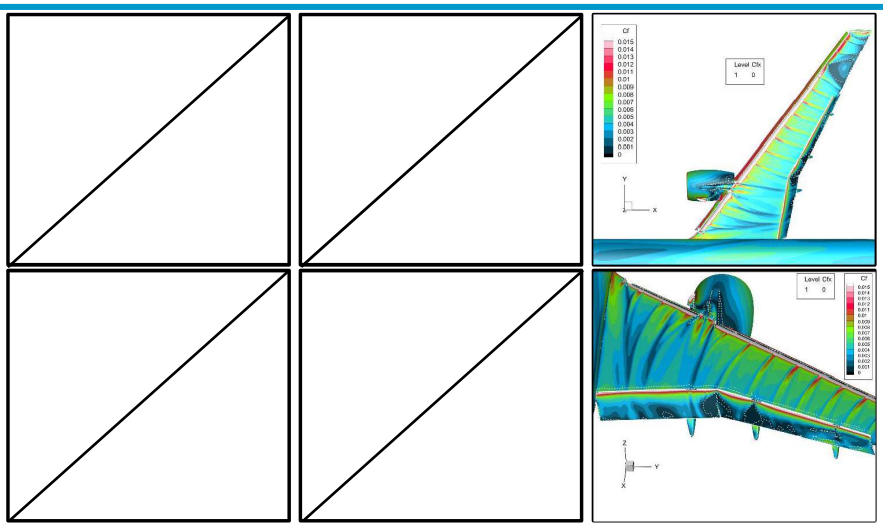
B6-HLWP4(ANSA) B7-Custom C3-HLWP4(Pointwise)



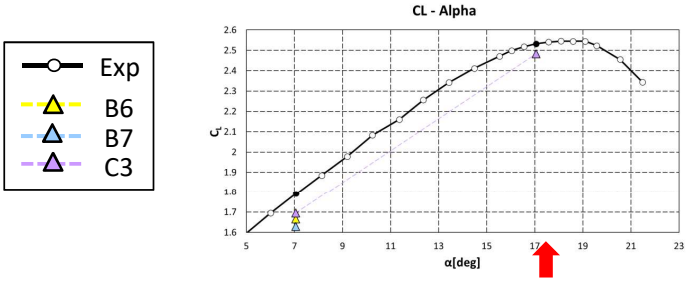
39

Surface Cf Contours（Case 3, 17.05deg）

ID-Grid(generated by)



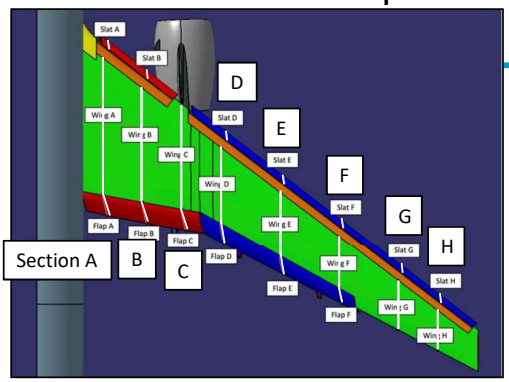
B6-HLWP4(ANSA) B7-Custom C3-HLWP4(Pointwise)



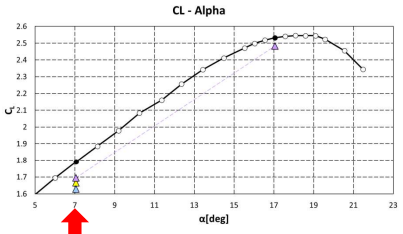
40

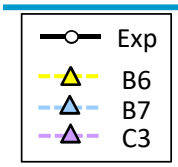
This document is provided by JAXA.

Surface Cp distribution (Case 3, 7.05deg)

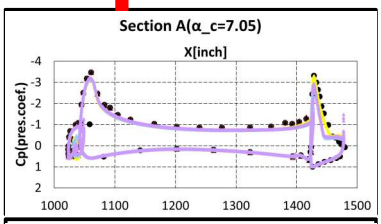


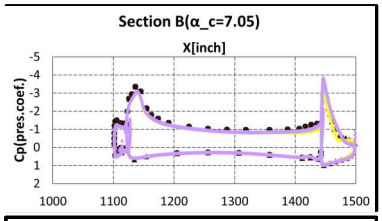
https://hiliftpw.larc.nasa.gov/Workshop4/DataForm.html

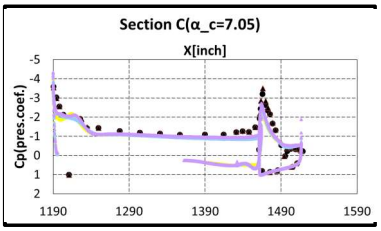


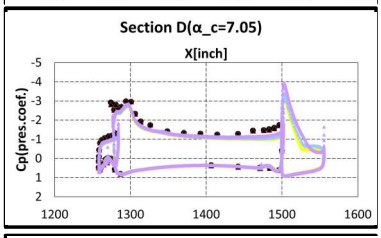


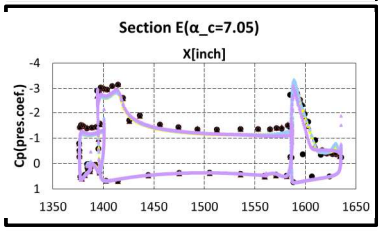
● Exp (40/37)
▲ Exp (43/40)
B6
B7
C3

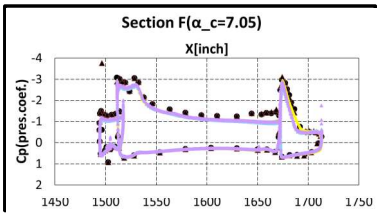


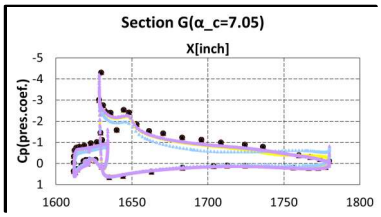


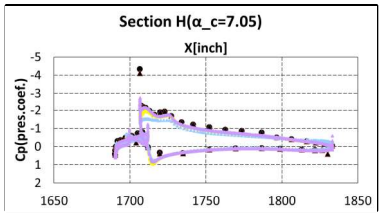




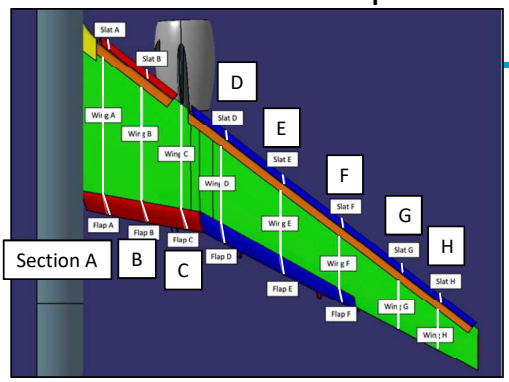




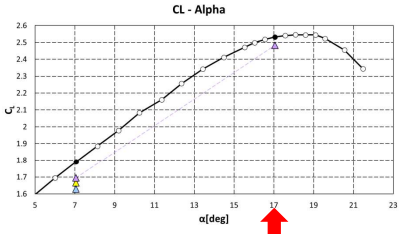


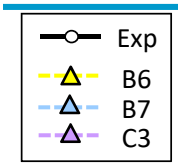


Surface Cp distribution (Case 3, 17.05deg)

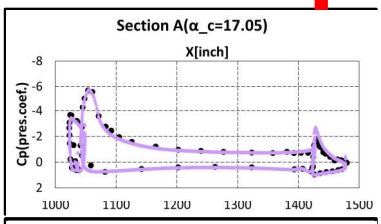


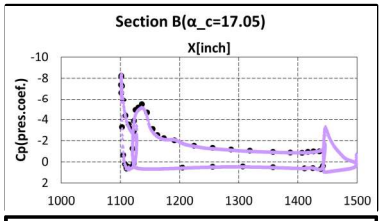
https://hiliftpw.larc.nasa.gov/Workshop4/DataForm.html

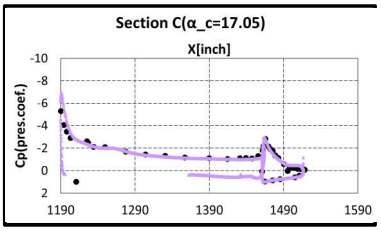


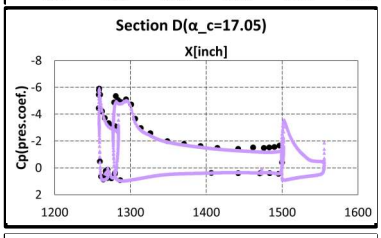


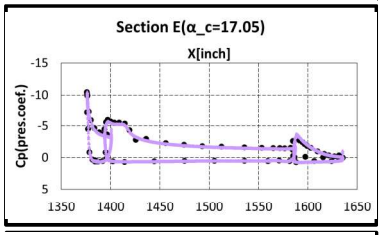
● Exp (40/37)
▲ Exp (43/40)
B6
B7
C3

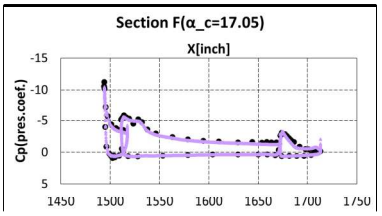


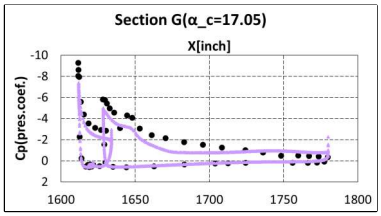


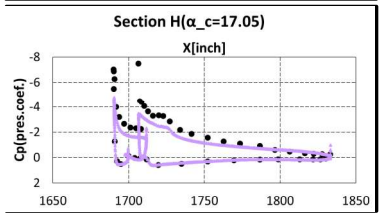












This document is provided by JAXA.

Case 4 : Steady computation

- Conditions
  - M = 0.2, Re = 5.00 x 10^6 (C_{ref} = 1), T_{ref} = 272.1K
  - AoA = 16.0deg

43

TMR提供格子（FAMILY1）

Grid Level	面あたりのノード数N
L1 (coarsest)	173958
L2	294161
L3	508099
L4	930671
L5	1679982
L6	3227904
L7 (finest)	5980721

This document is provided by JAXA.

Participants of Case 4

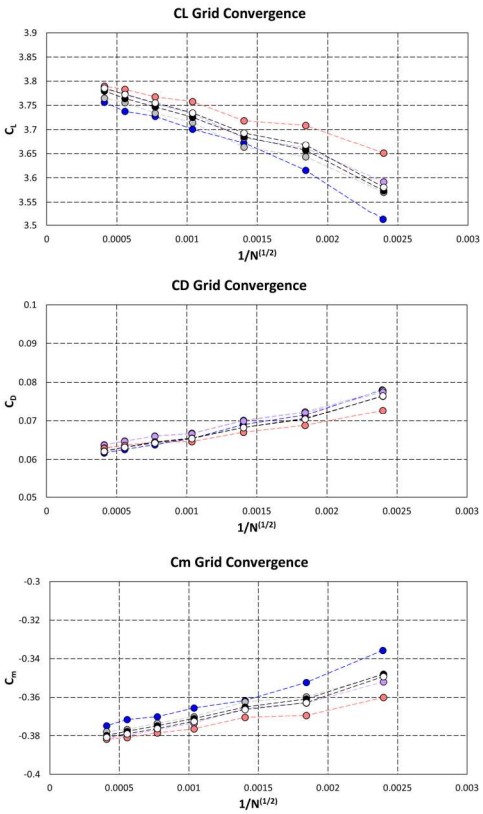
ID	Name	Organization	Code	Grid	Turbulence Model	Initial Condition
A5	Zauner Markus	JAXA	FaSTAR (Unstructured solver)	TMR提供格子(FAMILY1)	SA-noft2	Uniform flow (L7格子の計算のみL6格子の収束値をL7格子にマッピングし、この値を初期値にしてGlobal time stepを用いて計算)
A6	Zauner Markus	JAXA	FaSTAR (Unstructured solver)	TMR提供格子(FAMILY1)	SA-noft2	Uniform flow (L7格子の計算のみ Local time stepの未収束値を初期値にして Global time stepを用いて計算)
B8	山内優果	KHI	Cflow (Unstructured solver)	TMR提供格子(FAMILY1)	SA-neg	Uniform flow
C4	古谷龍太郎	JAXA	TAS (Unstructured solver)	TMR提供格子(FAMILY1)	SA-noft2-R(Crot=1)	Uniform flow
C5					SA	

Grid Convergence (1/2)

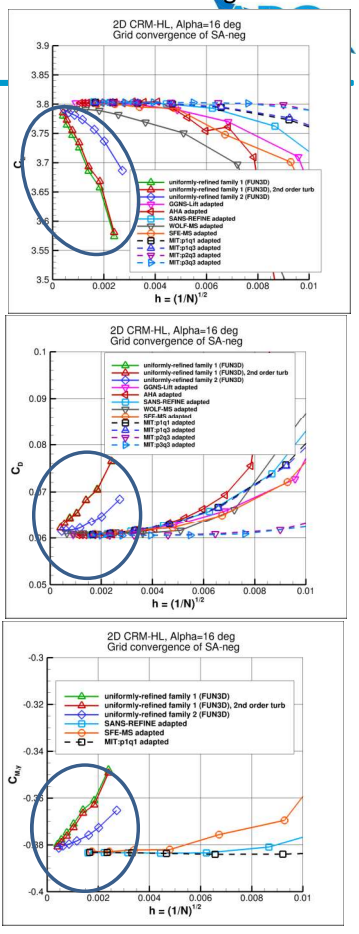
A5
A6
B8
C4
C5
F1
F2

F1 : FUN3D, Family 1, SA-neg
F2 : FUN3D, Family 1, SA-neg, 2nd order turbulence

A5とA6は重なっている
L1～L6格子のデータは同じもの
L7格子のデータは初期条件が異なる

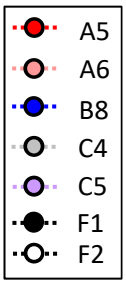


Turbulence Modeling Resource



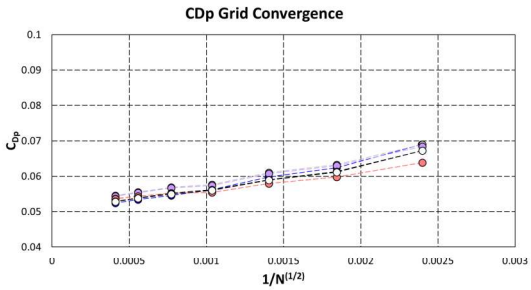
This document is provided by JAXA.

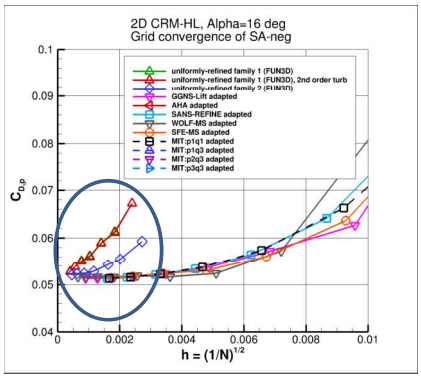
Grid Convergence（2/2）

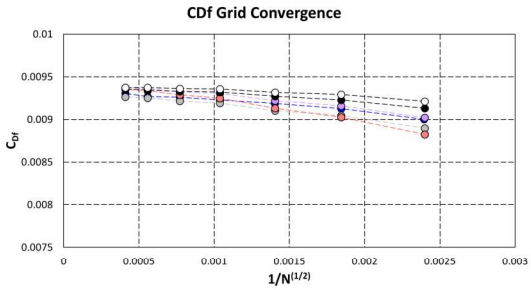


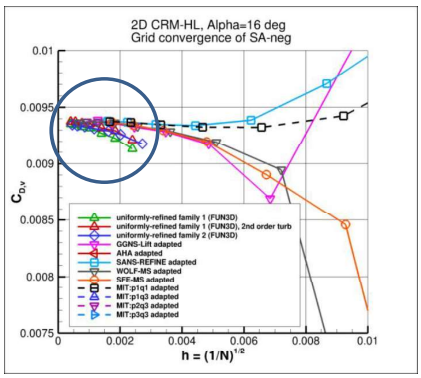
F1 : FUN3D, Family 1, SA-neg
F2 : FUN3D, Family 1, SA-neg,
2nd order turbulence

A5とA6は重なっている
L1～L6格子のデータは
同じもの
L7格子のデータは
初期条件が異なる

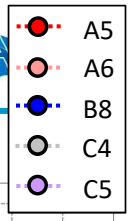


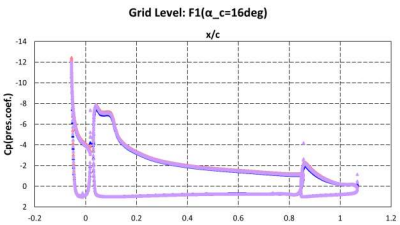


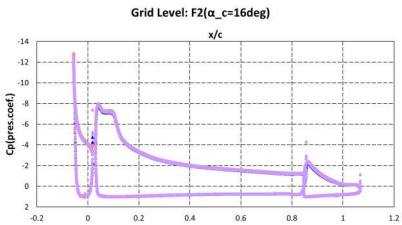


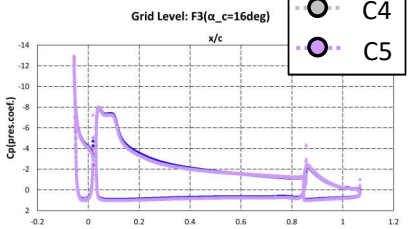


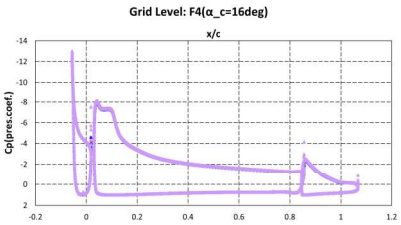
Surface Cp distribution

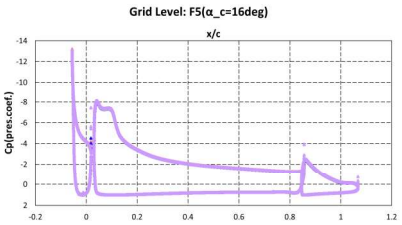


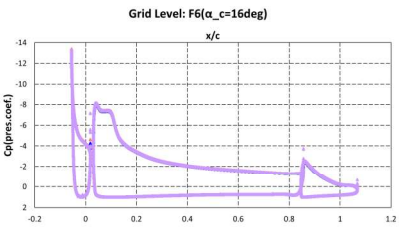


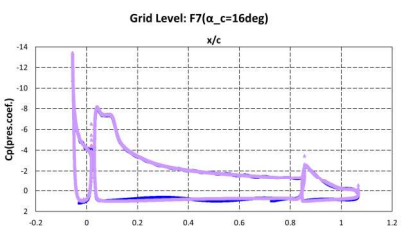


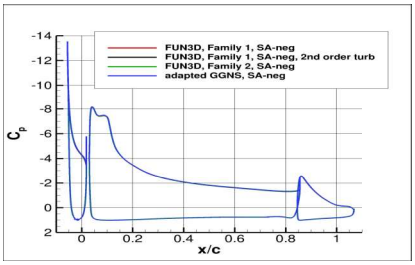












Turbulence Modeling Resource

This document is provided by JAXA.

Summary

- Case1
  - 空力係数はHLPW4と同じ傾向、ばらつき。
  - CFDの方が剥離を大きめに予測しておりCLが小さい。オイルフローとの比較や圧力分布の比較でも、剥離を大きく予測していることを確認。
  - 正しい剥離パターンで、空力係数(CLmax)を予測できた参加者はいない。外翼側のスラットトラックからの剥離が過大。内翼側からの失速にならない場合がある。
  - 初期値依存性がある(cold start vs warm start)。

Summary

- Case2
  - 参加者なし
- Case3
  - フラップ舵角効果の影響は困難。
- Case4
  - NASA TMRの結果と同様の結果であり、Verificationとして良好な結果。

This document is provided by JAXA.

謝辞

- 本資料を作成するにあたり、APC-8の参加者には、計算結果データを提出していただきました。また、APC有識者会議の皆様には、集計結果に関するご助言をいただきました。FMIC R&Dの松崎智明氏、菱友システムズの林謙司氏には集計作業のご支援をいただきました。上記の関係者の皆様に、ここに感謝の意を表します。

51

Discussion

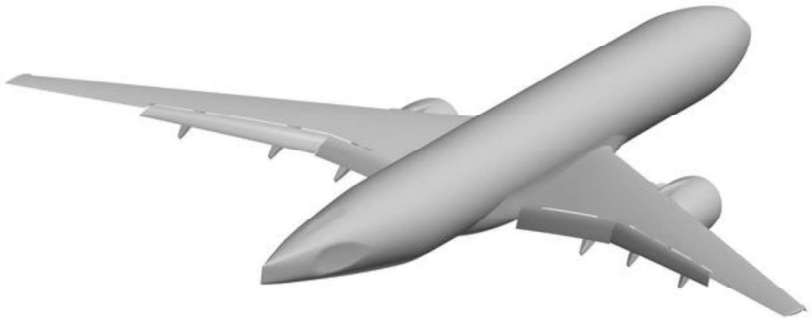
- 今後（APC-9）では、どこに着目すべきか？
- どんな風洞試験データが必要か？（例：全機と半裁の比較、ラフネス有無、境界層プロファイル、PIVによる空間速度分布など）
- CFDのばらつきを減らすにはどうしたら良いか？
- 定常RANS解析で改善する見込みはあるのか？
- Trackからの剥離が過大になる要因は？対策は？
- 床面境界層/風洞壁を模擬した解析を実施すべきか？
- 定常解析における解の収束性は？
- 最適な格子、乱流モデルは？あるいは、非定常計算？

52

This document is provided by JAXA.

APC-8のフォローアップの集計結果
Summary of APC-8 follow-up

橋本 敦 (JAXA)
Hashimoto Atsushi(JAXA)



Participants of Case 1

ID	Name	Organization	Code	Grid (generated by)	Description of the grid	Turbulence Model	Initial Condition
A1	Zauner Markus	JAXA	FaSTAR (Unstructured solver)	HLPW4(MEGG3D)		SA-noft2	Cold start
A2						SA-noft2-R-QCR2000	
A3						SA-noft2	Warm start
A4						SA-noft2-R-QCR2000	
B1	山内優果	KHI	Cflow (Unstructured solver)	HLPW4(MEGG3D)		SA-neg	Uniform flow
B2				HLPW4(Pointwise)	Pointwise grid(1.3.C)		
B3				HLPW4(ANSA)	ANSA(101.C)		
B4				Custom	Orthogonal octree + Body-Fitted layer grid	SA-neg	
B5						SA-R-QCR	
C1	古谷龍太郎	JAXA	TAS (Unstructured solver)	HLPW4(MEGG3D)		SA-noft2-R(Crot=1)	Uniform flow
C2							Low angle of attack
D1	中島吉隆	Hexagon	scFLOW (Unstructured solver)	Custom	Polyhedral mesh generated by scFLOW	SA-neg	Uniform flow
E1	船田雅也	Univ. of Tokyo	UTCart (Unstructured Cartesian solver)	Custom	Hierarchical orthogonal grid(100M)	SA-noft2 +Wall function	Uniform flow
E2					Hierarchical orthogonal grid(200M)		
E3					Hierarchical orthogonal grid(400M)		

This document is provided by JAXA.

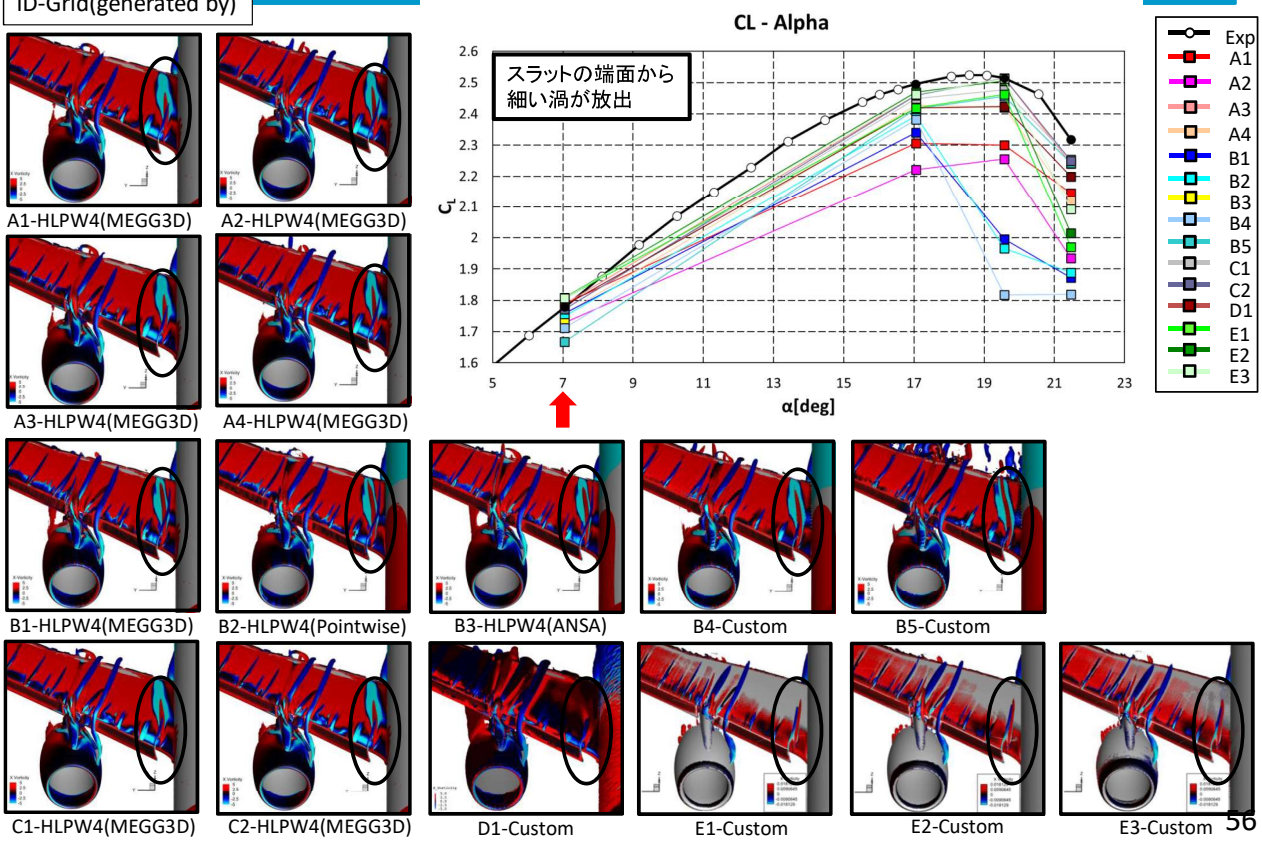
Case 1 : Steady computation

- Conditions
  - 3D CRM-HL flap angle : 40°/37°(inboard/outboard)
  - M = 0.2, Re = 5.49 x 10^6 (C_{ref} = 275.8inches), T_{ref} = 521°R
  - AoA = 7.05, 17.05, 19.57, 21.47deg

55

Q-Criterion Surface, X-Vorticity（Case 1, 7.05deg, Viewpoint 5）

ID-Grid(generated by)

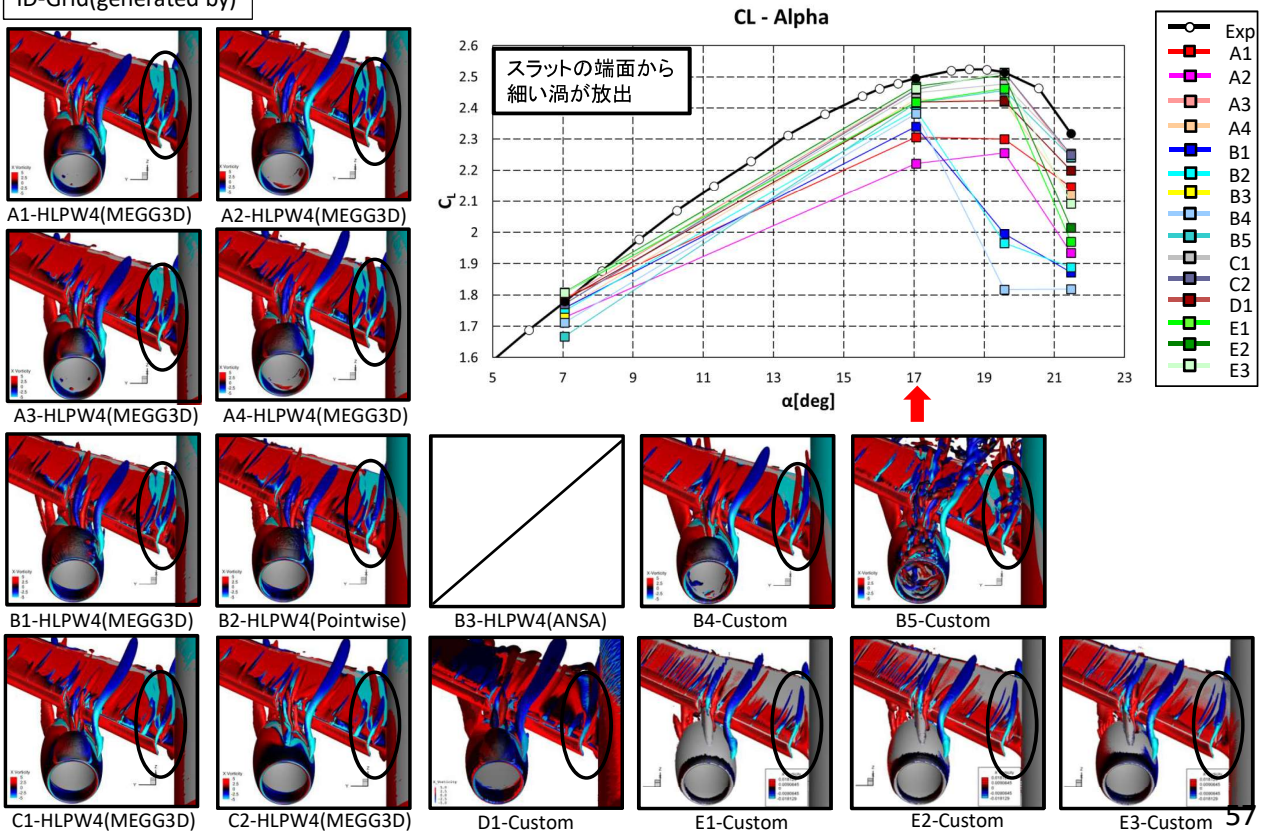


56

This document is provided by JAXA.

Q-Criterion Surface, X-Vorticity（Case 1, 17.05deg, Viewpoint 5）

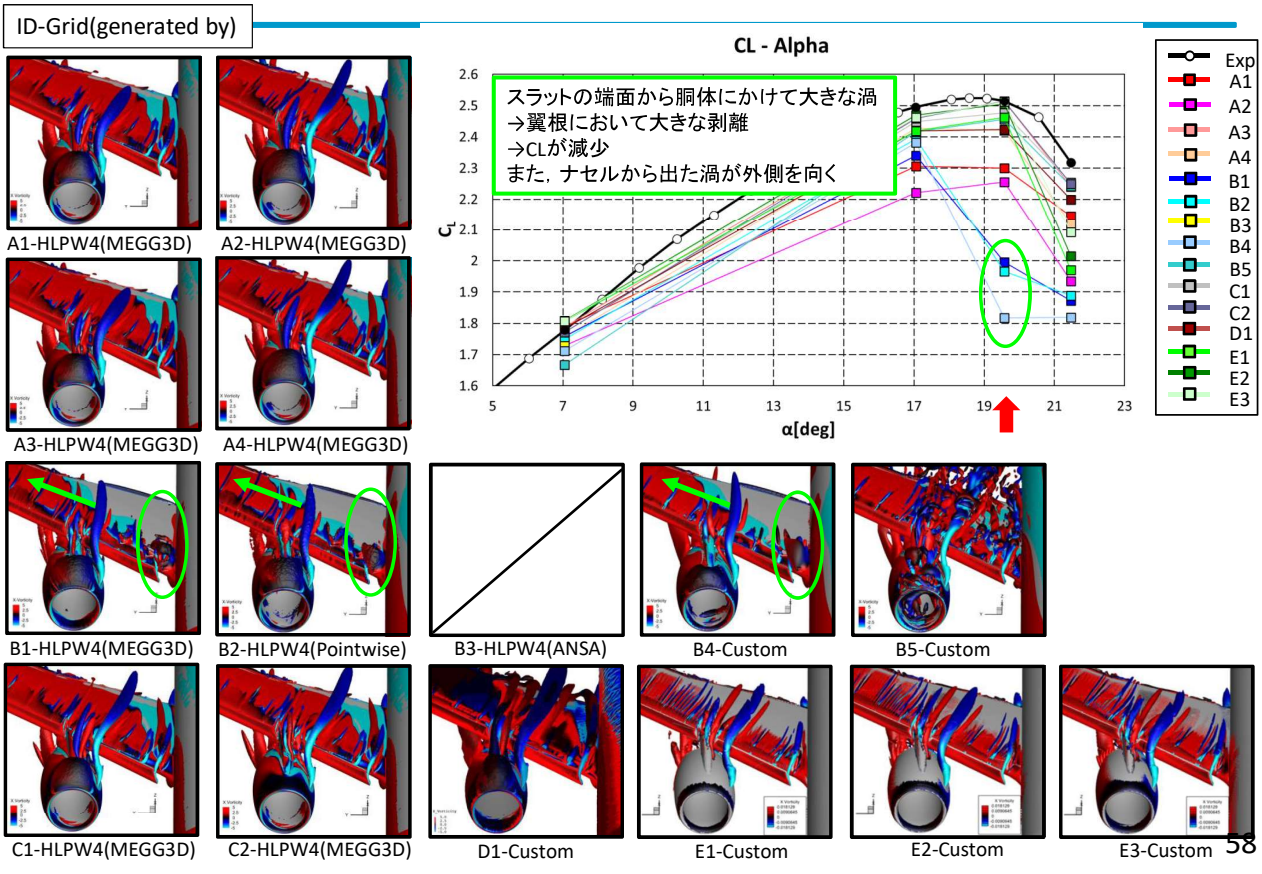
ID-Grid(generated by)



57

Q-Criterion Surface, X-Vorticity（Case 1, 19.57deg, Viewpoint 5）

ID-Grid(generated by)

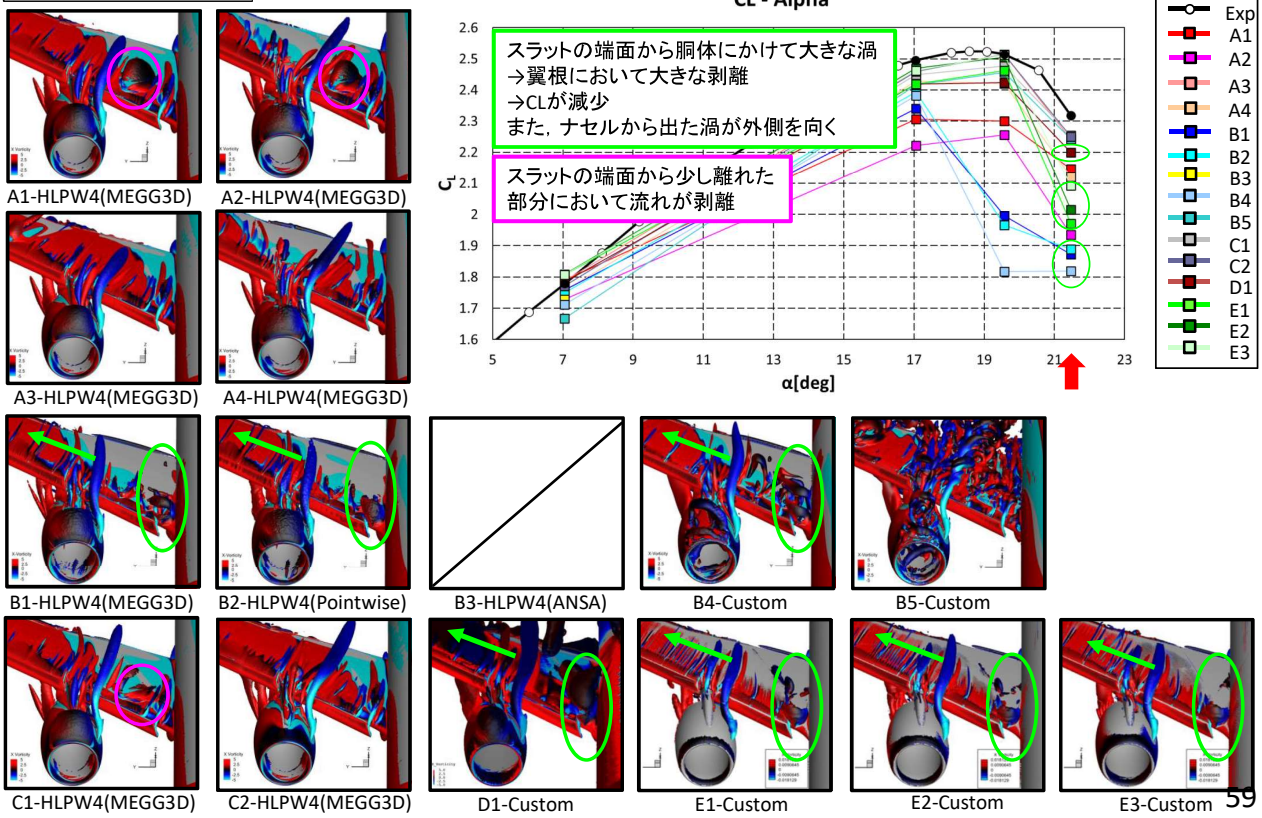


58

This document is provided by JAXA.

Q-Criterion Surface, X-Vorticity（Case 1, 21.47deg, Viewpoint 5）

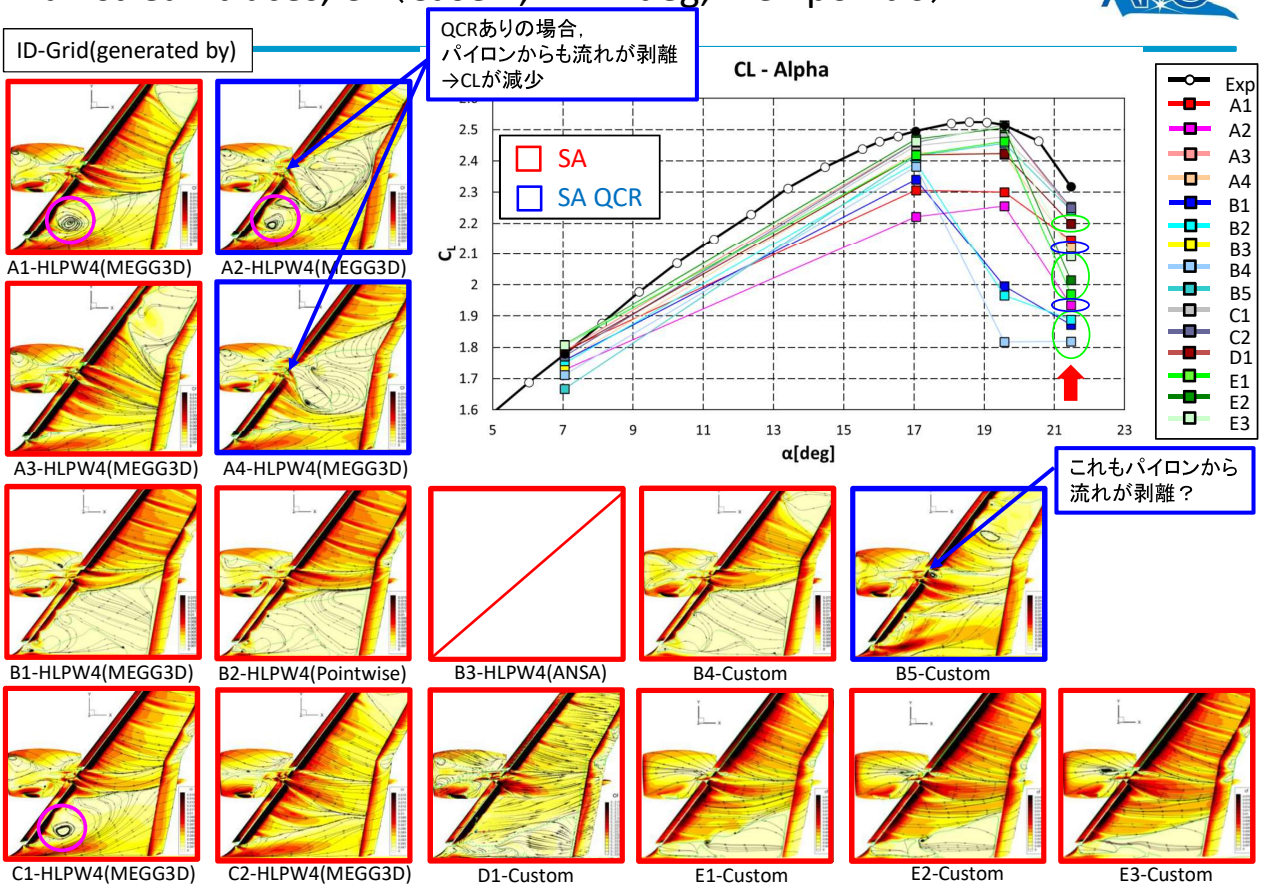
ID-Grid(generated by)



59

Wall-streamtraces, Cf（Case 1, 21.47deg, Viewpoint 6）

ID-Grid(generated by)

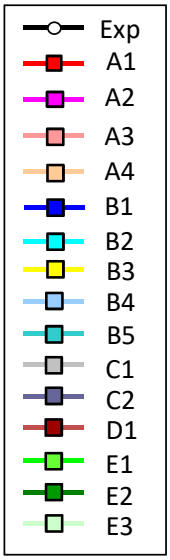


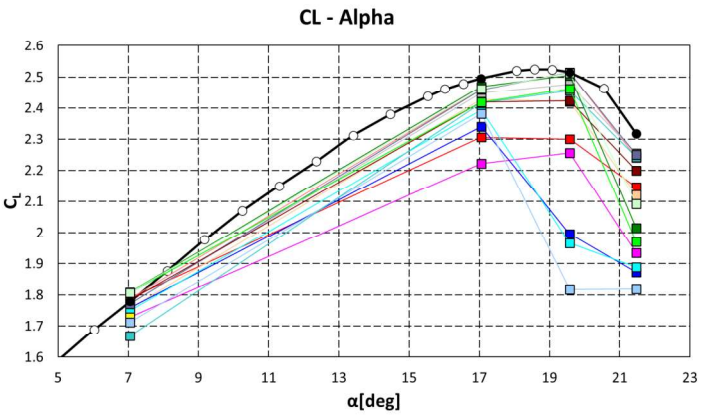
This document is provided by JAXA.

Classification by Participants

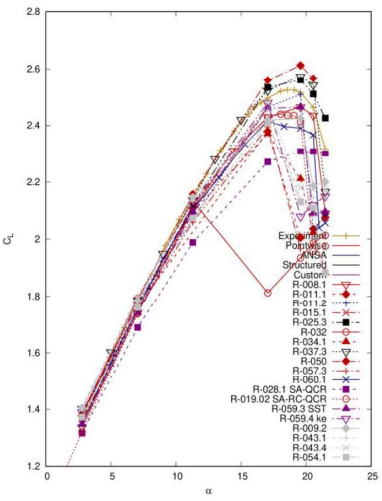
61

CL-Alpha, Case 1





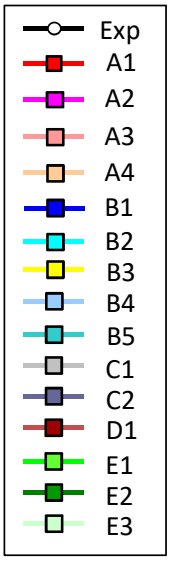
HLPW4
All Best-Practice Results
(03_GMGW3_HLPW4_RANS.pdf, p.17)

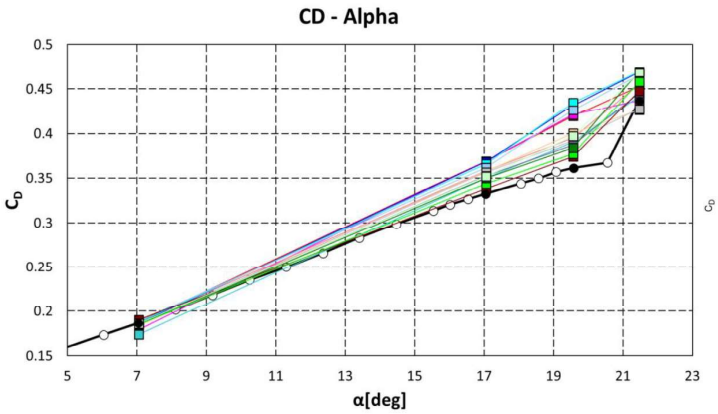


62

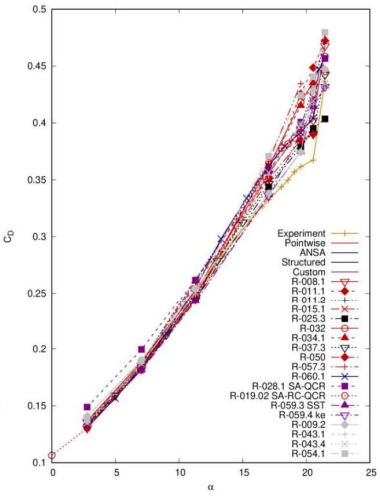
This document is provided by JAXA.

CD-Alpha, Case 1



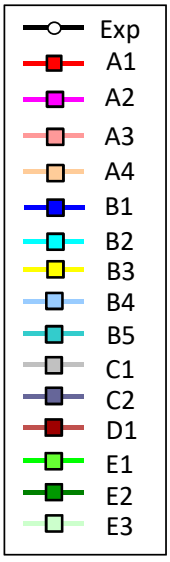


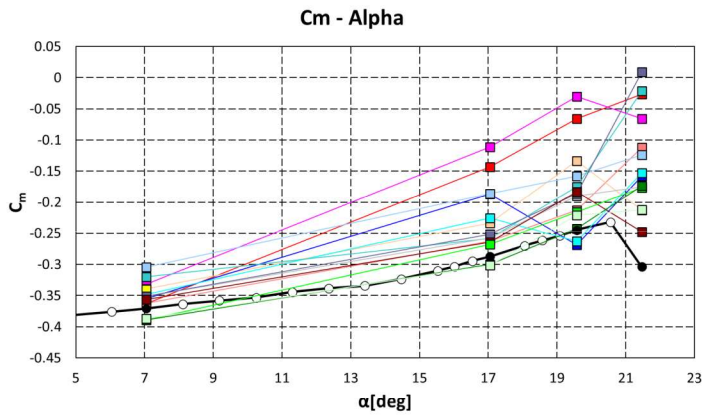
HLPW4
All Best-Practice Results
（03_GMGW3_HLPW4_RANS.pdf, p.17）



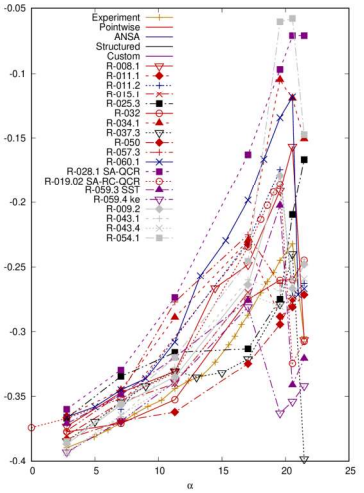
63

Cm-Alpha, Case 1





HLPW4
All Best-Practice Results
（03_GMGW3_HLPW4_RANS.pdf, p.17）

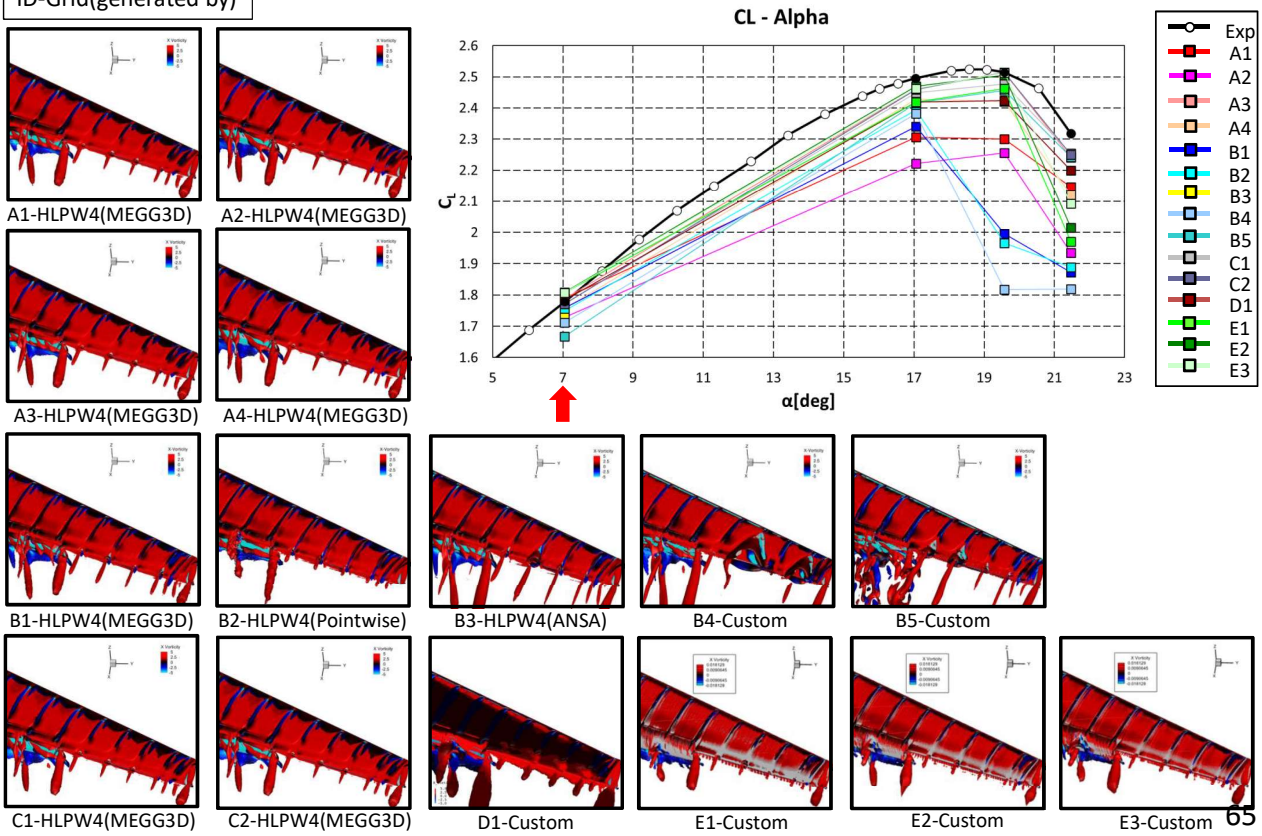


64

This document is provided by JAXA.

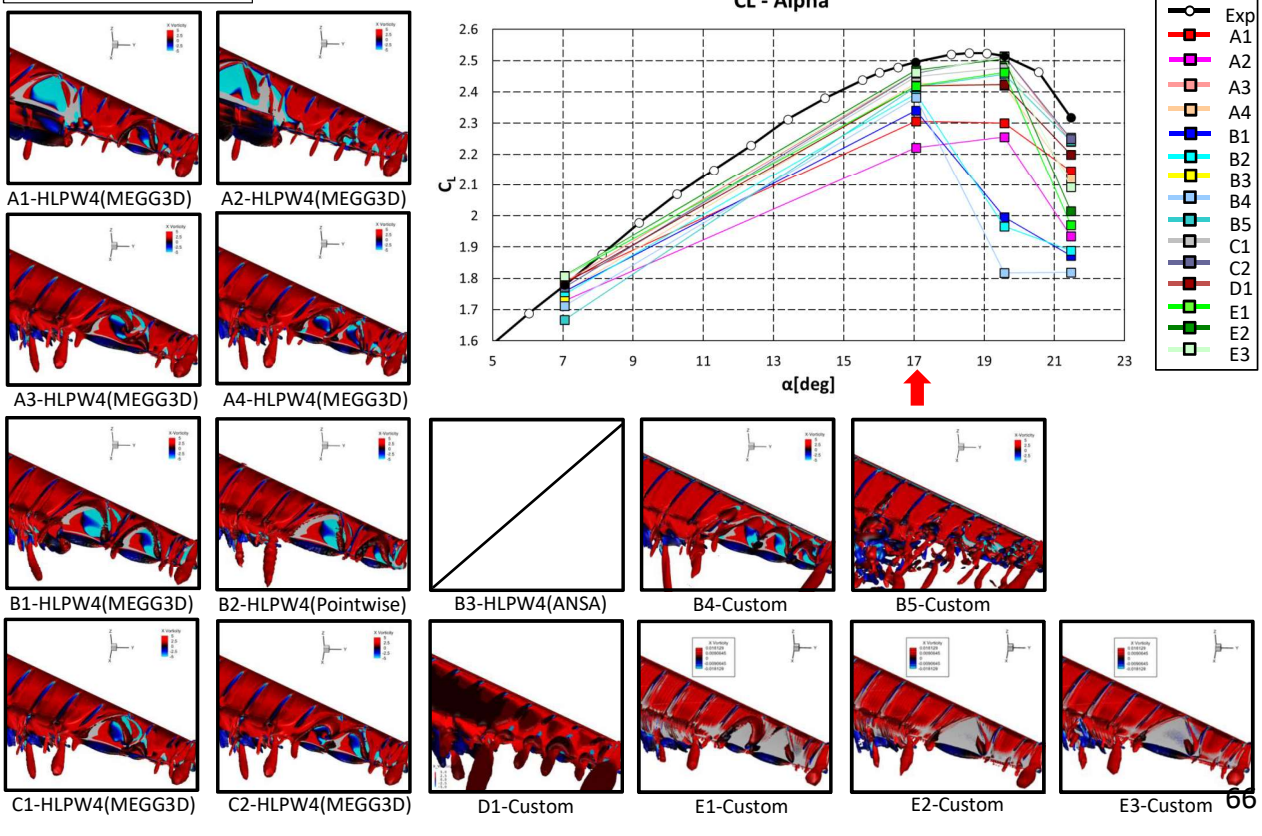
Q-Criterion Surface, X-Vorticity（Case 1, 7.05deg, Viewpoint 3）

ID-Grid(generated by)



Q-Criterion Surface, X-Vorticity（Case 1, 17.05deg, Viewpoint 3）

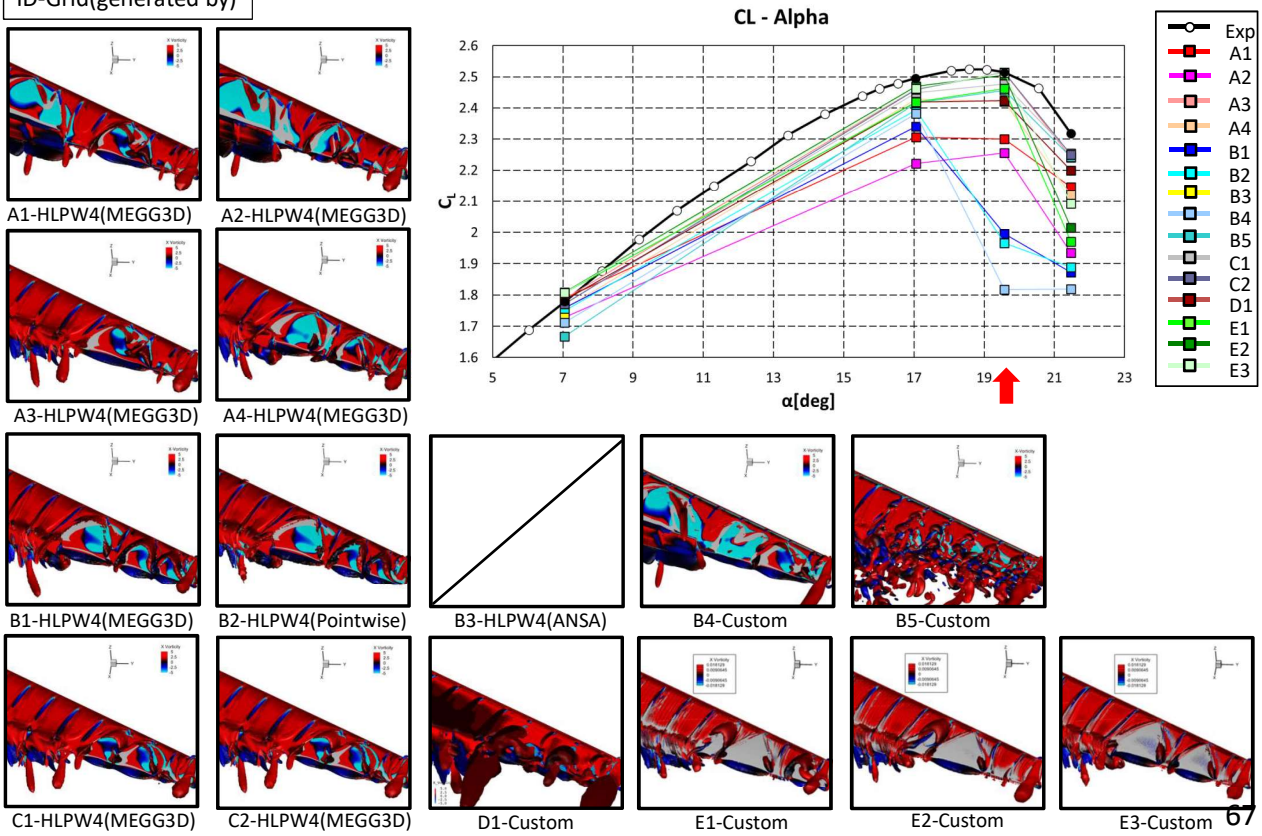
ID-Grid(generated by)



This document is provided by JAXA.

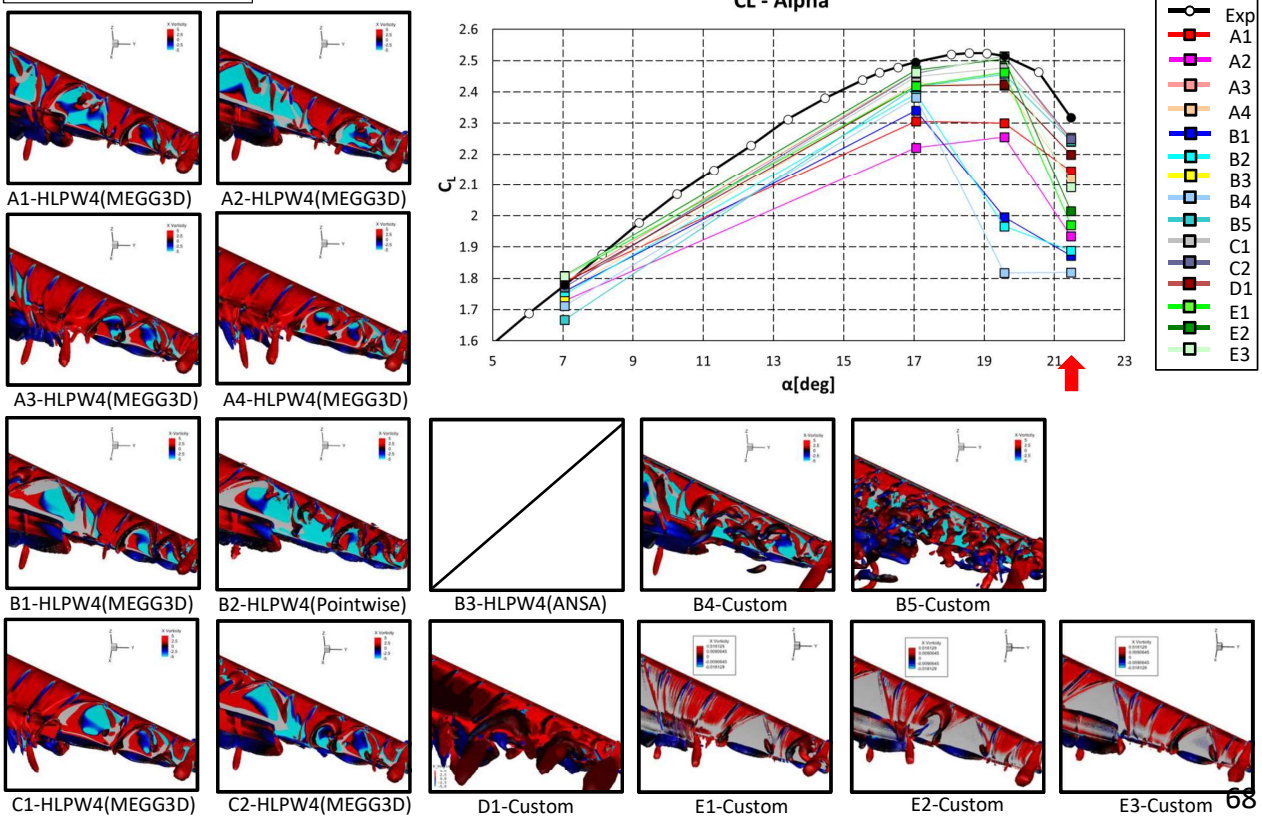
Q-Criterion Surface, X-Vorticity（Case 1, 19.57deg, Viewpoint 3）

ID-Grid(generated by)



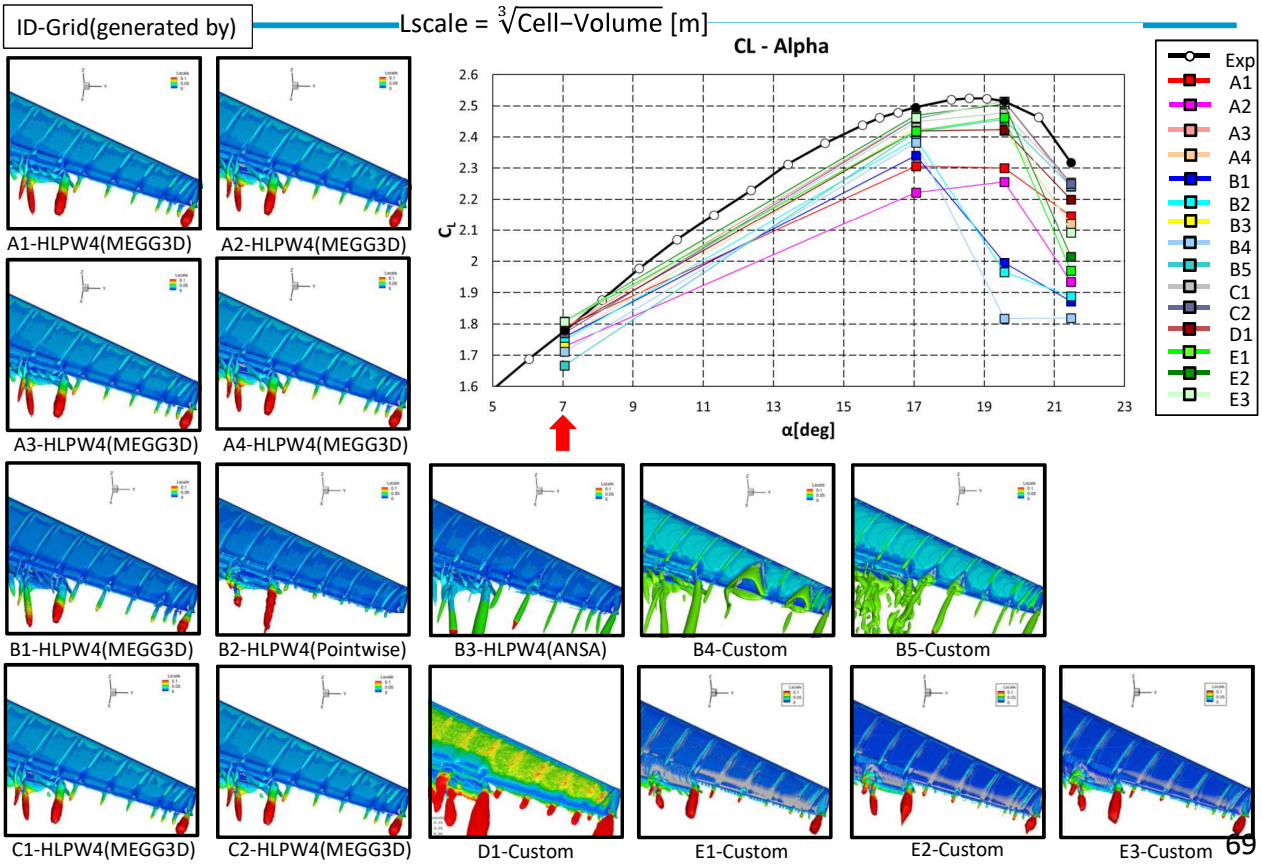
Q-Criterion Surface, X-Vorticity（Case 1, 21.47deg, Viewpoint 3）

ID-Grid(generated by)



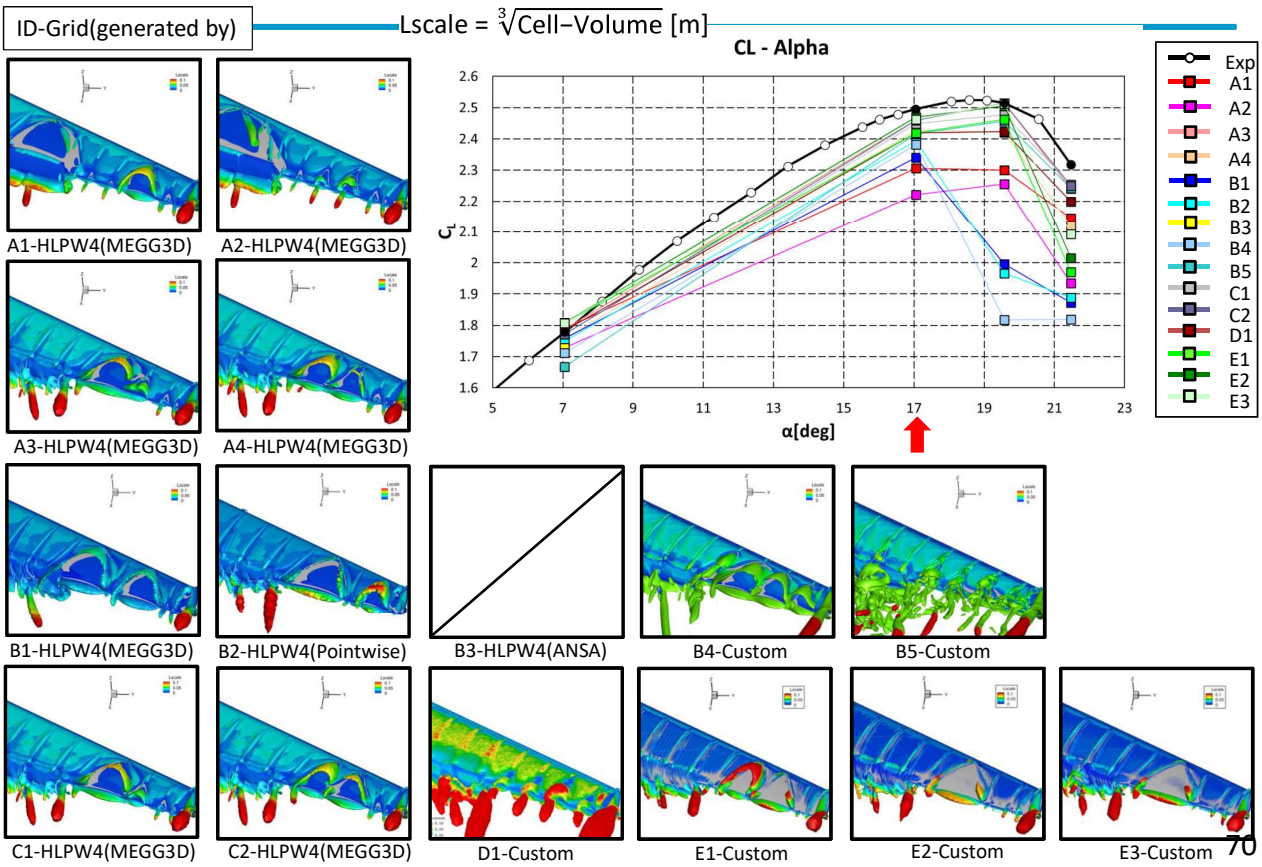
This document is provided by JAXA.

Q-Criterion Surface, Lscale（Case 1, 7.05deg, Viewpoint 3）



69

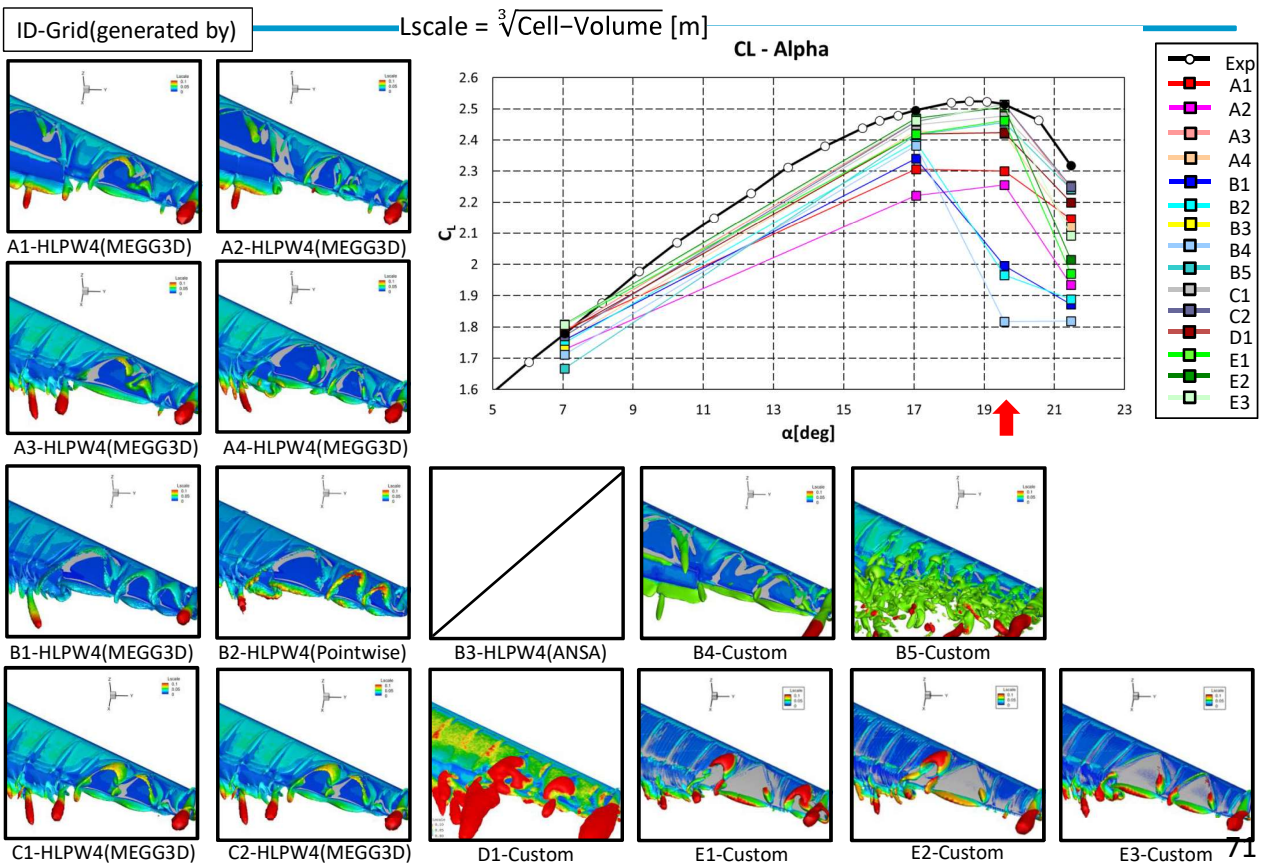
Q-Criterion Surface, Lscale（Case 1, 17.05deg, Viewpoint 3）



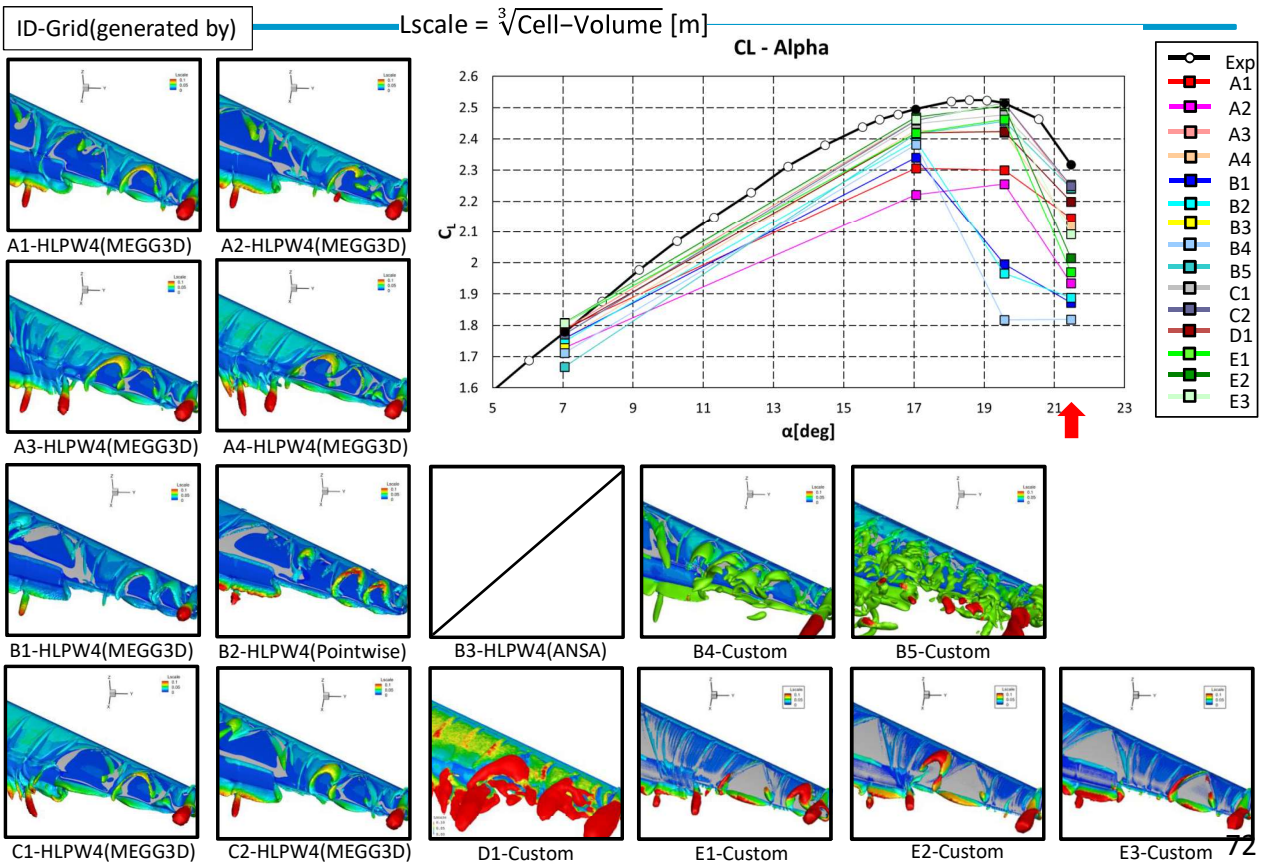
70

This document is provided by JAXA.

Q-Criterion Surface, Lscale（Case 1, 19.57deg, Viewpoint 3）



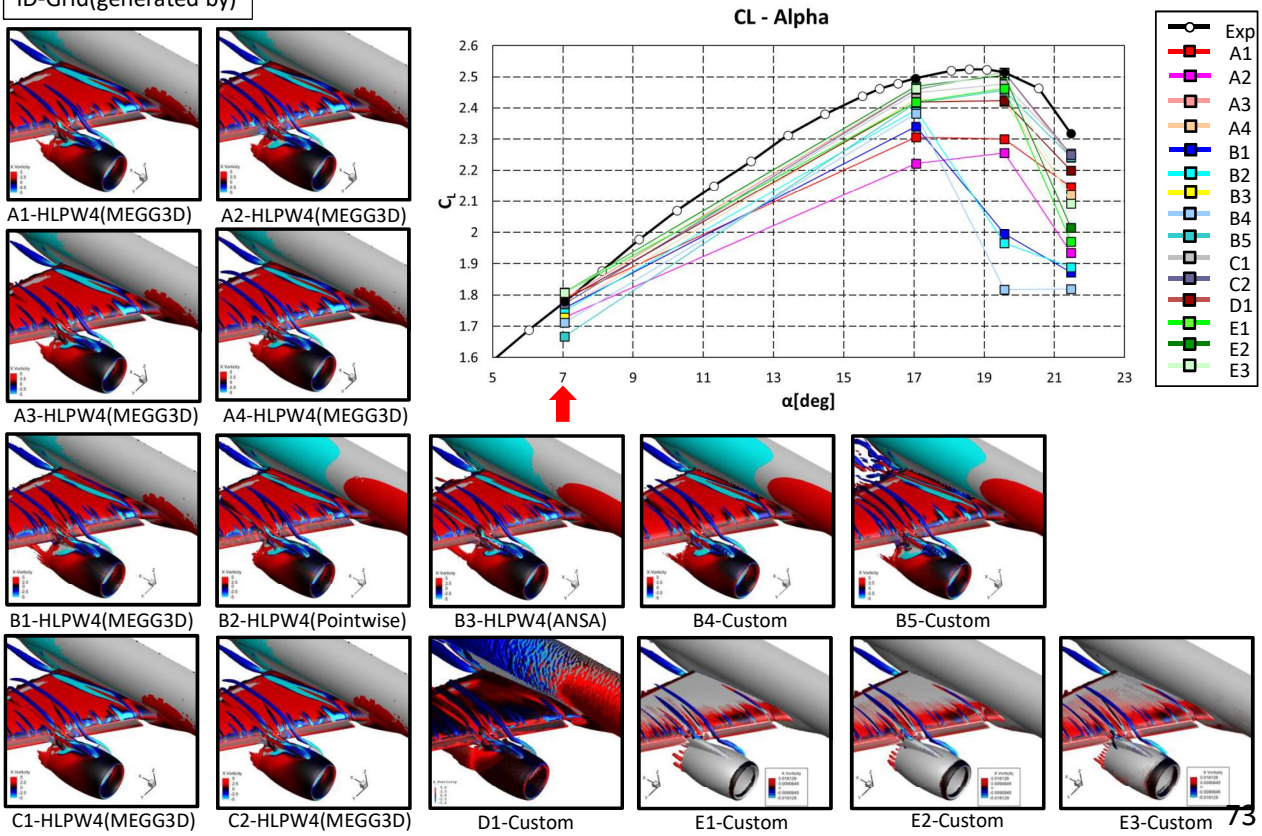
Q-Criterion Surface, Lscale（Case 1, 21.47deg, Viewpoint 3）



This document is provided by JAXA.

Q-Criterion Surface, X-Vorticity（Case 1, 7.05deg, Viewpoint 4）

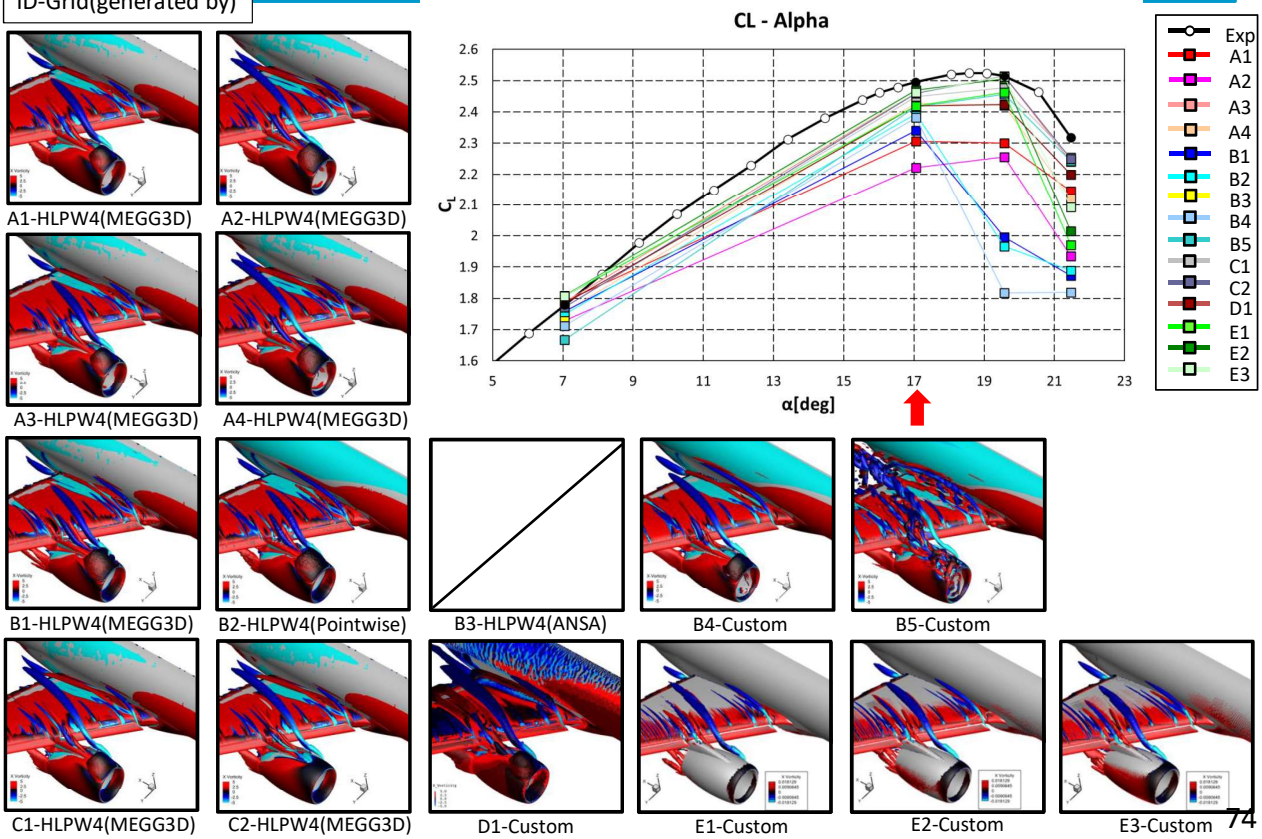
ID-Grid(generated by)



73

Q-Criterion Surface, X-Vorticity（Case 1, 17.05deg, Viewpoint 4）

ID-Grid(generated by)

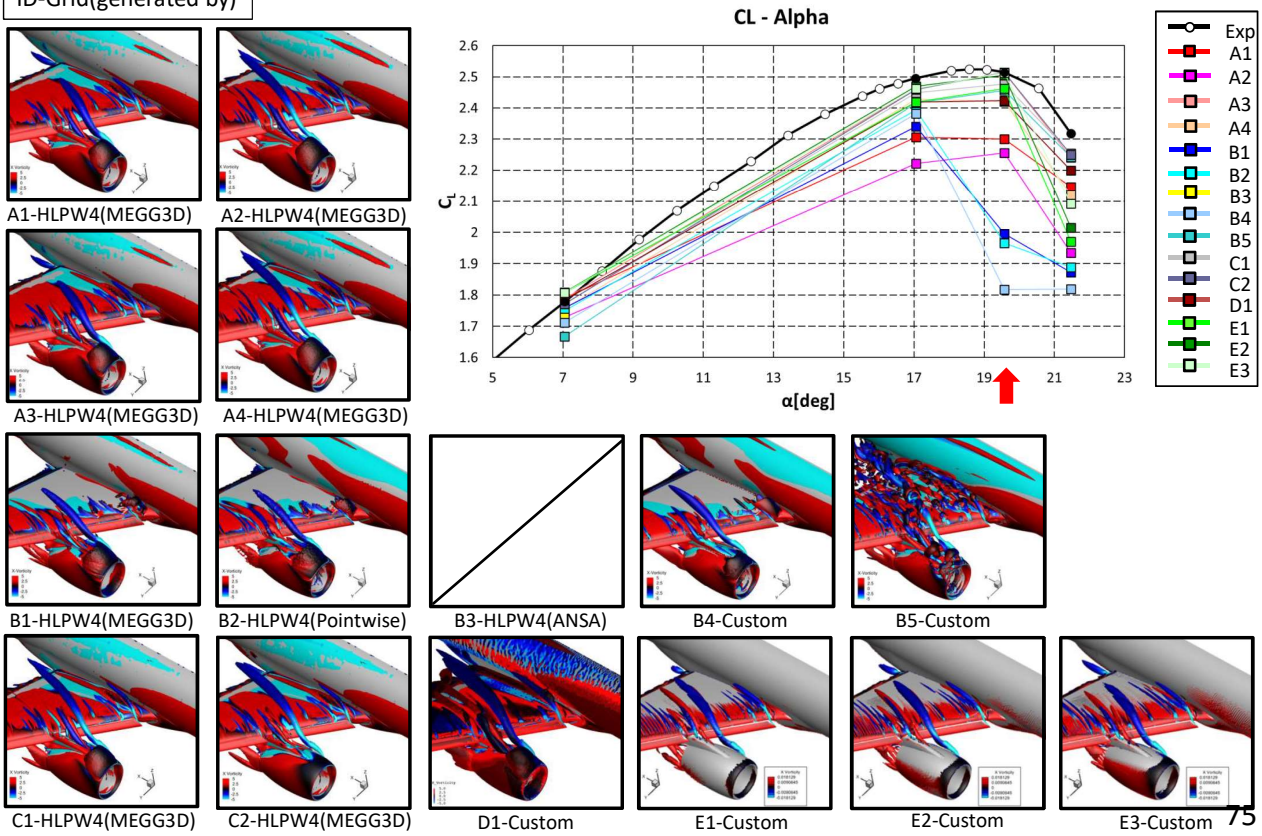


74

This document is provided by JAXA.

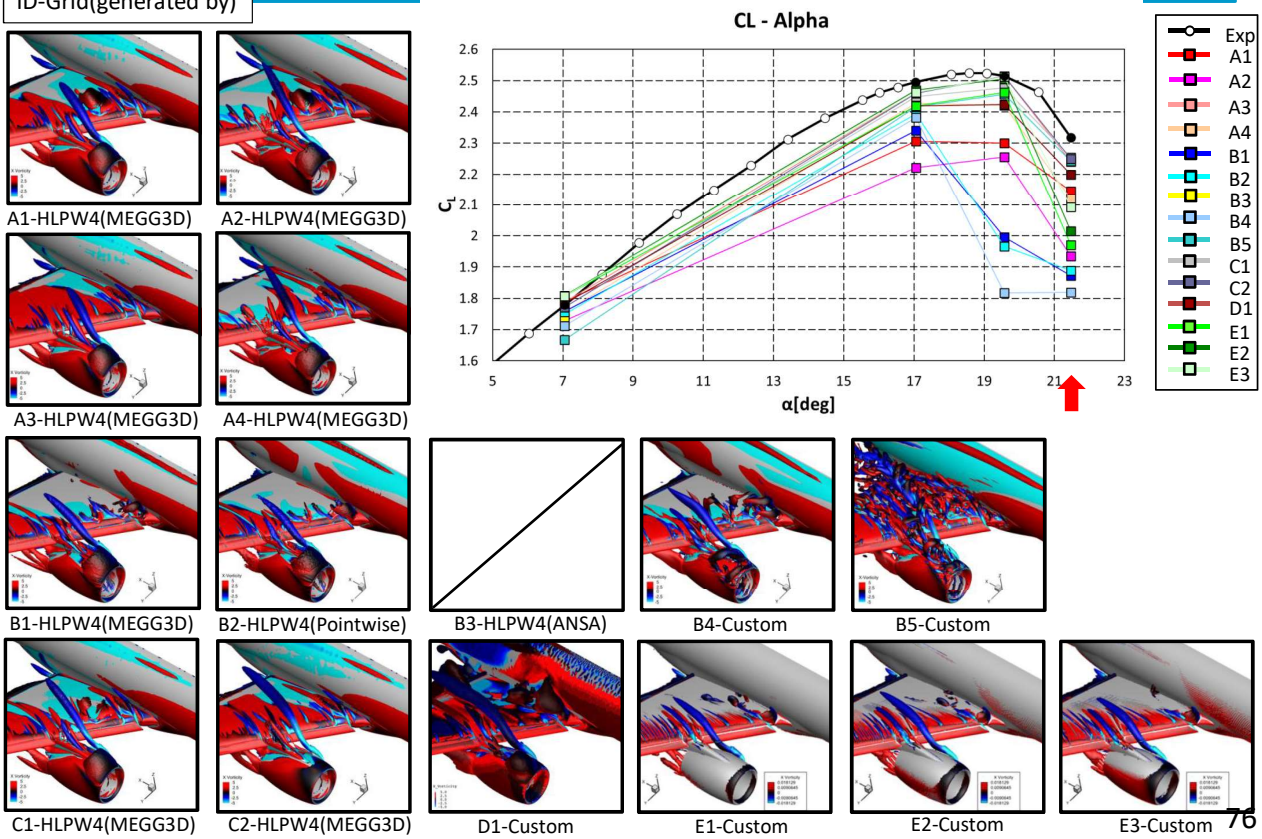
Q-Criterion Surface, X-Vorticity（Case 1, 19.57deg, Viewpoint 4）

ID-Grid(generated by)



Q-Criterion Surface, X-Vorticity（Case 1, 21.47deg, Viewpoint 4）

ID-Grid(generated by)

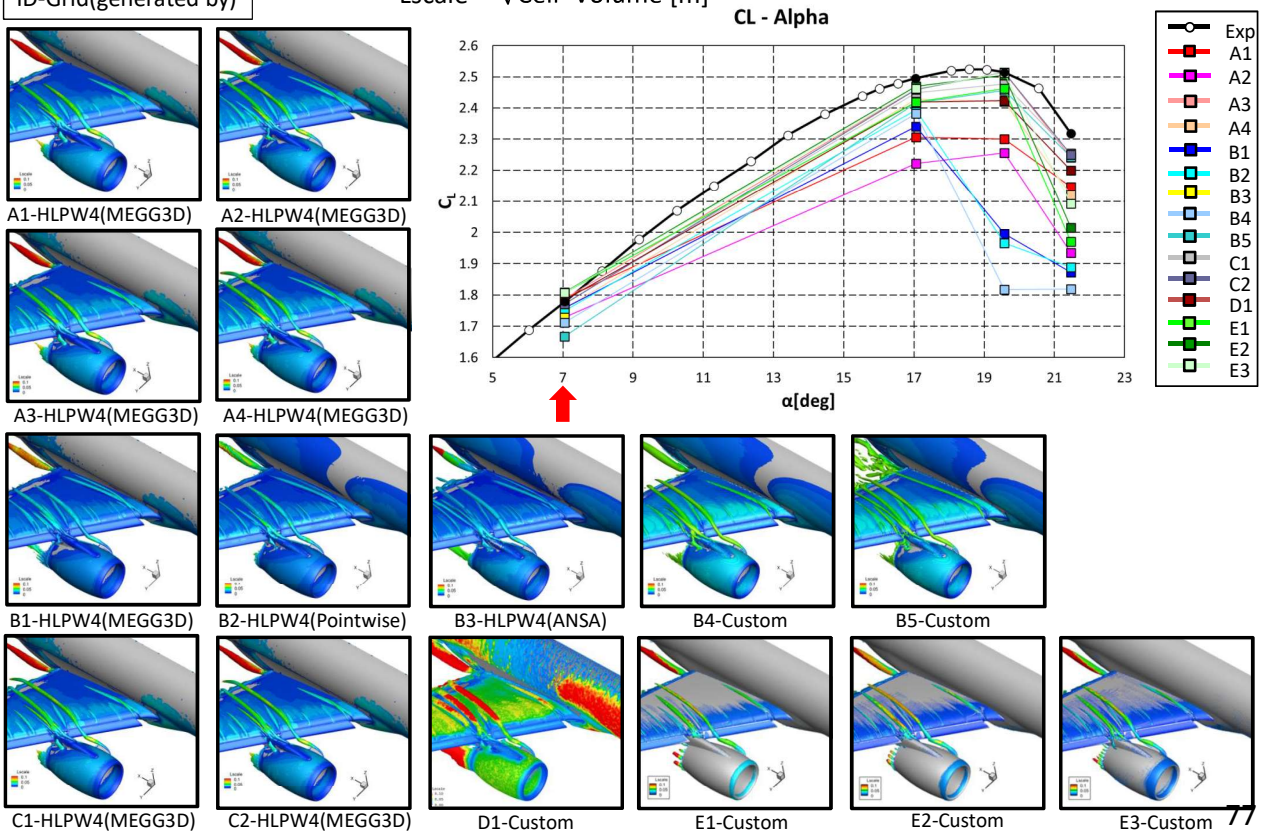


This document is provided by JAXA.

Q-Criterion Surface, Lscale（Case 1, 7.05deg, Viewpoint 4）

ID-Grid(generated by)

Lscale = $\sqrt[3]{\text{Cell-Volume}}$ [m]

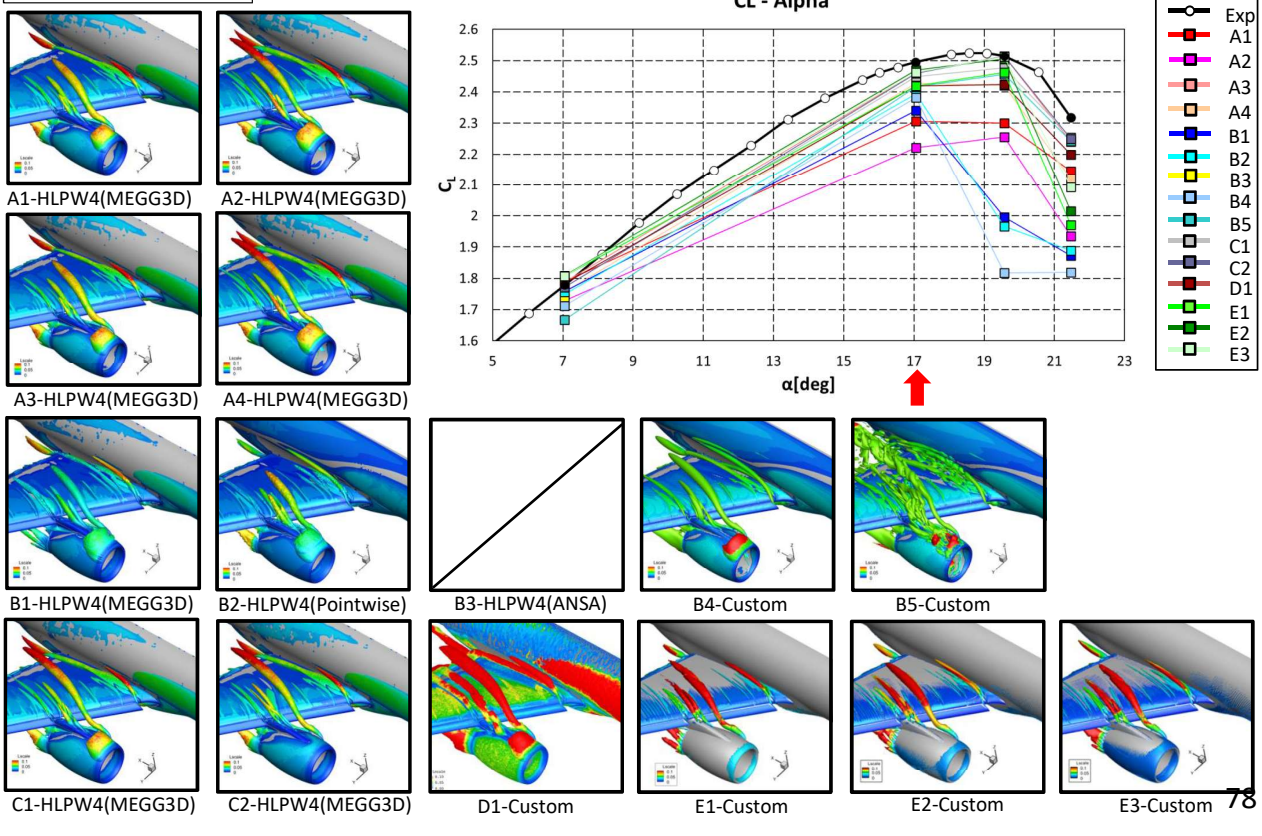


77

Q-Criterion Surface, Lscale（Case 1, 17.05deg, Viewpoint 4）

ID-Grid(generated by)

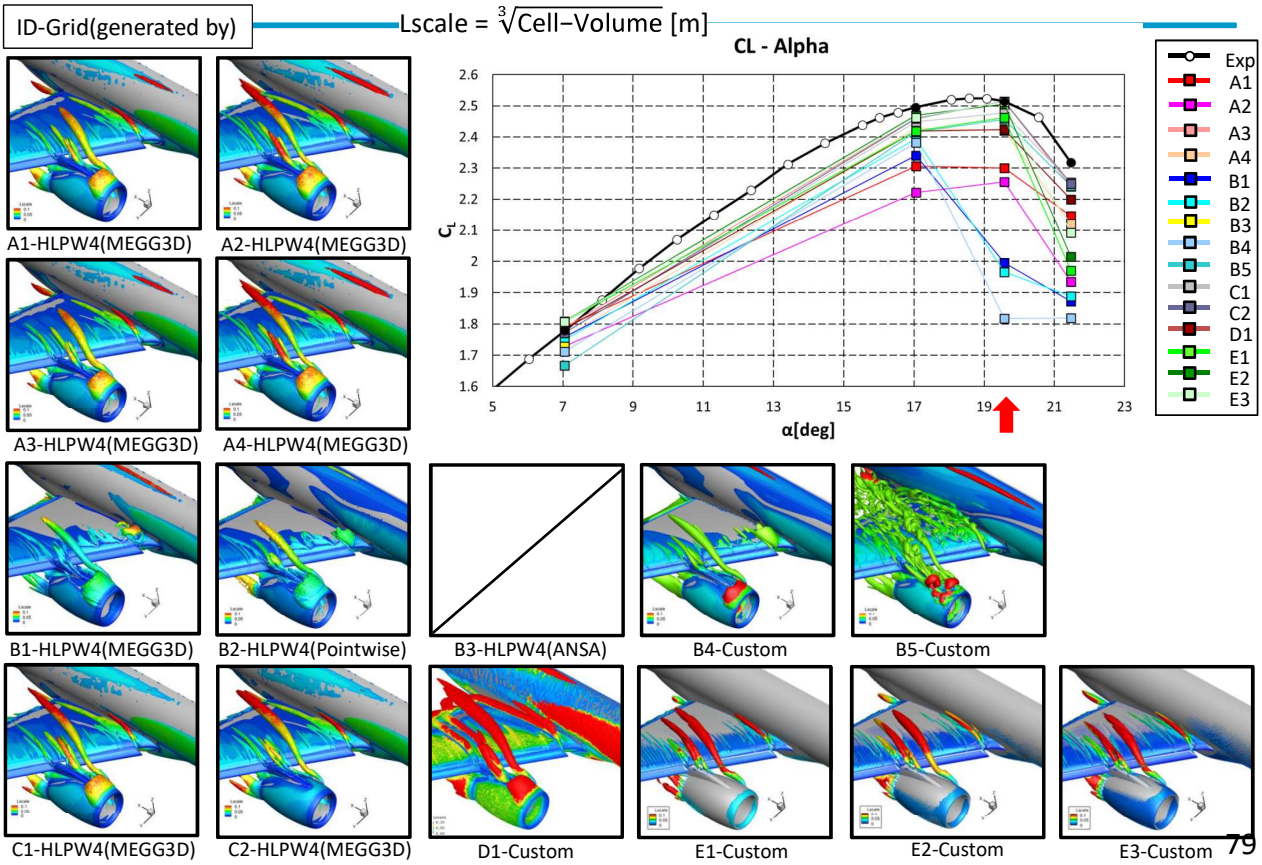
Lscale = $\sqrt[3]{\text{Cell-Volume}}$ [m]



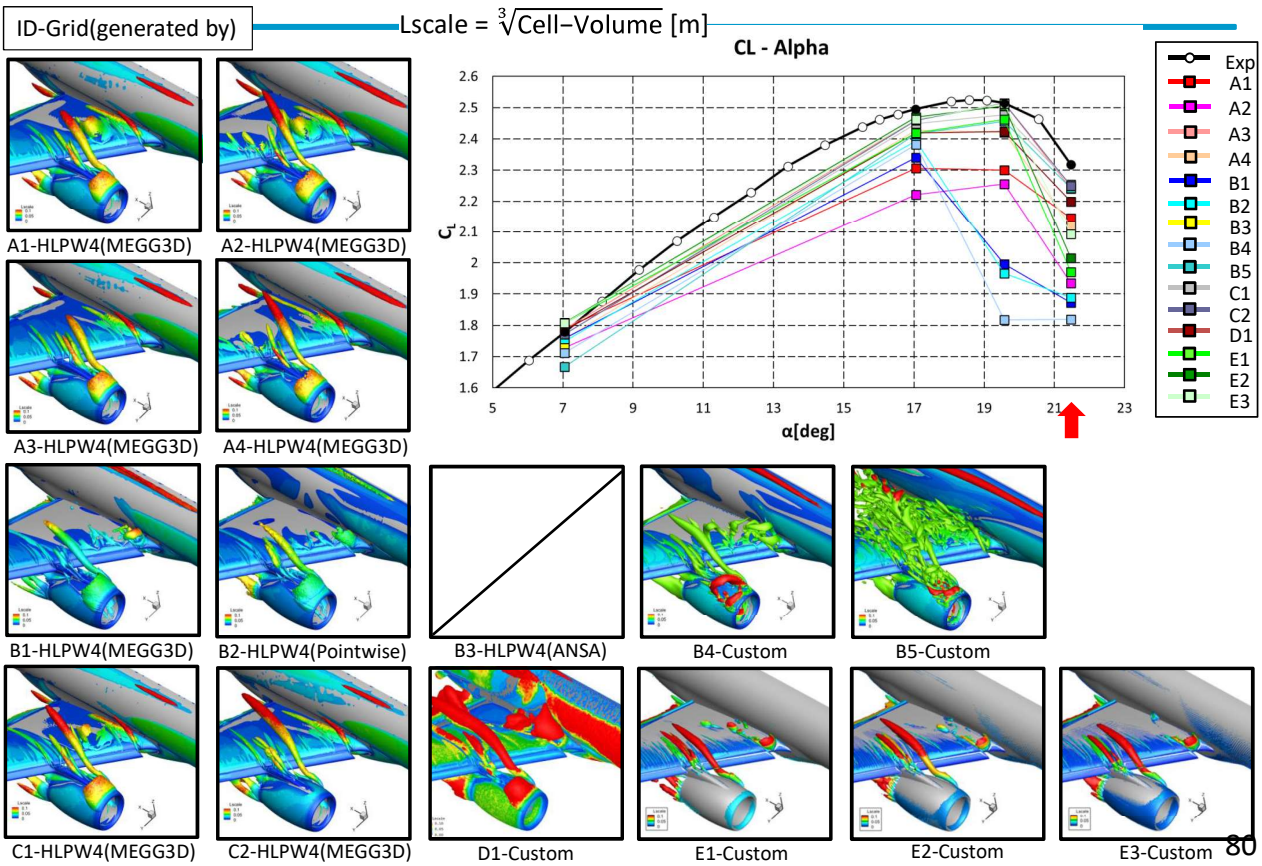
78

This document is provided by JAXA.

Q-Criterion Surface, Lscale（Case 1, 19.57deg, Viewpoint 4）



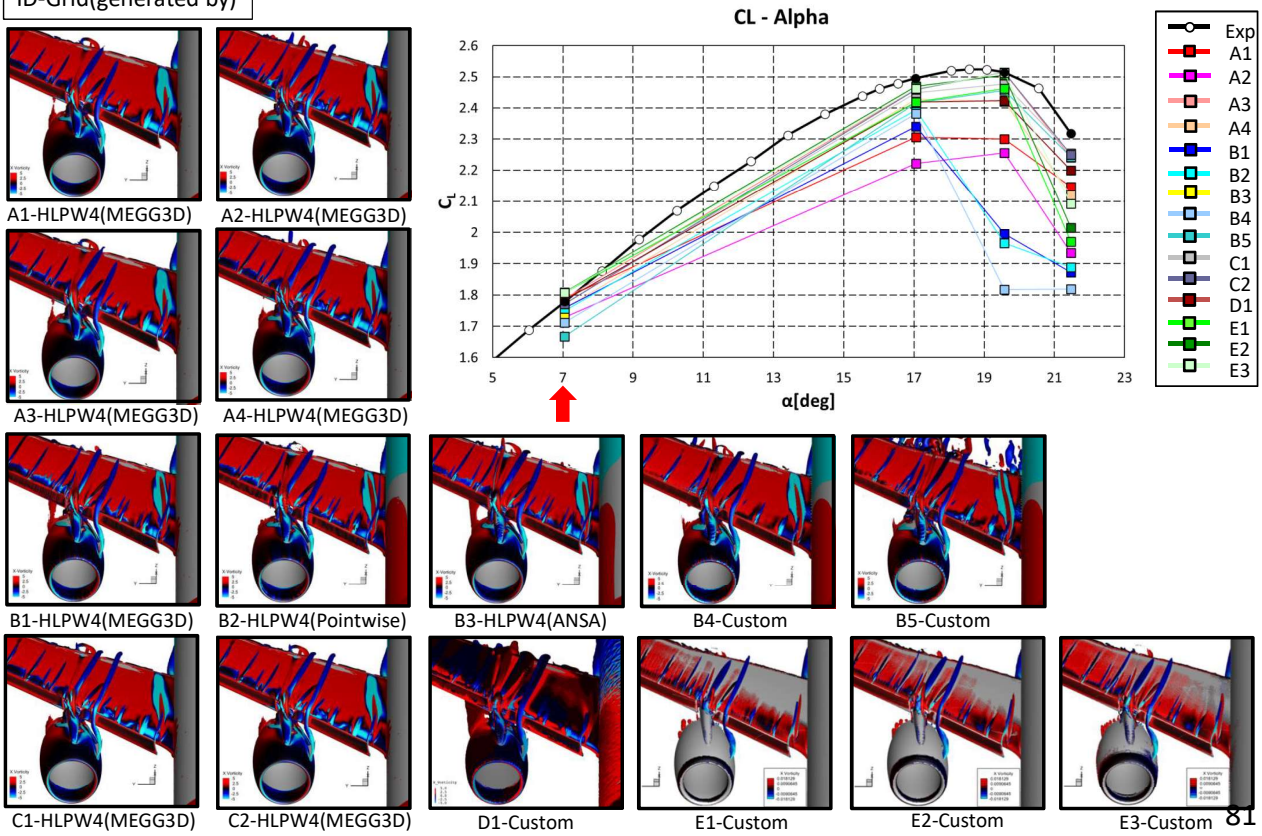
Q-Criterion Surface, Lscale（Case 1, 21.47deg, Viewpoint 4）



This document is provided by JAXA.

Q-Criterion Surface, X-Vorticity（Case 1, 7.05deg, Viewpoint 5）

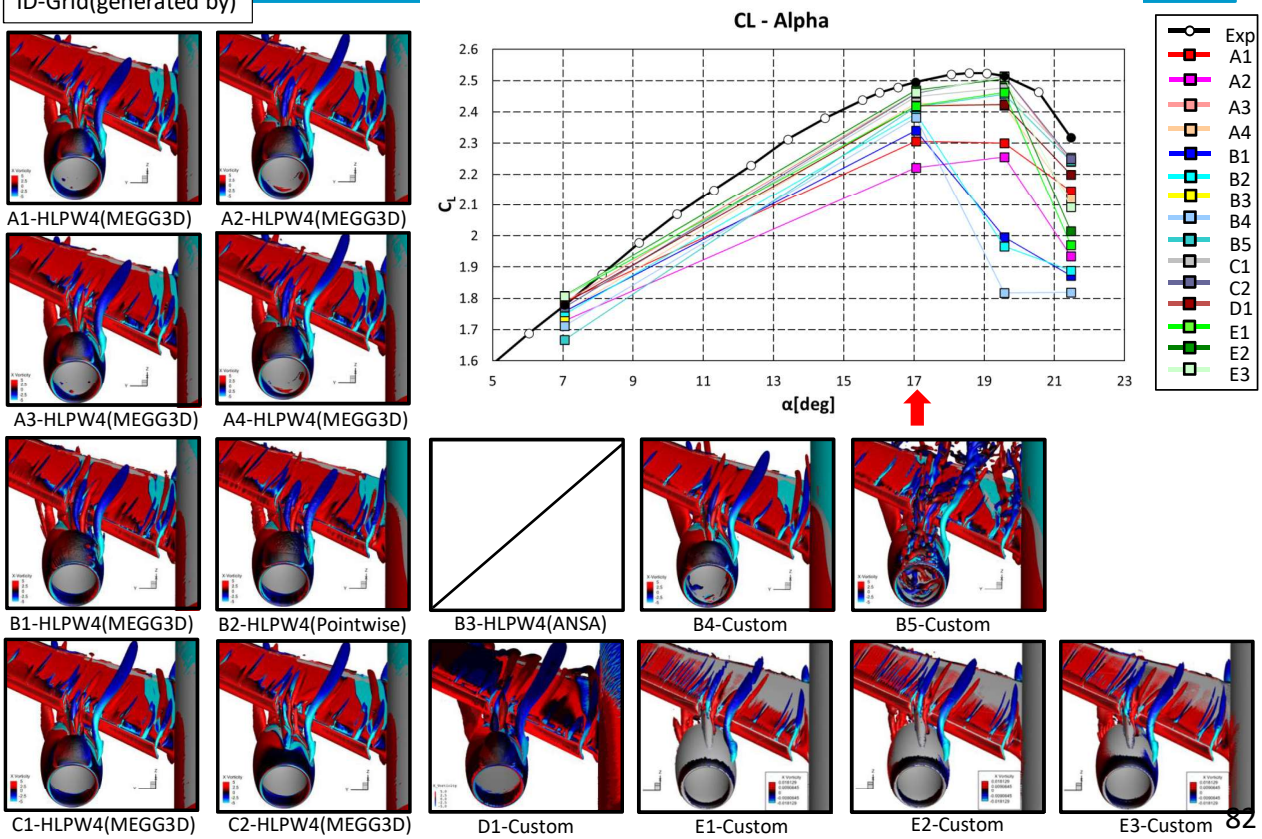
ID-Grid(generated by)



81

Q-Criterion Surface, X-Vorticity（Case 1, 17.05deg, Viewpoint 5）

ID-Grid(generated by)

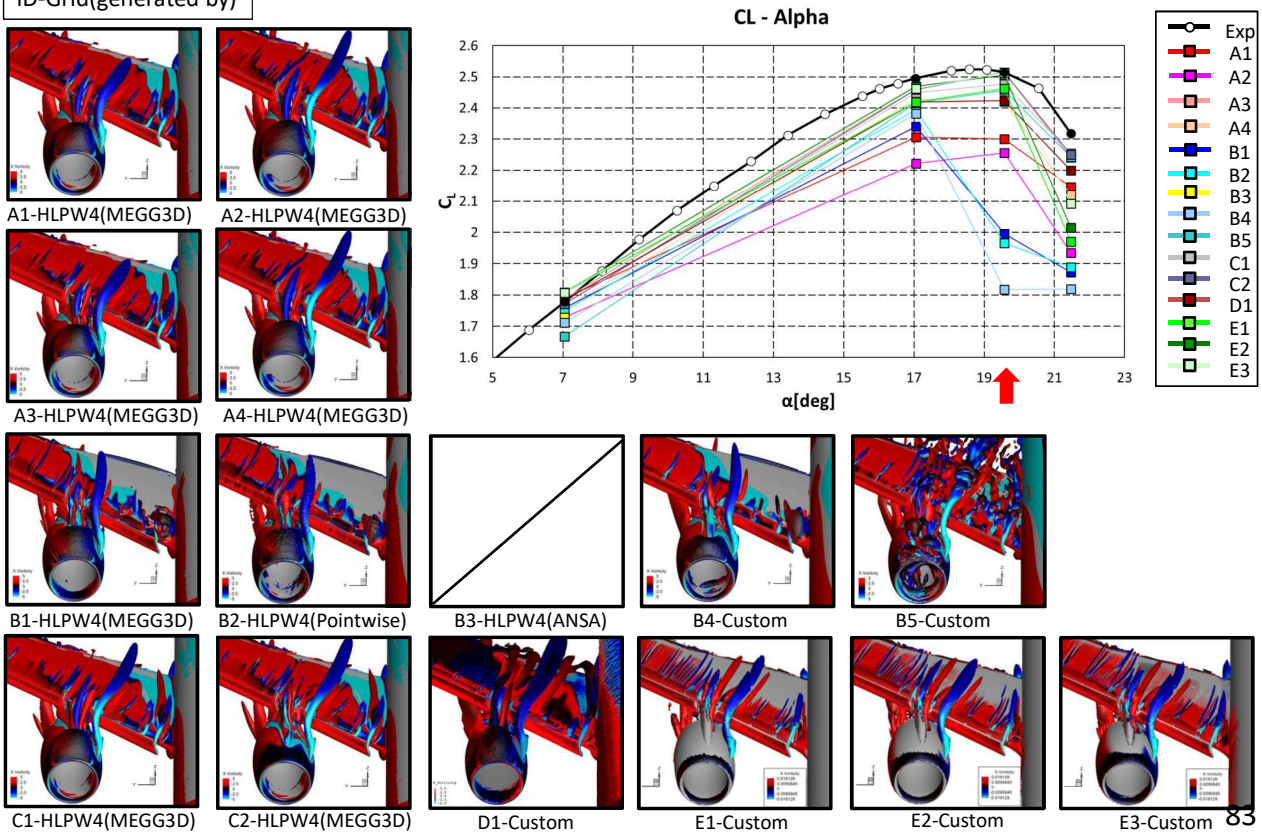


82

This document is provided by JAXA.

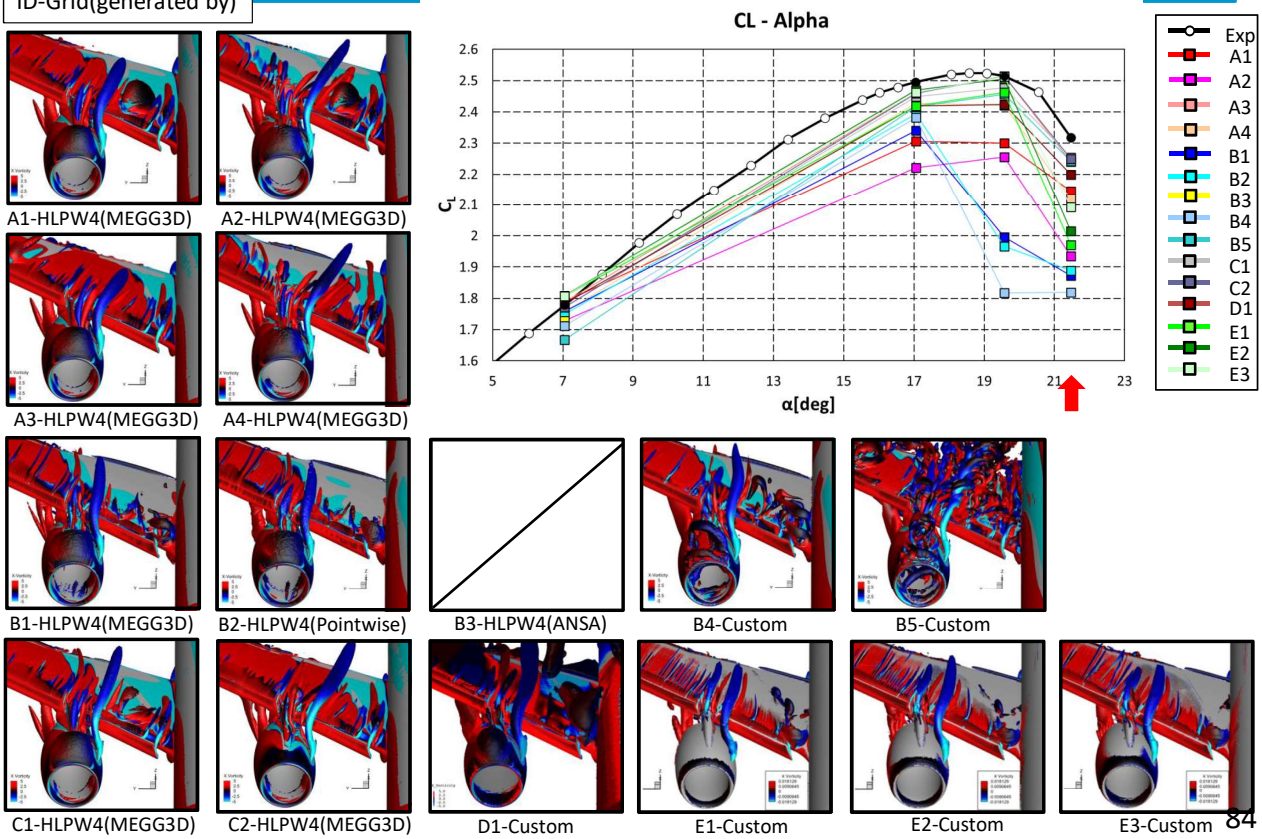
Q-Criterion Surface, X-Vorticity（Case 1, 19.57deg, Viewpoint 5）

ID-Grid(generated by)



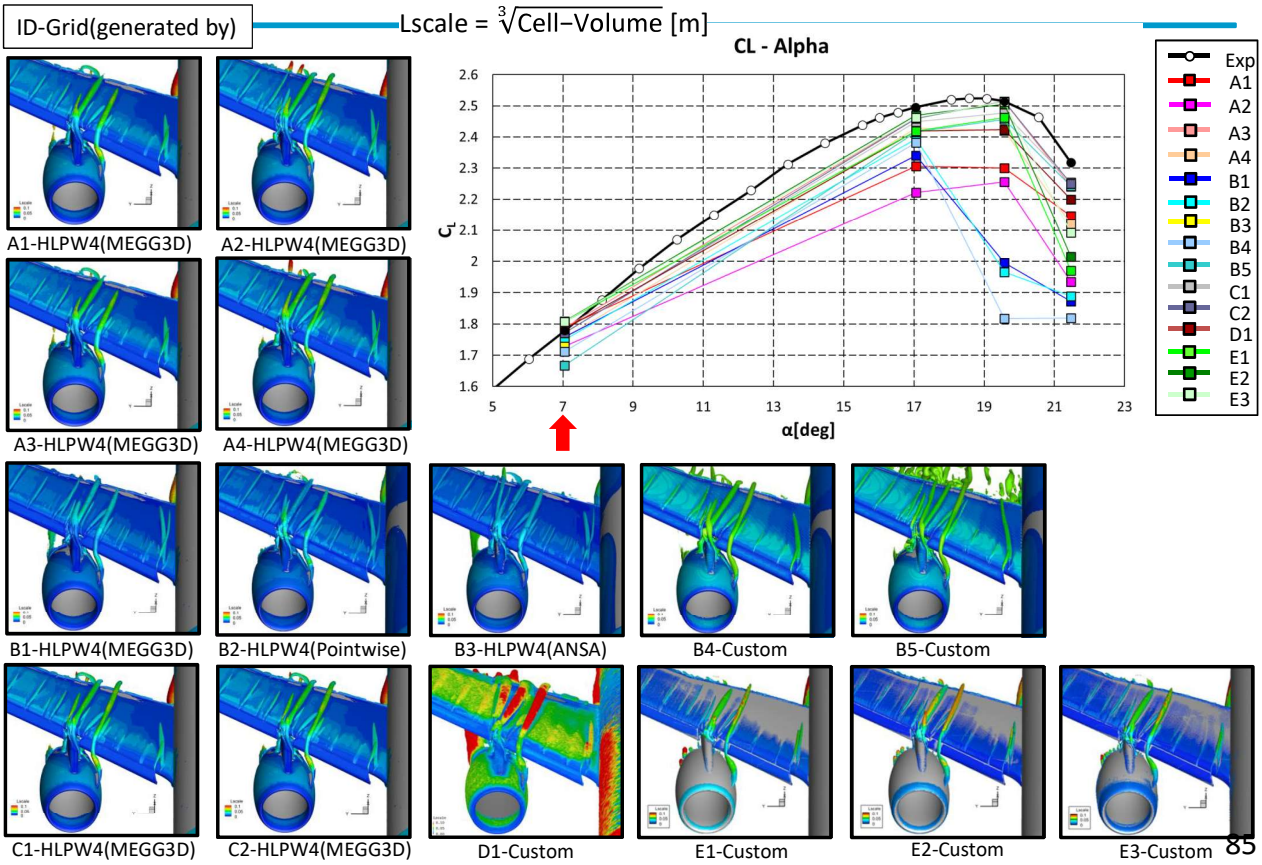
Q-Criterion Surface, X-Vorticity（Case 1, 21.47deg, Viewpoint 5）

ID-Grid(generated by)



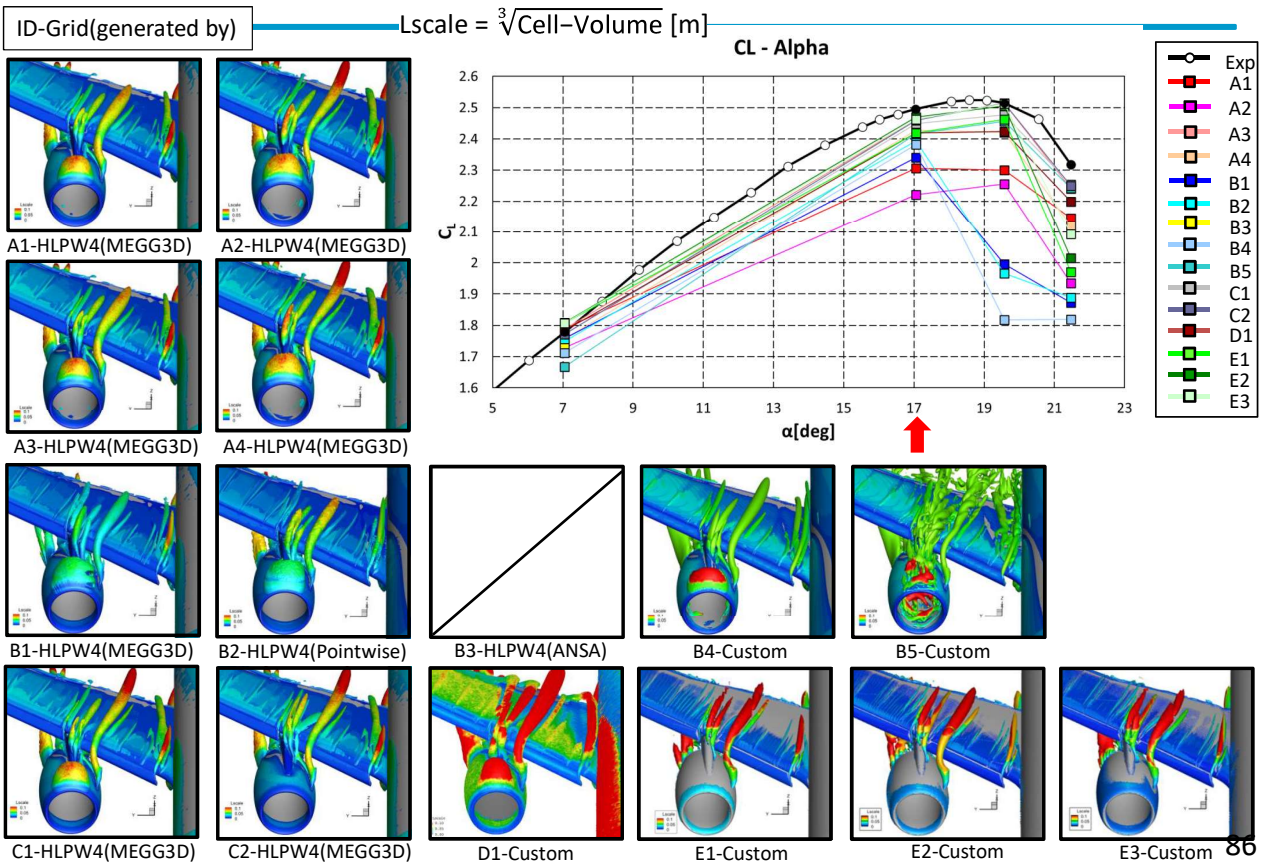
This document is provided by JAXA.

Q-Criterion Surface, Lscale（Case 1, 7.05deg, Viewpoint 5）



85

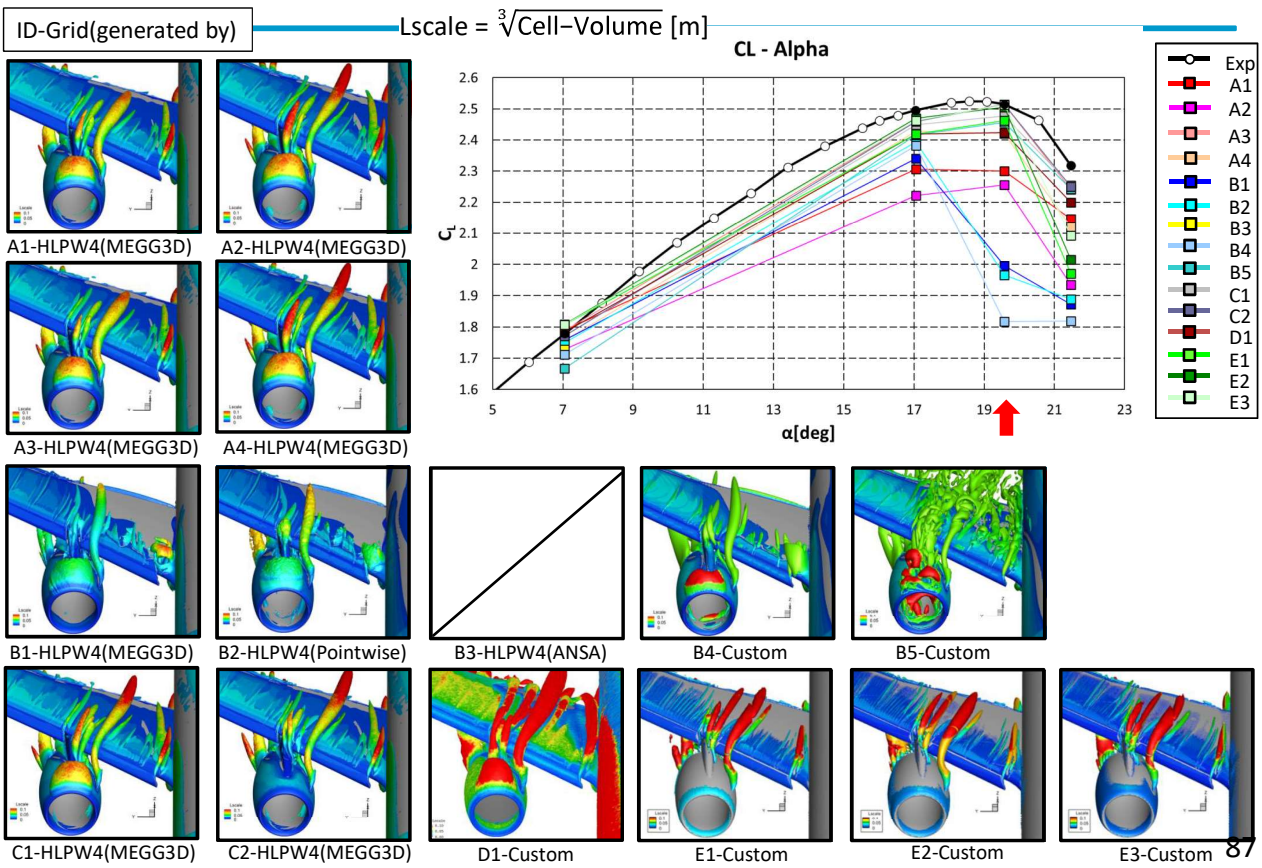
Q-Criterion Surface, Lscale（Case 1, 17.05deg, Viewpoint 5）



86

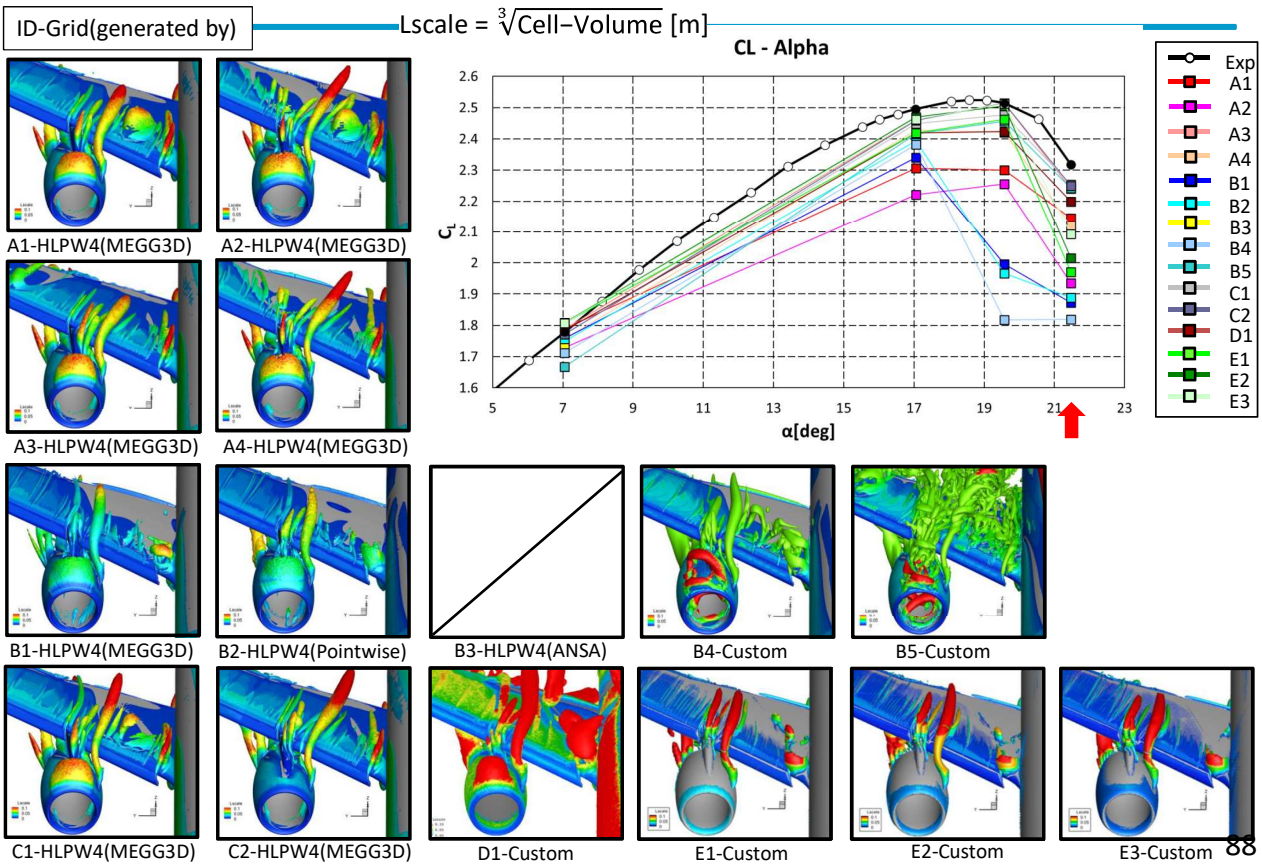
This document is provided by JAXA.

Q-Criterion Surface, Lscale（Case 1, 19.57deg, Viewpoint 5）



87

Q-Criterion Surface, Lscale（Case 1, 21.47deg, Viewpoint 5）



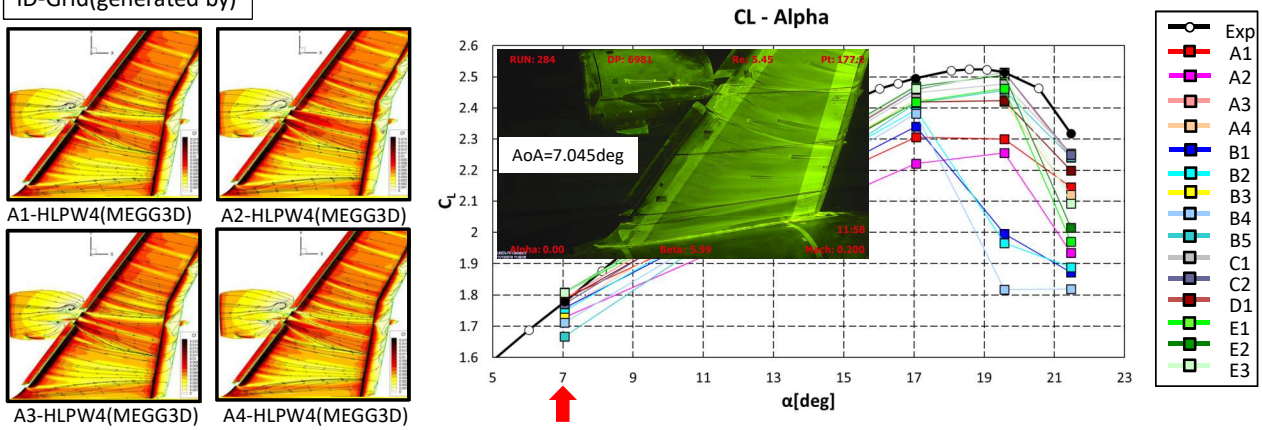
88

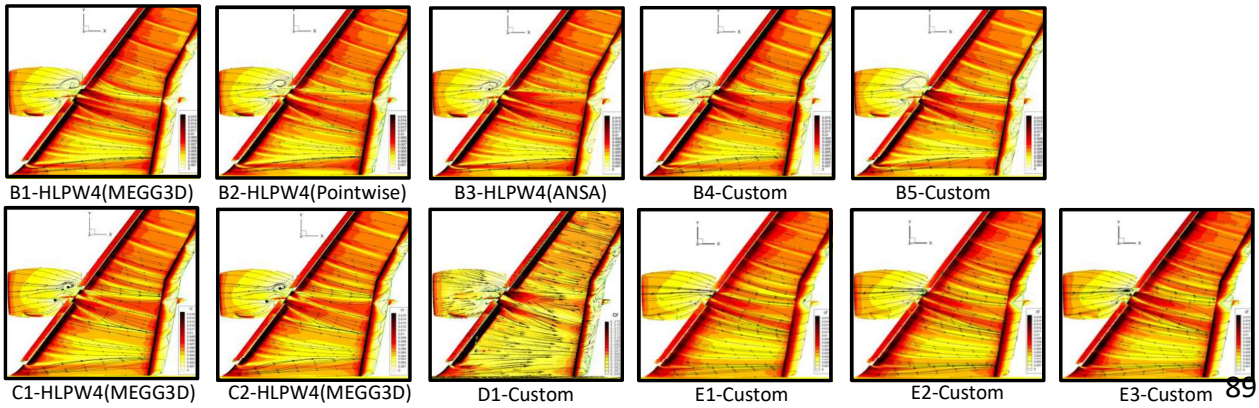
This document is provided by JAXA.

Wall-streamtraces, Cf（Case 1, 7.05deg, Viewpoint 6）

ID-Grid(generated by)

Green lines are contour lines at Cfx=0 in the figures.



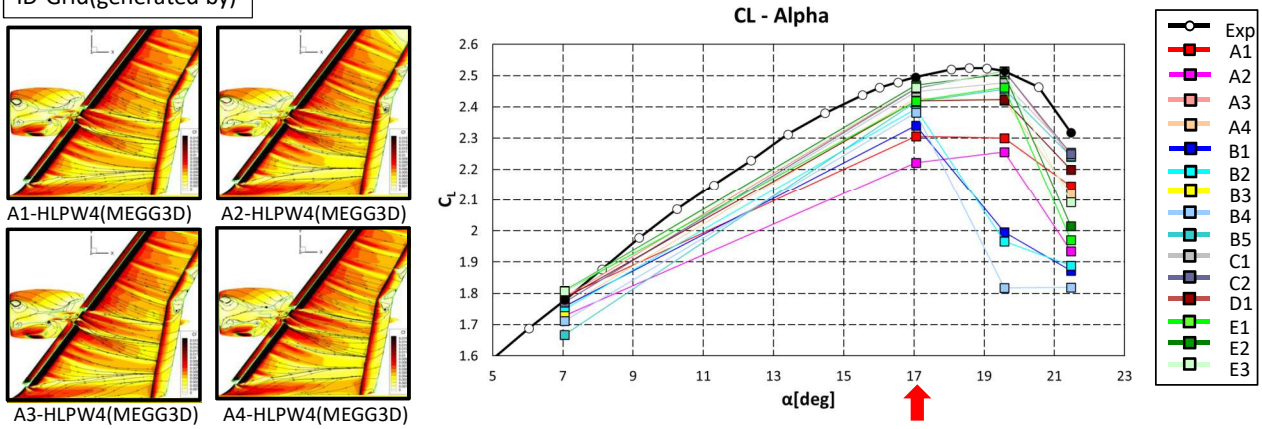


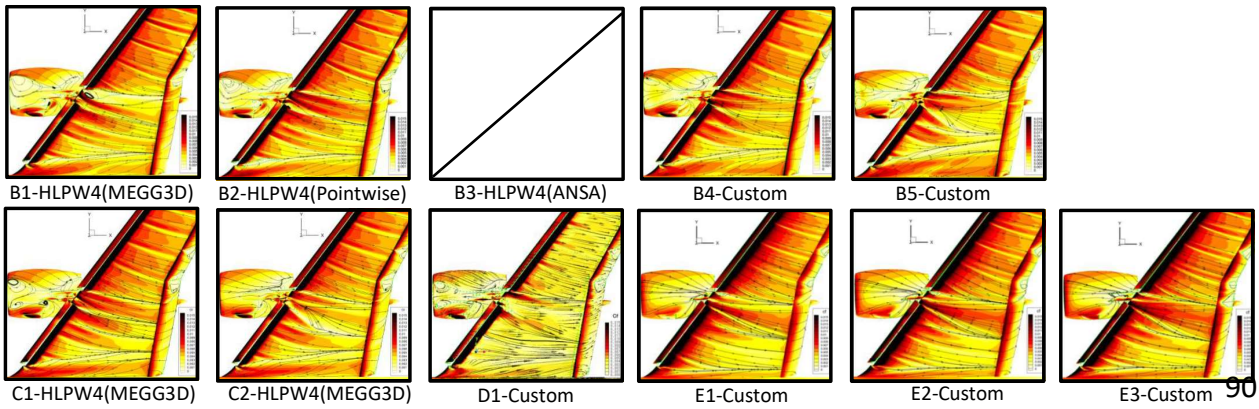
89

Wall-streamtraces, Cf（Case 1, 17.05deg, Viewpoint 6）

ID-Grid(generated by)

Green lines are contour lines at Cfx=0 in the figures.





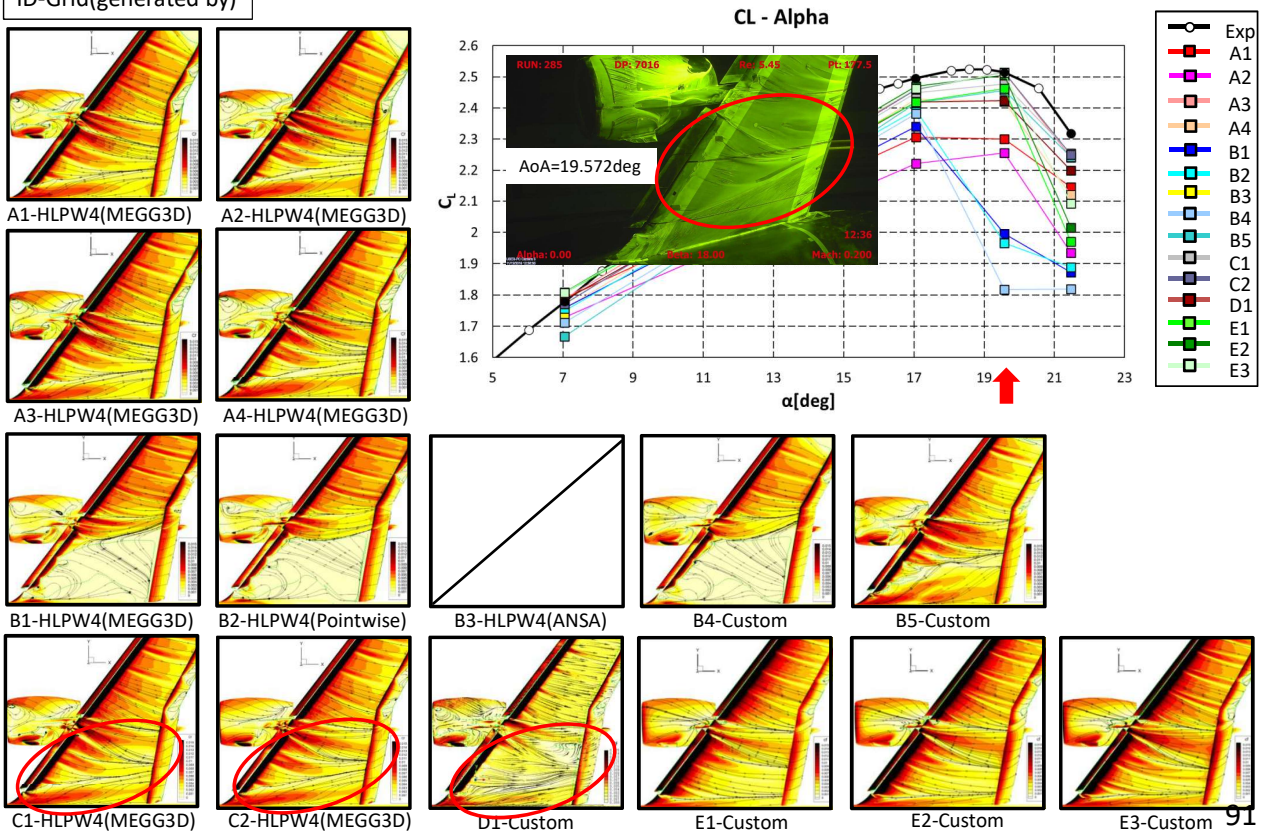
90

This document is provided by JAXA.

Wall-streamtraces, Cf（Case 1, 19.57deg, Viewpoint 6）

ID-Grid(generated by)

Green lines are contour lines at Cfx=0 in the figures.

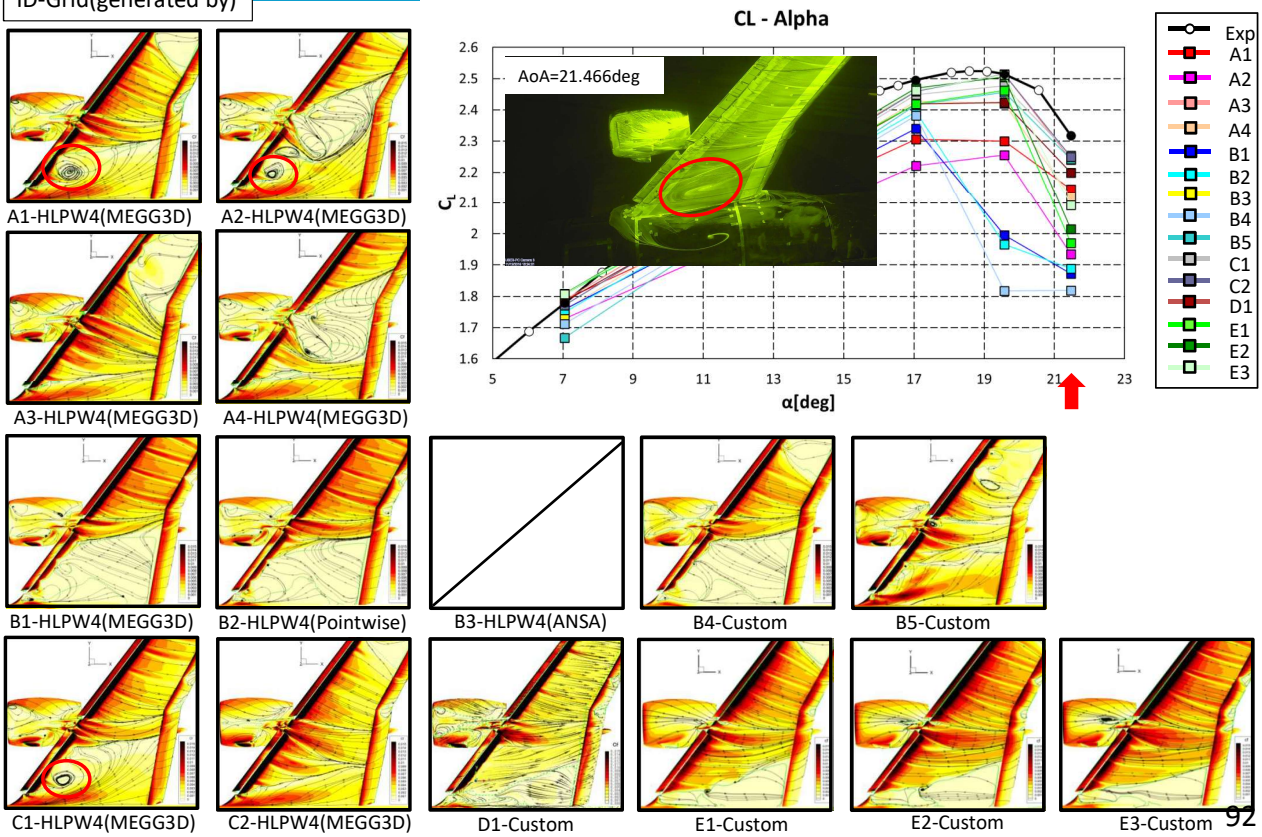


91

Wall-streamtraces, Cf（Case 1, 21.47deg, Viewpoint 6）

ID-Grid(generated by)

Green lines are contour lines at Cfx=0 in the figures.



92

This document is provided by JAXA.