Summary of the Second AIAA Stability and Control Prediction Workshop

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Overview

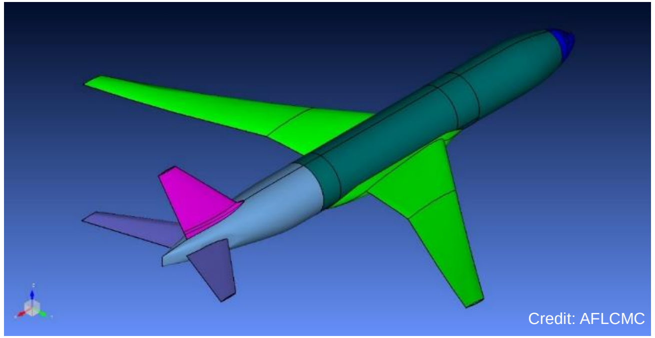
AIAA Stability and Control Prediction Workshop II (S&CPW2)

- Applied Aerodynamics and Atmospheric Flight Mechanics TCs
- Establish best practices for prediction of S&C derivatives
- Impartial forum for evaluating CFD predictions for S&C
- Identify areas requiring further research and development

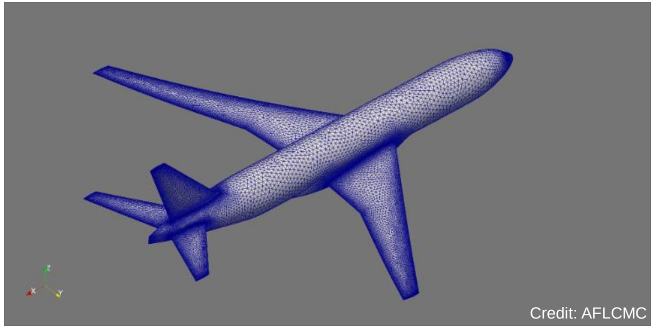
- Workshop II (SciTech 2025): static and dynamic stability derivatives
- Website: www.sandcpw.com, Email: sandcpw@gmail.com

Model Geometry

- Common Research Model (CRM)
  - 4^{th} Drag Prediction Workshop OML
  - ONERA vertical tail design
  - No engine nacelles or pylons
- Geometry provided as .igs/.stp files
- Common meshes generated using HeldenMesh and Pointwise tools
- Full-scale geometry
- Wind-tunnel-scale flow conditions



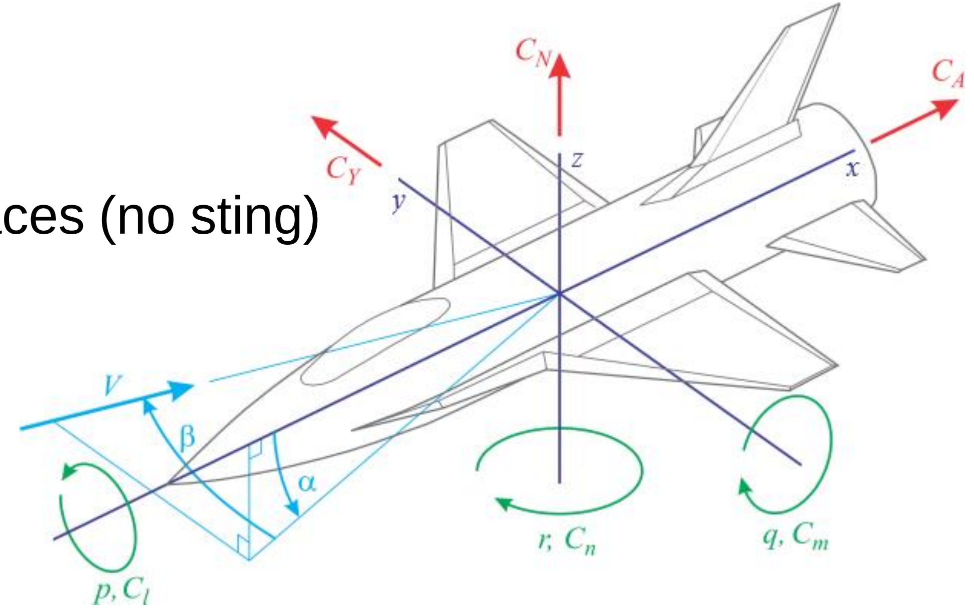
Clean S&CPW2 CRM geometry.



Example S&CPW2 mesh.

Definitions and Reference Quantities

- Body-axis coordinate system
- Standard orientation definitions
- Force accounting: only model surfaces (no sting)
- Force and moment coefficients:
  - Normal force: $C_N = C_z = \frac{F_z}{\bar{q}S}$
  - Axial force: $C_A = C_X = \frac{F_x}{\bar{q}S}$
  - Side force: $C_S = C_Y = \frac{F_y}{\bar{q}S}$
  - Pitching moment: $C_m = C_{M_y} = \frac{M_y}{\bar{q}S\bar{c}}$
  - Yawing moment: $C_n = -C_{M_z} = \frac{-M_z}{\bar{q}Sb}$
  - Rolling moment : $C_l = -C_{M_x} = \frac{-M_x}{\bar{q}Sb}$



Property	CFD	WT
Model scale	100%	2.40%
Wingspan (b), ft	192.8	4.627
Mean aerodynamic chord ($\bar{c}$), ft	22.98	0.552
Wing reference area (S), ft^2	4130	2.379

Summary of S&CPW2 Test Cases

$f_r = \omega l / 2V$

Static Test Cases

$(M = 0.052;\ Re = 200{,}000;\ T = 518°\mathrm{R})$

- **Case 1a:** α-sweep with sting
- **Case 1b:** β-sweep with sting $(\alpha = 0°)$
- **Case 1c:** β-sweep with sting $(\alpha = 4°)$
- **Case 1d:** α-sweep with sting and no tail
- **Case 4:** repeat Case 1 without sting

Participants report/submit:

- Data for each test case
- Static/dynamic stability derivatives

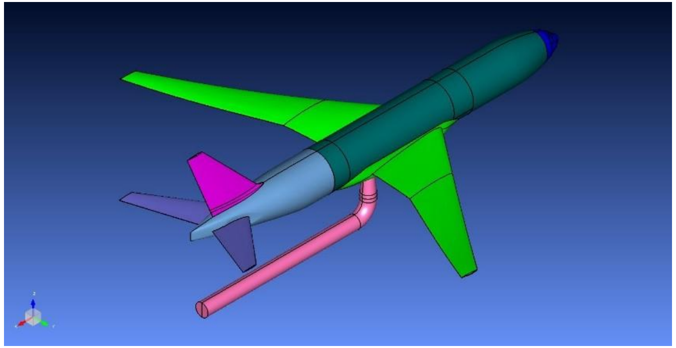
Dynamic Test Cases

$(\alpha_o = 3°;\ M = 0.036;\ Re = 140{,}000)$

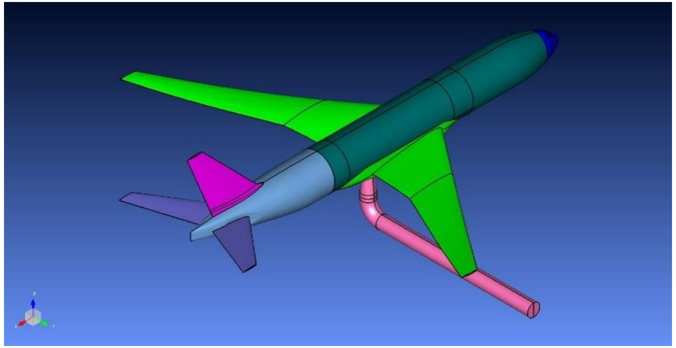
- **Case 2a:** pitch oscillation $(\pm 5°)$ with $f_r = [0.04, 0.06, 0.08, 0.10]$
- **Case 2b:** roll oscillation $(\pm 5°)$ with $f_r = [0.2, 0.4, 0.6, 0.8]$
- **Case 2c:** yaw oscillation $(\pm 5°)$ with $f_r = [0.2, 0.4, 0.6, 0.8]$
- **Case 3:** use alternative methods to determine static/dynamic derivatives
- **Case 5:** repeat Case 2 without sting

Red text = required case

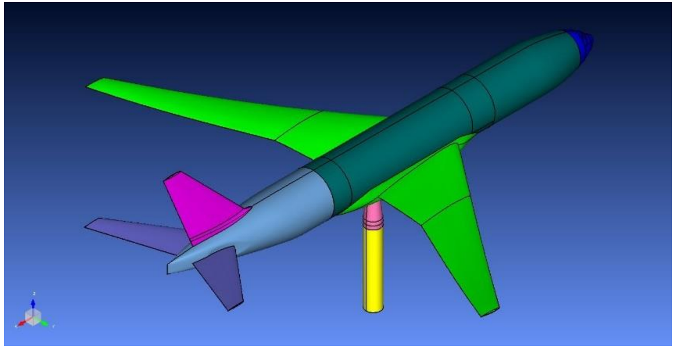
Test Case Geometry



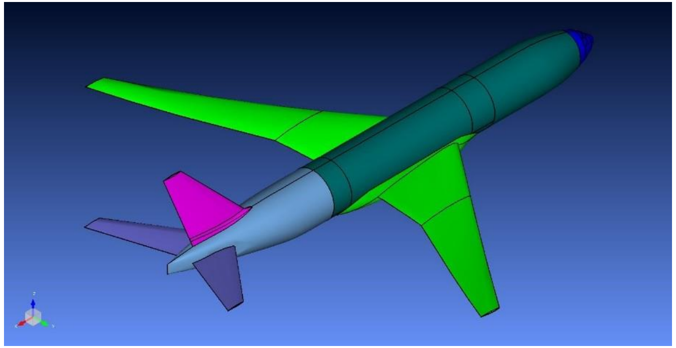
Static and roll oscillation (Case 1 and 2b)



Pitch oscillation (Case 2a)



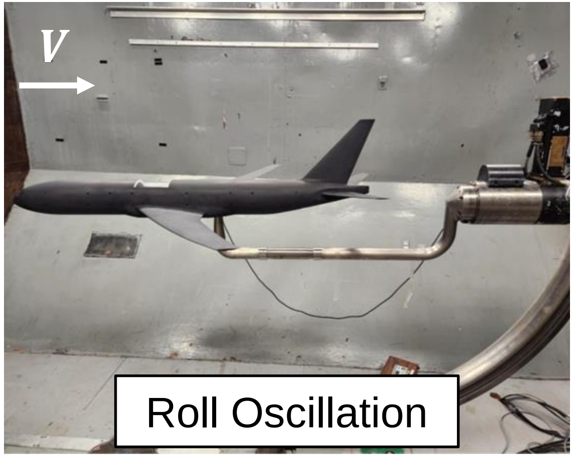
Yaw oscillation (Case 2c)

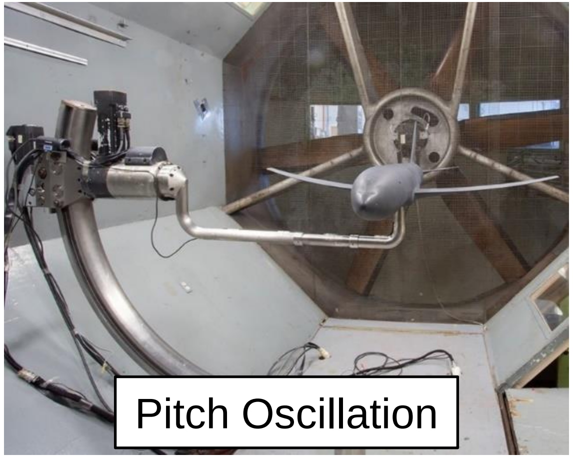


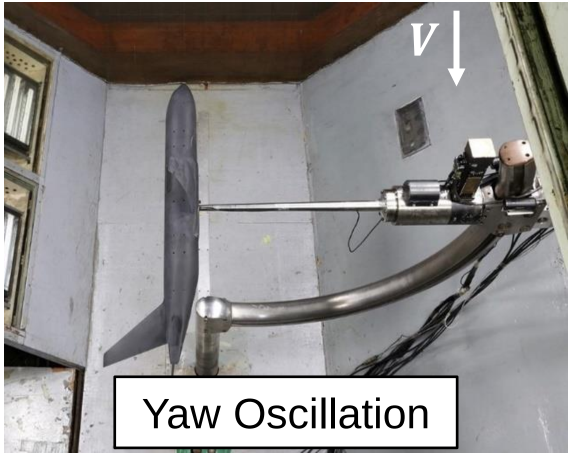
Clean/stingless (Case 4 and 5)

Wind-Tunnel Testing

- NASA Langley 12-Foot Low-Speed Tunnel
- Static and forced oscillation data for a 2.4% scale CRM
- Flow angularity and blockage corrections
- CFD results are blind (wind-tunnel data publicly released at S&CPW2)
- Full presentation and data: https://ntrs.nasa.gov/citations/20240016282







S&CPW2 Participants

Participant Names	Organization	Method
Dan Vicroy, Benjamin Simmons	Adaptive Aerospace Group and NASA Langley	Wind Tunnel
Daniel Enriquez	Altair Engineering	FlightStream
Wei Liao, Collin Strassburger	Bihrle Applied Research	FUN3D
Kelly Laflin, Steven Klausmeyer	Textron Aviation	FUN3D
Andrew Lofthouse, William Vogel	Air Force Life Cycle Management Center	Kestrel
Mehdi Ghoreyshi, Pooneh Aref	US Air Force Academy	Kestrel
Seung Yoo	NASA Armstrong Flight Research Center	STAR-CCM+
Zhuoneng Li, Andrea Da Ronch, Xupeng Sui	University of Southampton	STAR-CCM+

- **Participant ID numbers have been removed for public release of this presentation**
- **Participants are <u>not</u> ordered by their ID number on this slide**

Stability Derivative Calculation Approach

Static stability derivatives

- Central difference approximation
- Differentiation of local polynomial fit

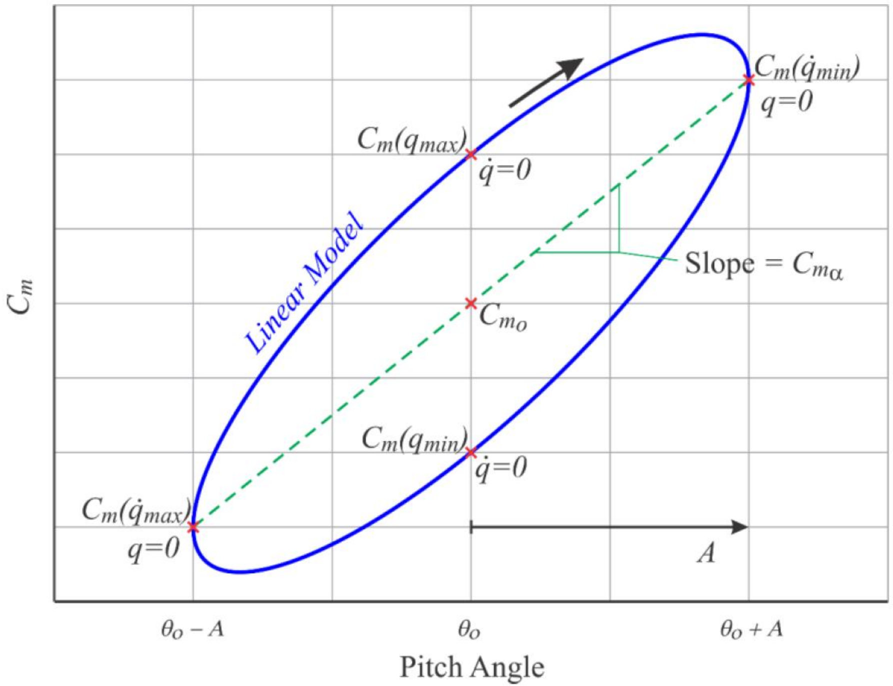
Dynamic stability derivatives

Vicroy, D. D., "A Guide to Forced Oscillation Data Processing and Analysis," NASA TP–20210023569.

- Integration method
  - $\overline{C_{m_q}}(\alpha_o) = \frac{4V}{\bar{c}\omega AT}\int_0^T C_m(t)\cos(\omega t)\,dt$
  - Legacy method; only valid in linear regions
- Specific point method
  - $\overline{C_{m_q}}(\alpha_o) = \frac{V}{\bar{c}A\omega}[C_m(q_{max}) - C_m(q_{min})]$
  - Preferred method; valid in nonlinear regions

CFD forced oscillation data processing

- Remove initial transients (if applicable)
- Resample to 5 Hz
- Apply a zero phase-shift digital low-pass 6th order Butterworth filter ($f_c = 5f_{osc}$)
- Trim data to include full cycles for analysis

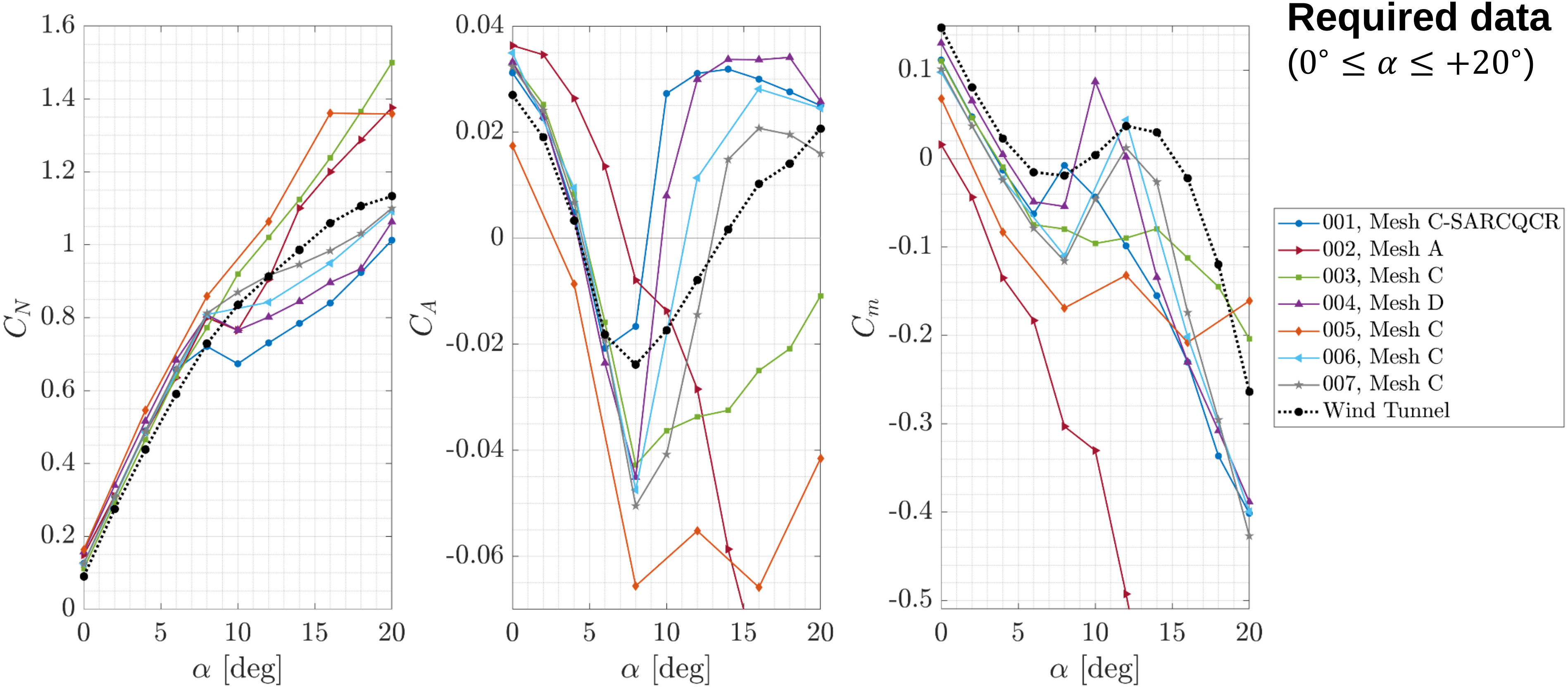


Example linear model hysteresis loop.

Comparison of Results

- One dataset was selected per participant per test case
- Sign corrections were applied to match the expected trends
- Meshes were renamed coarsest to finest (e.g., A = coarse, B = medium, C = fine, etc.)
- Distinguishing information is provided in the plot legends to inform participants on which dataset is shown
- Full comparison of results: https://ntrs.nasa.gov/citations/20240016445

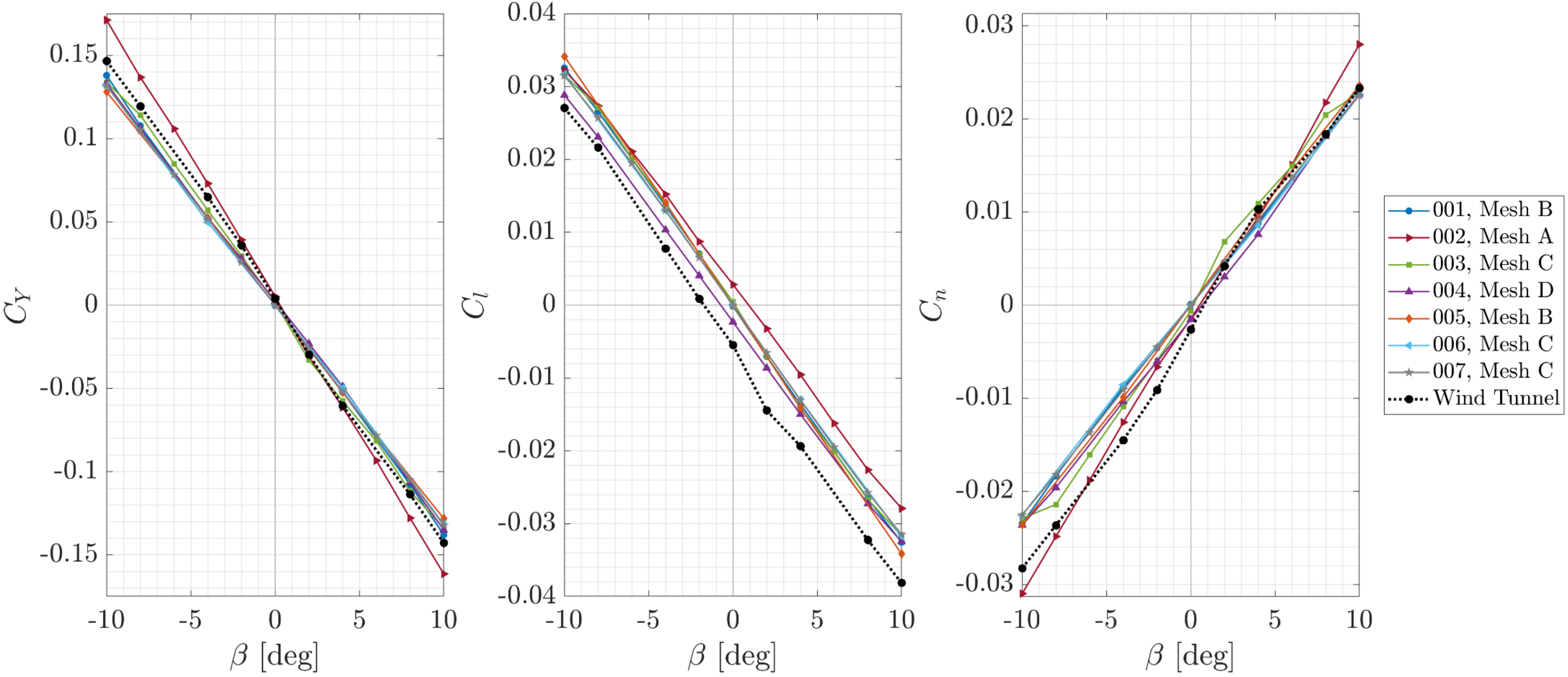
Case 1a: α-Sweep with Sting and Tail



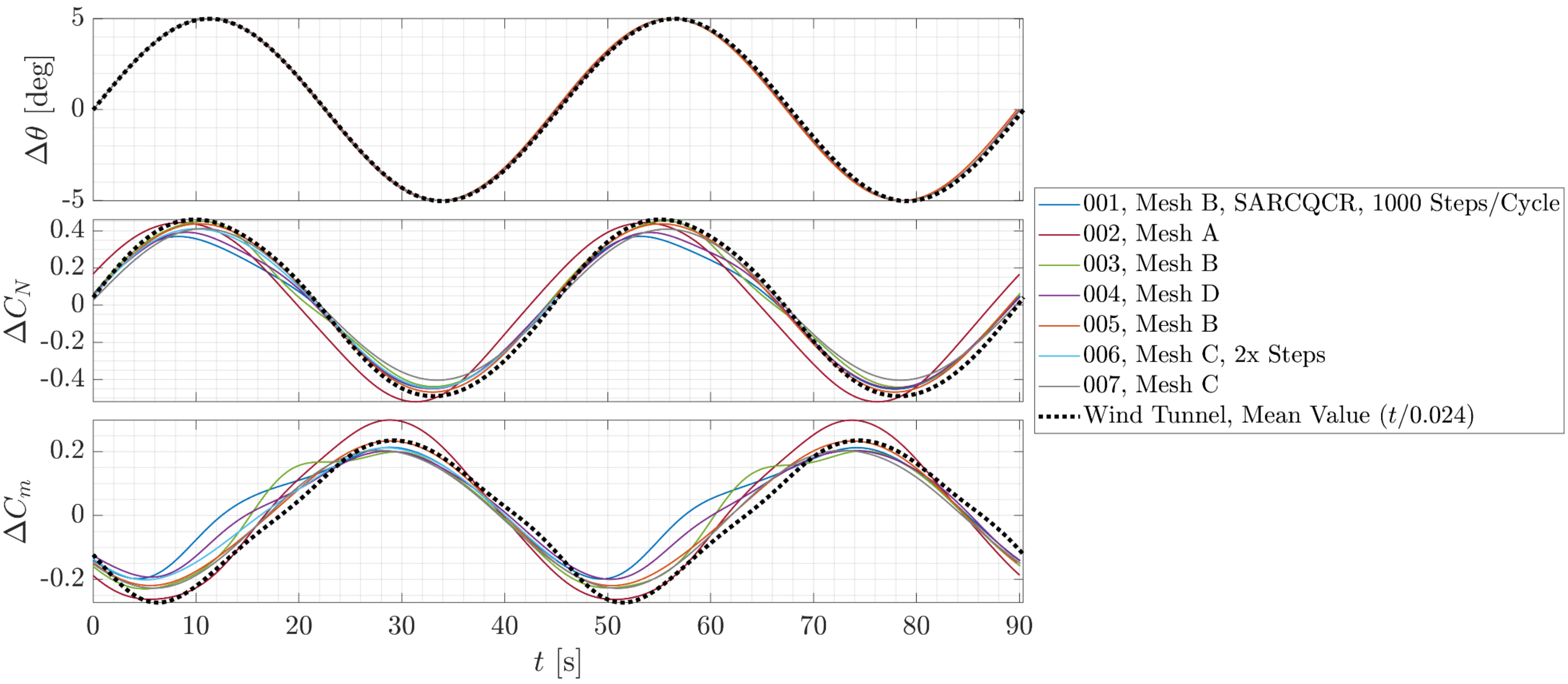
Required data

($0° \le \alpha \le +20°$)

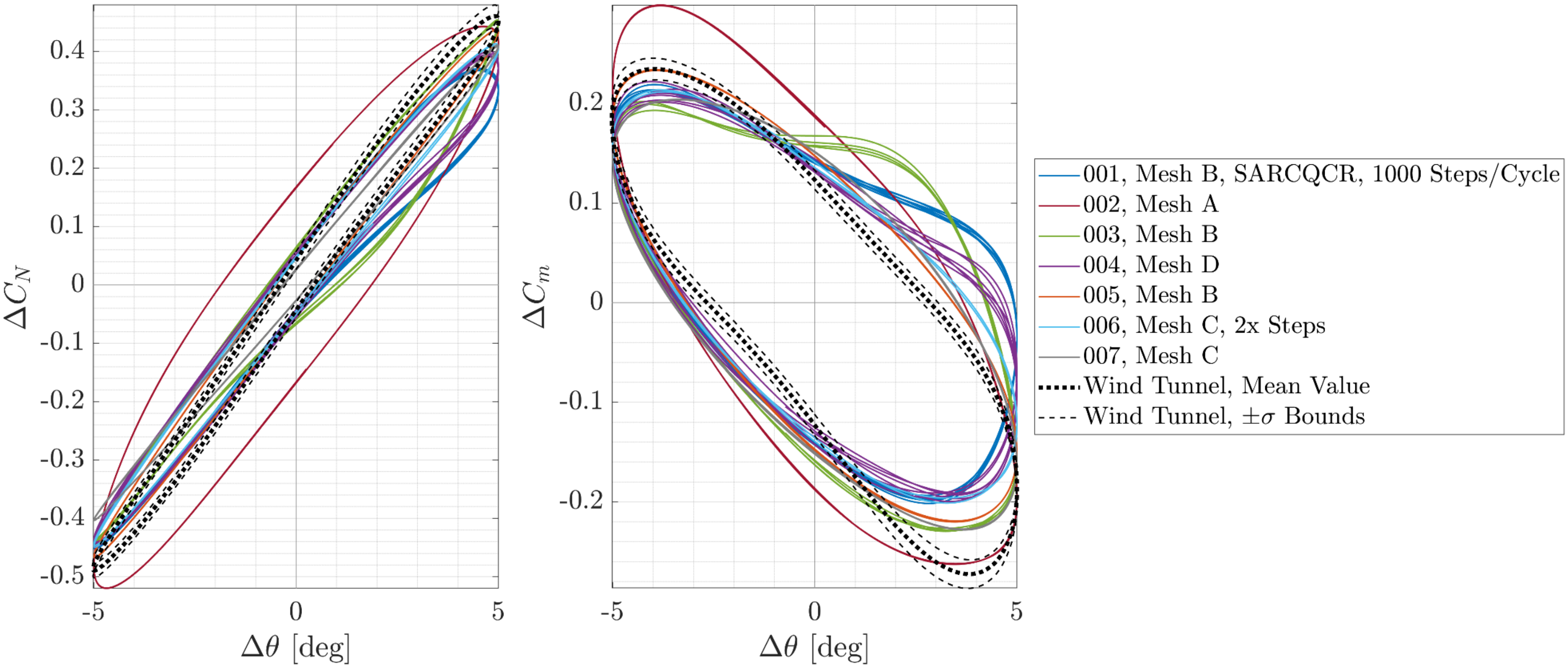
Case 1c: β-Sweep with Sting and Tail ($\alpha = 4°$)



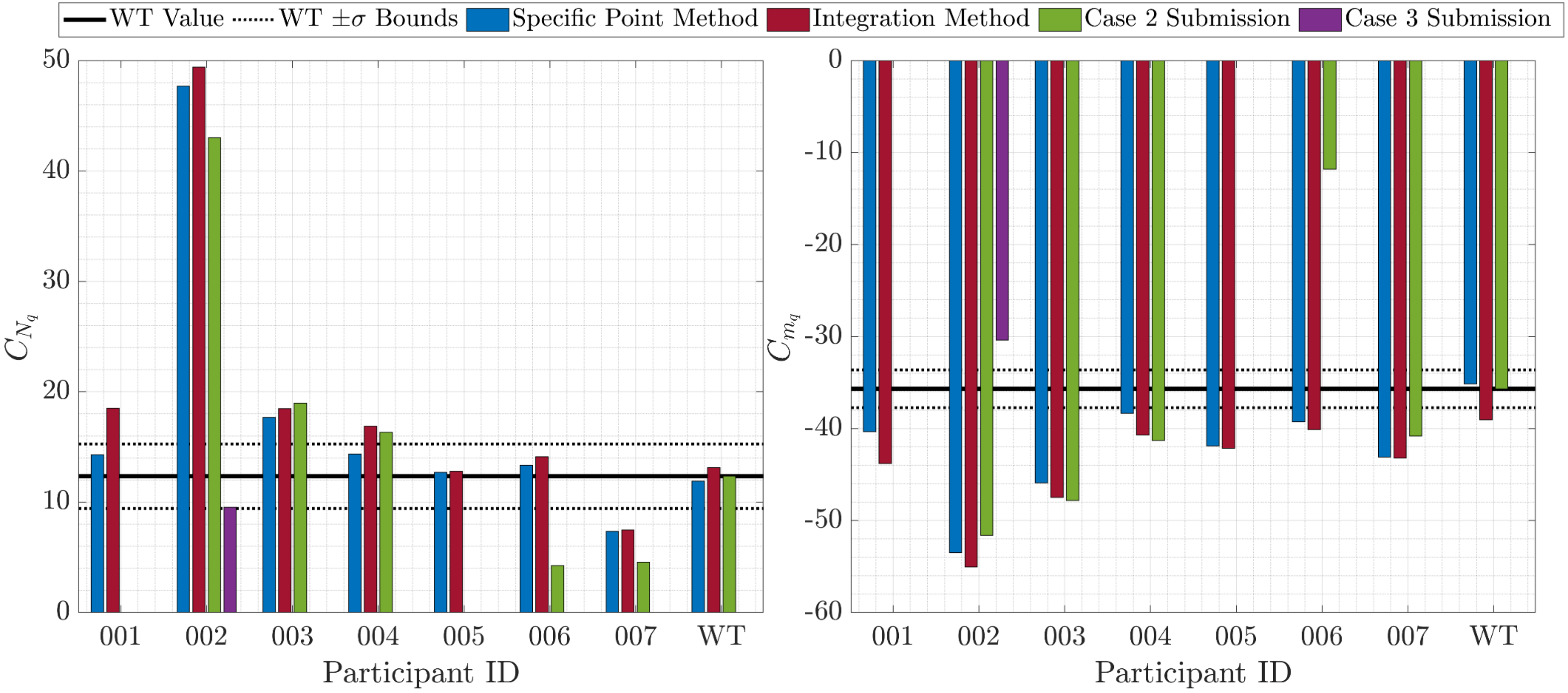
Case 2a: Time Histories ($f_r = 0.04$)



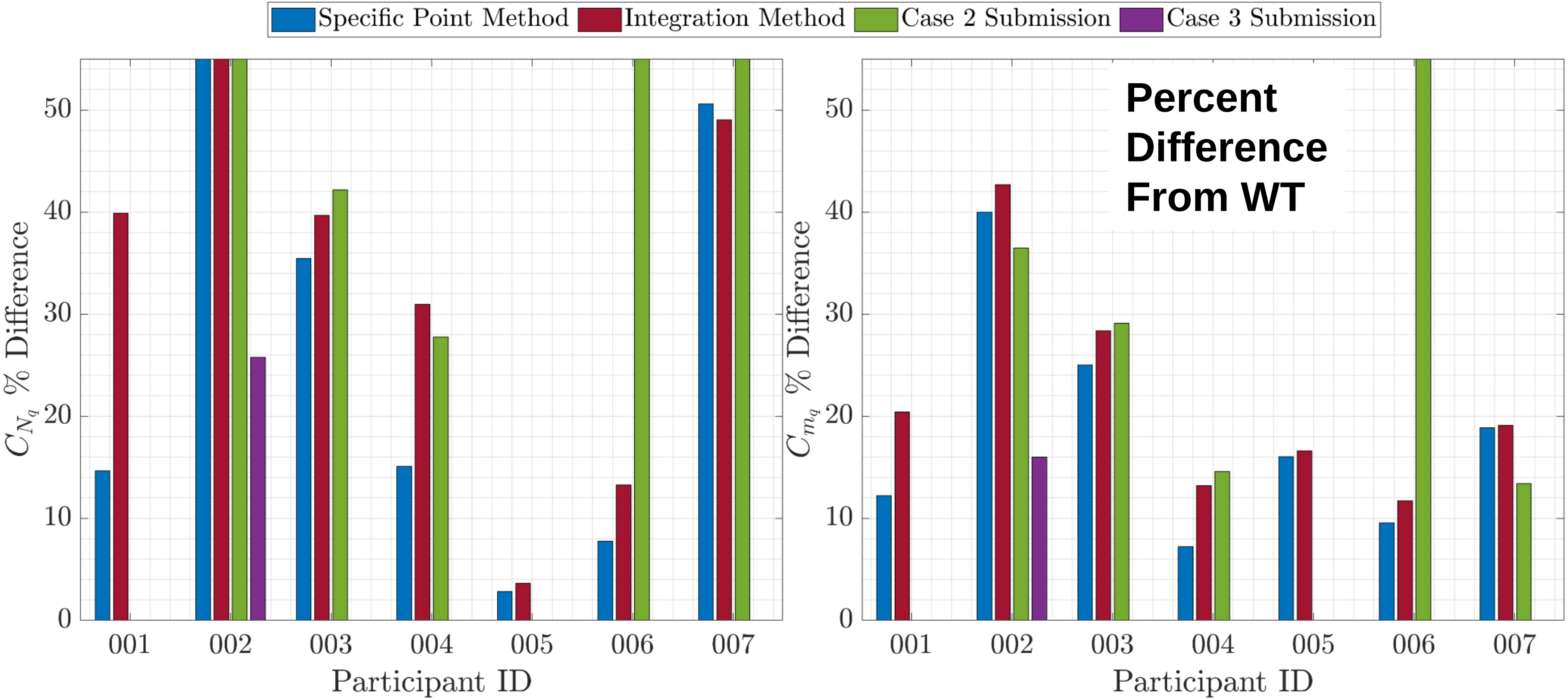
Case 2a: Hysteresis Loops ($f_r = 0.04$)



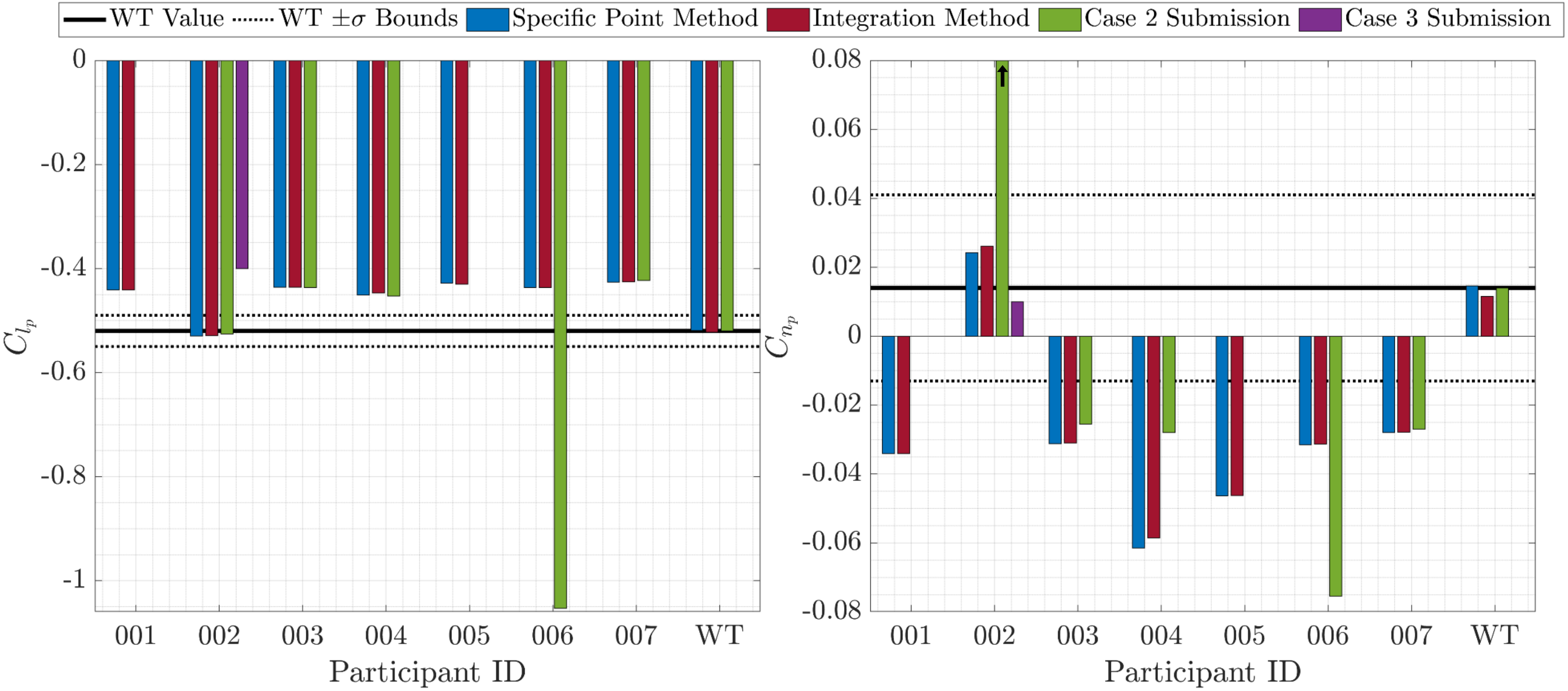
Case 2a: Dynamic Stability Derivatives ($f_r = 0.04$)



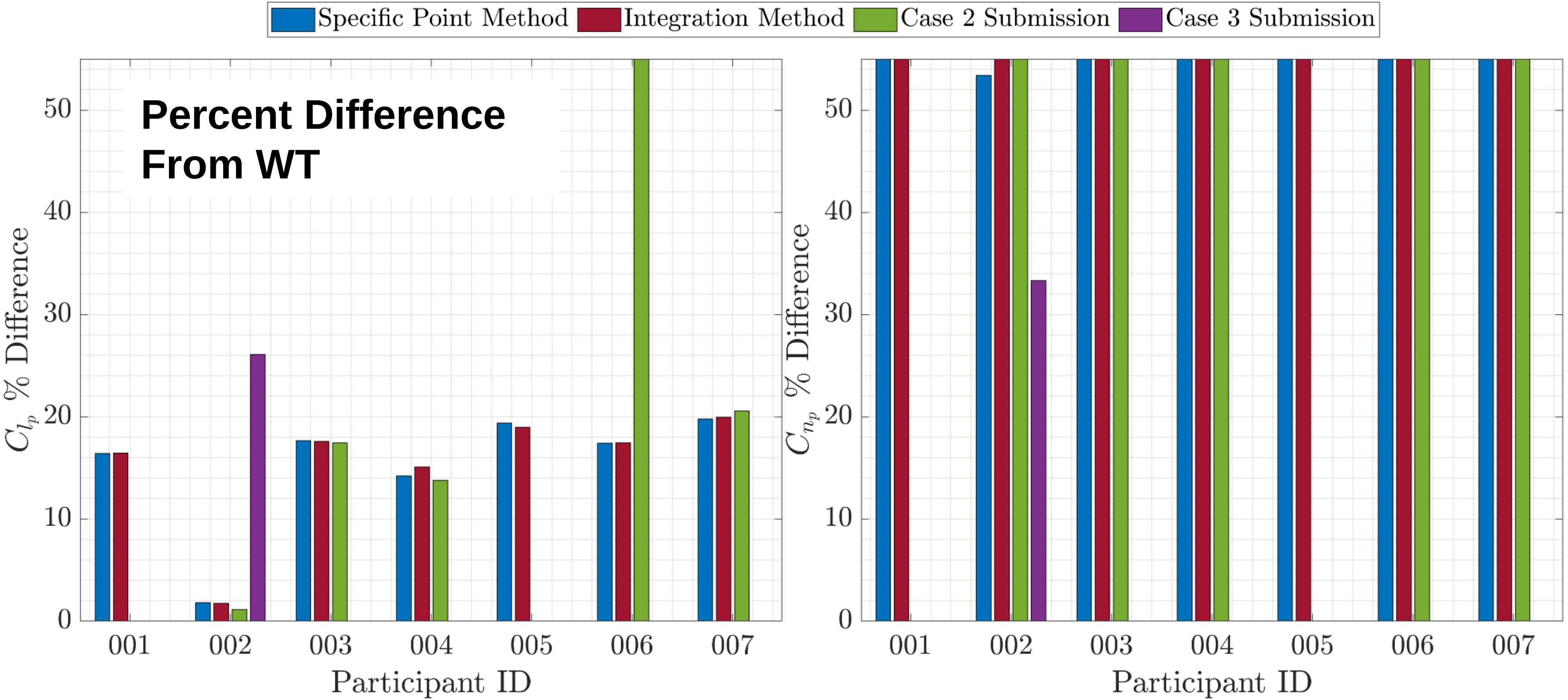
Case 2a: Dynamic Stability Derivatives ($f_r = 0.04$)



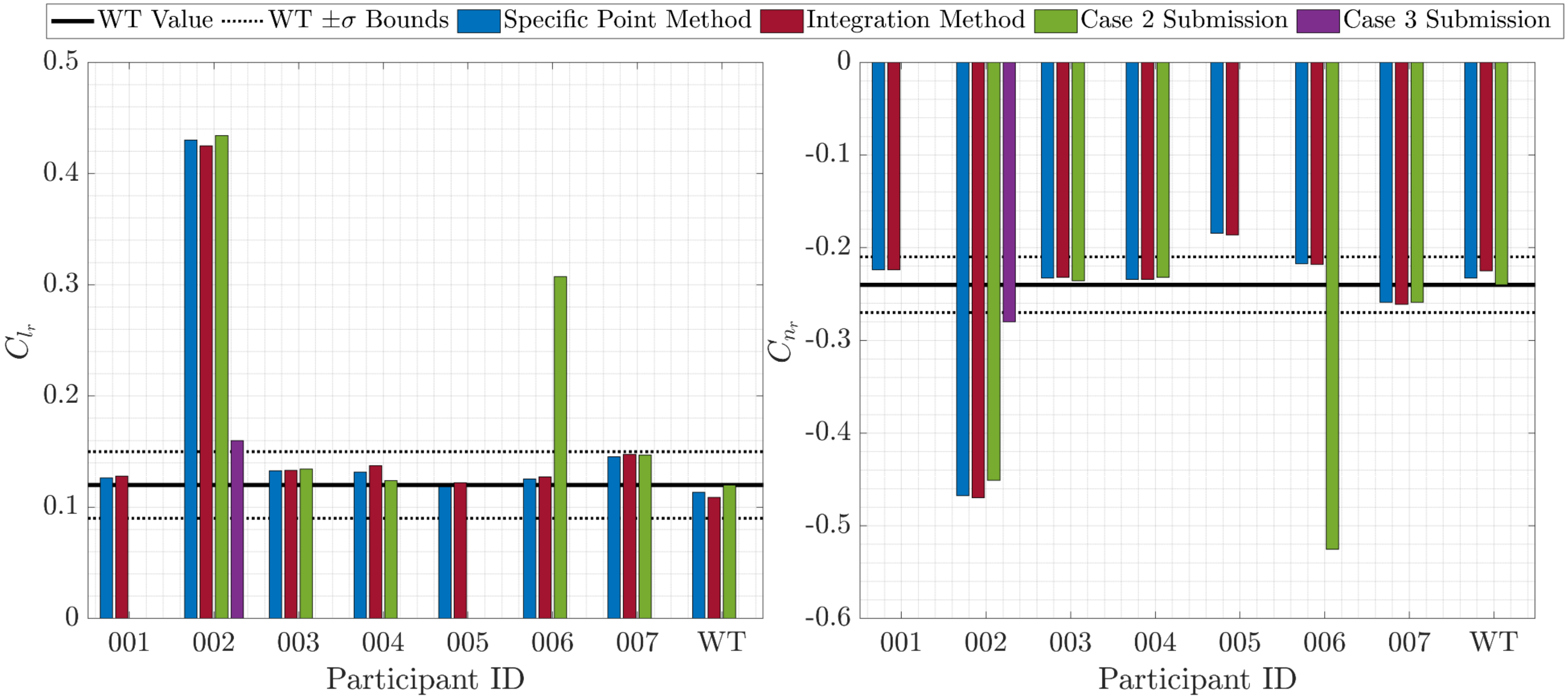
Case 2b: Dynamic Stability Derivatives ($f_r = 0.4$)



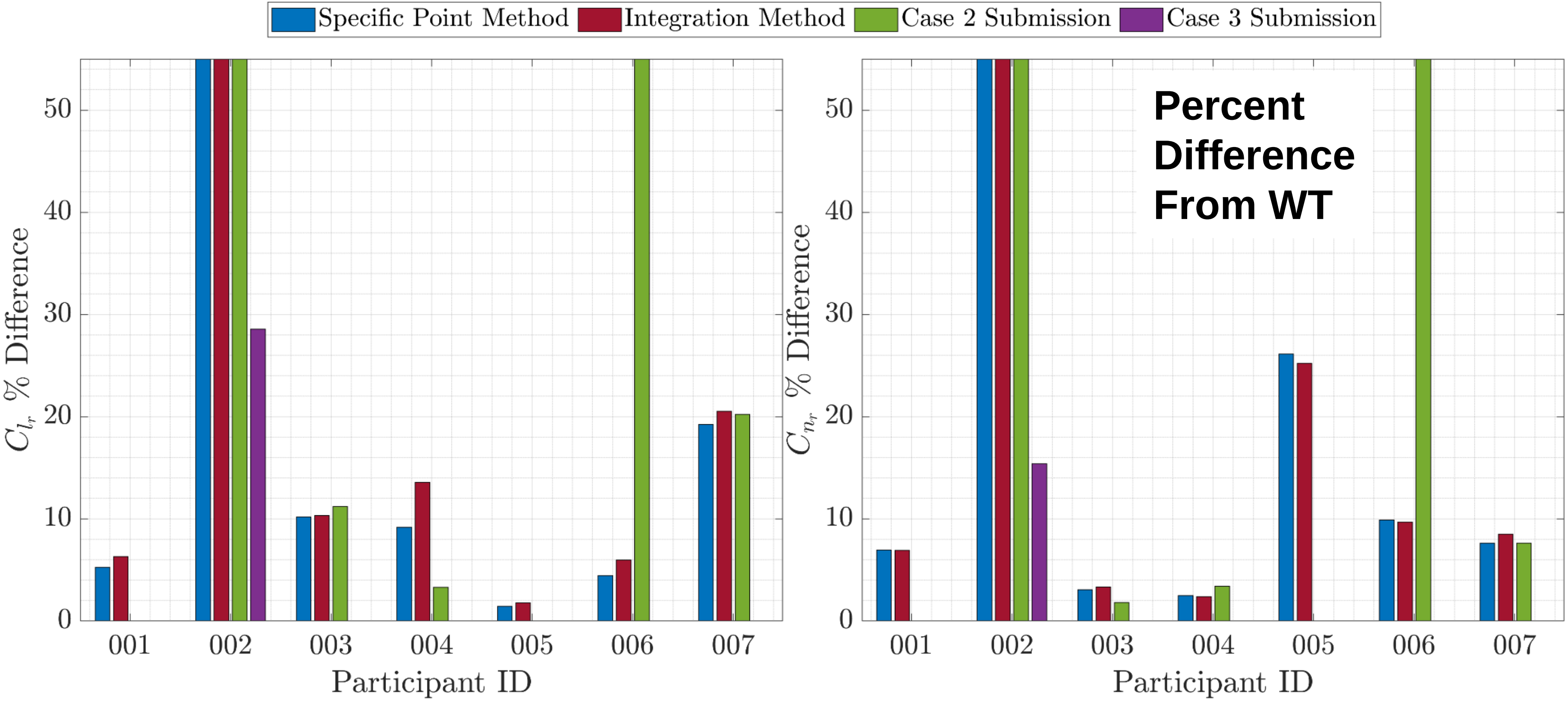
Case 2b: Dynamic Stability Derivatives ($f_r = 0.4$)



Case 2c: Dynamic Stability Derivatives ($f_r = 0.4$)



Case 2c: Dynamic Stability Derivatives ($f_r = 0.4$)



Concluding Remarks

- S&CPW2: CRM static/dynamic stability derivative prediction
  - Static angle of attack and sideslip sweeps
  - Roll, pitch, and yaw forced oscillation maneuvers
  - Blind comparison of CFD results to low-speed wind tunnel data
  - 7 participants submitted final CFD results (4 different CFD codes)
  - Community engagement and lessons learned for dynamic predictions
- Reasonable overall agreement, but room for improvement
- Best practices for dynamic derivative predictions are needed
- Determine next steps and future S&C prediction workshops

Acknowledgements

- Stability and Control Prediction Workshop II Organizers
  - Andrew Lofthouse, Air Force Life Cycle Management Center
  - Benjamin Simmons, NASA Langley Research Center
  - Dan Vicroy, Adaptive Aerospace Group, Inc.
  - William Vogel, Air Force Life Cycle Management Center
  - Norman Princen, The Boeing Company
  - Adam Clark, The Boeing Company
  - Brett Johnson, The Boeing Company
  - Matthew Prior, General Atomics – ASI
  - Steve Klausmeyer, Textron Aviation
  - Kelly Laflin, Textron Aviation
  - Charlie Harrison, Gulfstream Aerospace Corporation
- Workshop Participants (see earlier slide)
- AIAA Stability and Control Prediction Discussion Group
- Applied Aerodynamics and Atmospheric Flight Mechanics TCs

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