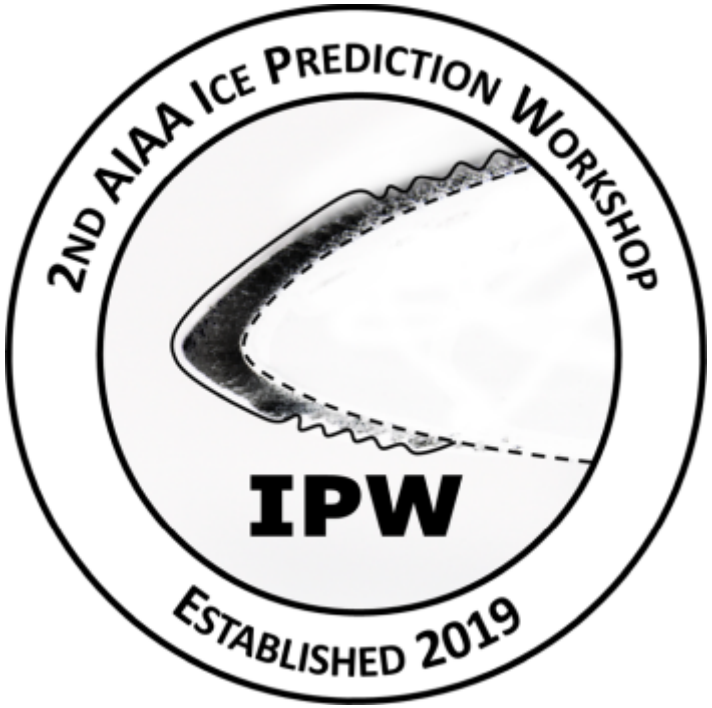


Gulfstream™

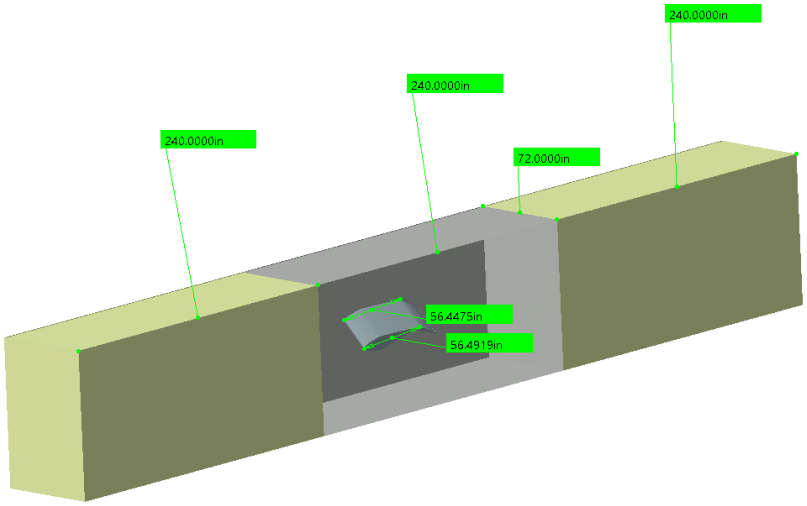
ICE PREDICTION WORKSHOP 2

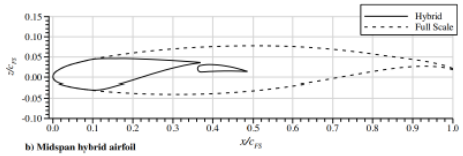
Greg Gathy | Applied Aerodynamic | 2023

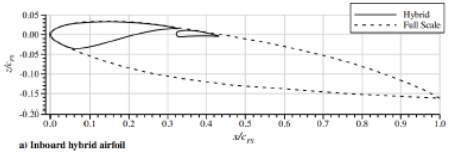
FOCUSING ON CRM CASES

Case 1: CRM-65 Mid-span Hybrid (3D)

Case 2: CRM-65 Inboard Hybrid (3D)







IPW-2 Case no.	Configuration	AoA	Speed	T_{static} (°C)	T_{total} (°C)	LWC (g/m^3)	MVD (µm)	Icing Time (minutes)
1.1	CRM65 Mid-span	3.7	130 kts	-3.6	-1.4	1.0	25	29
1.2	CRM65 Mid-span	3.7	130 kts	-8.5	-6.3	1.0	25	29
1.3	CRM65 Mid-span	3.7	130 kts	-26.0	-23.8	1.0	25	29
2.1	CRM65 Inboard	3.7	130 kts	-3.6	-1.4	1.0	25	29
2.2	CRM65 Inboard	3.7	130 kts	-8.5	-6.3	1.0	25	29
2.3	CRM65 Inboard	3.7	130 kts	-26.0	-23.8	1.0	25	29

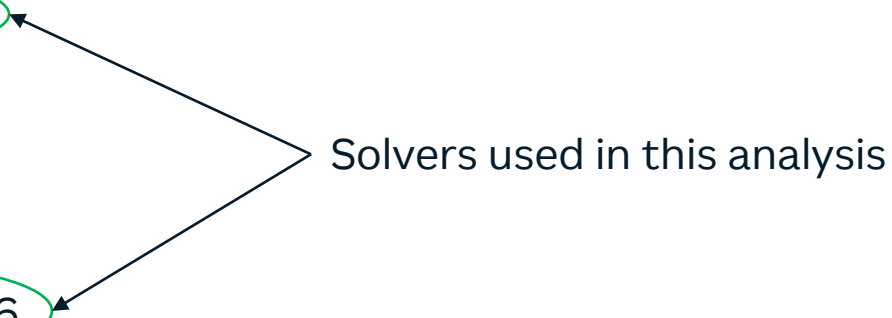
Assumptions:

- Wind tunnel alt 7,91ft
- Test section extension (20ft) FWD and AFT

Gulfstream

FLOW SOLVERS AND ICING AT GULFSTREAM

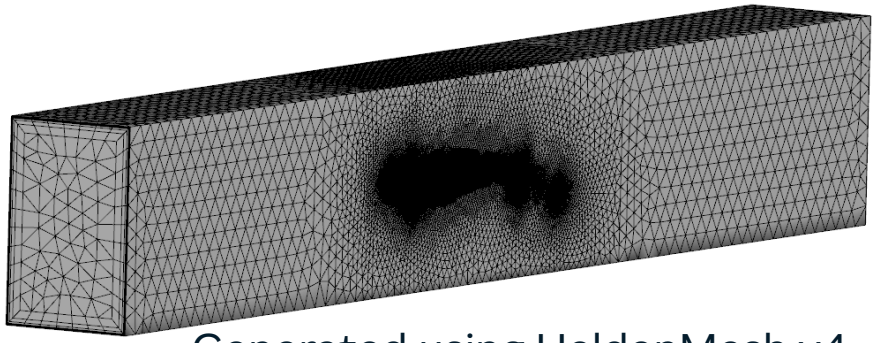
- Flow Solvers are mostly NASA based codes, including
  - USM3D v3
  - FUN3D v14
  - NSU3D v4
- Icing Solvers
  - LEWICE3D v3.6
  - STARCCM+



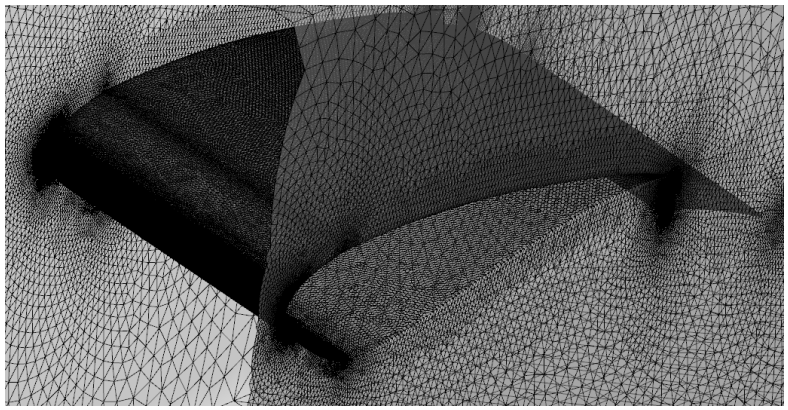
- Gulfstream has used these solvers over the past 20-years worth of aircraft programs
  - G650
  - GVII
  - GVIII
  - Government Programs (Special Missions)

USM3D INPUT

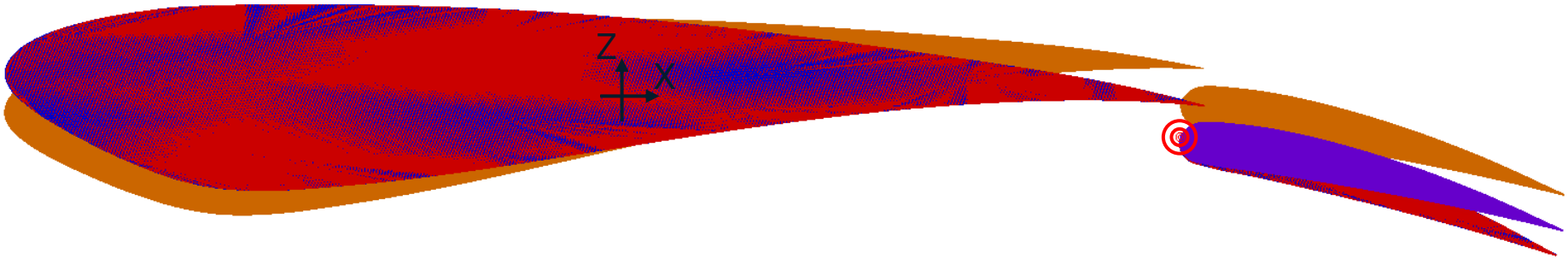
Case	AoA (deg)	KTAS	TAT (ºC)	Re	Chord (in)	S_{ref} (in^2)	Mesh Cells
1.1	3.7	130	-1.4	~7e6	56	4032	~39.1M
1.2			-6.3	~7e6			
1.3			-23.8	~7e6			
2.1			-1.4	~15e6	123	8,856	~37.5M
2.2			-6.3	~15e6			
2.3			-23.8	~15e6			



Generated using HeldenMesh v4



CAD GEOMETRY MODIFICATIONS



IPW Provided Grids

AoA 0° (Original CAD Geometry)

AoA 3.7° (rotated about y-axis at origin)

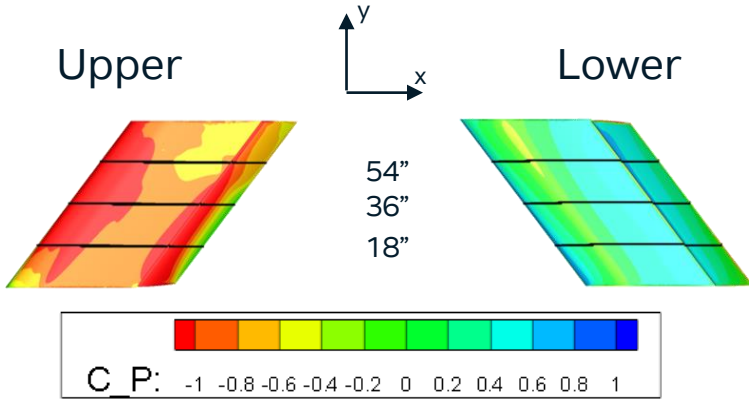
AoA 3.7° Flap 0° (Flap Rotated About ◎)

Matched Well Geometrically

Best C_P Match for Inboard CRM

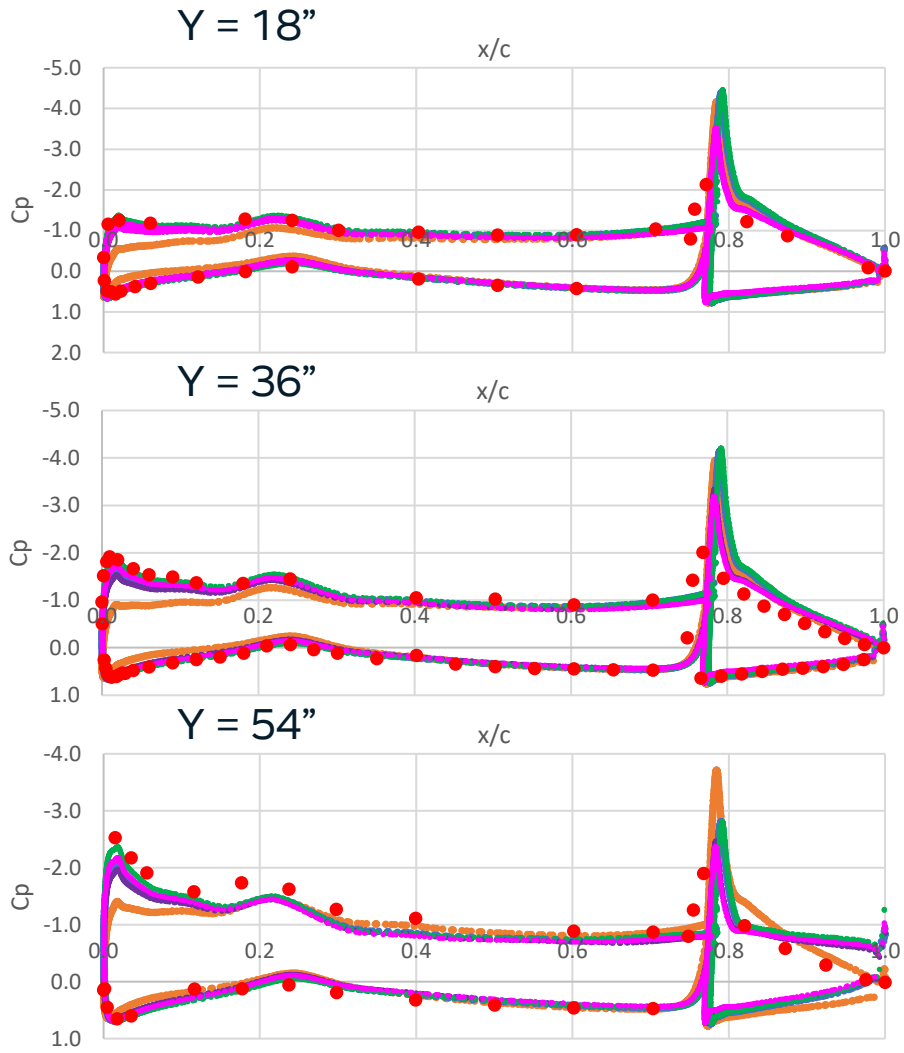
Mid-Span CRM model C_P matched best with AoA 4.7º

C_P CUT MATCHING: CRM MID-SPAN



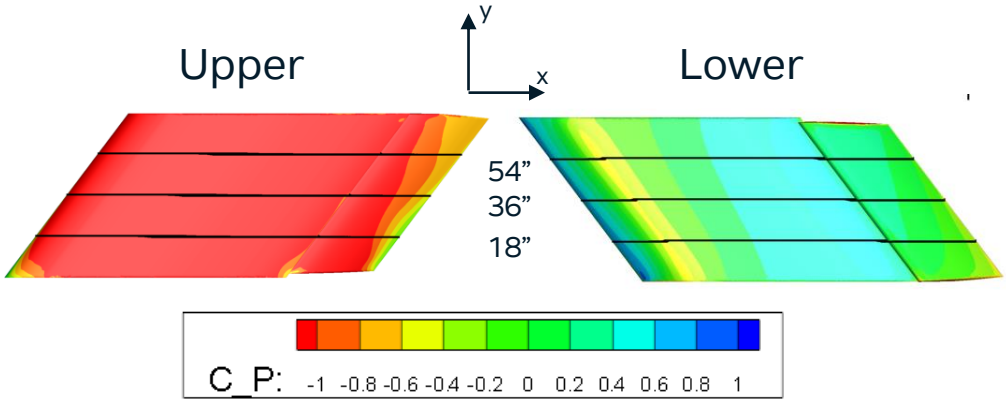
Best Match

C_P Matches best with the AoA 4.7º to get an equivalent peak at the LE

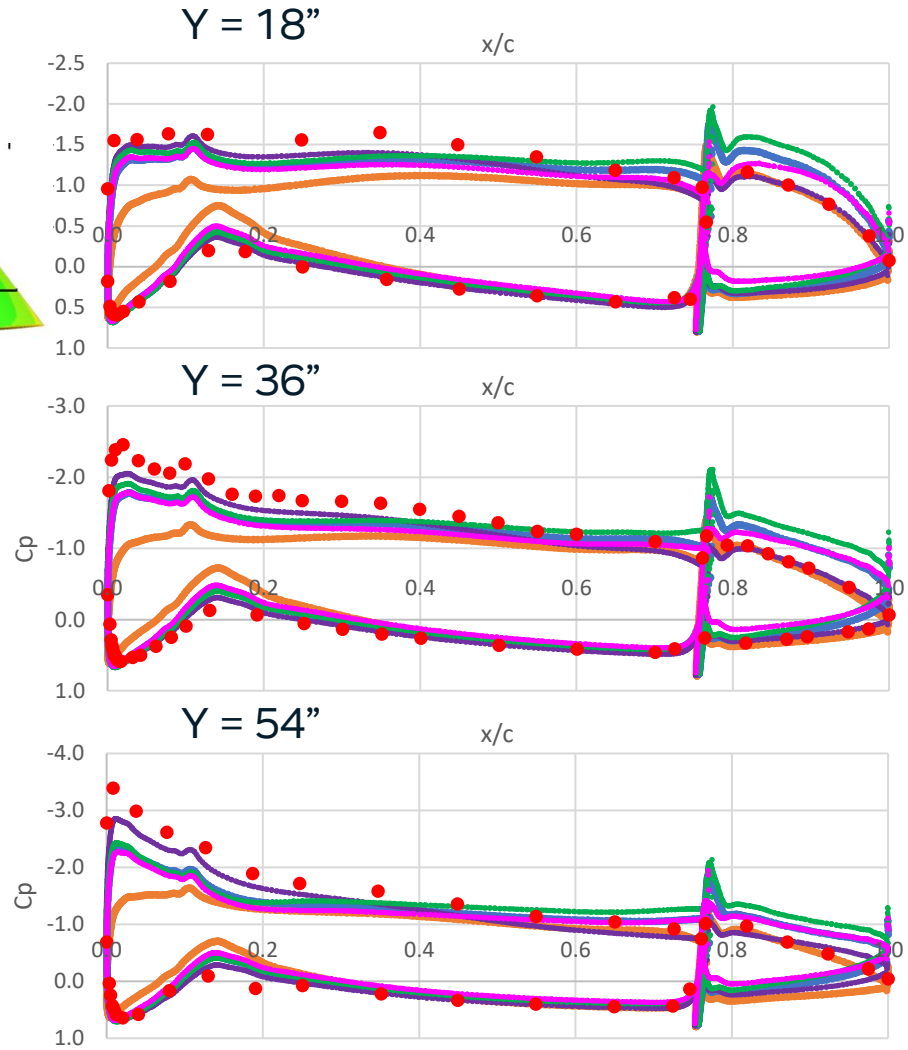


Gulfstream

C_P CUT MATCHING: CRM INBOARD



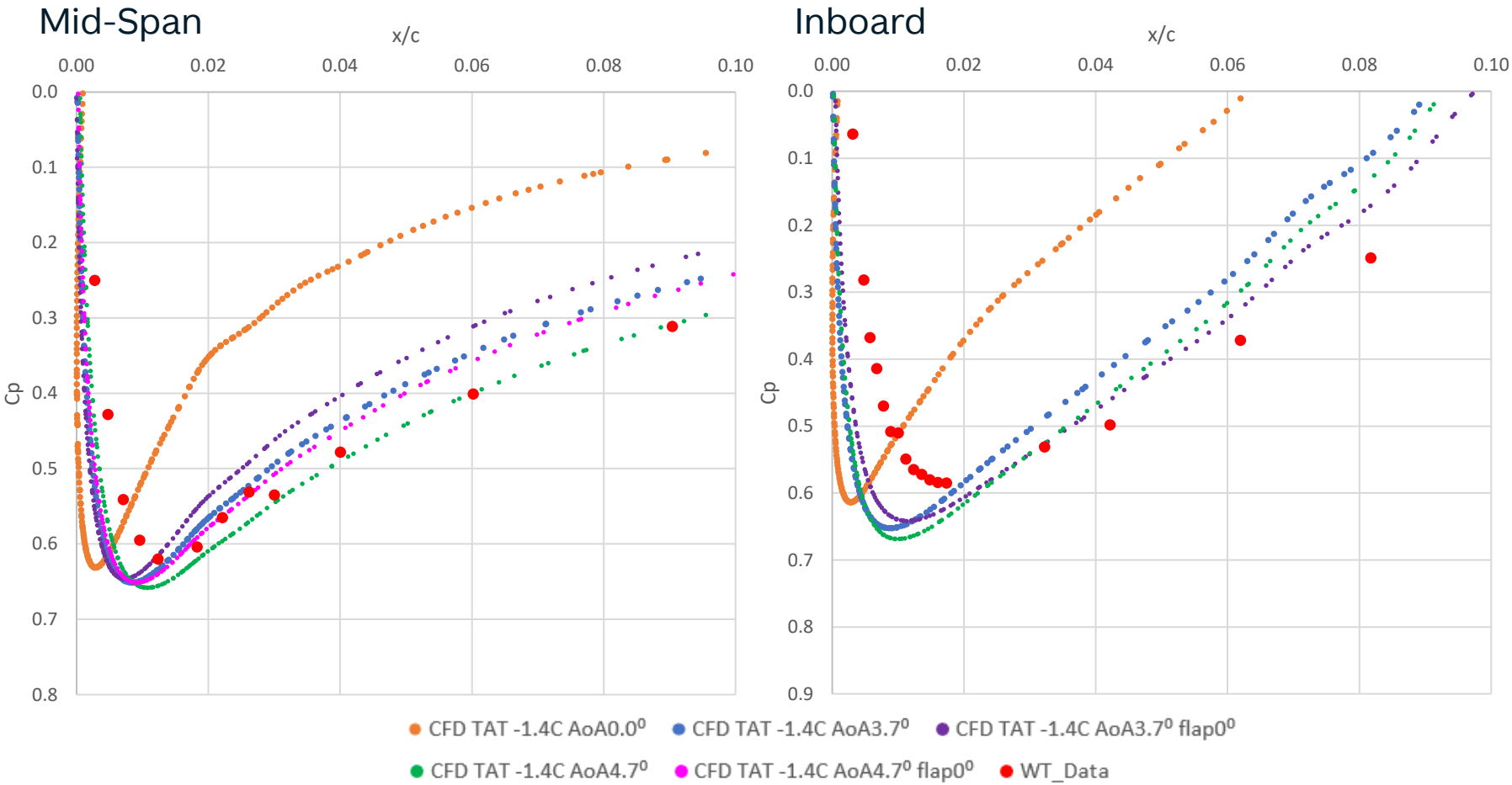
- WT_Data
- CFD TAT -1.4C AoA0.0^0
- CFD TAT -1.4C AoA3.7^0
- CFD TAT -1.4C AoA3.7^0 flap0^0 — Best Match
- CFD TAT -1.4C AoA4.7^0
- CFD TAT -1.4C AoA4.7^0 flap0^0



C_P Matches best with the AoA 3.7º but required flap adjustment to match flap and LE C_P peak

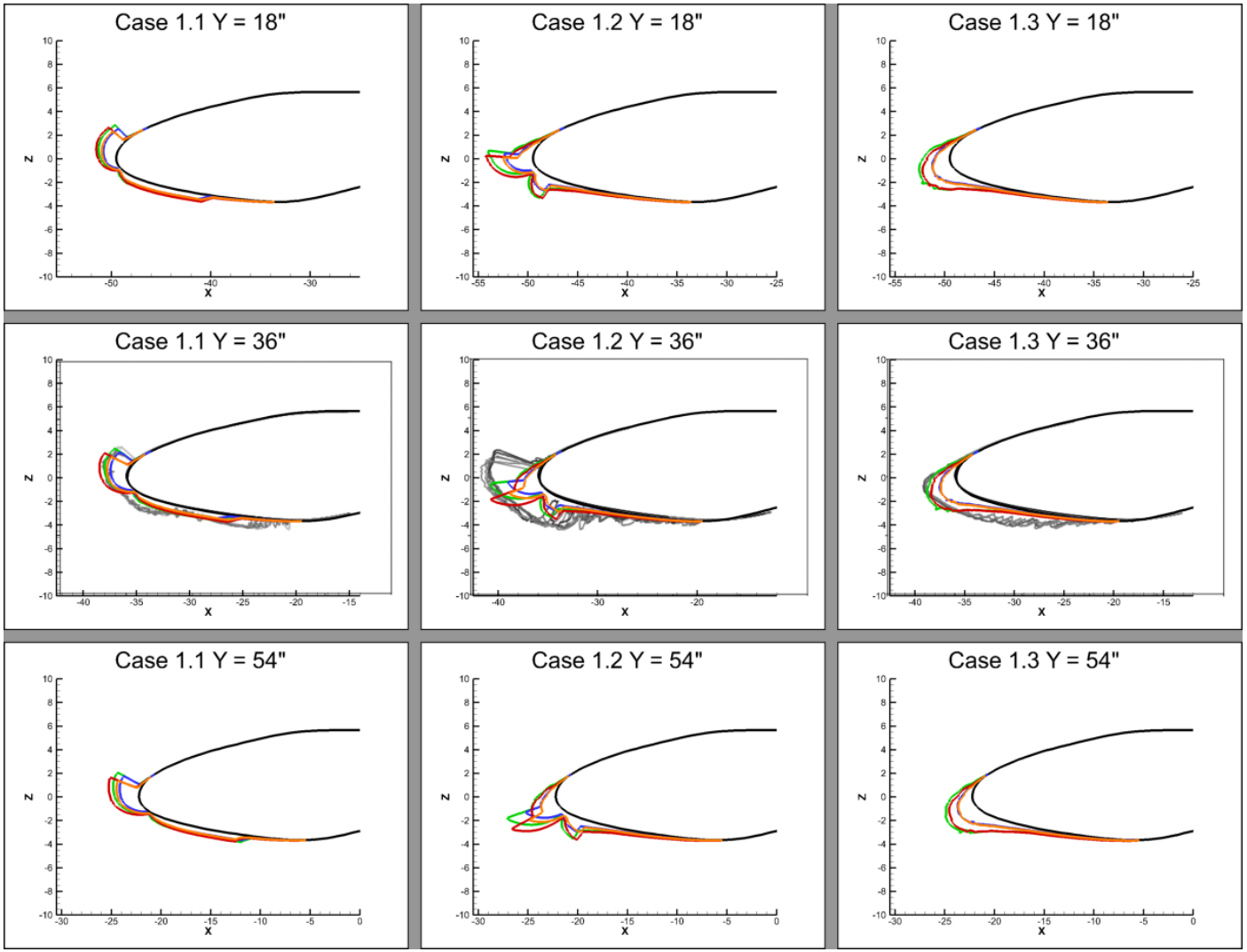
Gulfstream

36” STAGNATION COMPARE



Stagnation Locations Align with Previous C_P Section Cut Best Fit
Mid-Span AoA 4.7⁰
Inboard AoA 3.7⁰ with Flap 0⁰

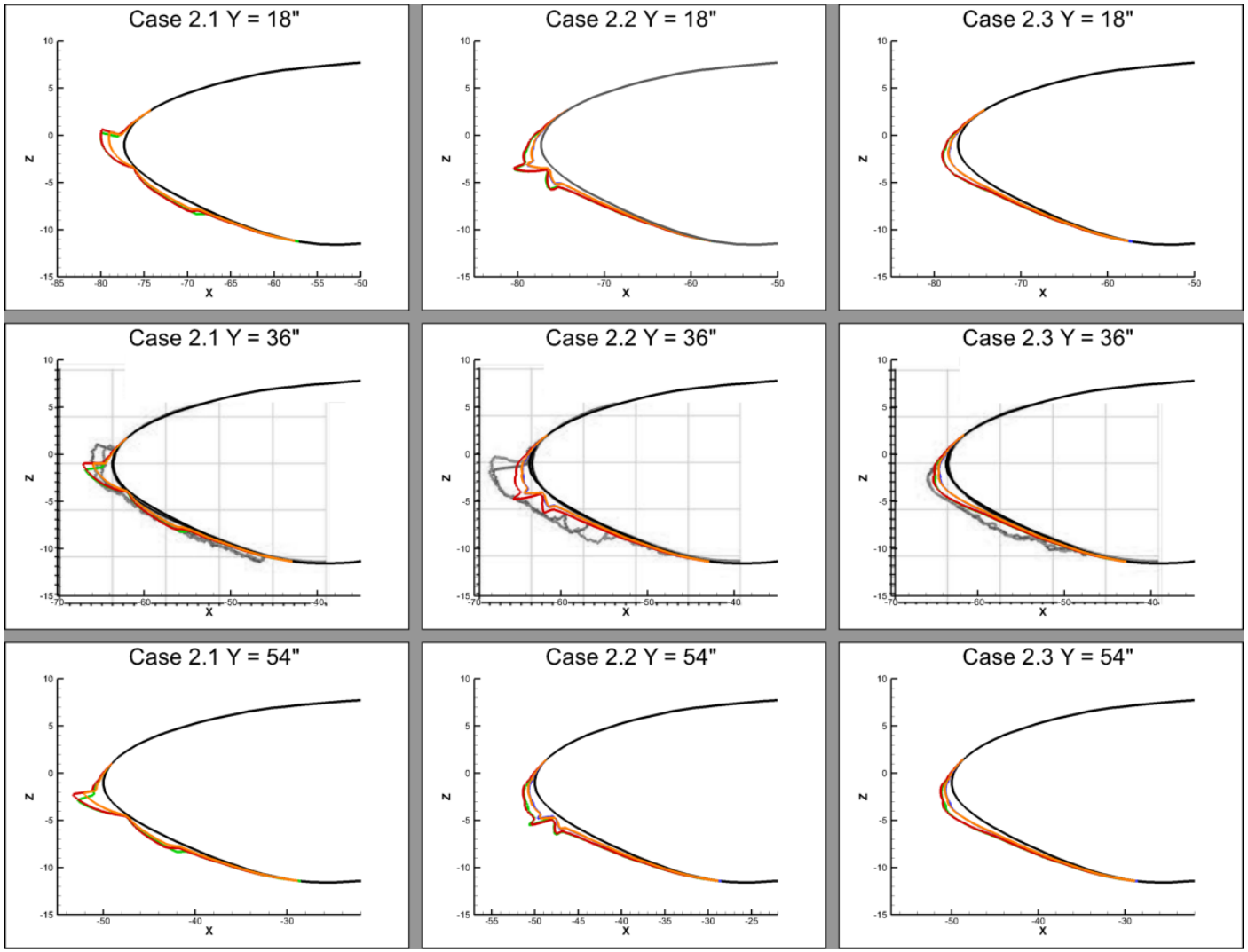
ICE SHAPE COMPARE: MID-SPAN



- Ice density was varied
  - 917kg/m^3
  - Sweep based
- Sweep based density matches better with WT
- Case 1.2 has the worst WT alignment
- Case with best C_P alignment provided best shape (Cal Rho AoA 4.7º)

SAT -3.6ºC | SAT -8.5ºC | SAT -26.0ºC

ICE SHAPE COMPARE: INBOARD



- Ice density was varied
  - 917kg/m^3
  - Sweep based
- Sweep based density matches better with WT
- Case 1.2 has the worst WT alignment
- Case with best C_P alignment provided best shape

SAT -3.6ºC | SAT -8.5ºC | SAT -26.0ºC

Gulfstream

SUMMARY

- Geometry adjustment was required to match C_P
  - Mid Span AoA 4.7º
  - Inboard AoA 3.7º and Flap 0º
- Sweep based density calculation ice shapes match wind tunnel ice shapes well
- Additional work that could be done
  - Why are the case 1.2 shapes mismatching (Scalloping?)
  - Refine AoA geometry
  - Can multishot ice build-up improve ice shape?
  - Roughness was not adjusted

Case 1.2

Gulfstream™
A GENERAL DYNAMICS COMPANY

THANK YOU