

Subsonic Ultra Green Aircraft Research: Phase V – Buffet Test Report

Neal A. Harrison

Boeing Research and Technology, Everett, WA

Anthony J. Sclafani, David Cerra, Eric D. Dickey

Boeing Commercial Airplanes, Long Beach, CA

Dharmendra Patel, Joseph Straccia

Boeing Research and Technology, Huntington Beach, CA

Paul Vijgen, Jeffrey Crouch, Christopher Otto, Kuo-Chieh Loh, Ashley Jones

Boeing Commercial Airplanes, Everett, WA

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NTRS Registered and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counter-part of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

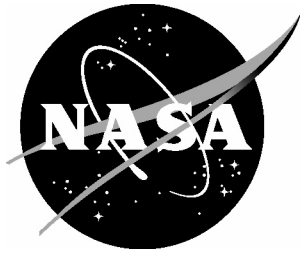
- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at <http://www.sti.nasa.gov>
- E-mail your question to help@sti.nasa.gov
- Phone the NASA STI Information Desk at 757-864-9658
- Write to:
NASA STI Information Desk
Mail Stop 148
NASA Langley Research Center
Hampton, VA 23681-2199

NASA/CR–20230005431



Subsonic Ultra Green Aircraft Research: Phase V – Buffet Test Report

Neal A. Harrison

Boeing Research and Technology, Everett, WA

Anthony J. Sclafani, David Cerra, Eric D. Dickey

Boeing Commercial Airplanes, Long Beach, CA

Dharmendra Patel, Joseph Straccia

Boeing Research and Technology, Huntington Beach, CA

Paul Vijgen, Jeffrey Crouch, Christopher Otto, Kuo-Chieh Loh, Ashley Jones

Boeing Commercial Airplanes, Everett, WA

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

Prepared for Langley Research Center
under Contract NNL16AA04B/80LARC20F0113

January 2025

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Available from:

NASA STI Program / Mail Stop 148
NASA Langley Research Center
Hampton, VA 23681-2199
Fax: 757-864-6500

Abstract

This test report summarizes work performed by the Boeing Subsonic Ultra-Green Aircraft Research (SUGAR) team in the Phase V Transonic Truss-Braced Wing contract task. The task was awarded in September 2020, and ended at the end of September 2022.

As a part of the SUGAR Phase V contract task, Boeing developed a wind tunnel test plan, model requirements, then fabricated and conducted a dedicated transonic buffet wind tunnel test. The test focused on the investigation of buffet onset, and the ability to accurately predict buffet onset for the TTBW configuration. This report summarizes the results and post-test analysis of the 9% scale, semispan, Transonic Truss-Braced Wing (TTBW) transonic buffet model tested at the NASA Ames Research Center Unitary Plan Wind Tunnel (UPWT) 11-Foot Transonic Wind Tunnel (11-Ft TWT) facility located at Moffett Field, CA. It was tested from January 24, 2022, through February 18, 2022.

The wind tunnel test was successful in capturing buffet onset at the model design dynamic pressure. Multiple configurations were tested starting in the wing-body-strut configuration and ending with the full configuration including wing-body-strut-nacelle/pylon, and flap hinge. The test also measured the effect of control surface deflections (ailerons and spoilers), as well as the effect of an outboard strut flap.

Steady data collected during the test included standard force and moment measurements, as well as wing, strut, nacelle, and body (fuselage) static pressures. These data were collected in a standard pitch-pause mode.

Unsteady data captured in the test, collected in continuous pitch mode, included wing and strut dynamic pressures, accelerations, and strains.

According to test data, previous concerns regarding critical buffet onset on the strut (at low vehicle lift coefficient) and in the wing-strut channel have been mitigated. Buffet onset on the TTBW appears to follow conventional wing-induced buffet onset mechanisms. However, the critical station where buffet onset first occurs has moved inboard to the wing-strut juncture span location (55-60% span) from the typical ~70% span location. Test data obtained by unsteady pressure transducers provided a good match to expected buffet onset modes.

An assessment of different tools and methodologies for predicting buffet onset was conducted. Reasonable agreement was found for buffet boundary predictions between most of the methods examined when using a forward trip location, with the greatest discrepancies from the pitching moment break and trailing edge pressure divergence methods. When an aft trip location was used the buffet boundary predictions diverged more significantly from unsteady pressure measurements. In addition, good agreement between the buffet onset trends were found when the Reynolds number, configuration, or spanload was changed.

Acknowledgements

The work documented in this report reflects the combined efforts of the Boeing enterprise SUGAR team. The coordinated effort of this team has produced this report. Funding for this effort was provided by the Advanced Air Vehicles Program, through the Advanced Air Transport Technology Project. The contract number is NNL16AA04B task order 80LARC20F0113.

The team would like to thank Gregory Gatlin and William Milholen of the NASA Langley Research Center for their guidance as the NASA Contracting Officer Technical Representatives. The team would also like to thank the NASA Ames 11-Ft Transonic Wind Tunnel support staff, in particular Ross Flach, Jennifer Everett, and Frank Kmac.

The contributing Boeing team members are noted below.

Boeing Team Members:

Neal Harrison
Michael Beyar
Gary Ige

Program Manager & Principal Investigator
Wind Tunnel Test Lead
Lead Wind Tunnel Test Engineer

Gail Barker
Jack Bourbonnais
David Cerra
Leo Chou
Scott Clayton
Jeffrey Crouch
Mark Dehaan
Bruce Detert
Eric Dickey
Lie-Mine Gea
Moeljo Hong
Sean Howe
Niko Intravartolo
Ashley Jones
Kuo-Chieh Loh
Christopher Otto
Dharmendra Patel
Khanh Pham
Eric Reichenbach
Matthew Roberts
Todd Schultz
Anthony Sclafani
Steven Shaw
Kamal Shweyk
Seth Skube
Joseph Straccia
Paul Vijgen
Peter Wilcox

Noise Test & Evaluation
Aeroelastic Analysis
Aerodynamics (BCA)
Aerodynamic Analysis
Wind Tunnel Test Support
Flight Sciences (BCA)
CFD Analysis
High-Speed Aerodynamics (BCA)
Aerodynamic Design
Aerodynamic Analysis
High-Speed Aerodynamics (BCA)
Aerodynamics (BCA)
Stability and Control
High-Speed Aerodynamics (BCA)
High-Speed Aerodynamics (BCA)
High-Speed Aerodynamics (BCA)
Stability and Control
Aerodynamic Analysis
Aeroelastic Design and Analysis
Aerodynamics
Noise Test & Evaluation
Aerodynamic Design (BCA)
High-Speed Aerodynamics (BCA)
Stability and Control (BCA)
Wind Tunnel Test Support
Aerodynamics
High-Speed Aerodynamics (BCA)
Wind Tunnel Test Engineer

Table of Contents

Abstract.....	1
Acknowledgements	2
List of Tables.....	5
List of Figures	6
Nomenclature.....	12
1.0 Transonic Truss-Braced Wing High-Speed Development and Testing	14
2.0 Transonic Truss-Braced Wing High-Speed Buffet Wind Tunnel Test	16
2.1 Test Introduction and Objectives.....	16
2.2 Test Facility	18
2.3 Model Description	19
2.4 Model Components	21
2.4.1 Fuselage.....	21
2.4.2 Wing	22
2.4.3 Strut	25
2.4.4 Jury Strut.....	27
2.4.5 Nacelle and Pylon	28
2.4.6 Flap Hinge Fairings	29
2.5 Model Instrumentation.....	30
2.5.1 Instrumentation specifications	30
2.5.2 Wing Instrumentation	31
2.5.3 Strut Instrumentation	33
2.5.4 Diagnostic Instrumentation	34
2.5.5 Wing and Strut Jig Twist Correction.....	37
2.6 Model Assembly and Installation.....	40
2.6.1 Model Installation.....	40
2.6.2 Model Coordinate Systems	44
2.6.3 Model Configuration Tracking	44
2.7 Test Conditions	45
2.8 Boundary Layer Transition and Trip Definition	47
2.9 Wind Tunnel Data Summary	49
2.9.1 Tunnel Corrections	49
2.9.2 Data Repeatability.....	52
2.9.3 Pitch-pause vs. Continuous Pitch Data Collection.....	54
2.9.4 Test-to-Test Comparison.....	55
2.9.5 Diagnostic Pressure Comparison	58
2.9.6 Reynolds Number Effects (Full Configuration)	63
2.9.7 Transition Study.....	65

2.9.8	<i>Wind Tunnel Component Build-Up</i>	76
2.9.9	<i>Wind Tunnel Buffet Assessment</i>	78
2.9.10	<i>Buffet Methods Comparison on a TTBW</i>	92
2.10	CFD Data Comparisons	107
2.10.1	<i>CFD Drag Component Increments</i>	111
2.10.2	<i>Floor Only vs. In-Tunnel CFD Simulations</i>	111
2.10.3	<i>CFD Buffet Predictions</i>	123
2.11	Assessment of Buffet TTBW Buffet Prediction	126
2.12	Stability and Control Testing	127
3.0	Final High-Speed Test Conclusions	150
4.0	Recommendations for Future High-Speed Testing	151
5.0	References	152
Appendix A – Buffet Test Run Matrix		A-1
Appendix B – Model Instrumentation Specifications		B-1

List of Tables

Table 2-1. Model Reference Quantities.....	17
Table 2-2. Wing Unsteady Pressure Transducer Locations	32
Table 2-3. Wing Accelerometer and Strain Gauge Locations	32
Table 2-4. Strut Unsteady Pressure Transducer Locations.....	33
Table 2-5. Strut Accelerometer and Strain Gauge Locations.....	33
Table 2-6. Nose Static Pressure Tap Locations (model scale coordinates).....	34
Table 2-7. WBF Static Pressure Tap Locations (model scale coordinates)	35
Table 2-8. Engine Nacelle Static Pressure Tap Locations (model scale coordinates)	36
Table 2-9. Sectional Incidence Variation	38
Table 2-10. Balance Load Limits	41
Table 2-11. Buffet Model Configuration Codes	44
Table 2-12. Buffet Test Operating Conditions	45
Table 2-13. Boundary Layer Trip Pattern Definition	48
Table 2-14. Boundary Layer Trip Heights	49
Table 2-15. OVERFLOW Run Matrix.....	110

List of Figures

Figure 1-1. The Transonic Truss-Braced Wing (TTBW) Configuration	14
Figure 1-2. Region of the TTBW strut that could be of concern for buffet.....	16
Figure 2-1. Mach 0.8 TTBW General Arrangement (Dimensions in Model Scale).....	17
Figure 2-2. NASA Ames Unitary Plan Wind Tunnel (UPWT) Aerial View	18
Figure 2-3. 9% Scale Semispan TTBW Wind Tunnel Model installed in the 11-ft Transonic Test Section of the NASA ARC Unitary Plan Wind Tunnel (UPWT) Complex	19
Figure 2-4. Buffet Model Components	20
Figure 2-5. Forward and Aft Keel Dam geometry [Keel Dam Size Shown Not to Scale for Clarity]	21
Figure 2-6. Buffet Model Wing	22
Figure 2-7. Effect of WBF Keel Dam.....	23
Figure 2-8. Model Spoilers.....	24
Figure 2-9. Model Ailerons	25
Figure 2-10. Model Strut Assembly	26
Figure 2-11. Outboard Strut Flap.....	26
Figure 2-12. Buffet Model Jury Strut	27
Figure 2-13. Engine and Pylon Installation	28
Figure 2-14. Buffet Model Flap Hinge Fairings	29
Figure 2-15. Outboard Flap Hinge Fairing Integral to Wing-Strut Fairing.....	29
Figure 2-16. Inboard Flap Hinge Fairing Integral to Nacelle Pylon [installed – left, removed – right]	29
Figure 2-17. Overall Model Instrumentation Suite.....	30
Figure 2-18. Model Wing Instrumentation (strut hidden for clarity)	31
Figure 2-19. Pressure Tap Nomenclature	31
Figure 2-20. Model Strut Instrumentation (wing hidden for clarity).....	33
Figure 2-21. Static Pressure Tap Locations on Nose of Fuselage.....	34
Figure 2-22. Wing-body Fairing Static Pressure Tap Locations.....	35
Figure 2-23. Forward and Aft Keel Dam Pressure Taps	36
Figure 2-24. Location of Nacelle Internal Static Pressure Taps	36
Figure 2-25. Jig-to-1G Delta Twist Distribution Correction at Mach 0.80, $C_L = 0.695$, Re_{MAC} $= 5.18M$	37
Figure 2-26. As-built QA Twist Data Applied to Jig-to-1G Twist Correction	39
Figure 2-27. Approximate Model 1G Twist Based on QA Twist Correction.....	39
Figure 2-28. Side View of Test Section with Semispan Model Installed	40
Figure 2-29. Wind Tunnel Balance Prior to Installation.....	41
Figure 2-30. Drawing of Wind Tunnel Balance.	42
Figure 2-31. Balance-Floor Gap Fillers.....	42

Figure 2-32. Operating Envelope of the 11' UPWT Transonic Test Section with Buffet Test Conditions Indicated in Red.	46
Figure 2-33. Wing and Strut Boundary Layer Trip Locations	48
Figure 2-34. Data Corrections for Drag Coefficient [$Re_{MAC}=5.18M$, $M=0.8$]	50
Figure 2-35. Data Corrections for Lift Coefficient [$Re_{MAC}=5.18M$, $M=0.8$]	51
Figure 2-36. Data Corrections for Pitching Moment Coefficient [$Re_{MAC}=5.18M$, $M=0.8$]	51
Figure 2-37. Data Repeatability for Lift Coefficient [$Re_{MAC}=5.18M$, $M=0.8$]	52
Figure 2-38. Data Repeatability for Drag Coefficient [$Re_{MAC}=5.18M$, $M=0.8$]	53
Figure 2-39. Data Repeatability for Pitching Moment Coefficient [$Re_{MAC}=5.18M$, $M=0.8$]	53
Figure 2-40. Data Repeatability for Drag Polar [$Re_{MAC}=5.18M$, $M=0.8$] with 2σ Bounds.	54
Figure 2-41. Comparison of the Drag Polar for Pitch Pause and Continuous Pitch Rate Data.	55
Figure 2-42. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Drag Polars at $Re_{MAC}\approx 2.17M$	56
Figure 2-43. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Lift Coefficient at $Re_{MAC}\approx 2.17M$	56
Figure 2-44. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Drag Coefficient at $Re_{MAC}\approx 2.17M$	57
Figure 2-45. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Pitching Moment Coefficient at $Re_{MAC}\approx 2.17M$	57
Figure 2-46. Effect of Sealing on Fuselage Nose Pressures for $Re_{MAC} = 5.2M$ and Mach = 0.8	58
Figure 2-47. Metal tape used to seal model to floor	59
Figure 2-48. Effect of Sealing on Wing Pressures for $Re_{MAC} = 5.2M$, Mach = 0.8, and CL = 0.695	60
Figure 2-49. Effect of Taping Model to Floor: Inboard Wing Pressures for C139, $Re_{MAC}=5.18M$, Mach=0.8, $\alpha=1.8$ deg	61
Figure 2-50. Effect of Taping Model to Floor: Inboard Wing Pressures for C139, Re_{MAC} =5.18M, Mach=0.8, $\alpha =3.3$ deg	61
Figure 2-51. Keel Dam Pressure Difference for a Range of Alphas	62
Figure 2-52. Effect of Reynolds number on Drag Polar at $M=0.8$	63
Figure 2-53. Effect of Reynolds Number on Chordwise Pressure Distribution: Inboard Wing [$M=0.80$, $\alpha=4.0^\circ$].	64
Figure 2-54. Effect of Reynolds Number on Chordwise Pressure Distribution: Mid Wing [$M=0.80$, $\alpha=4.0^\circ$].	64
Figure 2-55. Effect of Reynolds Number on Chordwise Pressure Distribution: Outboard Wing [$M=0.80$, $\alpha=4.0^\circ$].	65

Figure 2-56. Lift Curve Comparison for Trip Patterns T1, T3, and T4 [$M=0.80$, $Re_{MAC}=5.18M$].	66
Figure 2-57. Drag Polar for Trip Patterns T1, T3, and T4 [$M=0.80$, $Re_{MAC}=5.18M$].	67
Figure 2-58. Wing Pressure Comparison: Midspan Region, T1 vs. T3 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].	68
Figure 2-59. Wing Pressure Comparison: Outboard Region, T1 vs. T3 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].	69
Figure 2-60. Wing Pressure Comparison: Midspan Region, T3 vs. T4 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].	70
Figure 2-61. Wing Pressure Comparison: Outboard Region, T3 vs. T4 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].	70
Figure 2-62. Drag Polar for Trip Patterns T3 and T3.1 [$M=0.80$, $Re_{MAC}=5.18M$].	71
Figure 2-63. Wing Pressure Comparison: Midspan Region, T3 vs. T3.1 [$M=0.80$, $Re_{MAC}=5.18M$].	72
Figure 2-64. Wing Pressure Comparison: Outboard Region, T3 vs. T3.1 [$M=0.80$, $Re_{MAC}=5.18M$].	73
Figure 2-65. Effect of Strut Trip on Vehicle Drag Polar at $Re_{MAC}=5.18M$, $Mach=0.8$	74
Figure 2-66. Pressure comparison in the wing-strut channel region for T1 vs. T5 [$M=0.8$, $Re_{MAC}=5.18M$, $\alpha=2.1^\circ$].	75
Figure 2-67. Pressure comparison in the wing-strut channel region for T1 vs. T5 [$M=0.8$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].	75
Figure 2-68. C_L vs. α for WBS (C141) configuration, $Mach=0.8$.	76
Figure 2-69. C_L vs. α for WBS (C141) and WBSNP (C142) configurations.	77
Figure 2-70. C_L vs. α for WBS (C141), WBSNP (C142) and WBSNPF (C139) configurations.	77
Figure 2-71. Sample Wing/Strut Spanload Plot [Config C139, Run 297, $M=0.8$, $Re_{MAC}=5.2M$, $\alpha=2.1^\circ$].	79
Figure 2-72. Wing Upper Surface Pressure Contours [Config C139, Run 297, $M=0.8$, $Re_{MAC}=5.18M$].	80
Figure 2-73. Pitching Moment Curve	81
Figure 2-74. Initial Buffet Curve According to Pitch Break Method [Config C139, Trip T1, $Re_{MAC}=5.2M$].	82
Figure 2-75. Trailing Edge Pressure Divergence Method	83
Figure 2-76. Trailing Edge Pressure Divergence Method Critical Span	83
Figure 2-77. Initial Buffet Curve According to Trailing Edge Divergence Method [Config C139, Trip T1, $Re_{MAC}=5.2M$].	84
Figure 2-78. Axial Force Offset Method	85
Figure 2-79. AFO: Baseline Repeatability [Config C139, Trip T1, $Re_{MAC}=5.2M$].	85
Figure 2-80. Example Wing Strain Gauge RMS Data	87

Figure 2-81. Buffet Onset Boundary Based on Strain Gauge Data [Config C139, Trip T1, $Re_{MAC}=5.2M$].	87
Figure 2-82. Example Wing Accelerometer RMS Data	88
Figure 2-83. Buffet Onset Boundary Based on Accelerometer Data [Config C139, Trip T1, $Re_{MAC}=5.2M$].	89
Figure 2-84. Representative Kulite RMS p' Signal [Config C139, $M=0.8$, Trip T1, $Re_{MAC}=5.2M$].	90
Figure 2-85. Power Spectral Density (PSD) [Config C139, $M=0.8$, Trip T1, $Re_{MAC}=5.2M$].	91
Figure 2-86. Buffet Onset Comparison [Config C139, Trip T1, $Re_{MAC}=5.2M$].	92
Figure 2-87. Buffet Method Comparison: Legacy Methods [Config C139, Trip T1, $Re_{MAC}=5.2M$].	93
Figure 2-88. Buffet Method Comparison: Strain Gauges and Kulites [Config C139, Trip T1, $Re_{MAC}=5.2M$].	94
Figure 2-89. Buffet Method Comparison: Accelerometers and Kulites [Config C139, Trip T1, $Re_{MAC}=5.2M$].	95
Figure 2-90. Buffet Method Comparison: 0° Aileron Deflection [Config C139, Trip T1, $Re_{MAC}=5.2M$, $\delta_{IBAIL}=\delta_{OBAIL}=0^\circ$].	96
Figure 2-91. Buffet Method Comparison: -5° Aileron Deflection [Config C139, Trip T1, $Re_{MAC}=5.2M$, $\delta_{IBAIL}=\delta_{OBAIL}=-5^\circ$].	97
Figure 2-92. Buffet Method Comparison: $+5^\circ$ Aileron Deflection [Config C139, Trip T1, $Re_{MAC}=5.2M$, $\delta_{IBAIL}=\delta_{OBAIL}=5^\circ$].	98
Figure 2-93. AFO: Aileron Effect [Config C139, Trip T1, $Re_{MAC}=5.2M$].	99
Figure 2-94. Pressure Distribution: Aileron Effect [Config C139, Trip T1, $M=0.75$, $Re_{MAC}=5.2M$].	99
Figure 2-95. Aileron Deflection Effect on Spanloads [Config C139, Trip T1, $M=0.75$, $Re_{MAC}=5.2M$].	100
Figure 2-96. AFO: Strut Flap Effect [Config C139, Trip T1, $Re_{MAC}=5.2M$].	101
Figure 2-97. AFO: Wing Trip Location Effect [Config C139, $Re_{MAC}=5.2M$].	102
Figure 2-98. Buffet Method Comparison: Effect of Tripping [Config C139, $Re_{MAC}=5.2M$].	103
Figure 2-99. Buffet Method Comparison: Effect of Reynolds Number [Config C139].	104
Figure 2-100. Buffet Method Comparison: Model Configuration Effect [Trip T1, $Re_{MAC}=5.2M$].	106
Figure 2-101. Pressure Distribution: Model Configuration Effect [$M=0.8$, Trip T1, $Re_{MAC}=5.2M$].	106
Figure 2-102. Buffet Semispan CFD Model	107
Figure 2-103. CFD Model Details Showing Keel Dams and Adapter Plate	108
Figure 2-104. CFD Model in Proximity of Test Section Floor	109

Figure 2-105. CFD Model with Profile Plate (yellow) and Keel Dams (blue, purple, red) Shown in Proximity of Test Section Floor	109
Figure 2-106. Forward Trip Wing Pressure Comparison at Design Condition: Inboard Wing [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	112
Figure 2-107. Forward Trip Wing Pressure Comparison at Design Condition: Midboard Wing [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	113
Figure 2-108. Forward Trip Wing Pressure Comparison at Design Condition: Outboard Wing [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	114
Figure 2-109. Forward Trip Strut Pressure Comparison at Design Condition: Inboard Strut [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	115
Figure 2-110. Forward Trip Strut Pressure Comparison at Design Condition: Outboard Strut [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	115
Figure 2-111. Forward Trip Wing Pressure Comparison at 1.3g Condition: Inboard Wing [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	116
Figure 2-112. Forward Trip Wing Pressure Comparison at 1.3g Condition: Midboard Wing [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	117
Figure 2-113. Forward Trip Wing Pressure Comparison at 1.3g Condition: Outboard Wing [M=0.8, Re _{MAC} =5.2M, Fwd Trip].	118
Figure 2-114. Forward Trip Wing Pressure Comparison at MMO Condition: Inboard Wing [M=0.85, Re _{MAC} =5.2M, Fwd Trip].	119
Figure 2-115. Forward Trip Wing Pressure Comparison at MMO Condition: Midboard Wing [M=0.85, Re _{MAC} =5.2M, Fwd Trip].	120
Figure 2-116. Forward Trip Wing Pressure Comparison at MMO Condition: Outboard Wing [M=0.85, Re _{MAC} =5.2M, Fwd Trip].	121
Figure 2-117. Boundary Layer Displacement Thickness (δ_1) in the Ames 11ft Test Section (11).	121
Figure 2-118. OVERFLOW Boundary Layer (BL) Approximation on the Test Section Floor at Mach 0.8.	122
Figure 2-119. BUFFET code output indicating whether buffet has been reached.	123
Figure 2-120. Buffet Prediction Comparisons for Forward Trip Location (5% Chord, Left) & Aft Trip Locations (25% Chord, Right).	124
Figure 2-121. Effect of Strut Flap Position on Buffet Prediction Using AFO Method [Config C139, Aft Trip T3, Re _{MAC} =5.2M].	125
Figure 2-122. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, Re _{MAC} =2.16M, M=0.5].	127
Figure 2-123. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, Re _{MAC} =2.16M, M=0.8].	128

Figure 2-124. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	129
Figure 2-125. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient - zoomed in. [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.89$].	130
Figure 2-126. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient - zoomed in. [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	130
Figure 2-127. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].	131
Figure 2-128. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].	132
Figure 2-129. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	132
Figure 2-130. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.89$].	133
Figure 2-131. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	134
Figure 2-132. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.89$].	135
Figure 2-133. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=3.29M$, $M=0.89$].	135
Figure 2-134. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.89$].	136
Figure 2-135. Effect of Spoilers on the Lift Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].	137
Figure 2-136. Effect of Spoilers on the Lift Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].	137
Figure 2-137. Effect of Spoilers on the Lift Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	138
Figure 2-138. Effect of Spoilers on the Drag Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].	139
Figure 2-139. Effect of Spoilers on the Drag Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].	140
Figure 2-140. Effect of Spoilers on the Drag Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	140
Figure 2-141. Effect of Spoilers on the Pitching Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].	141
Figure 2-142. Effect of Spoilers on the Pitching Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].	141

Figure 2-143. Effect of Spoilers on the Pitching Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	142
Figure 2-144. Effect of Spoilers on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].	143
Figure 2-145. Effect of Spoilers on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].	144
Figure 2-146. Effect of Spoilers on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].	144
Figure 2-147. Effect of Strut Flap Deflection on the Pitching Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.5$].	145
Figure 2-148. Effect of Strut Flap Deflection on the Pitching Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.8$].	146
Figure 2-149. Effect of Strut Flap Deflection on the Pitching Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.89$].	146
Figure 2-150. Effect of Strut Flap Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.5$].	147
Figure 2-151. Effect of Strut Flap Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.8$].	148
Figure 2-152. Effect of Strut Flap Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.89$].	148

Nomenclature

AR	Aspect ratio
b_{ref}	Wing reference span
BCA	Boeing Commercial Airplanes
BL	Boundary Layer
BMC	Balance moment center
BR&T	Boeing Research & Technology
c	Local chord
C_D	Vehicle drag coefficient
C_l	Sectional lift coefficient
C_L	Vehicle lift coefficient
$C_{L,IB}$	Vehicle lift coefficient at initial buffet onset
CFD	Computational fluid dynamics
C_{PM}	Vehicle pitching moment coefficient
C_{RM}	Vehicle rolling moment coefficient
c_{ref}	Wing reference chord (equivalent to MAC)
C_{PTE}	Pressure coefficient at the trailing edge
ESP	Electronically scanned pressure
FEM	Finite Element Modeling
FHF	Flap Hinge Fairing
FS	Full scale
IB	Inboard

IBAIL	Inboard Aileron
LHS	Left-hand side
M	Mach number
MAC	Mean aerodynamic chord [inches]
MB	Midboard
M _{DD}	Drag divergence Mach number
M _{MO}	Maximum operating Mach number
MRC	Moment reference center
MS	Model station [inches] or model scale
NP	Nacelle and pylon
OB	Outboard
OBAIL	Outboard Aileron
OML	Outer mold line
p'	Root Mean Square (RMS) of pressure (lb/in ²)
q	Tunnel dynamic pressure [lb/ft ²]
QA	Quality assurance
Re	Reynolds number [/ft.]
Re _{MAC}	Reynolds number based on mean aerodynamic chord
RH	Right-hand
S _{ref}	Wing reference area
SA	Spalart-Allmaras turbulence model
SST	Shear-Stress Transport turbulence model
SUGAR	Subsonic Ultra-Green Aircraft Research
TE	Trailing Edge
TED	Trailing Edge Down [degrees]
TEU	Trailing Edge Up [degrees]
TS	Tunnel station [inches]
UPWT	Unitary Plan Wind Tunnel (NASA Ames Research Center)
TTBW	Transonic Truss-Braced Wing
TWICS	Transonic Wall Interference Correction System
TWT	Transonic Wind Tunnel
WBF	Wing/body fairing
α	Angle of attack [degrees]
δ	Device deflection [degrees]

1.0 Transonic Truss-Braced Wing High-Speed Development and Testing

In 2008-2010, Boeing conducted the first Subsonic Ultra-Green Aircraft Research (SUGAR) study for NASA. In this study, Boeing identified and analyzed advanced concepts and technologies for aircraft that would fly in the 2030-2035 timeframe. Large possible improvements in fuel consumption, emissions, and noise were identified and roadmaps developed for key technologies. The conclusion of the first phase of research spawned several new research areas that further maturation in subsequent Phases of work. One of the concepts identified in this study (shown in Figure 1-1) was the Transonic Truss-Braced Wing (TTBW).



Figure 1-1. The Transonic Truss-Braced Wing (TTBW) Configuration.

In SUGAR Phase III, high speed lines were developed for a Mach 0.745 TTBW design. High fidelity analysis results were validated via a wind tunnel test at the Ames 11-Ft Transonic Wind Tunnel (TWT), using a 4.5% scale, full-span model. Results from this test aided in reducing the uncertainty of predicted TTBW aircraft performance.

Two high-speed wind tunnel tests were conducted as part of the SUGAR TTBW Phase IV contract. Initiated in July 2017, Phase IV focused on development of a high-fidelity aerodynamic design for a Mach 0.80 transonic truss-braced wing to enable increased fleet productivity. The first wind tunnel test of this phase was a follow-on entry of the Phase III M=0.745 TTBW model. The test occurred between January 23 and February 9, 2018, for a total of 210 occupancy hours. The NASA designation for this test was 11-0343, and the Boeing test designation was LB-649B. The model was 4.5% scale and had a wingspan of 7.7 feet. The test focused on determining the model drag buildup at Mach 0.5, determining drag polars from cruise Mach number to max operating Mach number, verifying the CFD based truss system drag increment, and verifying the drag rise of the

overall configuration. In addition, stability and control data were collected up dive through Mach number where model loads allowed. Additional focus was placed on the quantification of model roughness effects on data collected during the previous test entry.

The second test entry was of the Phase IV $M=0.80$ TTBW model. The test occurred between July 14 and August 2, 2019, for a total of 238 occupancy hours. The NASA designation for this test was 11-0367, and the Boeing test designation was LB-652A. The model was 4.5% scale and had a wingspan of 7.7 feet. The test began with a data reduction and methods check in which the $M=0.745$ model was briefly installed to ensure test-to-test repeatability of results. Once the data reduction was checked and test-to-test repeatability verified, the $M=0.80$ model was then installed in the test section. The test focused on verifying the aerodynamic performance of the $M=0.80$ vehicle by measuring the model drag buildup, drag polars from cruise Mach number to max operating Mach number, and verifying the drag rise of the overall configuration. Pressure data were collected for all test points. However, model strength limitations significantly limited the amount of instrumentation that could fit into the model. In addition to performance data, stability and control data, including control surface effectiveness, was collected.

In addition to the SUGAR program, a separate project funded by NASA in 2017 examined risk reduction topics for a potential TTBW X-Plane demonstrator aircraft. One part of this study investigated the TTBW potential for high-speed buffet onset at both high and low lift coefficients. As shown in Figure 1-2, the local downflow of the strut near the wing-strut juncture can lead to significant flow acceleration on the underside of the strut, potentially leading to buffet onset when at very low lift coefficients. In this study, predictions of the vehicle buffet boundary were made using internal Boeing codes and methods. Disagreement in code predictions highlighted the necessity for investigation of current methods, which are largely based on empirical data from previous cantilever-wing aircraft. The study therefore focused on the development of a semispan buffet-focused wind tunnel test so that buffet prediction methods could be validated. In-tunnel computational predictions of different model mounting options, model height offset effects, and the effects of the tunnel installation on model performance were performed. Particular attention was focused on the interaction of the over-wing flow (and shock) with the wind tunnel boundary layer due to the proposed semispan installation. A proposed layout of the necessary model instrumentation and a preliminary test plan were constructed, including a study to select the appropriate wind tunnel for the test program. The Ames 11-ft Transonic Wind Tunnel was determined to be the best option for this study.

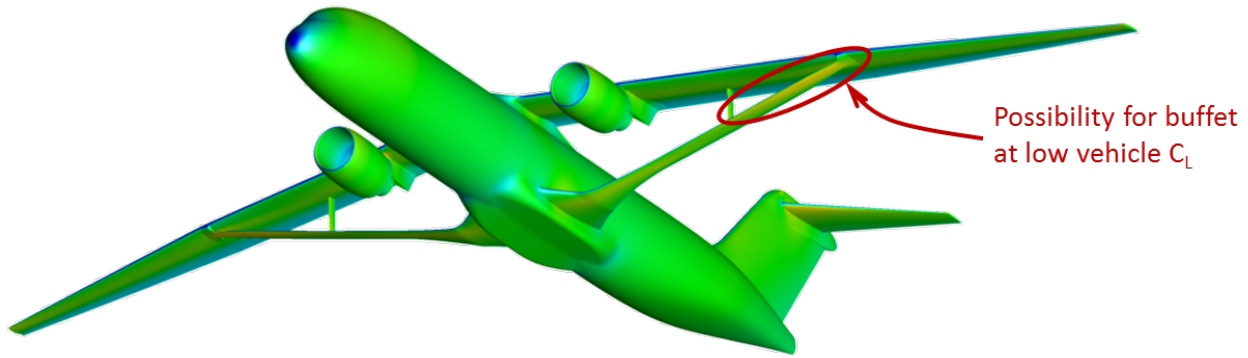


Figure 1-2. Region of the TTBW strut that could be of concern for buffet.

SUGAR Phase V was awarded in September 2020. One of the objectives of this contract was to study high-speed buffet onset by conducting the proposed buffet-focused transonic wind tunnel test. The detailed task included test planning, fabrication of a new semispan wind tunnel model, conducting pretest estimates, and execution of the test.

2.0 Transonic Truss-Braced Wing High-Speed Buffet Wind Tunnel Test

This report summarizes the Phase V TTBW transonic buffet wind tunnel campaign, including descriptions of test objectives, model features, facility parameters, data quality, comparisons of pretest CFD results to measured data, and an assessment of buffet prediction methods. The Boeing designation for the buffet test is LB-667A, and the NASA test designation is 11-0415. Test data from this entry is presented in full in Appendix C.

2.1 Test Introduction and Objectives

The buffet test utilized the same nominal $M=0.80$ TTBW design/geometry developed and tested as a full-span model in SUGAR Phase IV. However, the test requirements and objectives called for a more heavily instrumented and robust model as compared to previous test entries. These requirements drove the model design towards a new, larger-scale semispan model capable of withstanding potential flow unsteadiness at very high load factors as well as having increased internal volume to accommodate the larger suite of model instrumentation used for assessing buffet onset. The new model was tested in the 11-ft transonic test section at the NASA Ames Unitary Plan Wind Tunnel (UPWT) complex located at Moffett Field, CA. The four-week (320 occupancy hour) test entry took place from January 24 through February 18, 2022. The general arrangement of the tested configuration, including rough model dimensions is shown in Figure 2-1. Key model reference quantities of the configuration are included in Table 2-1.

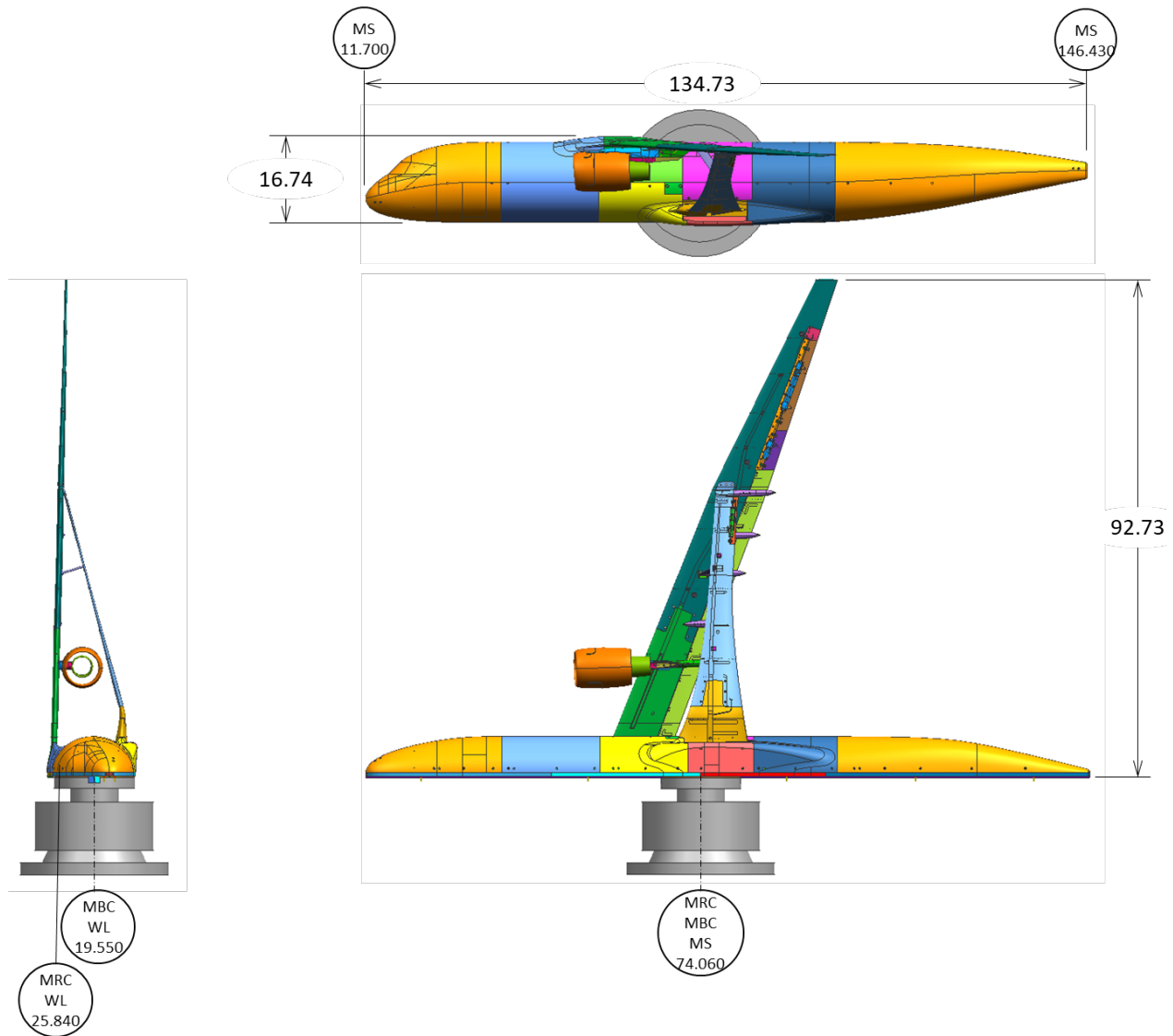


Figure 2-1. Mach 0.8 TTBW General Arrangement (Dimensions in Model Scale).

Table 2-1. Model Reference Quantities.

Reference Quantities	
S_{ref}	1722.9011 in ²
b_{ref}	183.5280 in
c_{ref}	9.9257 in
AR	19.565

The wind tunnel test had the following main test objectives:

- 1) Determine buffet boundary and characteristics for the TTBW configuration
- 2) Perform computational predictions of buffet boundary using existing methods and assess the ability of these methods to accurately assess buffet boundary for a TTBW
- 3) Gather force and moments at transonic condition around potential buffet boundaries
- 4) Determine the influence of control surface and outboard strut flap deflections on buffet boundary
- 5) Gather accelerometer, strain-gauge, static pressure transducer and unsteady pressure transducer data to determine buffet boundary

2.2 Test Facility

The buffet test was conducted in the 11-ft transonic test section at the NASA Ames Unitary Plan Wind Tunnel (UPWT) complex located at Moffett Field, CA. A depiction of the UPWT facility is shown in Figure 2-2.

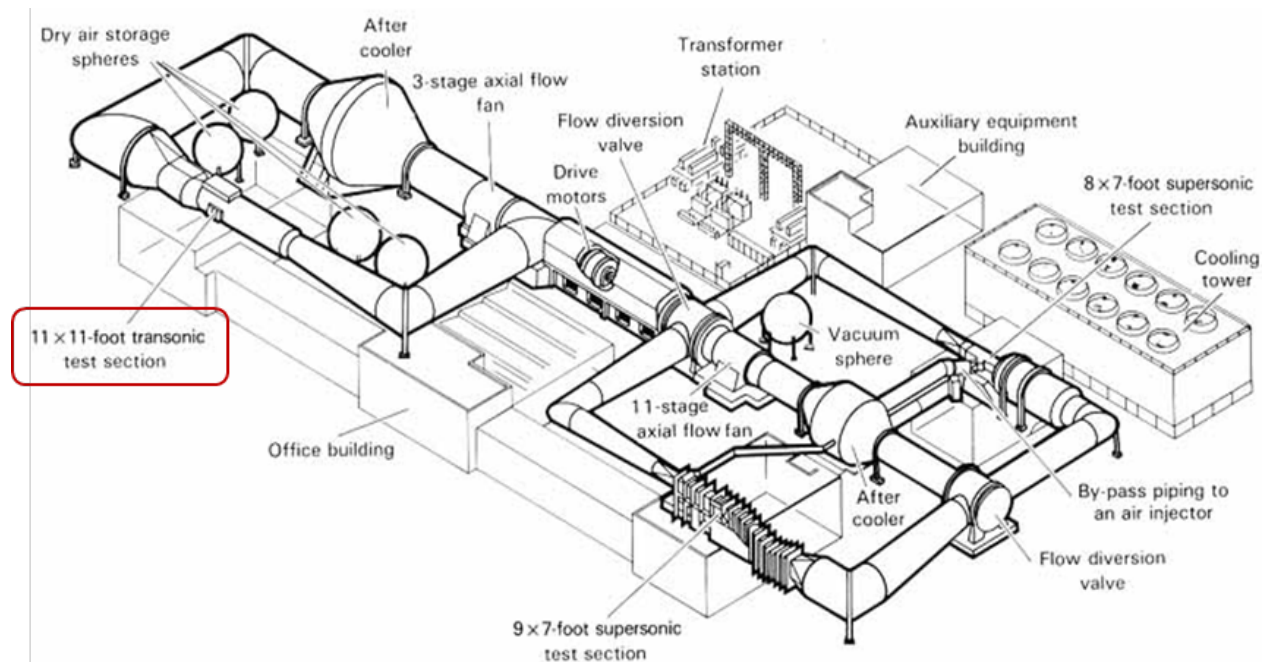


Figure 2-2. NASA Ames Unitary Plan Wind Tunnel (UPWT) Aerial View.

The Mach capability in the 11-ft test section ranges from 0.2 to 1.45 with a Reynolds number variation from 0.3 to 9.8M per foot. Tunnel operating pressure can be varied from 432 to 4,608 psfa. The transonic test section is 11' high, 11' wide, and 22' in length. Model installation details and drawings for the test entry including the model, support system, and balance interface are provided in subsequent sections of this report.

2.3 Model Description

The wind tunnel model (Figure 2-3) is a semispan, 9% scale representation of the M=0.80 TTBW (1104-001-RG) aircraft configuration developed in the SUGAR Phase IV contract. The model fuselage incorporates an integral standoff designed to raise the model up to minimize the effects of the tunnel boundary layer. Relative to the original geometry, the wing-body fairing upper surface has been locally modified for operation as a semispan model in the Ames 11-ft TWT. (Details later in the report.)



Figure 2-3. 9% Scale Semispan TTBW Wind Tunnel Model installed in the 11-ft Transonic Test Section of the NASA ARC Unitary Plan Wind Tunnel (UPWT) Complex.

The model was designed to be modular so that the different components of the wing/truss system could be tested separately to determine the net effect of each component. In this way, the test results could be used to validate the conceptual drag and lift build-up methodology to help support sizing of future TTBW aircraft configurations. Model components (shown in Figure 2-4) include fuselage, wing, strut, nacelle and pylon, flap hinge fairings, and jury strut. The model also has deflectable ailerons, spoilers, and an outboard strut flap. Due to model strength limitations arising from the high-aspect ratio wing and extensive internal instrumentation suite, the wing could not be tested without the main strut installed. In addition, the jury strut was not tested in this entry due to strength and safety concerns.

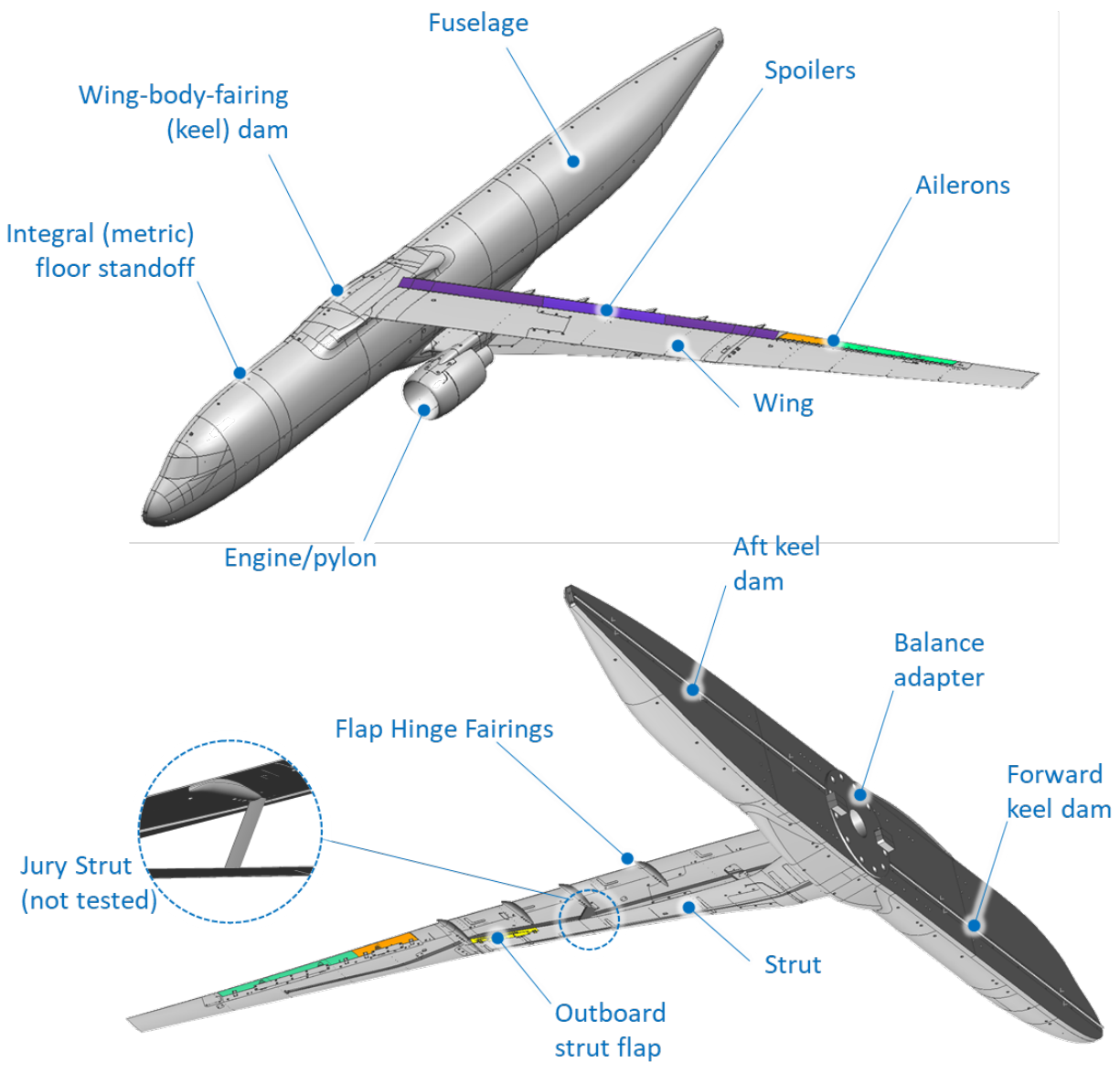


Figure 2-4. Buffet Model Components.

2.4.2 Wing

The wing geometry represents the 1-g cruise loft of the 1104-001-RG M = 0.80 TTBW design. A model jig twist correction suitable to achieve the target 1-g twist was developed for the targeted tunnel conditions (Mach 0.8, $C_L=0.695$, $Re_{MAC} = 5.18M$) and applied to the model design. The model wing includes extensive instrumentation, including static pressure orifices, accelerometers, dynamic pressure transducers, and two strain gauges with backups. Wing instrumentation is described in detail in Section 2.5.2 of this report. The model wing (Figure 2-6) represents the left-side wing of the aircraft, and includes deflectable inboard and outboard aileron surfaces, and detachable inboard, mid, and outboard spoiler panels. The wing flap hinge fairings and nacelle-pylon are detachable from the wing.

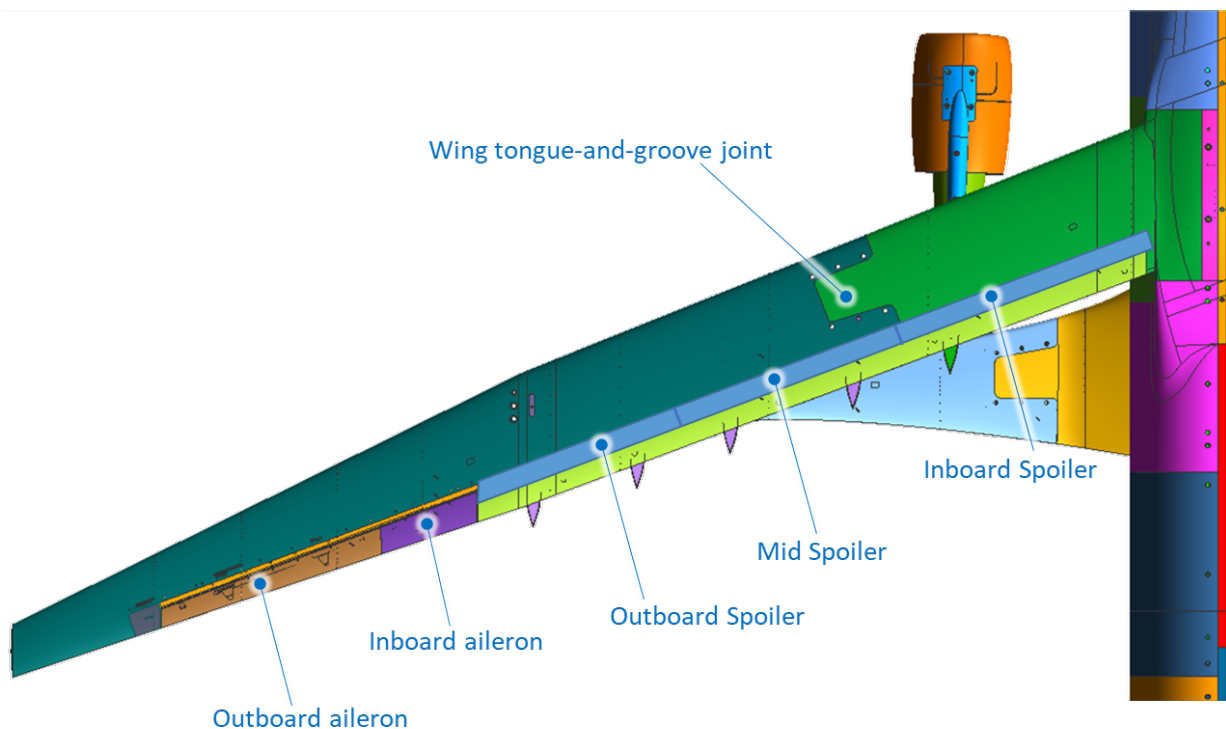


Figure 2-6. Buffet Model Wing.

Due to the lack of availability of a material billet of the desired material (Aermet 100) large enough to use for the entire model span, the buffet model wing has a permanently bonded tongue-and-groove joint located just outboard of the engine. 15-5 stainless steel was used for the inboard wing while leaving the stronger material for the regions of the wing with higher stress concentrations. This compromise enabled the wing to be constructed more quickly and with the strength necessary to execute the desired test program. In addition, a machining error during model manufacture resulted in an undercut of the wing upper surface from approximately 63-79% model semispan starting near the leading edge and ending near the local wing midchord. This undercut was determined to be not sufficient in size enough as to significantly alter the

model strength and testing limits (i.e., tunnel dynamic pressure). However, to return the wing upper surface to an acceptable tolerance to the design contour, the affected area was coated in an epoxy-carbon nanosphere resin, then machined and hand-worked to within the original surface tolerance allowables. This repair was resilient during testing, and did not cause any known changes to model performance during testing.

2.4.2.1 Wing/Body Fairing

The shape of the wing/body fairing (WBF) was modified for the buffet model relative to the 1104-001-RG geometry. This modification was made so that the inboard wing loading of the semispan model more closely resembled that of a full-span configuration; the loading difference is due to the interaction of the wind tunnel boundary layer with the WBF upper surface flow. In addition to this OML shape change, an additional keel dam was designed and installed along the edge of the WBF to prevent the formation of a vortex that was predicted during pre-test CFD studies. The left side of Figure 2-7 is an OVERFLOW solution at Mach=0.8 and $C_L=0.91$ showing details of the local flow field without the keel dam installed. With the dam missing, the low-momentum fluid from the tunnel boundary layer is syphoned up by the WBF low pressure region, resulting in the formation of a strong vortex.

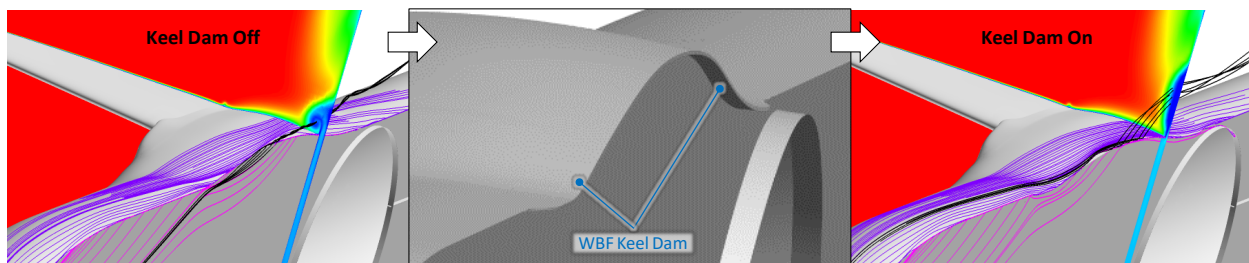


Figure 2-7. Effect of WBF Keel Dam.

The image in the middle of the figure above shows the WBF keel dam in an isometric view looking aft and outboard. Its shape, position, and size were designed to disorganize the local flow structures in an attempt to eliminate the formation of the vortex. The off-body streamlines shown on the right side of Figure 2-7 (black lines) indicate that the vortex structure is successfully destroyed with the keel dam installed. Details of the pretest CFD analysis are described in more detail in Section 2.10.

2.4.2.2 Wing Spoilers

The full-scale TTBW configuration includes nine spoiler panels per wing. However, similar to the previous wind tunnel tests of this configuration the wind tunnel model groups these panels into three separate spanwise banks of spoilers (inboard, mid, and outboard sections). These panels are bolt-on components, with a different part for each position and deflection angle. Since the spoilers attach externally to the wing, when they are installed some wing pressure taps are

blocked. The spoiler deflection angles available for the model are -2.5° , -5° , -10° , -30° , and -60° , where a negative deflection is defined as spoiler trailing edge up about the spoiler hingeline. Figure 2-8 shows the model with a bank of spoiler panels installed.

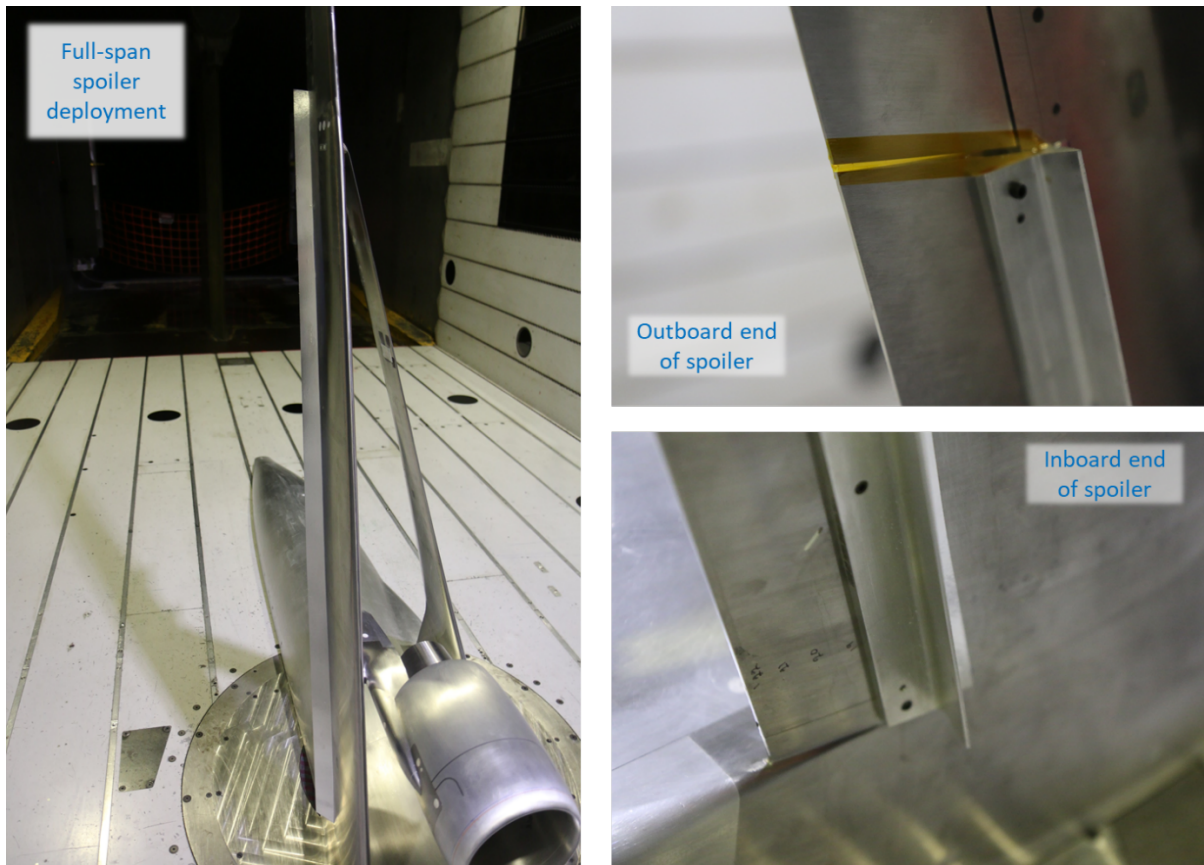


Figure 2-8. Model Spoilers [Source: NASA].

2.4.2.3 Wing Ailerons

The model includes deflectable ailerons that are split into inboard and outboard spanwise segments that can be deflected independently (see Figure 2-9). The inboard aileron extends from 61.4% to 69.4% semispan, and the outboard aileron extends from 69.4% to 87.8% semispan. The model is capable of aileron deflection angles of -2.5° , -5° , -10° , -30° , -40° , $+2.5^\circ$, $+5^\circ$, $+10^\circ$, $+20^\circ$, and $+30^\circ$; positive deflection signifies aileron trailing edge down about the aileron hingeline. Since the ailerons are mounted to a hinge, deflection angles are set using a series of angle brackets. Instrumentation on the ailerons is described in Section 2.5.2.

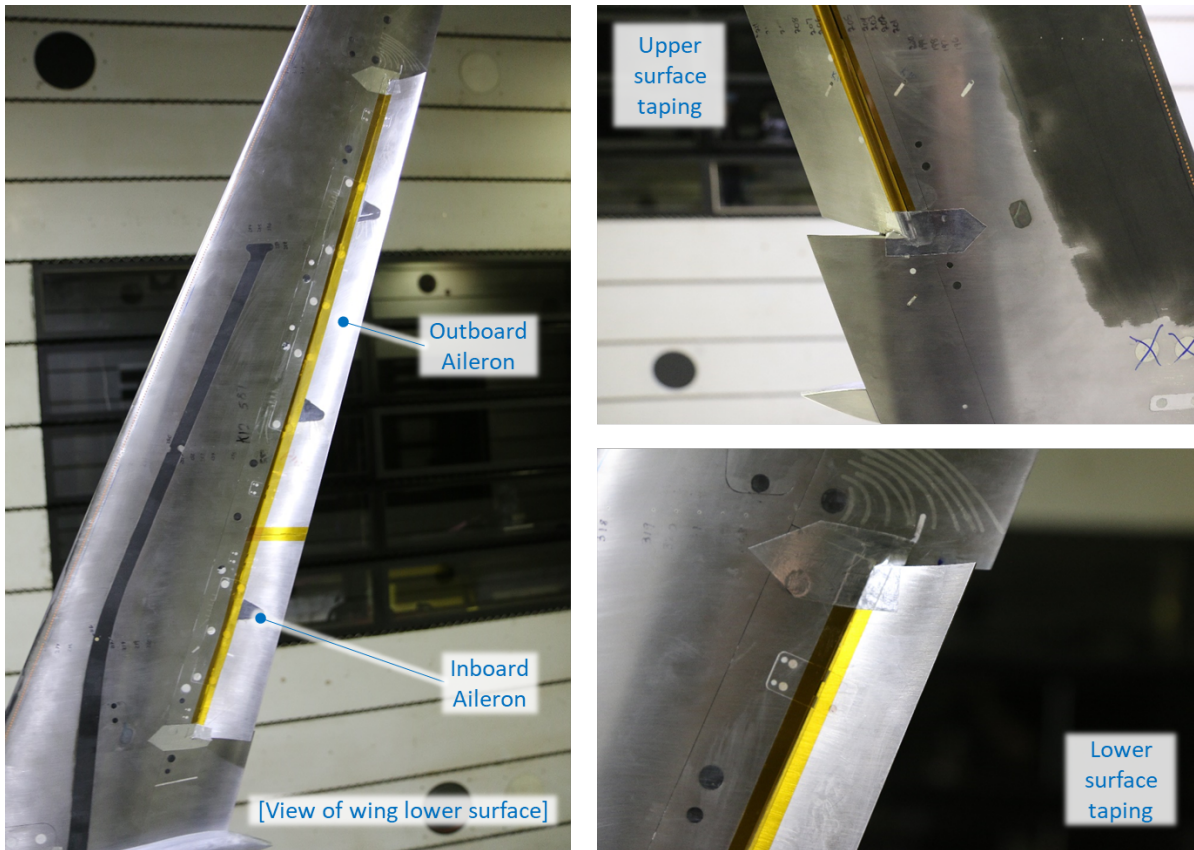


Figure 2-9. Model Ailerons [Source: NASA].

2.4.3 Strut

The model strut assembly is shown below in Figure 2-10. The strut includes a deflectable (plain) trailing-edge flap on the outboard portion of the strut. Similar to the wing, a permanently bonded tongue-and-groove joint was created in the strut to make use of available material billets of Aermet 100. The strut is designed to permanently integrate the forward portion of the most outboard flap hinge fairing at the wing-strut joint location. This design was selected to provide maximum strength to the strut where it joins to the wing as this is the region of the highest model stresses. As a result when the flap hinge fairings are removed from the model for testing, this fairing must remain installed. Permanent inclusion of this fairing into the model was considered the best compromise for performance and model strength. The drag increment for this fairing is not expected to significantly alter the FHF-off cruise performance level as its drag increment is less than the measurable balance accuracy. The strut also contains provisions for installation of a jury strut, which is detailed in Section 2.4.4. The strut contains extensive instrumentation, including static pressure orifices, an accelerometer, dynamic pressure transducers, and strain gauges (with backups). Strut instrumentation is described in detail in Section 2.5.3 of this report.

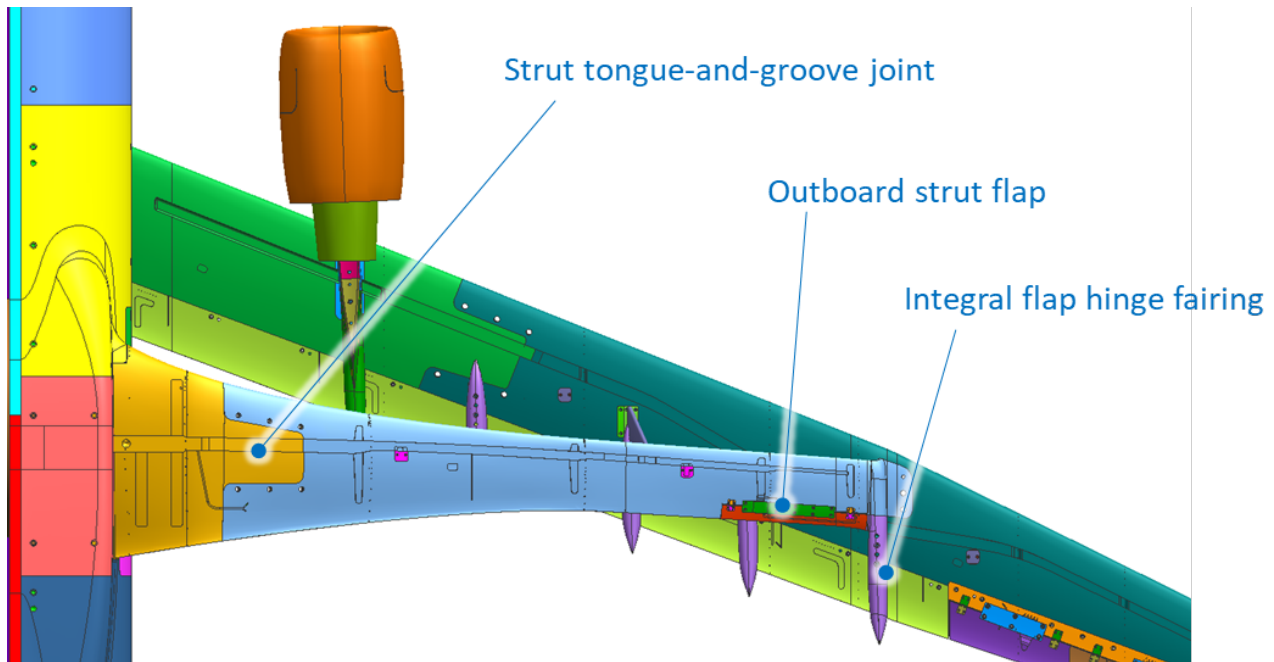


Figure 2-10. Model Strut Assembly.

2.4.3.1 Outboard Strut Flap

As shown in Figure 2-11, the model includes a deflectable outboard strut flap. This flap is used to alter the flow in the tightest confines of the wing/strut channel. The flap is a 20% chord simple-hinged device that extends from 46.3% to 56.3% semispan. The flap is capable of -4° , -2° , 2° , and 4° in addition to the 0° (cruise) position. Positive deflection angle signifies strut flap trailing edge down about the strut flap hingeline. Since the strut flap is mounted to a hinge, deflection angles are set using a series of angle brackets. Instrumentation on the strut flap is described in Section 2.5.3.

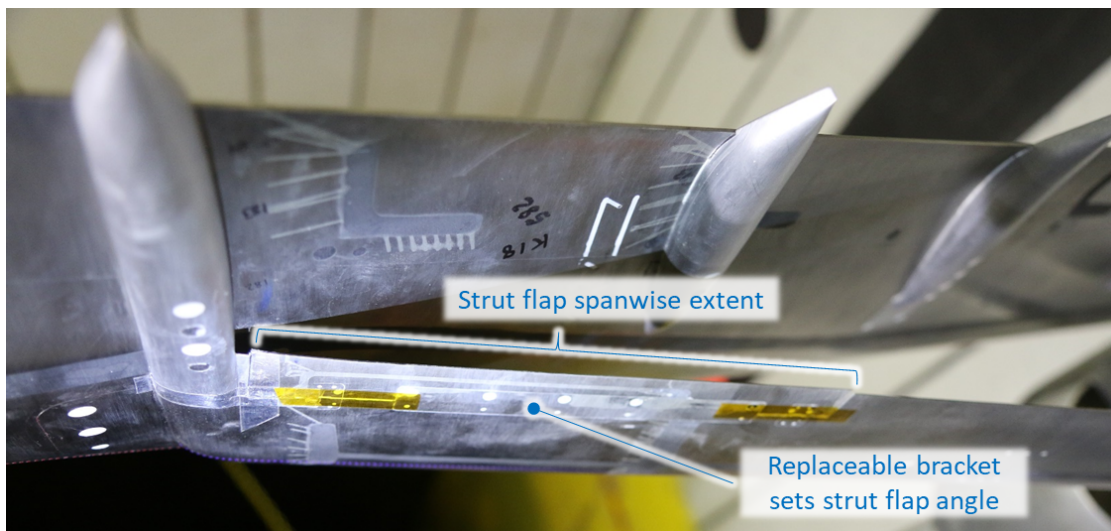


Figure 2-11. Outboard Strut Flap [Source: NASA].

2.4.4 Jury Strut

The model includes a removable jury strut that attaches to the strut upper surface. Due to concerns regarding the strength of the component at model scale, the jury strut was designed to slot into the wing lower surface. In this way, the jury strut was prevented from taking any significant structural load during testing when the wing and strut deflected under load. When it was installed, the testing team decided that the component was insufficiently strong and rigid to resist the significant aerodynamic loads in the tunnel. The jury strut was therefore not tested during this entry. Blanking plates were installed in the wing and strut to return the jury strut foot attachment pockets back to OML contour. Figure 2-12 is a side view of the installed jury strut.



Figure 2-12. Buffet Model Jury Strut [Source: NASA].

2.4.5 Nacelle and Pylon

The flow-through nacelle and pylon loft surface definitions are the same as those used for previous TTBW wind tunnel models. However, the nacelle and pylon rigging was adjusted to fit the jig twist used for the buffet model wing loft definition. No changes were made to the nacelle shape from the previous testing to account for changes in nacelle mass flow ratio (MFR) from testing at a different Reynolds number.

The nacelle and pylon are removable, with blanking plates installed into the wing lower surface when testing in the ‘engine off’ configuration as shown on the left side of Figure 2-13. In addition, the engine pylon has a flap hinge fairing component that can be removed when needed. The flap hinge fairing pylon integration is described in Section 2.4.6. Engine instrumentation is described in Section 2.5.

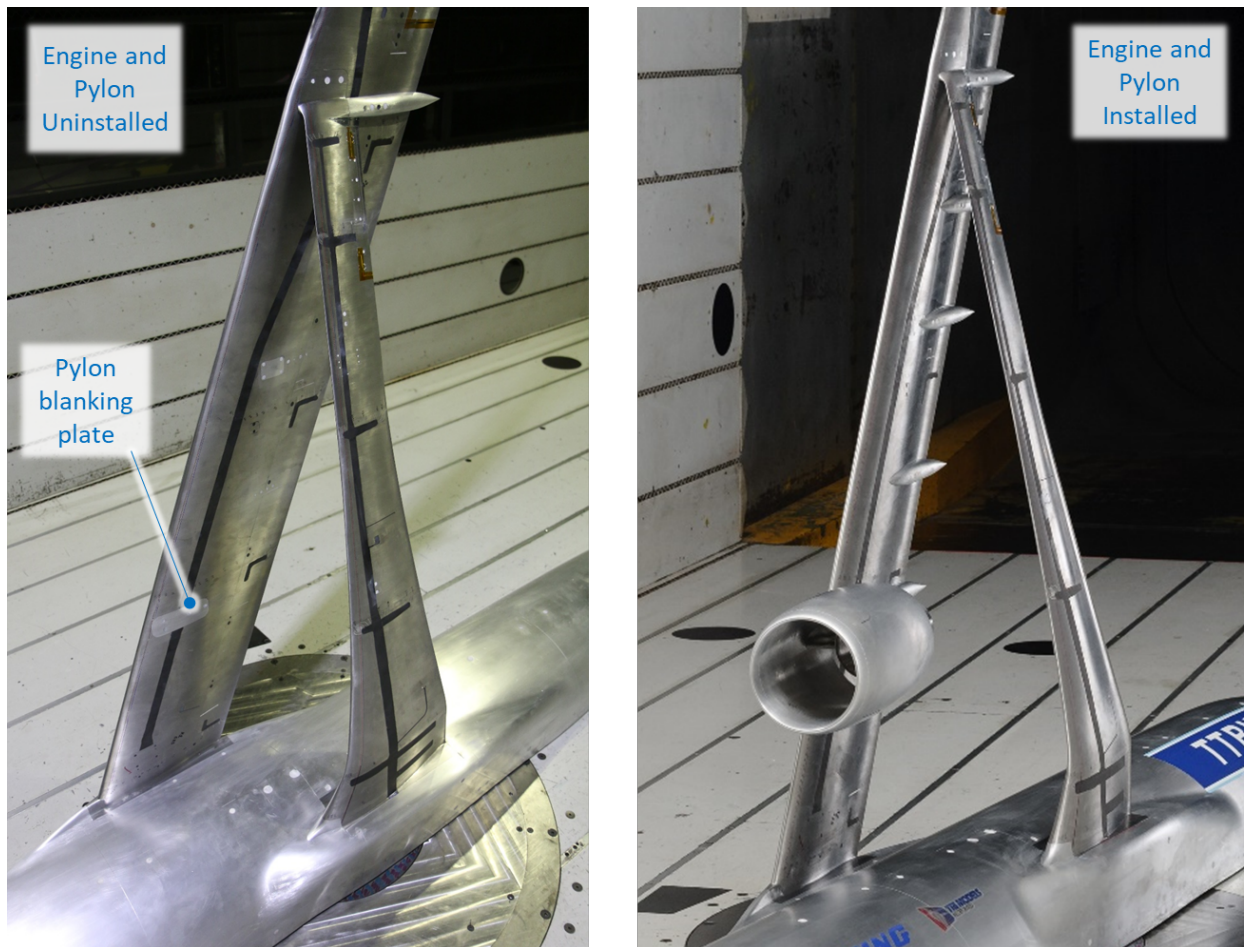


Figure 2-13. Engine and Pylon Installation [Source: NASA].

2.4.6 Flap Hinge Fairings

The model includes five removable flap hinge fairings as shown in Figure 2-14. The forward half of the outboard-most fairing is integrated with the wing-strut juncture fairing as shown in Figure 2-15, and therefore, cannot be tested without this FHF installed. All other flap hinge fairings were designed to be removable for the current model, including the engine pylon flap hinge fairing that is integral to the engine pylon (shown in Figure 2-16). The flap hinge fairings do not contain any instrumentation.

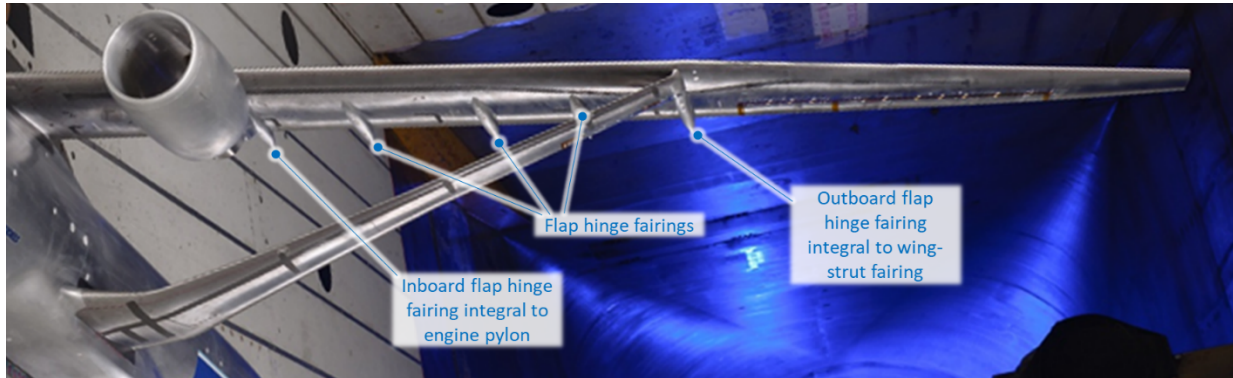


Figure 2-14. Buffet Model Flap Hinge Fairings [Source: NASA].

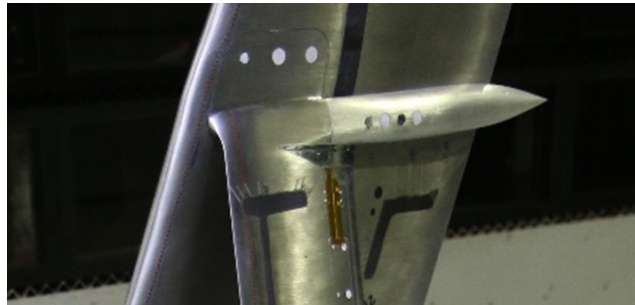


Figure 2-15. Outboard Flap Hinge Fairing Integral to Wing-Strut Fairing [Source: NASA].

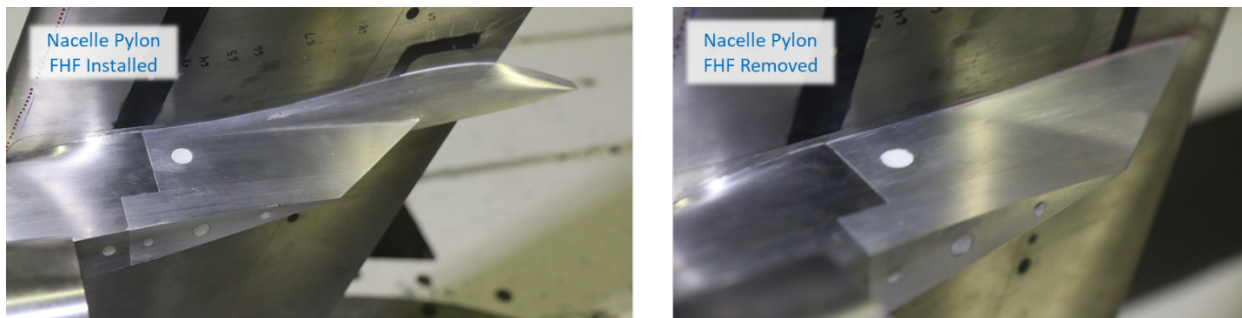


Figure 2-16. Inboard Flap Hinge Fairing Integral to Nacelle Pylon [installed – left, removed – right; Source: NASA].

2.5 Model Instrumentation

The buffet model is heavily instrumented so that many different buffet boundary prediction techniques can be investigated and compared. In addition to the five-component force and moment balance described in Section 2.6.1, the model instrumentation suite includes static pressure measurements, unsteady pressure measurements, accelerometers, and strain gauges. A general cartoon of the model instrumentation is shown in Figure 2-17; the details of this instrumentation suite are described in the sections below.

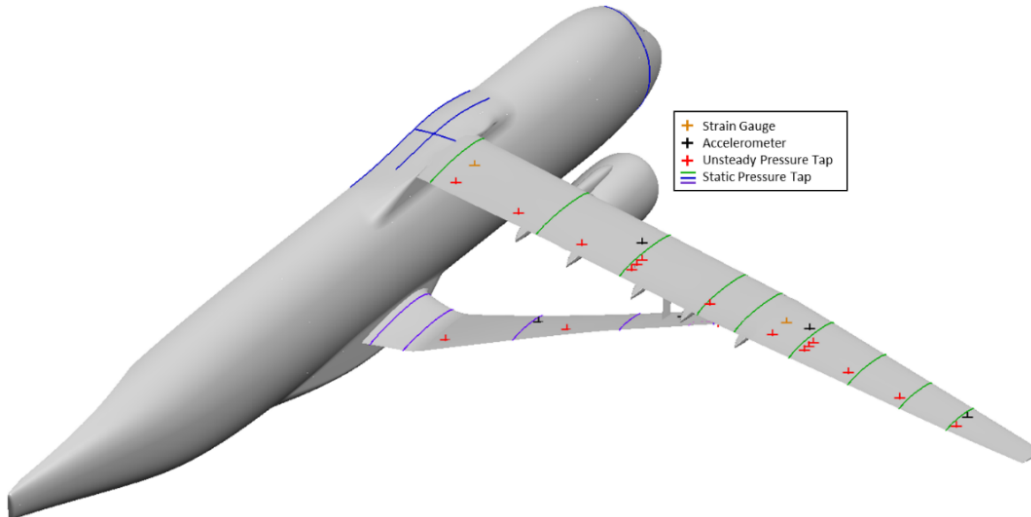


Figure 2-17. Overall Model Instrumentation Suite.

2.5.1 Instrumentation specifications

In this section, a brief description of model instrumentation hardware is given. Detailed specifications for each type are shown in Appendix B.

All unsteady pressures transducers used in the wind tunnel model are Kulite®, ‘Ultraminiature Thin Line Pressure Transducers’, model no. LQ-062-50A. The selected model had a 50 psi pressure range. Kulite® specification data sheet is shown in Appendix B Figure B-1.

Wing static pressures were measured using the tunnel PSI system. EPS modules with a range of ± 15 psid and 64 ports each were used to measure the surface pressure for all pressure taps with an accuracy of 0.25% of the measured value.

Accelerometers used on the model were type PCB 352A71. These sensors have a range of ± 500 g and resolve a frequency range of 0.5 to 10,000 Hz with $\pm 5\%$ error. Accelerometer specification data sheet is shown in Appendix B Figure B-2.

The model used three constantan foil Micro Measurements strain gauges of type EA-06-060PB-350 with a strain range of $\pm 3\%$ and 350 Ohm $\pm 0.2\%$ resistance that are used on the wing to measure bending moment and two more strain gauges are used on the strut to measure axial

force. For the backup gauges, type Micro Measurements Tee Rosette strain gauges of type CEA-06-062UT-350 are installed with the same strain range of $\pm 3\%$ and 350 Ohm $\pm 0.4\%$ resistance. Strain gauge specification data sheets are shown in Appendix B Figures B-3 and B-4.

2.5.2 Wing Instrumentation

A schematic of the wing instrumentation is shown in Figure 2-18, with the wing upper surface data shown on the right side of the image, and the wing lower surface shown on the left. In this figure, rows of static pressure taps are indicated as green lines, unsteady pressure transducers are indicated as red points, strain gauge locations are indicated as orange points, and accelerometers are indicated as black points.

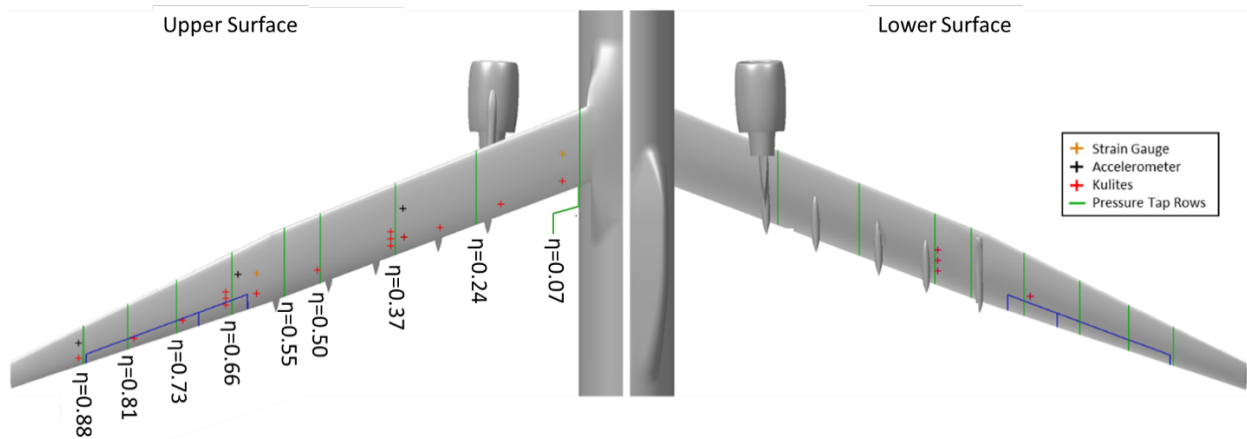


Figure 2-18. Model Wing Instrumentation (strut hidden for clarity).

The wing contains 330 static pressure taps, 19 Kulite unsteady pressure transducers (14 on the upper surface and 5 on the lower surface), three accelerometers, and two strain gauges. The outboard strain gauge location contains a backup gauge. The describing nomenclature key for wing pressures is shown in Figure 2-19. The key shows that all pressure tap locations are labeled with a combination of the model component (wing, or strut), the tap location as a function of wing semispan percentage, upper or lower surface location, and percentage wing chord. Kulite® locations are indicated by an added 'K' prefix to the codes described below.

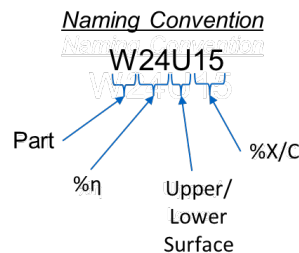


Figure 2-19. Pressure Tap Nomenclature.

Precise locations of the unsteady pressure transducers are found in Table 2-2.

Table 2-2. Wing Unsteady Pressure Transducer Locations.

Upper Surface			Lower Surface		
η	X/C	Sensor ID	η	X/C	Sensor ID
0.1	0.85	KW10U85	0.38	0.75	KW38L75
0.2	0.85	KW20U85	0.50	0.50	KW50L50
0.3	0.85	KW30U85	0.50	0.65	KW50L65
0.38	0.65	KW38U65	0.50	0.80	KW50L80
0.38	0.75	KW38U75	0.65	0.65	KW65L65
0.38	0.85	KW38U85			
0.5	0.80	KW50U80			
0.6	0.80	KW60U80			
0.65	0.60	KW65U60			
0.65	0.70	KW65U70			
0.65	0.80	KW65U80			
0.72	0.80	KW72U80			
0.8	0.80	KW80U80			
0.89	0.80	KW89U80			

Wing gauge and accelerometer locations are shown in Table 2-3.

Table 2-3. Wing Accelerometer and Strain Gauge Locations.

Type	η	X/C	Sensor ID
Accelerometer	0.36	0.40	AW36
Accelerometer	0.63	0.40	AW63
Accelerometer	0.89	0.40	AW89
Strain Gauge	0.6	0.50	WBM1
Strain Gauge	0.6	0.50	WBM2
Strain Gauge	0.1	0.50	WBM3

2.5.3 Strut Instrumentation

The instrumentation on the strut is shown in Figure 2-20, with the strut upper surface shown on the right side of the image, and the strut lower surface shown on the left. In this figure, rows of static pressure taps are indicated in purple, unsteady pressure transducers are indicated as red points, the strain gauge location is indicated as an orange point, and accelerometers are indicated as black points.

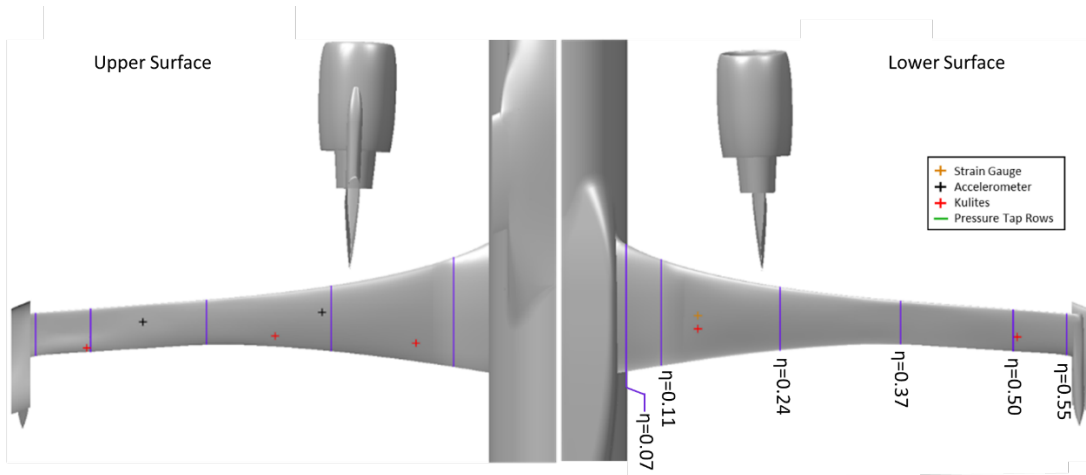


Figure 2-20. Model Strut Instrumentation (wing hidden for clarity).

The strut contains 145 static pressure taps, 5 unsteady pressure transducers (Kulites), two accelerometers, and one axial strain gauge (plus a gauge backup). Unsteady pressure locations are found in Table 2-4. Pressure instrumentation nomenclature follows the same format as described for the wing in Figure 2-19. Strut strain gauge and accelerometer locations are shown in Table 2-5.

Table 2-4. Strut Unsteady Pressure Transducer Locations.

Upper Surface			Lower Surface		
η	X/C	Sensor ID	η	X/C	Sensor ID
0.15	0.80	KS15U80	0.15	0.65	KS15L65
0.30	0.80	KS30U80	0.50	0.65	KS50L65
0.50	0.90	KS50U90			

Table 2-5. Strut Accelerometer and Strain Gauge Locations.

Type	η	X/C	Sensor ID
Accelerometer	0.25	0.40	AS25
Accelerometer	0.44	0.40	AS44
Strain Gauge	0.15	0.50	SAF1
Strain Gauge	0.15	0.50	SAF2

2.5.4 Diagnostic Instrumentation

The fuselage and engine contain several different arrays of static pressure taps. These taps are used primarily for diagnostic purposes during the test. Pressures were added to the nose of the fuselage as a measure of fuselage boundary layer immersion – previous CFD studies showed that loading on the nose changed dramatically as a function of tunnel floor boundary layer height. Pressure taps were also located on either side of the forward and aft keel dams to determine if there was any areas of significant leakage around the dams. Also, pressure taps were located in two rows on the upper wing-body fairing to determine if the upper dam was successfully minimizing flow between the integral standoff and the floor. Finally, pressure taps were located inside the engine nacelle flowpath to diagnose any potential internal separation that may alter the engine mass flow ratio. The details of these areas are presented below.

2.5.4.1 Nose Pressure Taps

The location of five static pressure taps on the nose of the fuselage are shown in Figure 2-21. The taps are located at the constant station of $X = 20.7$ in the model scale and are equally spaced from 5% to 95% arclength. These pressure taps are used to determine the loading on the nose, which varies significantly based on the thickness of the tunnel floor boundary layer.

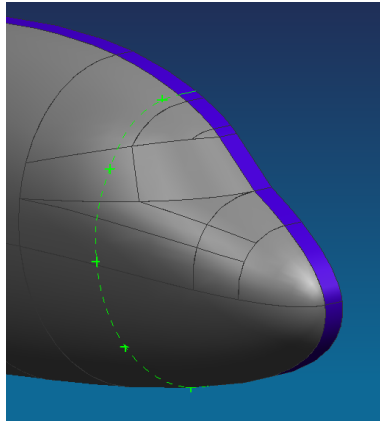


Figure 2-21. Static Pressure Tap Locations on Nose of Fuselage.

Table 2-6 contains the X, Y, and Z coordinates of each tap in the model coordinate system.

Table 2-6. Nose Static Pressure Tap Locations (model scale coordinates).

X (in)	Y (in)	Z (in)
20.7	0.8832	24.9532
20.7	3.9114	22.5678
20.7	5.0534	18.8006
20.7	4.0221	14.9981
20.7	0.8814	12.7016

2.5.4.2 Wing-Body Fairing Pressure Taps

Figure 2-22 shows the location of static pressure taps on the wing-body fairing (WBF). One row is comprised of five equally spaced taps at a 0.20" interval (model scale) at a constant X-station of X=60.454" (X=671.7106" full scale). These pressure taps are used for detection of potential vortical flows emanating from the gap between the model and tunnel floor, as described in Section 2.4.2.1.

The second row of taps is arranged at a constant Y-station of Y=-0.2" (Y=-2.222" full scale). These taps are equally spaced in 0.50" increments (model scale) in the downstream direction along the arclength, and are intended to measure shock location over the WBF.

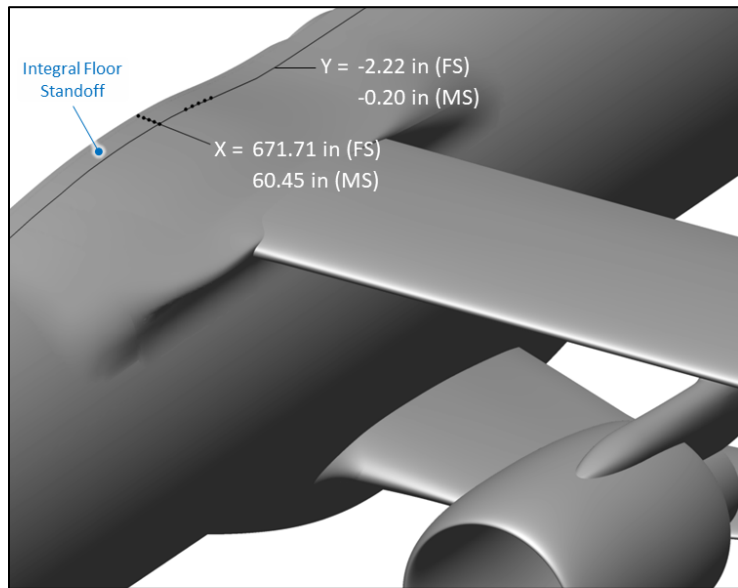


Figure 2-22. Wing-body Fairing Static Pressure Tap Locations.

Table 2-7 contains the X, Y, and Z coordinates of each WBF tap in the model coordinate system.

Table 2-7. WBF Static Pressure Tap Locations (model scale coordinates).

X-Station Row			Y-Station Row		
X (in)	Y (in)	Z (in)	X (in)	Y (in)	Z (in)
60.454	-0.200	28.285	62.454	-0.200	28.153
60.454	-0.400	28.287	62.952	-0.200	28.101
60.454	-0.600	28.287	63.450	-0.200	28.040
60.454	-0.800	28.284	63.948	-0.200	27.971
60.454	-1.000	28.277	64.446	-0.200	27.899

2.5.4.3 Keel Dam pressure Taps

The wind tunnel model contains 10 static pressure taps located on the underside of the base plate in order to monitor possible airflow (i.e., lack of sealing) across the keel dams. Tap locations are shown in Figure 2-23 as bold + symbols. Taps are offset from the keel dam and cover plates to avoid additional o-ring seals.

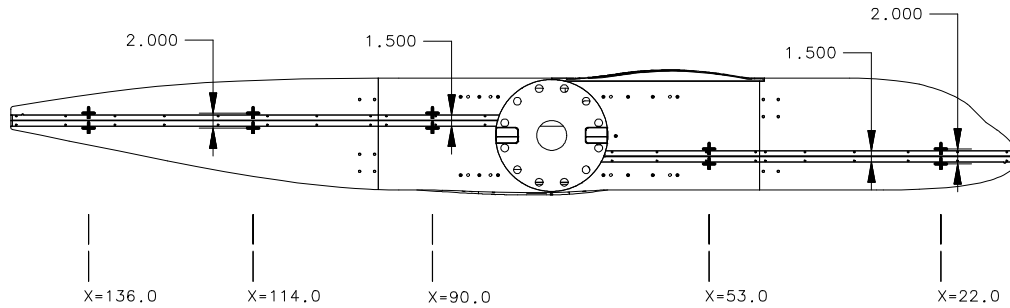


Figure 2-23. Forward and Aft Keel Dam Pressure Taps.

2.5.4.4 Engine Nacelle Pressure Taps

The engine contains four static pressure taps at equally-spaced radial locations. These taps are used for monitoring the pressure inside the engine, as a surrogate for detecting flow separation within the nacelle that may affect inlet spillage levels. Table 2-8 contains the X, Y, and Z coordinates of each tap in the model coordinate system for the jig geometry. The locations of these pressure taps are shown in Figure 2-24 by red + symbols.

Table 2-8. Engine Nacelle Static Pressure Tap Locations (model scale coordinates).

X (in)	Y (in)	Z (in)
52.668	-17.292	23.920
53.006	-17.258	19.669
52.859	-21.561	19.666
52.524	-21.511	23.916

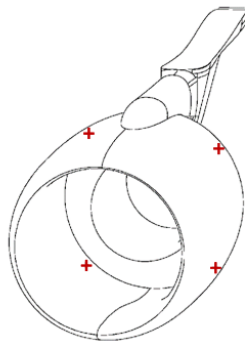


Figure 2-24. Location of Nacelle Internal Static Pressure Taps.

2.5.5 Wing and Strut Jig Twist Correction

To account for the effect of model loads on wing and strut twist distributions in the wind tunnel, an analysis was performed to determine a net twist correction to counteract these effects. The twist correction was determined through the use of a detailed finite element model (FEM). The FEM model analyzed the wind tunnel model geometry at the target tunnel flow conditions to determine the model's change in twist under load. This twist correction was then inversely applied to the vehicle design 1G twist distribution, resulting in a vehicle 'jig' shape. The flow conditions used for this analysis corresponded to a wind tunnel dynamic pressure of 994 psf (model mean aerodynamic chord (MAC) Reynolds number of 5.18M at Mach=0.80). The net change in twist determined by this analysis is shown in Figure 2-25. The model twist change under load reflects the relative stiffness of the inboard wing and strut combination – inboard wing and strut twist changes are small. The wing twist change is more significant outboard of the wing-strut attachment location since it is free to deflect. Since the wing tends to wash-out under load, the jig twist correction requires an increase in sectional twist as a function of span location.

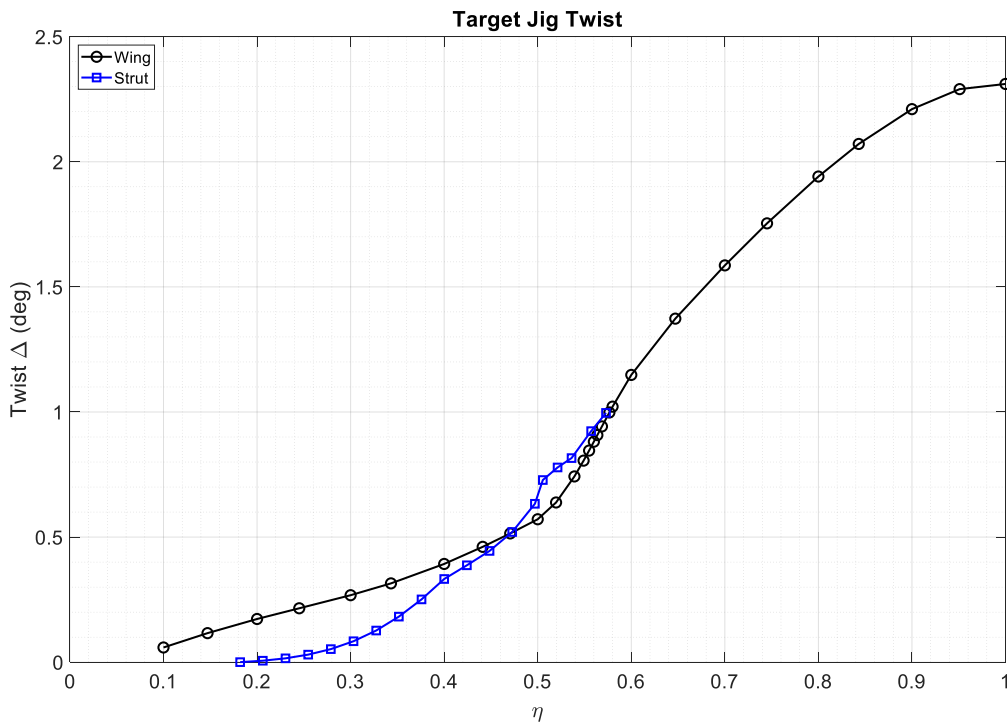


Figure 2-25. Jig-to-1G Delta Twist Distribution Correction at Mach 0.80, $C_L = 0.695$, $Re_{MAC} = 5.18M$.

2.5.5.1 Model Build Accuracy

The model was inspected for adherence to the build accuracy specified in the model statement of work upon completion of the model build and assembly. These checks included inspections of adherence to specified model surface contours, surface finishes, forward and aft facing steps, as well as wing and strut incidence/twist checks. Table 2-9 shows the Quality Assurance (QA) reports from Tri Models that summarizes the sectional incidence variation for the wing and strut across the span of the model. As specified in the model statement of work the tolerance for angular measurements is $\pm 0.10^\circ$. Per this requirement, there is one measured station on the strut, which exceeds this tolerance. The -47" span location on the strut is out of alignment by -0.118° (leading edge down). On the wing, four stations are out of alignment, located at -79", -83", -87", and -91". All stations exceed this tolerance with the leading edge pointing down. The station at -87" is the most critical with an alignment mismatch of -0.218° . Based on aeroelastically twisted CFD performed on this contract (which had a much larger twist delta) this degree of misalignment on the outer wing panel is not expected to have a significant effect on buffet onset.

Table 2-9. Sectional Incidence Variation.

Buttline (Y-Value)	Wing Incidence [LE Up = Pos(+)]	Strut Incidence [LE Up = Pos(+)]
-7"	-0.016°	-0.011°
-11"	-0.008°	-0.006°
-15"	-0.012°	-0.021°
-19"	-0.007°	-0.005°
-23"	-0.004°	-0.004°
-27"	-0.021°	+0.019°
-31"	-0.004°	+0.003°
-35"	-0.013°	-0.034°
-39"	-0.012°	+0.038°
-43"	-0.014°	-0.051°
-47"	-0.013°	-0.118°
-51"	-0.013°	-0.067°
-55"	-0.017°	
-59"	-0.040°	
-63"	-0.034°	
-67"	-0.021°	
-71"	-0.022°	
-75"	-0.063°	
-79"	-0.127°	
-83"	-0.174°	
-87"	-0.218°	
-91"	-0.197°	

Figure 2-26 and Figure 2-27 show the measured QA twist changes compared to the jig-to-1G twist deltas as well as the approximate effect on the target 1G twist (should the aeroelastic deflection in the tunnel match pre-test calculations). As shown, the net change to absolute twist levels is small, and is not expected to significantly change results in the tunnel, particularly near buffet.

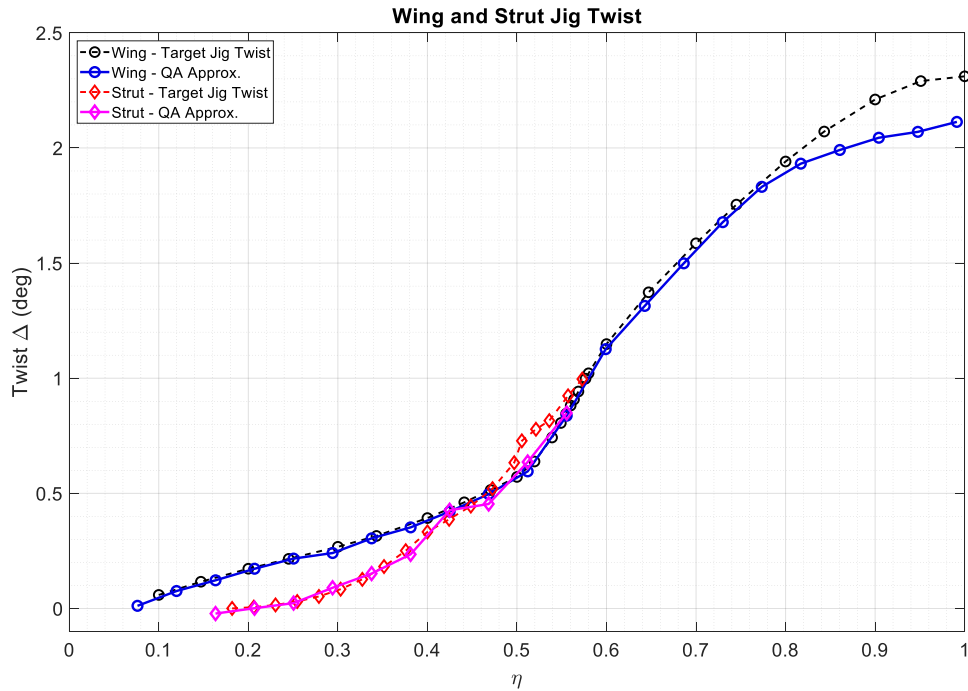


Figure 2-26. As-built QA Twist Data Applied to Jig-to-1G Twist Correction.

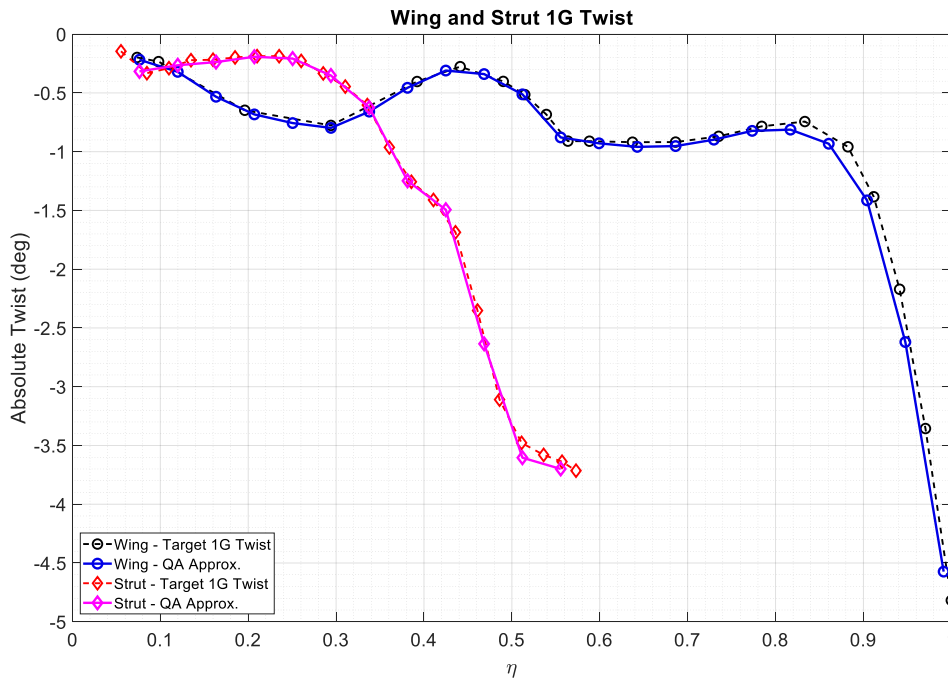


Figure 2-27. Approximate Model 1G Twist Based on QA Twist Correction.

2.6 Model Assembly and Installation

2.6.1 Model Installation

The model was mounted in the 11-ft transonic test section using the NASA ARC-11-30K semispan balance. The center of the five-component balance, which was recalibrated for this test entry, is located at a test section tunnel station of 106.0", which corresponds to a model moment reference center (MRC) location of 74.060" in the model system (see Figure 2-28). The balance is mounted on a turntable that provided the pitch control of the model. The angle of attack range of the turntable is -6° to $+17^{\circ}$. For this test the slots in the floor have been filled. The effect of the gap between the model and the floor was minimized using a series of keel dams as described in Section 2.4.1.

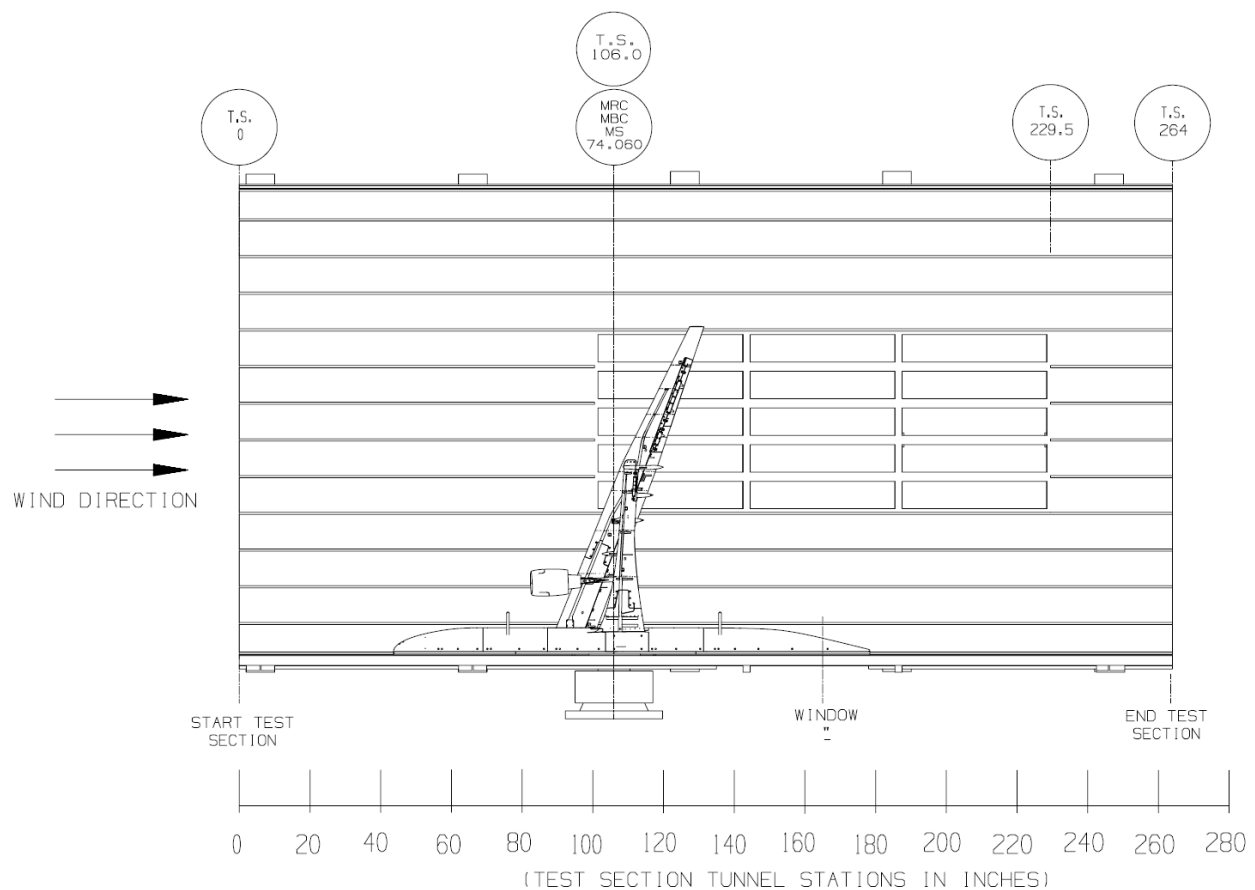


Figure 2-28. Side View of Test Section with Semispan Model Installed.

The load limits for the ARC-11-30K balance are given in Table 2-10 for all five components. The balance is shown in Figure 2-29 before installation in the wind tunnel. Details about the balance flange and location of the moment center are shown in Figure 2-30. Prior to installation of the model, check loads were applied to the balance to ensure that loads were in accordance

with expected calibration curves. A wind-on repeatability check was performed once the model was installed.

Table 2-10. Balance Load Limits.

Component	ARC-11-30K Balance Load Ranges
Normal Force, lb	$\pm 30,000$
Axial Force, lb	$\pm 3,000$
Pitching Moment, in-lb	$\pm 300,000$
Rolling Moment, in-lb	$\pm 1,350,000$
Yawing Moment, in-lb	$\pm 150,000$

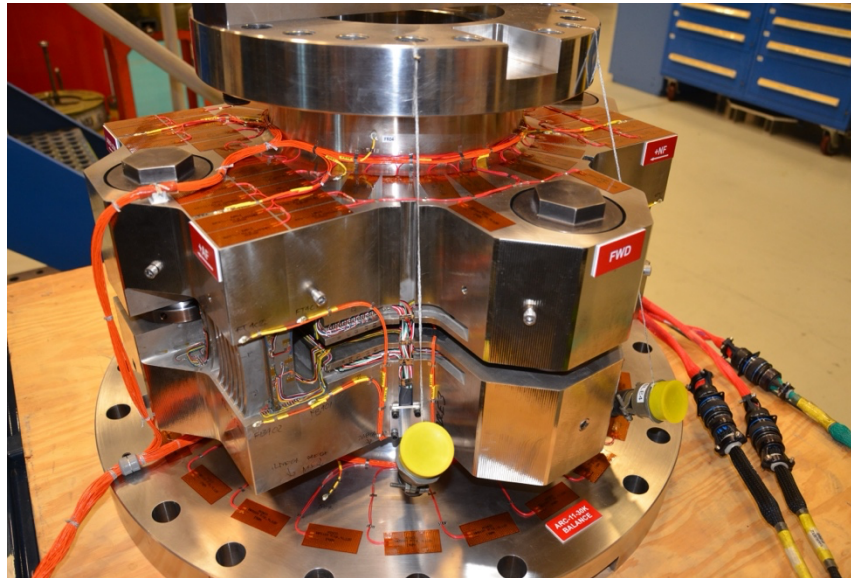


Figure 2-29. Wind Tunnel Balance Prior to Installation [Source: NASA].

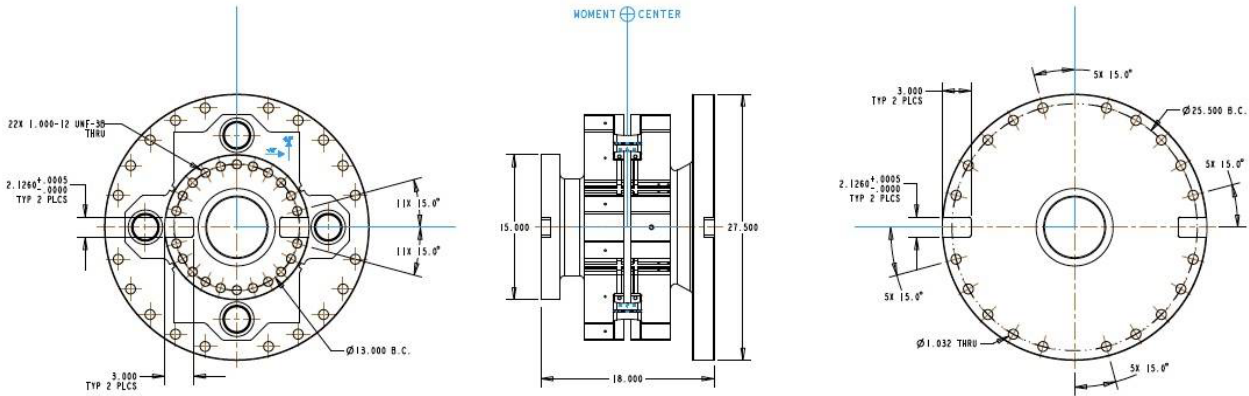


Figure 2-30. Drawing of Wind Tunnel Balance.

When the model was installed on the balance, a 0.025 – 0.030” gap was discovered between the top of the balance windshield and the floor. Investigation of this step revealed that a 0.050” thick spacer typically used for semispan installations had not been installed. The resulting step was considered to be too small to warrant uninstallation of the model and windshield fairing. In addition, a 0.36” gap (refer to Figure 2-31) typically covered by the model fuselage was also discovered. The exposure of the gap was a consequence of the TTBW high aspect ratio design; the model scale was reduced below typical levels in order to fit the model within allowable tunnel span-fraction, which ultimately resulted in a reduced model fuselage diameter. Since pretest CFD showed a high potential for leakage in this area (leakage between the wing upper surface and floor was the direct reason for extending the upper dam), a filler was designed and 3D-printed to fill this gap while maintaining sufficient clearance to prevent fouling of the balance. The gap fillers are installed both above and below the model fuselage as shown in Figure 2-31.

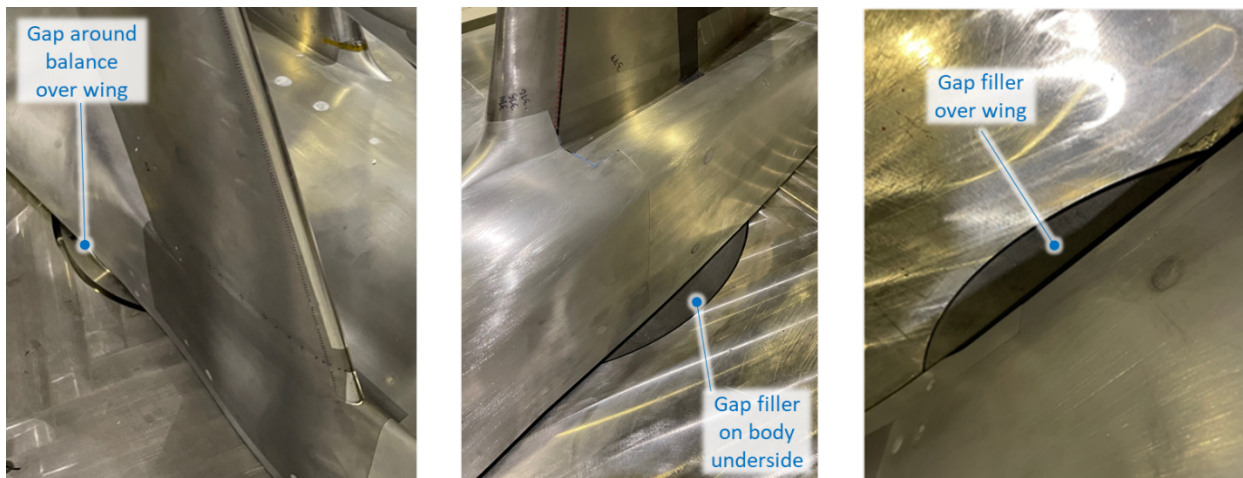


Figure 2-31. Balance-Floor Gap Fillers [Source: NASA].

The tubing for the static pressure ports and cabling for the strain gauges, Kulites®, and accelerators were routed through the wing or fuselage and out of the test section via a hole through the center of the balance. The static pressure, turntable encoder and tunnel condition signals were measured by the Steady Data System (SDS). The SDS is composed of nine PSI-ESP modules capable of measuring 64 pressures each within the range of ± 15 psid. There were also two mSDIs (micro Scanner Digitizing Interface) installed in the fuselage of the model used for multiplexing the eight ESP signals through a single fiber-optic cable. The Kulite®, strain gauge, turntable encoder, and balance signals were measured by the Dynamic Data System (DDS) acquisition system. The DDS is composed of the Dynamic Data Acquisition (DDA) system and the Dynamic Data Processing & Storage (DDP) system. This DDA is an NI PXI-1045 chassis populated with PXI-4462 4 channel input modules. The modules are capable of 204.8 ksamples/s with an 80 kHz bandwidth. There are a total of 7 chassis combining for a total of 392 dynamic data channels. Both the SDS and DDS data are then saved to the AERONET server, which can be accessed by the customer. The accelerometers and strain gauges were connected to the DDS and BLAMS model safety of flight.

2.6.2 Model Coordinate Systems

The coordinate system sign conventions for the force and moment balance and for the model fuselage reference system are shown below.

Balance axis sign convention:

- (+) X is aft, from nose to tail of the model (Axial Force, Rolling Moment)
- (-) Y is out the left wing (Side Force, Pitching Moment)
- (+) Z is up, from the landing gear box to the top of the fuselage (Normal Force, Yawing Moment)

Data presented in this report are shown in a combined coordinate system with the follow conventions:

- (+) Lift is up
- (+) Drag is aft
- (+) Side Force is out the right wing
- (+) Pitching moment is nose-up
- (+) Rolling moment is right wing-down
- (+) Yawing moment is nose-right

2.6.3 Model Configuration Tracking

The configurations tested during this test entry were defined by a series of configuration numbers in the run matrix. For each configuration number there is an alpha-numeric code as well as a letter code intended to abbreviate the component names. These configurations are described in Table 2-11.

Table 2-11. Buffet Model Configuration Codes.

Config Code	Description	Fuselage & Gear Sponson	Wing & Strut	Nacelle, Core, Pylon	Flap Fairings	Jury Strut
C136*	B	X				
C139	WBSNPF	X	X	X	X	
C141	WBS	X	X			
C142	WBSNP	X	X	X		
C143*	WBSNPFJ	X	X	X	X	X

Where:

- W = Wing
- B = Body (fuselage)
- S = Strut
- NP = Nacelle (including nacelle core) and pylon
- F = Flap Hinge Fairings
- J = Jury Strut

*Note: Configurations C136 and C143 were not tested.

2.7 Test Conditions

The test was conducted over a range of conditions as permitted by allowable model load limits. These loads were continuously monitored during testing by a series of strain gauges on the model to ensure safety. The nominal range of conditions established for this test are shown by the red, dashed lines in Figure 2-32. The primary condition of interest, for which the model jig twisted was defined to produce the target 1G twist distribution under load, was a tunnel Re of 6.3M/ft and Mach of 0.80 (Re_{MAC} of 5.18M). However, high speed testing was completed at different dynamic pressures based on the configuration tested and anticipated model loads. Complete configuration testing, including the wing and strut, was conducted at two unit Reynolds numbers, 6.3 M/ft and 8.0M/ft, which correspond to a mean aerodynamic chord (MAC) Reynolds numbers of 5.18M and 6.58M, respectively. Depending on the configuration being tested, occasional reductions in the run maximum angle of attack resulted from reaching maximum limit loads (including safety margin) on the model. Control surface effectiveness testing (for both aileron and spoiler) was carried out at lower dynamic pressures due to increased model loads associated with control surface deflection. The high-Mach test conditions were focused primarily on identifying buffet boundaries and quantifying the aerodynamic characteristics of the configuration at and near buffet onset. A summary of Reynolds and Mach ranges of interest for the test are presented in Table 2-12.

Table 2-12. Buffet Test Operating Conditions.

Re ($\times 10^6$ /ft)	Re _{MAC} ($\times 10^6$)	Mach	Primary Objective
2.625	2.17	0.20 – 0.92	Control surface effectiveness, match Re from previous full-span test
4.80	3.97	0.50 – 0.92	Control surface effectiveness
6.3	5.18	0.50 – 0.92	High-Speed Data, model aeroelastic twist match
8.0	6.58	0.70 – 0.85	Highest Re, model loads-limited

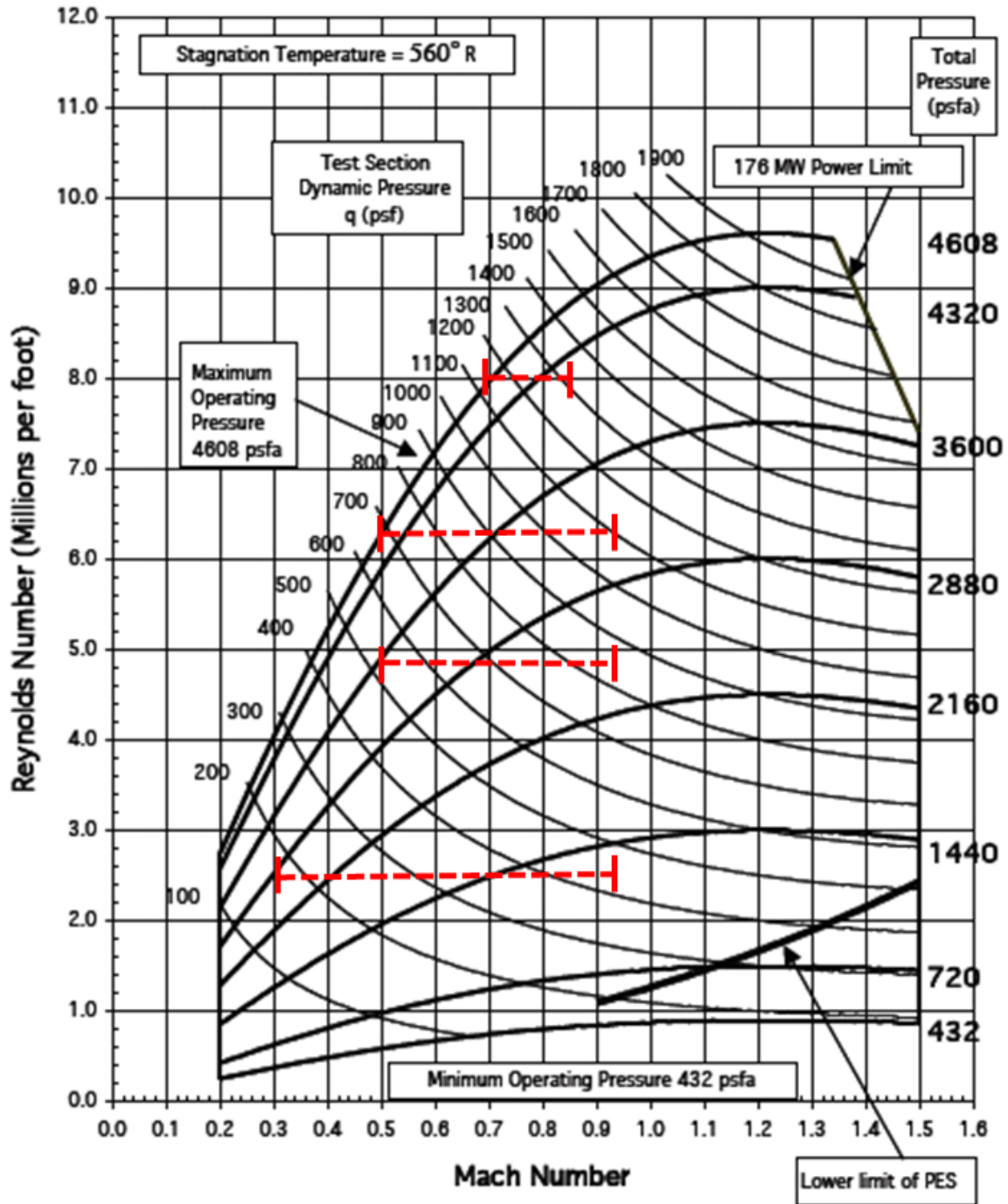


Figure 2-32. Operating Envelope of the 11' UPWT Transonic Test Section with Buffet Test Conditions Indicated in Red.

2.8 Boundary Layer Transition and Trip Definition

The buffet model was tested using several different series of trip dots. These dots were applied using specially designed fixtures that ensure precise and repeatable application of trip dots over the course of the test. The primary purpose of the trip dots is to force boundary layer transition to occur at a known location to ensure repeatability and consistency in the performance data over the course of the test campaign. This is important since model laminar run distances can vary over time as the model accumulates scratches or damage. In addition a known trip location, this technique enables improved consistency in test-to-CFD predictions because it reduces the possibility of data variation due to inconsistencies in laminar runs. Ideally, the dots are sized and located such that their effect results in boundary layer characteristics similar to higher Reynolds number flow. In the case of buffet testing, simulating boundary layers with different shape factors and thicknesses can provide additional information since buffet onset is primarily a function of boundary layer-shock interactions.

Prior to the test, CFD was used to quantify changes in wing and strut shock strength/position, spanload, boundary layer displacement thickness, and shock-induced separation due to variation in wing boundary layer transition location at primary test Reynolds number ($Re_{MAC}=5.18M$). Throughout these studies strut boundary layer transition location of 10% strut chord was held fixed. This study was done for several key flight conditions including cruise Mach at the design C_L , cruise Mach at 1.3g C_L , and the maximum operating Mach number (M_{MO}). The latter two conditions are based on specifications in the Federal Aviation Regulations (FARs) regarding the range of conditions required for buffet-free operation. The CFD study determined that a trip location of 25% of the local wing chord provided the best overall match of wind tunnel boundary layer properties with flight Reynolds number data. This location was therefore selected as the nominal location for the aft trip. The complete aft trip definition, called T3, includes an inboard wing ramp-up from the leading edge at the wing root to 25% chord at a semispan location (η) of 27%. A more aggressive aft transition pattern, called T4, was also defined by abruptly shifting the trip dots aft from 25% to 40% of MAC outboard of the nacelle – this pattern would have the thinnest boundary layer entering the shock. In addition to the two aft trip locations, a forward trip was set at 5% of MAC with a minimum distance of 0.34” back from the leading edge. This T1 forward trip pattern is consistent with previous Ames 11-Ft TWT wind tunnel entries, and provides the highest likelihood of repeatability over the duration of the test.

A summary of the trip patterns used in the test are summarized in Table 2-13. Boundary Layer Trip Pattern Definition. A detailed description of each trip pattern used in this test is presented in Table 2-14. A wing planform drawing showing the transition locations is given in Figure 2-33. All trip patterns have trips installed on the fuselage, nacelles and pylon, vertical and horizontal stabilizers.

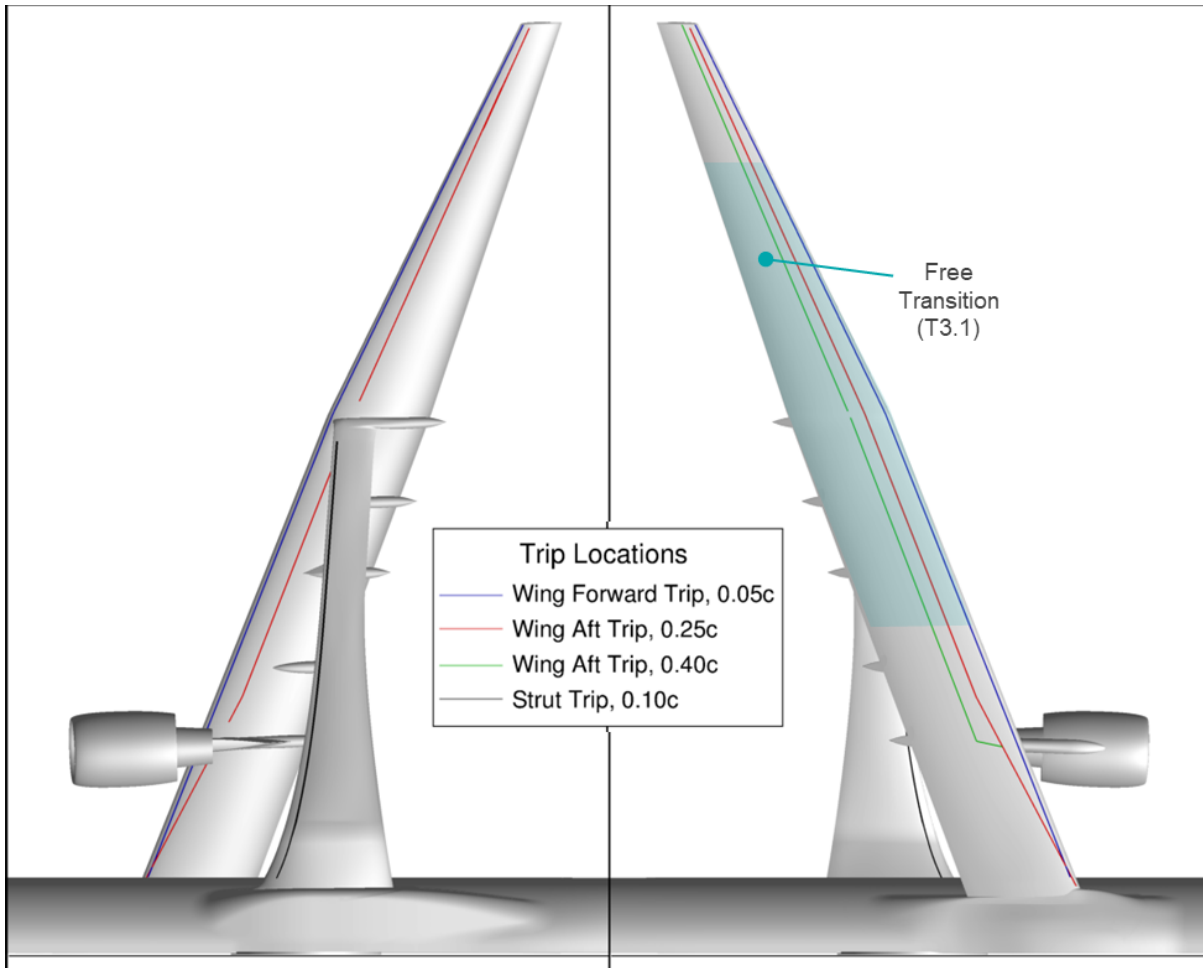


Figure 2-33. Wing and Strut Boundary Layer Trip Locations.

Table 2-13. Boundary Layer Trip Pattern Definition.

Trip Location (% x/c)	IB Wing (side-of-body to $\eta=27\%$)	OB Wing ($27\% < \eta < 100\%$)	Strut (side-of-body to $\eta=58\%$)
T1	5%	5% or 0.34" back from LE	10%
T2	5%	5% or 0.34" back from LE	10%
T3	Tapered 5% to 25%	25%	10%
T3.1	Tapered 5% to 25%	Trip off: $\eta=35\%$ to $\eta=85\%$ 25% everywhere else	10%
T4	Tapered 5% to 25%	Stepped to 40%	10%
T5	5%	5% or 0.34" back from LE	Trip off (free transition)
T6	Tapered 5% to 25%	25%	10%

Table 2-14. Boundary Layer Trip Heights.

	T1 (Forward Trip)		T2 (Forward Trip, Low Re)		T3 (Aft Trip 1)		T4 (Aft Trip 2)		T5 (Strut Trip Off)		T6 (Aft Trip 1, Increased Ht)	
Part	Height (mil)	Color	Height (mil)	Color	Height (mil)	Color	Height (mil)	Color	Height (mil)	Color	Height (mil)	Color
Wing	4.0	Chrome Red	6.5	Orange	5.0	Magenta	7.2	Satin/Gold	4.0	Red	6.5	Orange
IB Strut	5.0	Magenta	8.0	Forest Green	5.0	Magenta	5.0	Magenta	None	None	5.0	Magenta
OB Strut	4.0	Chrome Red	6.5	Orange	3.5	Chrome	3.5	Chrome	None	None	4.0	Red
Body	4.0	Red	8.0	Forest Green	4.0	Red	4.0	Red	4.0	Red	4.0	Red
Nacelle Internal	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte
Nacelle External	3.1	Silver Matte	6.5	Orange	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte
Core Internal	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome
Core External	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome
Bifurcator	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome	3.5	Chrome
Pylon	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte	3.1	Silver Matte

2.9 Wind Tunnel Data Summary

This section details results and data obtained during the buffet test. Effects of boundary layer transition, model component build-up, buffet boundary, and in-test repeatability will be discussed. All test data shown are fully corrected and presented in the stability axis unless otherwise noted. Angle of attack data are based on the in-tunnel corrected angle of attack values from the ALPHAC data parameter. A copy of the wind tunnel test matrix is provided in Appendix A for reference. In addition, discussion of control surface effectiveness data acquired in the test is described in Section 2.12, with the exception of aileron and outboard strut flap surface deflections investigated for their effect on buffet boundary.

2.9.1 Tunnel Corrections

The wind tunnel data processed by the NASA Ames facility was based on a standard set of corrections. These corrections included buoyancy and blockage (determined using the in-tunnel pressure measurement-based WICS system). A sample of the data corrections for drag, lift, and pitching moment are shown in Figure 2-34 to Figure 2-36 for the C139 (complete) configuration using the forward trip location (T1) at $M=0.80$ and $Re_{MAC}=5.18M$. For the ‘Buoyancy’ and ‘TWICS’ curves the corrections are applied individually to the uncorrected data set while all corrections are cumulatively applied in the ‘Fully Corrected’ series.

The drag data presented in Figure 2-34 show the relative size of the data corrections as applied to the drag coefficient for the baseline configuration. At the lowest angle of attack, the buoyancy correction increases the drag coefficient by 5 to 6 counts while the TWICS correction (which primarily addressed model blockage effects) reduces drag coefficient by 5 to 6 counts. The net result is minimal change in drag when all corrections are applied. Conversely, at the highest angle of attack, the buoyancy correction increases the drag coefficient by ~5 counts while the TWICS correction reduces drag coefficient by ~36 counts. The net result is a 31 count reduction in corrected drag coefficient relative to the uncorrected value. By comparison the corrections to lift coefficient (Figure 2-35) and pitching moment coefficient (Figure 2-36) are small.

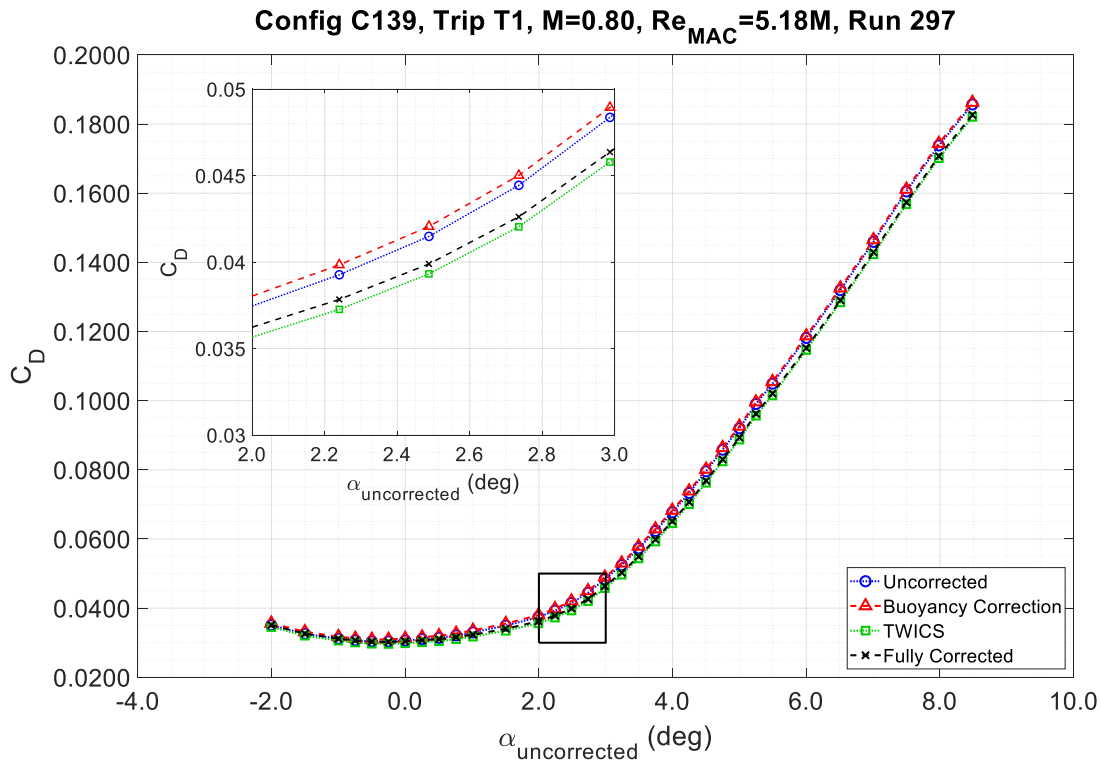


Figure 2-34. Data Corrections for Drag Coefficient [$Re_{MAC}=5.18M$, $M=0.8$].

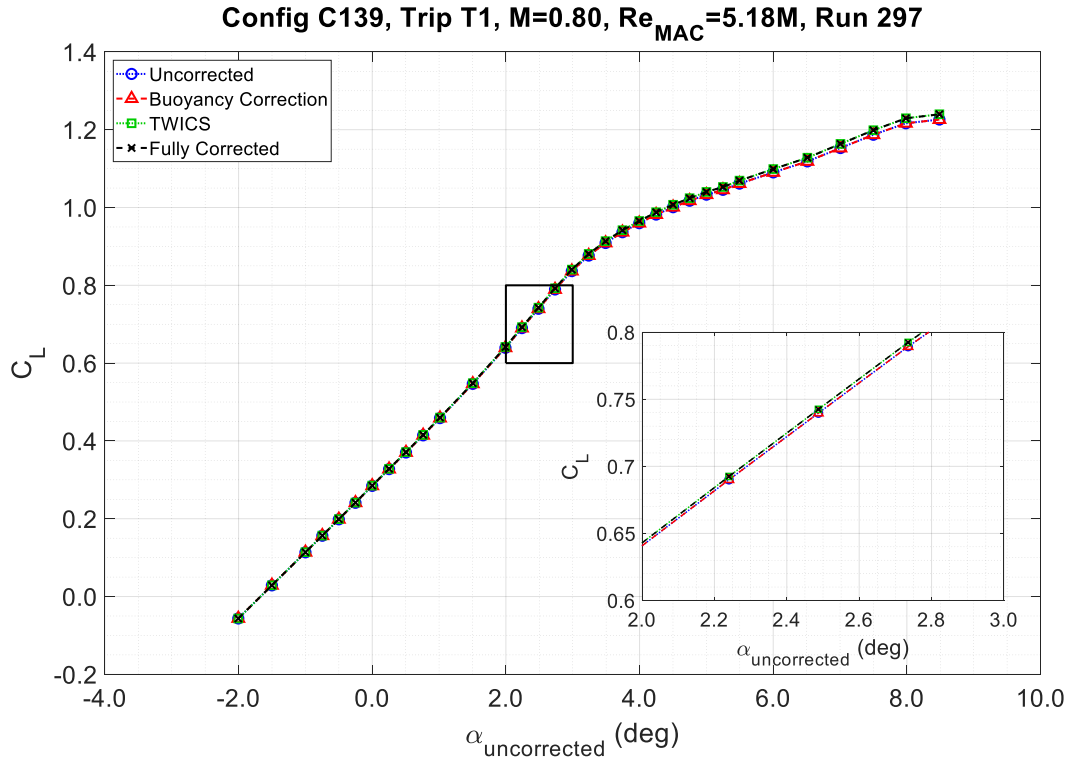


Figure 2-35. Data Corrections for Lift Coefficient [$Re_{MAC}=5.18M$, $M=0.8$].

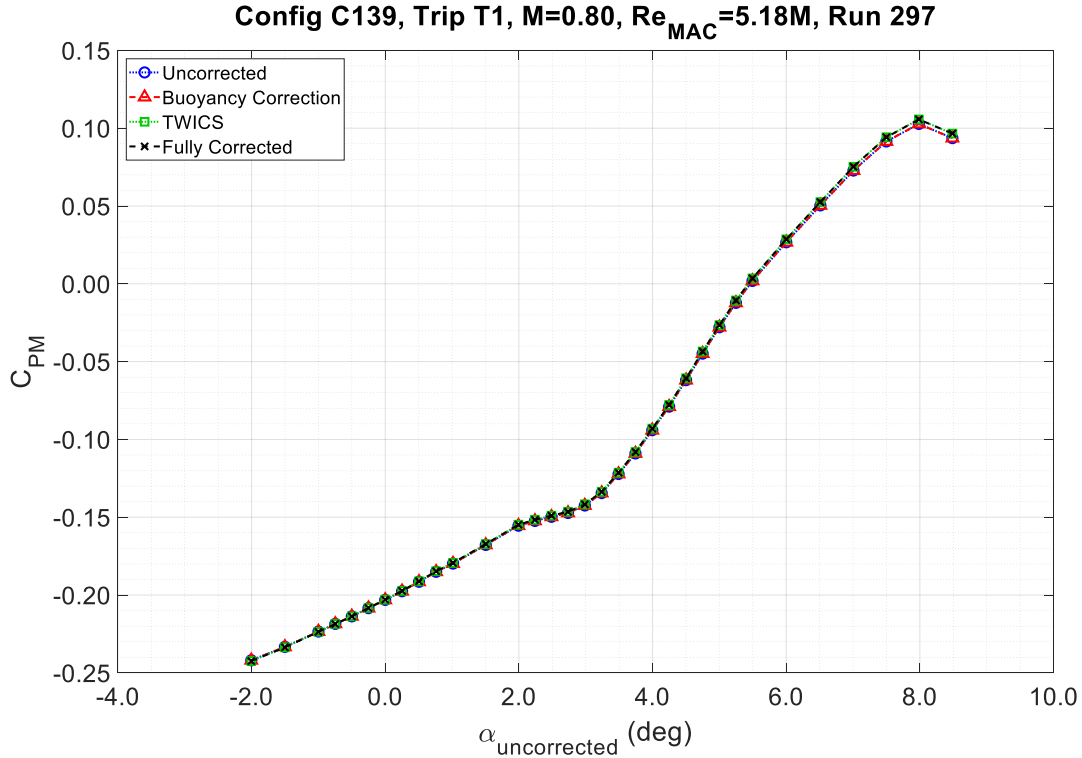


Figure 2-36. Data Corrections for Pitching Moment Coefficient [$Re_{MAC}=5.18M$, $M=0.8$].

2.9.2 Data Repeatability

Repeat runs of the C139 configuration with the T1 trip pattern at $Re_{MAC}=5.18M$, $M=0.8$ were taken throughout the test campaign to assess the repeatability of the test measurements. Figure 2-37 through Figure 2-39 show the repeatability of the lift, drag and pitching moment measurements for nine repeat runs. To assess the variability in the drag measurements, the standard deviation between the repeat run test data and the best fit curve was calculated for test points with angles of attack below the pitch break point (i.e., for test points with predominantly attached flow). The result was a 2σ of 1.7 drag counts, which is plotted as upper and lower C_D bounds in Figure 2-40.

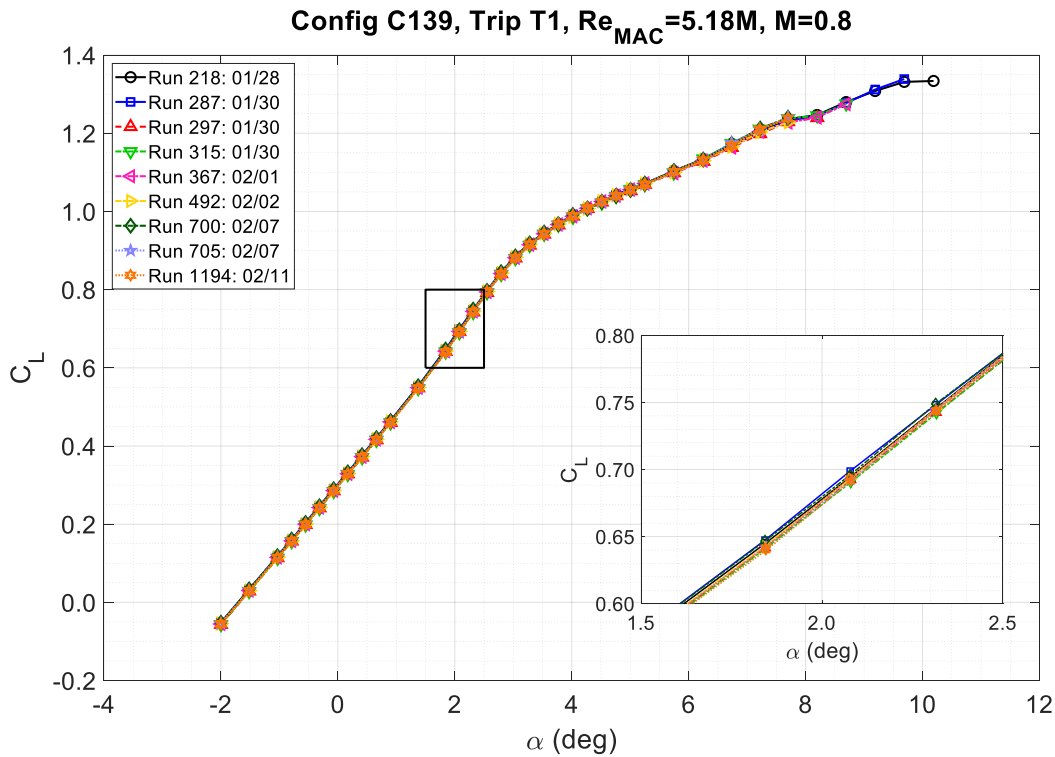


Figure 2-37. Data Repeatability for Lift Coefficient [$Re_{MAC}=5.18M$, $M=0.8$].

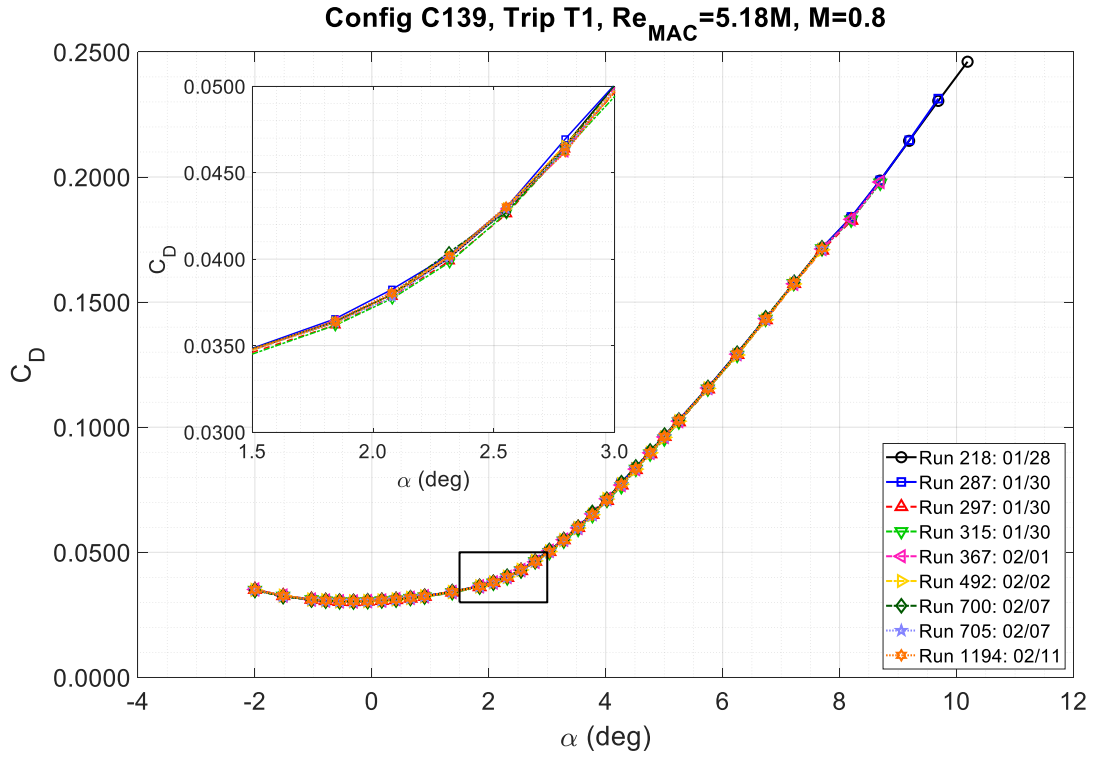


Figure 2-38. Data Repeatability for Drag Coefficient [$Re_{MAC}=5.18M$, $M=0.8$].

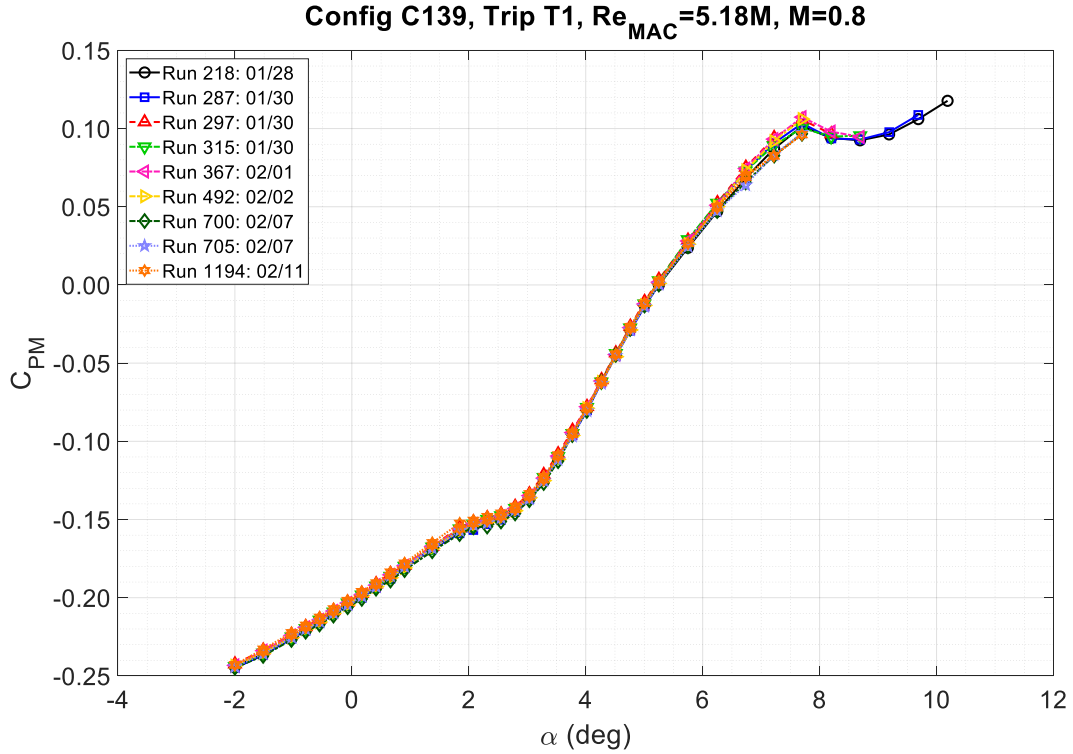


Figure 2-39. Data Repeatability for Pitching Moment Coefficient [$Re_{MAC}=5.18M$, $M=0.8$].

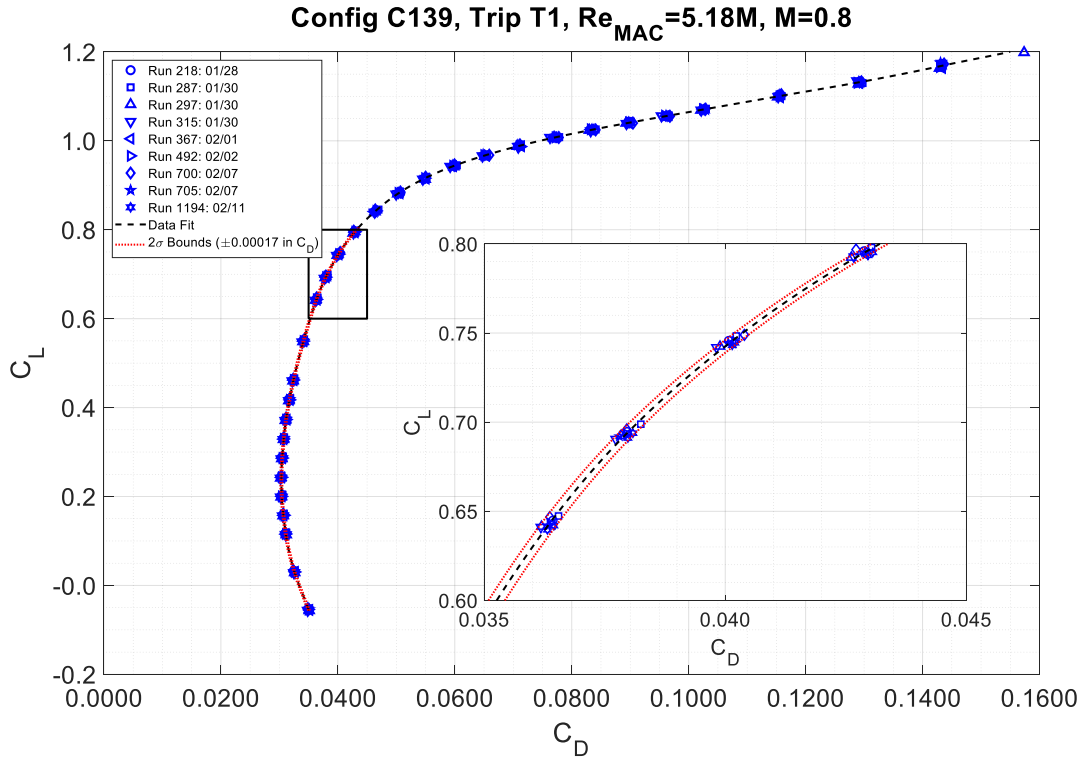


Figure 2-40. Data Repeatability for Drag Polar [$Re_{MAC}=5.18M$, $M=0.8$] with 2σ Bounds.

2.9.3 Pitch-pause vs. Continuous Pitch Data Collection

Data were acquired during the wind tunnel test in both pitch pause (PP) and continuous pitch rate (CPR) modes. During PP runs, data were recorded with the model at a fixed angle of attack before adjusting pitch to the next angle of attack. Conversely, during CPR runs, data were recorded while the model angle of attack was varied continuously without dwelling at specific angles of attack. During early testing, CPR data were obtained at three pitch rates (0.05deg/s, 0.10deg/s, 0.20deg/s) to determine if the spectral content of the unsteady data measurements varied significantly as a function of pitch rate. The objective of this study was to determine the optimal pitch rate that collects the needed unsteady data while minimizing the amount of time required for a CPR run. Figure 2-41 compares the CPR drag polars at those three pitch rates to the PP data. At high angles of attack, the CPR data exhibits high variability, which increases with decreasing pitch rate. Based on the measured results, a rate of 0.10deg/sec was chosen for all subsequent CPR runs as it offered the best balance between Mach tolerance and dynamic data sample sizes.

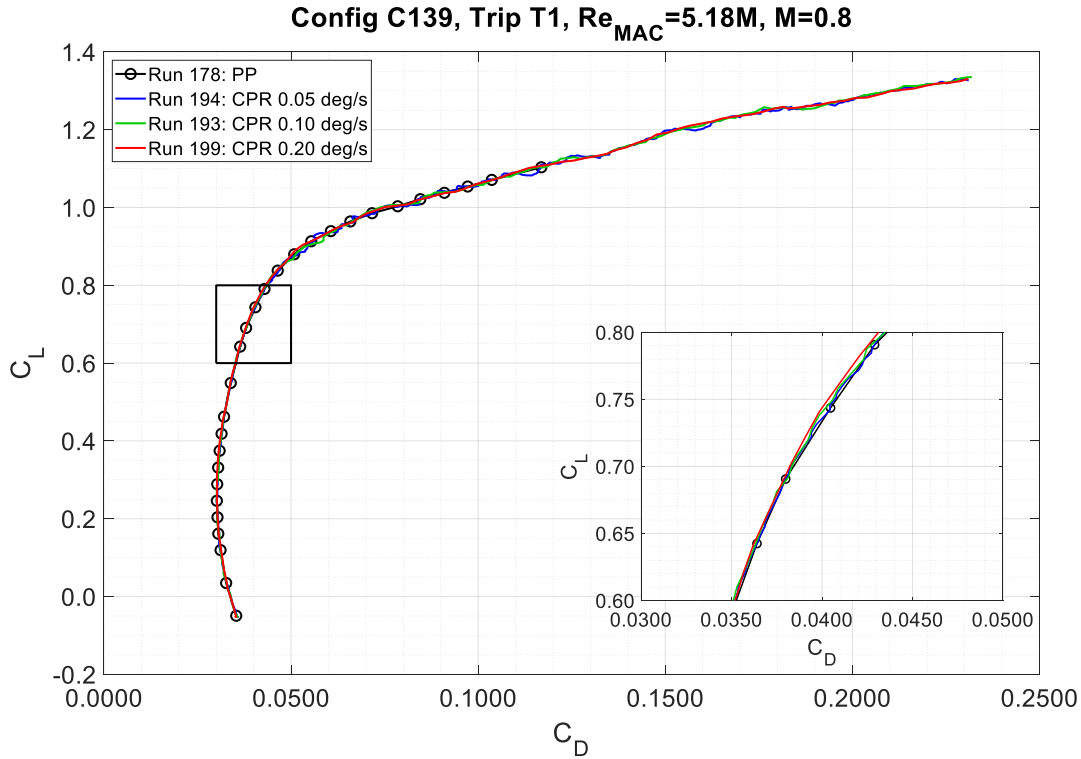


Figure 2-41. Comparison of the Drag Polar for Pitch Pause and Continuous Pitch Rate Data [$Re_{MAC}=5.18M$, $M=0.8$].

2.9.4 Test-to-Test Comparison

High speed testing was conducted in 2019 on a 4.5%-scale, full-span TTBW model (Boeing test designation LB-652A, NASA test designation 11-0367) during Phase IV of the SUGAR program. The test focused on verifying the aerodynamic performance of the $M=0.80$ vehicle up to the maximum operating Mach number. Relative to the Phase V high speed testing, the Phase IV tests were limited to a relatively low Reynolds number of $Re_{MAC}=2.17M$. Figure 2-42 through Figure 2-45 provide a comparison of the measured lift, drag and pitching moment of the two entries at the same Reynolds number for Mach numbers of 0.5, 0.8 and 0.85. Since the model installations were significantly different – the full-span test utilized a sting mount and had the vertical tail installed, whereas the buffet test is a semispan installation with no empennage installed – this comparison can be used only for deriving configuration component drag and control surface effectiveness increments. As anticipated, drag of the semispan buffet installation is significantly higher due to tunnel wall boundary layer model interactions, and inclusion of the integral standoff. Lift coefficient shows an offset in zero-lift angle of attack and a relatively small change in lift curve slope. Also as anticipated, pitching moment shows the greatest variation in behavior due to the model's immersion in the tunnel boundary layer.

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

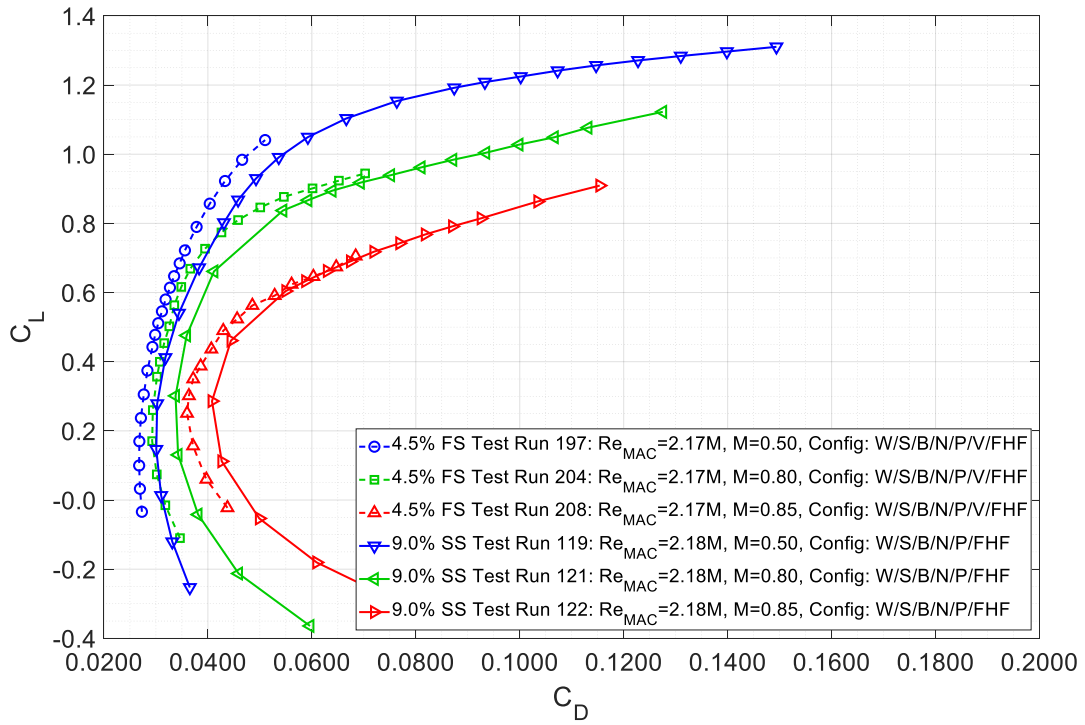


Figure 2-42. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Drag Polars at $Re_{MAC} \approx 2.17M$.

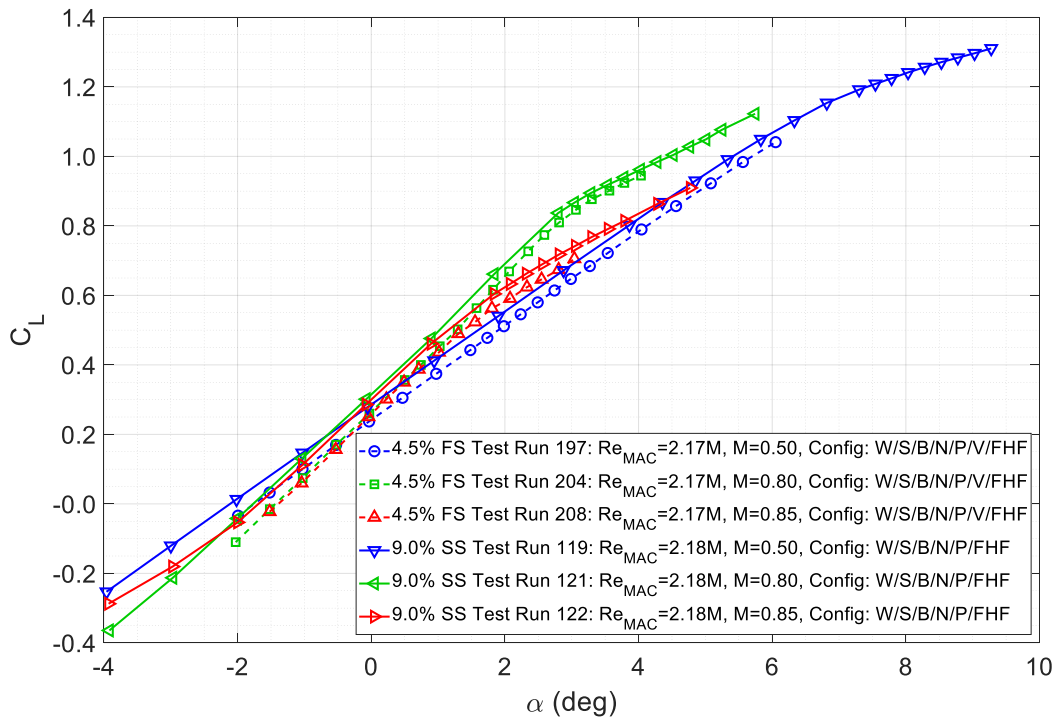


Figure 2-43. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Lift Coefficient at $Re_{MAC} \approx 2.17M$.

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

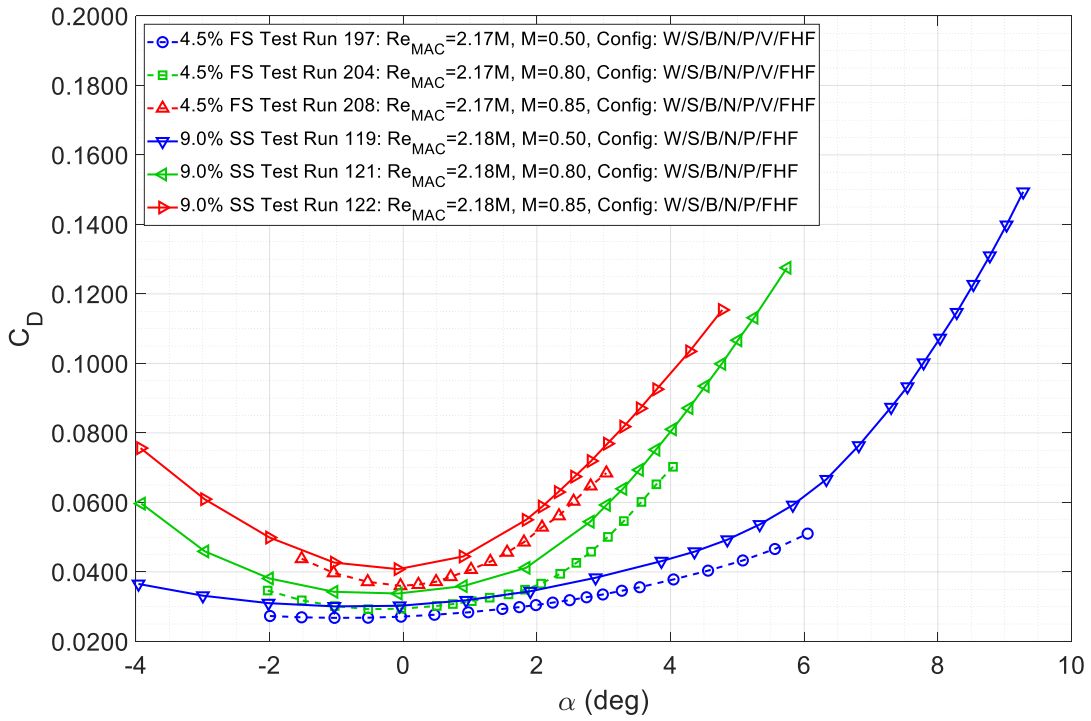


Figure 2-44. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Drag Coefficient at $Re_{MAC}=2.17M$.

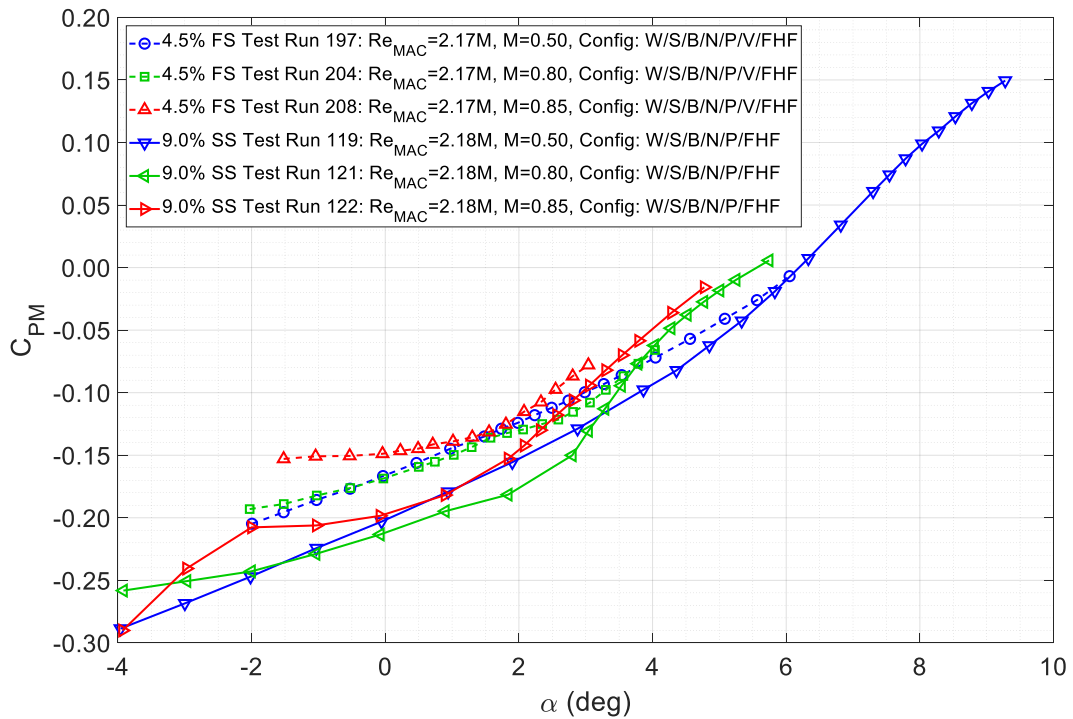


Figure 2-45. Comparison of 4.5% Scale Full-Span and 9.0% Scale Semispan Test Pitching Moment Coefficient at $Re_{MAC}=2.17M$.

2.9.5 Diagnostic Pressure Comparison

As described in Section 2.5.4, the model contained several arrays of static pressures designed for use as diagnostic tools during testing. This section contains the results of those investigations.

2.9.5.1 Fuselage Nose Pressures

As described in Section 2.5.4.1, the model was instrumented with an array of static pressures around the nose of the vehicle to help determine the degree of model boundary layer immersion. A previous study identified a trend in which higher boundary layer thicknesses had an effect of suppressing flow around the nose of a semispan model fuselage. A comparison of measured static pressures with CFD predictions was made to determine if the boundary layer simulated in pre-test computations was adequately representing conditions in the wind tunnel. In Figure 2-46, the static pressures measured in the wind tunnel were compared to computational predictions.

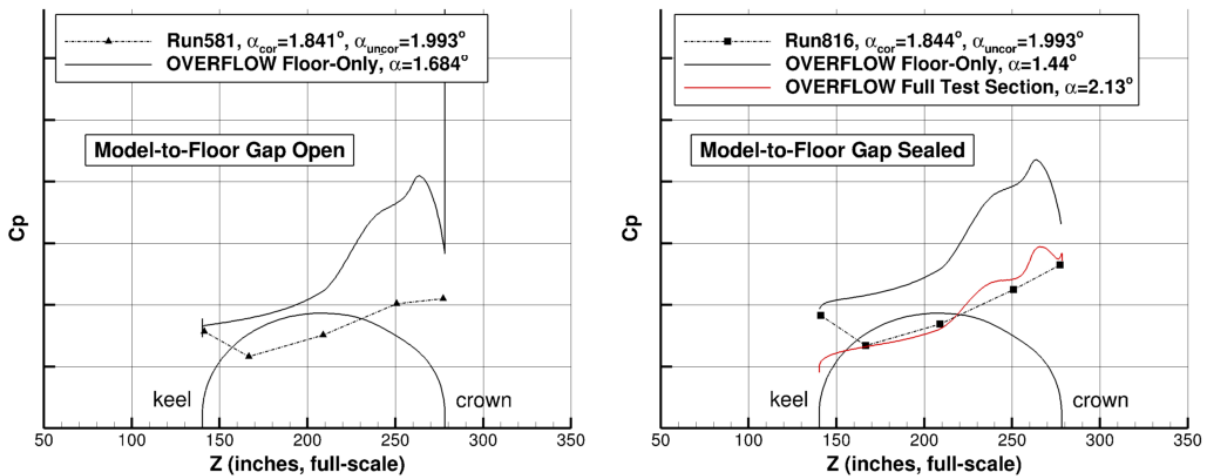


Figure 2-46. Effect of Sealing on Fuselage Nose Pressures for $Re_{MAC} = 5.2M$ and $Mach = 0.8$.

When simulating the under-model gap but only the floor of the tunnel (left image above), static pressure measurements between test and CFD are not in good agreement, with test data showing significant variation from keel to crown. Sealing the gap for a floor-only model produces only a small variation in nose pressure levels (right image), suggesting that the poor correlation is not caused by improper modeling of flow physics associated with the gap flow. OVERFLOW data from the in-tunnel simulation generated during the first TTBW risk reduction contract (see Figure 2-102) was utilized to shed light on this SUGAR Phase V data analysis. The red curve in the plot on the right of Figure 2-46 are pressure data extracted from the in-tunnel solution. The CFD-to-test comparison is significantly improved when the model is analyzed installed in the test section suggesting that more complete modeling is required to accurately capture this effect. Given the good agreement between the measured pressures and the CFD data, it is assumed that the boundary layer model in CFD was an adequate representation of that in the tunnel.

2.9.5.2 Effect of Taping to Floor

A gap between the model and floor is required to prevent the model from contacting the test section floor during testing as it would result in erroneous balance measurements. However, this gap is not desirable from an aerodynamic perspective since flow between the model and floor can significantly alter pressures on the aircraft, particularly on the inboard wing and wing-body-fairing region. To prevent flow from passing freely underneath the model, a series of keel dams (see Sections 2.3, 2.4, and 2.10) were developed to minimize the effect air flowing through the gap has on model performance. The keel dams effectively reduce the size of the gap from 0.3" down to approximately 0.1" (actual distance between keel dam edge and floor varies). The gap's effect on model pressures was captured with a series of fixed-alpha diagnostic runs where the gap was completely sealed by applying metal tape to the fuselage profile plate and floor. Figure 2-47 includes several pictures of the taped model in the C139 configuration.

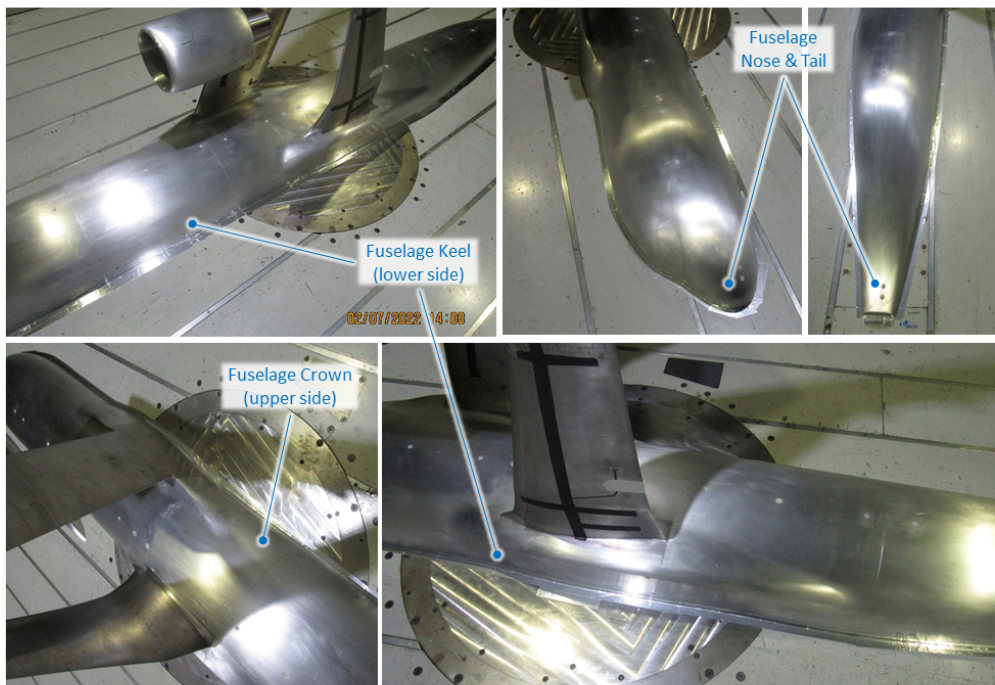


Figure 2-47. Metal tape used to seal model to floor [Source: NASA].

To provide guidance for what effect is expected in the tunnel by sealing to the floor, a comparison in OVERFLOW was made for sealed/unsealed configurations. Results in Figure 2-48 show how sealing the gap altered wing pressures at the design condition. Only the inboard three pressure rows are compared because the effect of sealing is essentially gone by 24% semispan. For the side-of-body row at 7%, the gapped pressure data are in better agreement with free-air results, which is expected given that the wing/body fairing was redesigned to better match free-air data with the gap open.

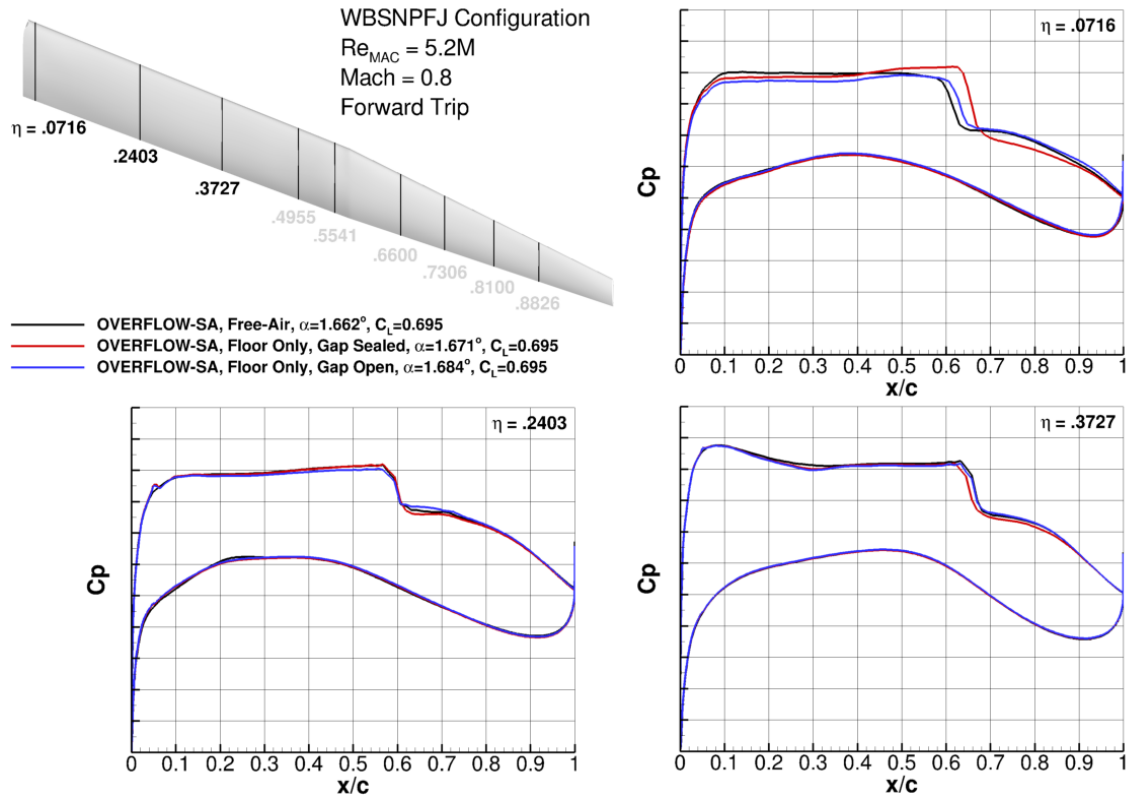


Figure 2-48. Effect of Sealing on Wing Pressures for $Re_{MAC} = 5.2M$, $Mach = 0.8$, and $C_L = 0.695$.

Given the significant amount of time required to apply the tape in the tunnel, only two diagnostic runs were made with the gap sealed. Uncorrected alphas of 2.0° and 3.5° (1.8° and 3.3° corrected) were set and the tunnel run for $Re_{MAC} = 5.18M$, $Mach = 0.8$ conditions. The “taped” wing pressure coefficients are compared to the corresponding “untaped” for the two angles of attack in Figure 2-49 and Figure 2-50. The wing pressure comparison is limited to the inboard three rows as the effect of taping the model to the floor is expected to diminish as a function of increasing distance from the floor. A comparison of the tape effect on inboard wing pressures shows a very small change in inboard wing shock position at 1.8° angle of attack. This change is seen in the 7.2% semispan station. By 24.0% span, the pressure distributions are identical. The slight disagreement in shock location at 37.3% span is not believed to be the result of the tape installation. Results at 3.3° show the same trends, with the tape effect tapering out by the 24.0% span station.

Overall, the inboard wing pressure comparisons show only minor changes when sealing the model-to-floor gap with metal tape. This is the desired outcome since it demonstrates that the effect of the gap between the model and the test section floor has been successfully mitigated using tight tolerances and strategically placed keel dams.

Wing C_p - Config C139, $M=0.80$, $Re/ft=6.3M$

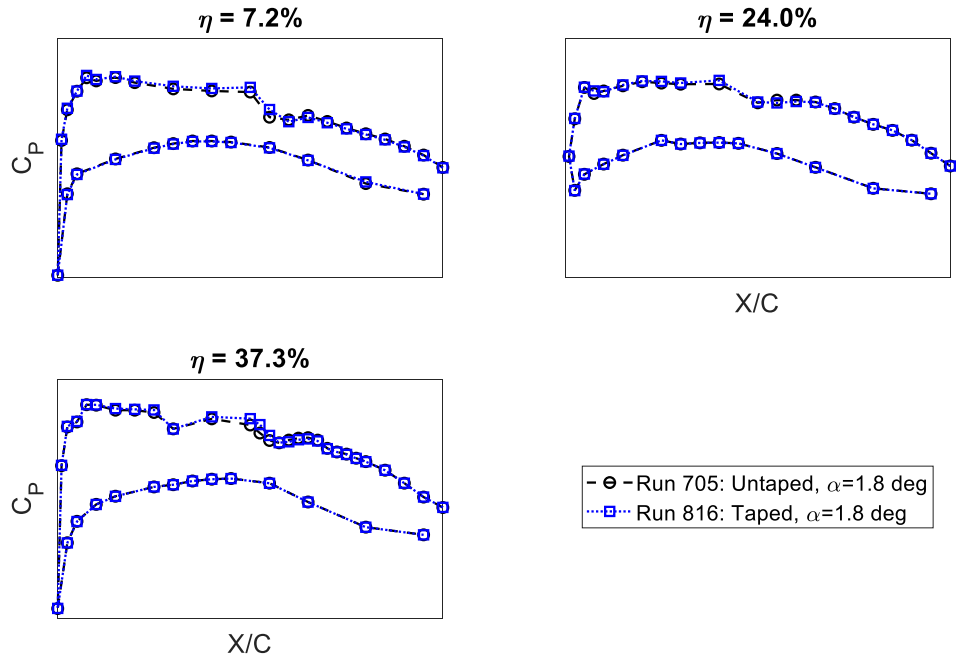


Figure 2-49. Effect of Taping Model to Floor: Inboard Wing Pressures for C139, $Re_{MAC}=5.18M$, $Mach=0.8$, $\alpha=1.8$ deg.

Wing C_p - Config C139, $M=0.80$, $Re/ft=6.3M$

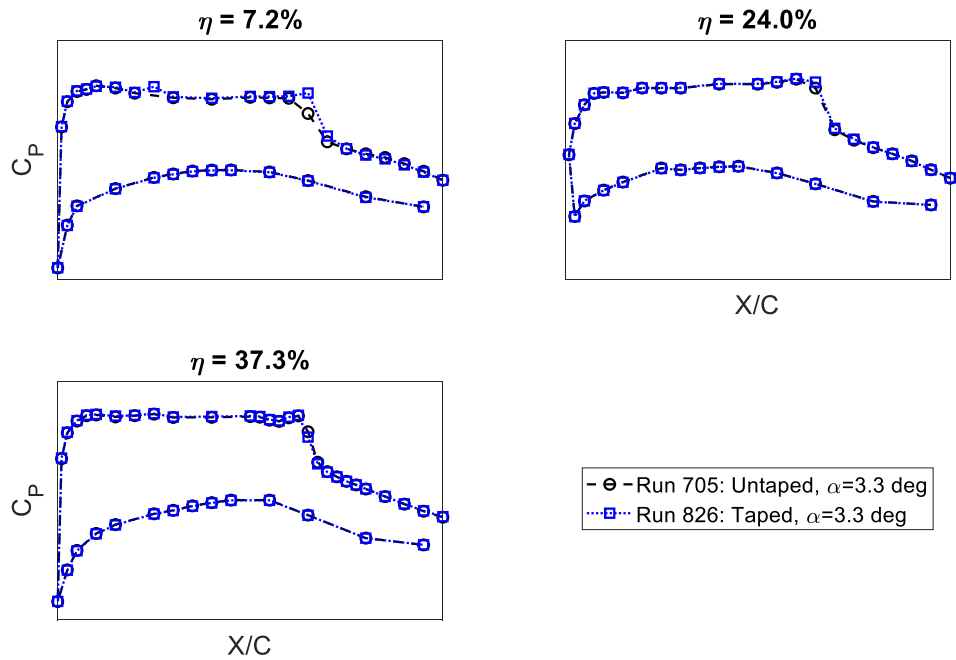


Figure 2-50. Effect of Taping Model to Floor: Inboard Wing Pressures for C139, $Re_{MAC}=5.18M$, $Mach=0.8$, $\alpha=3.3$ deg.

2.9.5.3 Keel dam pressures

Two sets of static pressure ports were installed on either side of the forward and aft keel dams to assess the amount of relative air movement across the dam. The locations of these ports are provided in Figure 2-23. If the pressure difference measured across the keel dam is high, the effectiveness of the dam in restricting air flow through the gap could be called into question.

Figure 2-51 is a plot of ΔC_p as a function of body X-station for a range of alphas at $Re_{MAC}=5.18M$ and $Mach=0.8$. Here ΔC_p is defined as $(C_p)_{upper} - (C_p)_{lower}$. The figure includes an inset image showing a side view of the fuselage bottom plate with keel dams, adapter plate, and pressure port location marked by the letters A through E. The letters are also used to label the data points.

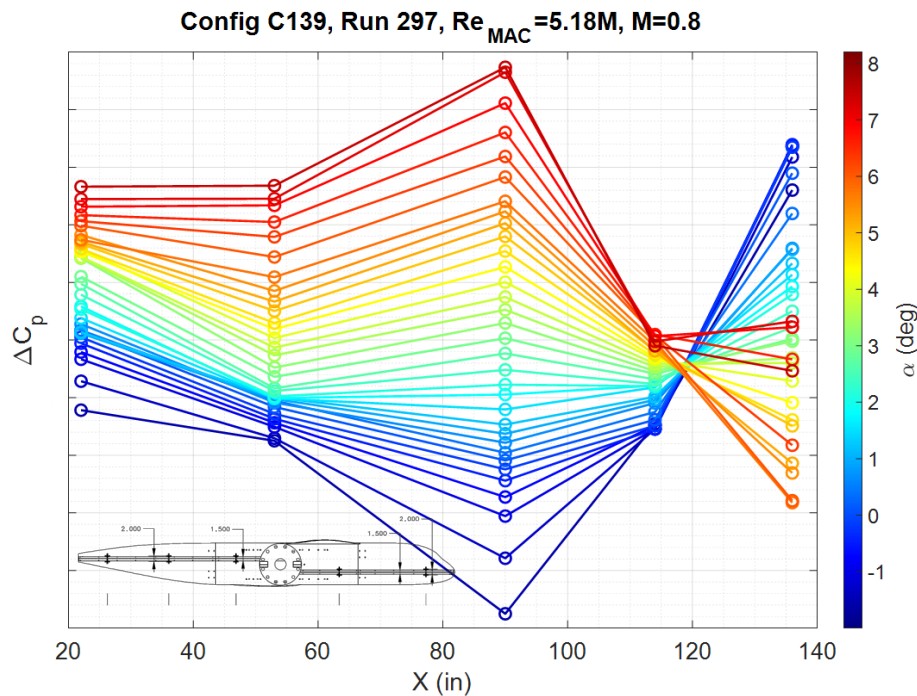


Figure 2-51. Keel Dam Pressure Difference for a Range of Alphas.

The tight range on the left vertical axis in Figure 2-51 is the first indication that the keel dams are working as intended in restricting air flow through the gap. The accuracy of the C_p data is about ± 0.002 , so the measured deltas are well outside the instrumentation accuracy limits. However, the magnitude of the ΔC_p is low given the pressure differentials that would be generated by ineffective dams. This suggests the air movement in the gap is being effectively restricted by the presence of the dams.

2.9.6 Reynolds Number Effects (Full Configuration)

Utilizing the variable-density capability of the 11-ft transonic test section, data were acquired for Reynolds numbers ranging from $Re_{MAC}=2.16M$ to $Re_{MAC}=6.58M$. Figure 2-52 presents drag polars at four Reynolds numbers for the C139 configuration at $M=0.8$. Drag coefficient at the cruise condition ($C_L=0.695$) shows a general trend of drag reduction as Re increased.

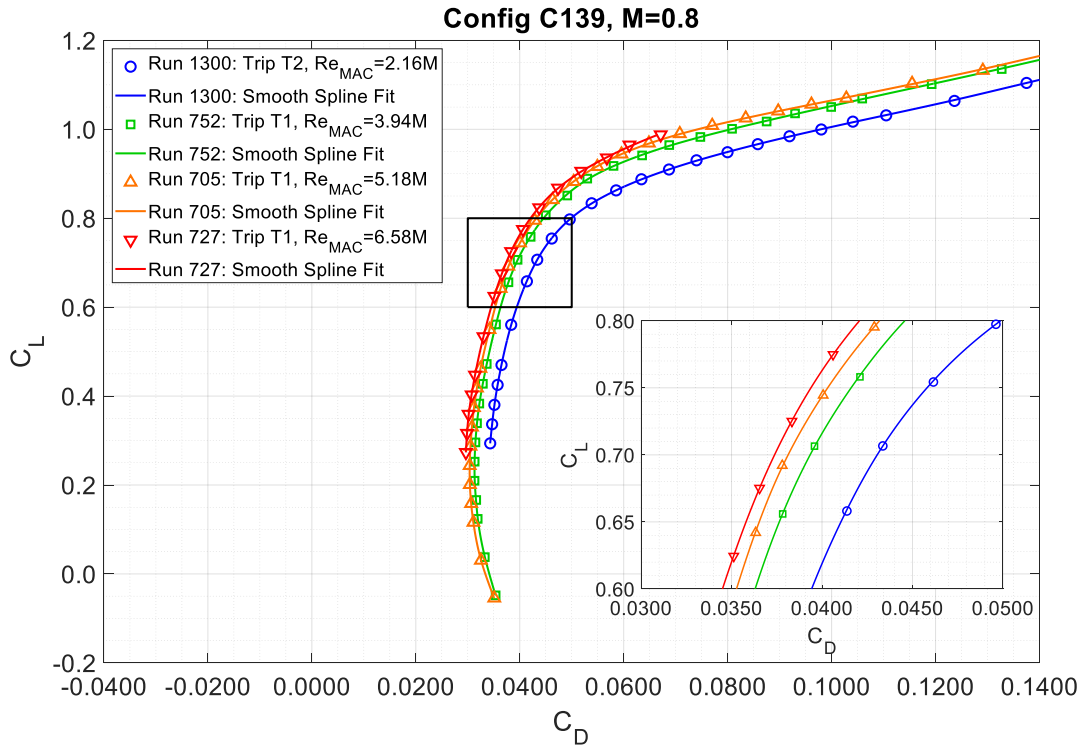


Figure 2-52. Effect of Reynolds number on Drag Polar at $M=0.8$.

The pressure distributions shown in Figure 2-53 – Figure 2-55 show the changes in wing pressure distribution for the inboard, mid, and outboard wings as a function of Re for a constant angle of attack. Since angle of attack is held constant for these runs, circulation increases with Re and the shock moves aft.

Wing C_p - C139, $M=0.80$

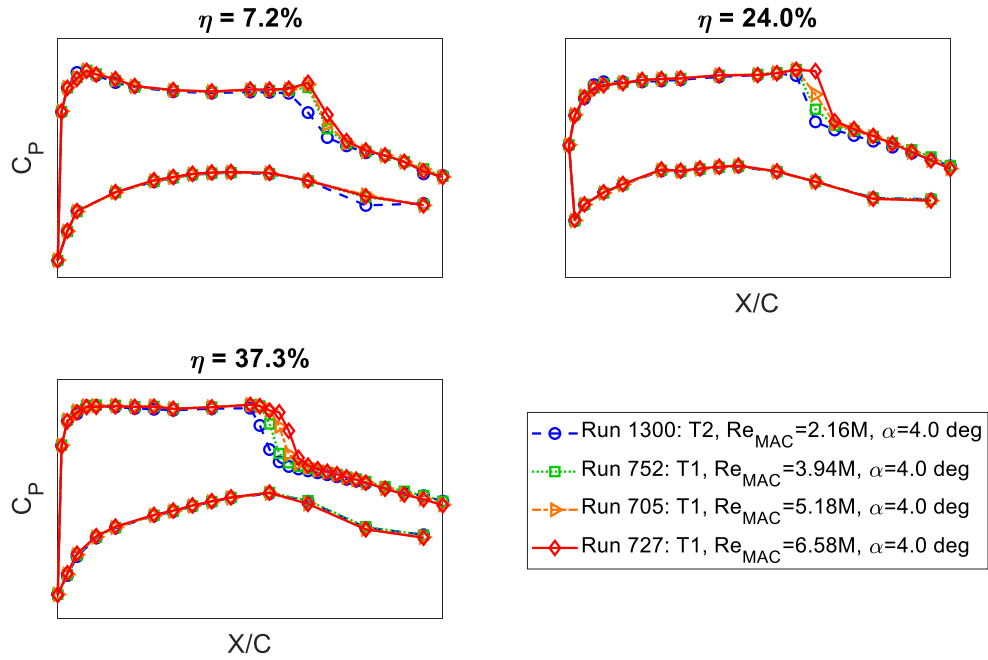


Figure 2-53. Effect of Reynolds Number on Chordwise Pressure Distribution: Inboard Wing [$M=0.80$, $\alpha=4.0^\circ$].

Wing C_p - C139, $M=0.80$

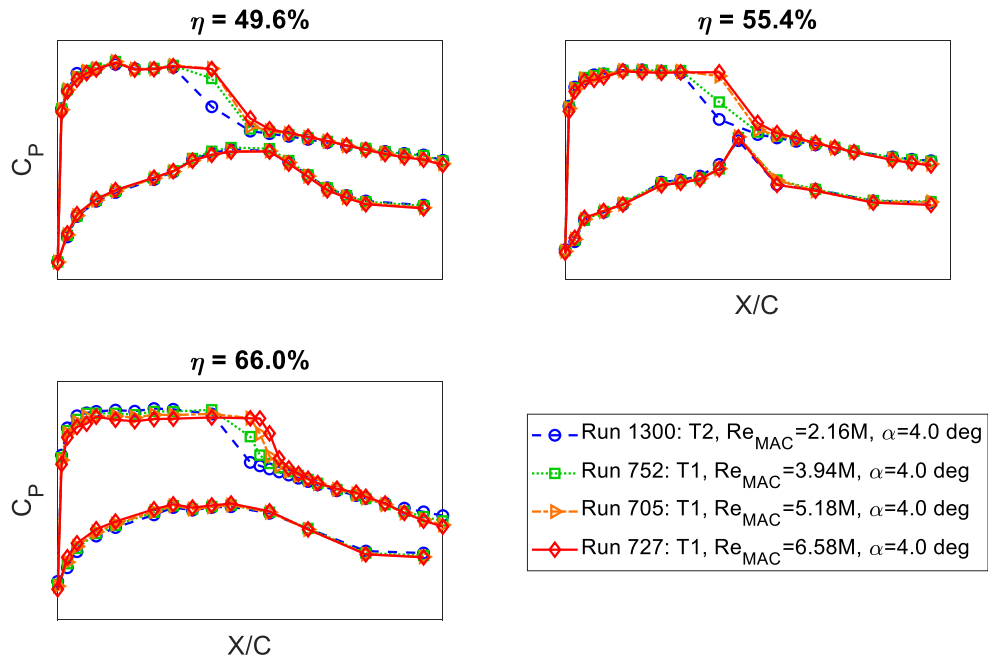


Figure 2-54. Effect of Reynolds Number on Chordwise Pressure Distribution: Mid Wing [$M=0.80$, $\alpha=4.0^\circ$].

Wing C_p - C139, $M=0.80$

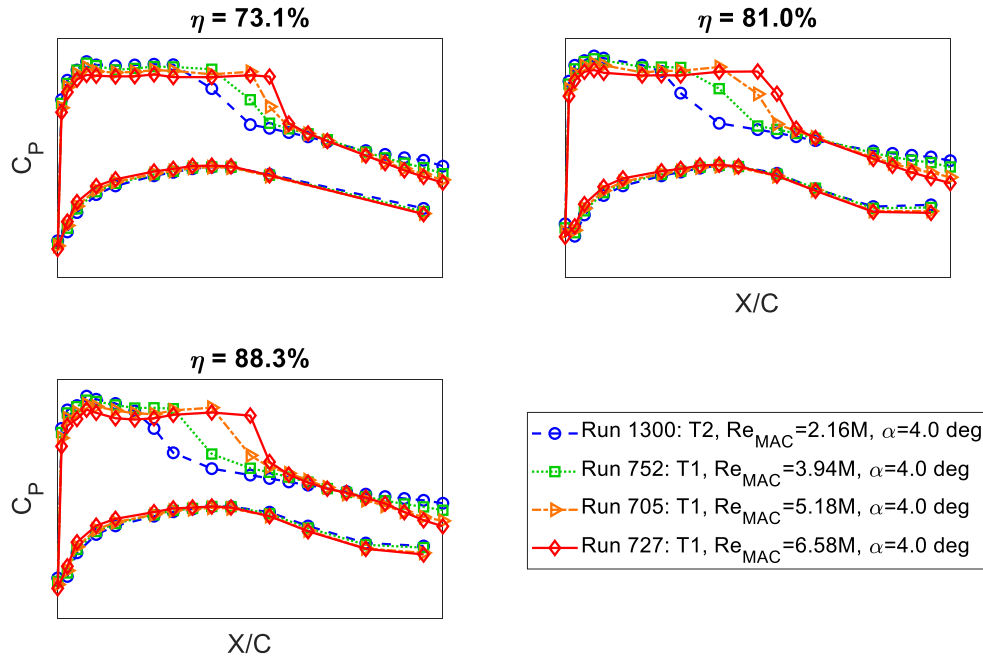


Figure 2-55. Effect of Reynolds Number on Chordwise Pressure Distribution: Outboard Wing [$M=0.80$, $\alpha=4.0^\circ$].

2.9.7 Transition Study

A series of wing and strut trip dot applications was tested on the C139 configuration to investigate the effect that boundary layer characteristics have on lift, drag, sectional pressures, and buffet onset (buffet onset implications will be discussed in Section 2.9.10.2). Trip dot chordwise location and height for the various applications tested are defined in Table 2-13 and Table 2-14, respectively. Test results at the nominal Re_{MAC} of 5.18M and cruise design Mach of 0.8 are compared to verify expected trends and provide insight on wing shock characteristics.

Figure 2-56 and Figure 2-57 compare corrected lift and drag data for the forward trip (T1) and two aft trip (T3 and T4) patterns. Repeat runs are included for T1 and T4 data (refer to Figure 2-33 for information regarding the three trip patterns presented in the following plots).

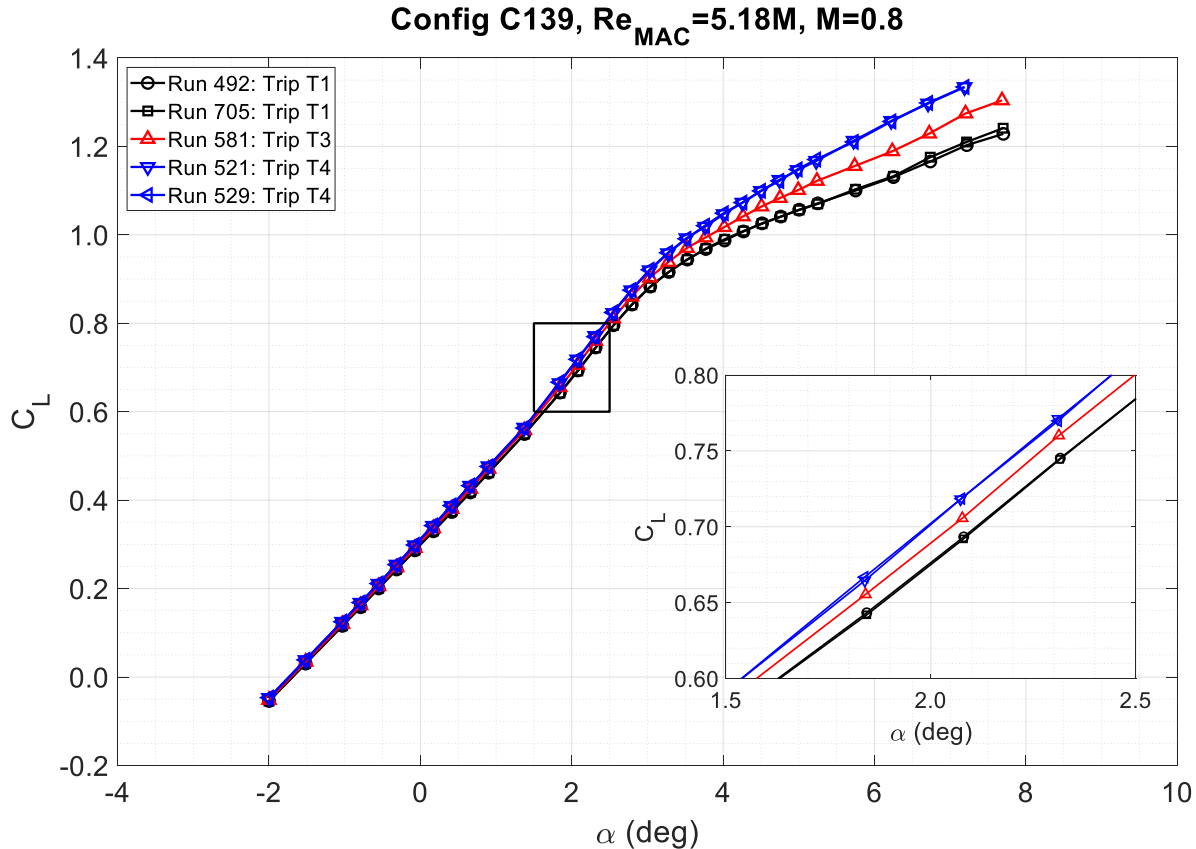


Figure 2-56. Lift Curve Comparison for Trip Patterns T1, T3, and T4 [$M=0.80$, $Re_{MAC}=5.18M$].

The lift curve comparison shows the expected trend of increased lift at a given angle of attack as boundary layer transition moves aft. This lift increase is due to increasing laminar flow runs on the main lifting surface as the trip moves aft; longer laminar runs create a thinner boundary layer and thus an increase in effective airfoil camber, which ultimately results in higher circulation levels. The inset plot in Figure 2-56 shows a significant increase in lift-curve slope as transition moves aft, with an increase in C_L of ~ 0.03 at 2° angle of attack (near the nominal design lift coefficient).

The drag polar comparison in Figure 2-57 shows a significant drag reduction at the design C_L of 0.695 going from forward trip (T1) to aft trip (T3 and T4). The inset plot indicates moving wing trip aft results in a 15-to-20 count drag reduction. As with the lift curve comparison, this drag trend with transition location is expected. Aft trip allows for reduced angle of attack to maintain the same lift level, which translates to lower drag levels. Note that the change in drag levels measured in the tunnel include increased drag from the trips themselves.

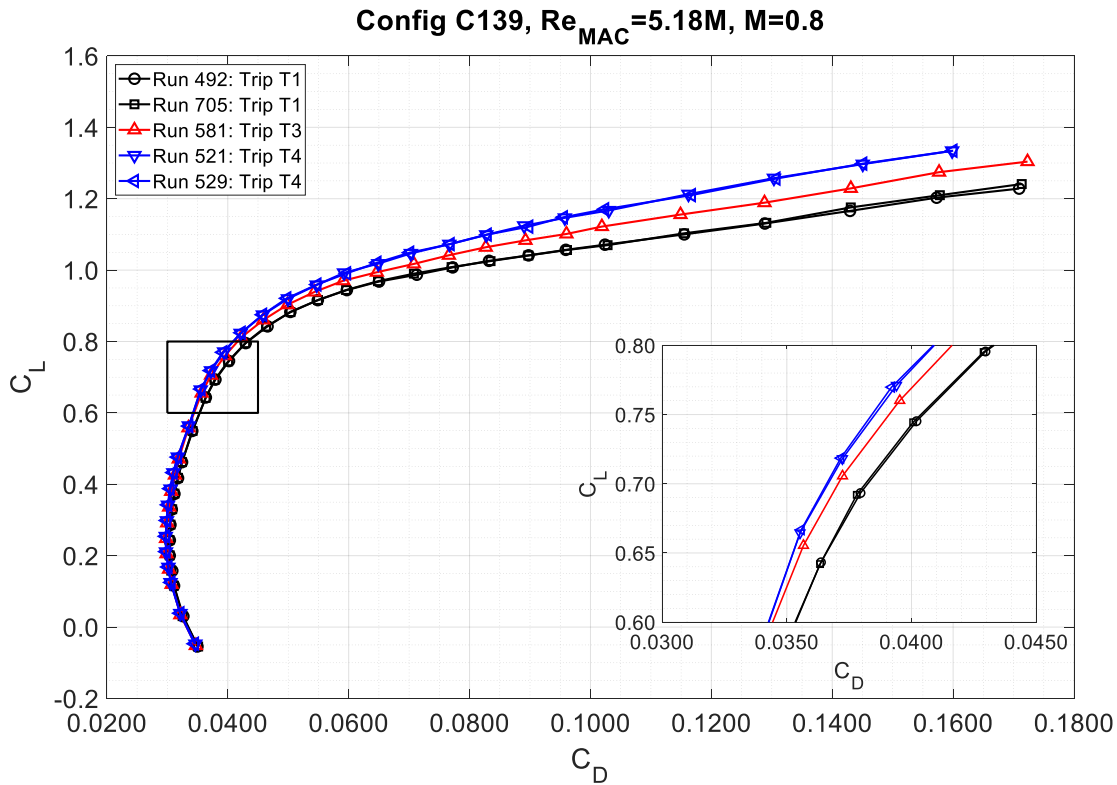


Figure 2-57. Drag Polar for Trip Patterns T1, T3, and T4 [$M=0.80$, $Re_{MAC}=5.18M$].

2.9.7.1 Forward Trip T1 vs. Aft Trip T3

A CFD study was conducted prior to the start of the buffet test to investigate the effect of wing boundary layer transition location on various flow field quantities such as surface pressure, spanload, and shock-induced separation patterns. The results were compared to a fully turbulent solution at flight Reynolds number to determine a preferred or nominal wing trip location. Tripping the wing boundary layer at 5% of the local chord provided a better match on spanload when compared to flight Re results, and reduces the potential for variability in laminar runs over the course of the test. For these reasons, a forward trip location was used for the majority of performance testing, both in this test entry and in the previous full-span TTBW wind tunnel tests. However, significant variations in trip location were a critical element of buffet testing since changes in the boundary layer provide valuable insight into the shock-induced separation phenomena that are the cause of buffet onset.

The pretest CFD study on transition location identified a nominal aft trip location of 25% of the local wing chord as providing the best match of shock characteristics and boundary layer thickness to flight Reynolds number. For this reason, aft trip wind tunnel data are expected to better represent buffet onset characteristics of the flight vehicle.

Figure 2-58 and Figure 2-59 compare wing pressures measured during the buffet test at the design Mach number of 0.8 and angle of attack of 4° , which is near buffet onset. The figures

compare only the mid-to-outboard pressure rows since the critical span station is expected to be in this region. The primary difference in wing pressure characteristics due to trip location is the shock position. The T3 aft trip data indicate the shock moves aft roughly 4% to 6% of the local chord resulting in increased loading. The increase in wing loading is the reason for higher lift levels at higher alphas as shown in Figure 2-56. The further aft shock position (and thinner boundary layer) associated with the T3 aft trip location will contribute to more representative buffet onset characteristics.

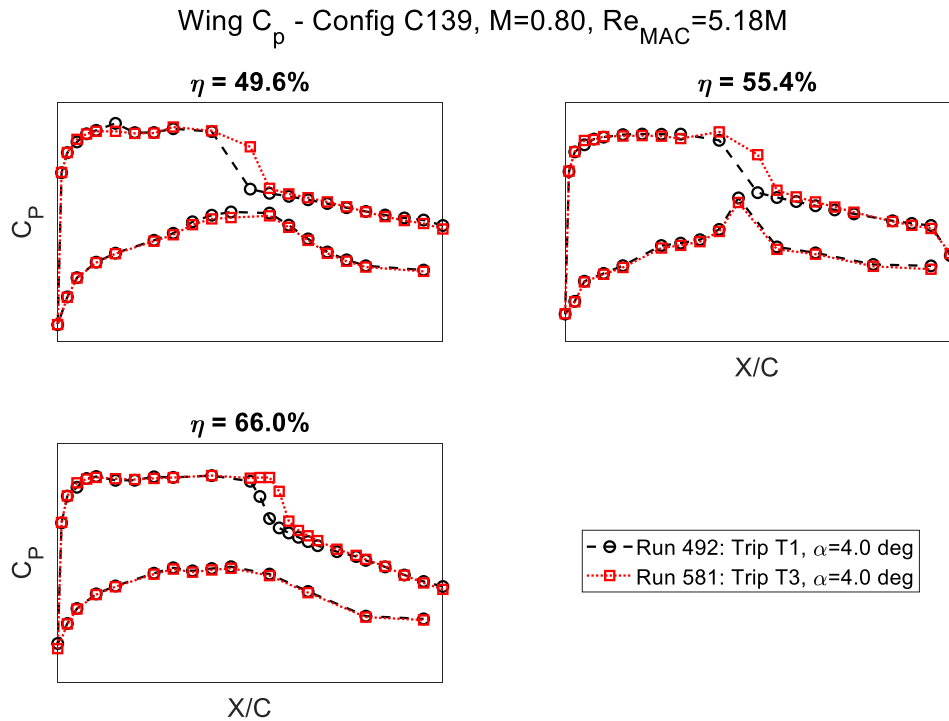


Figure 2-58. Wing Pressure Comparison: Mid-Span Region, T1 vs. T3 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].

Wing C_p - Config C139, $M=0.80$, $Re_{MAC}=5.18M$

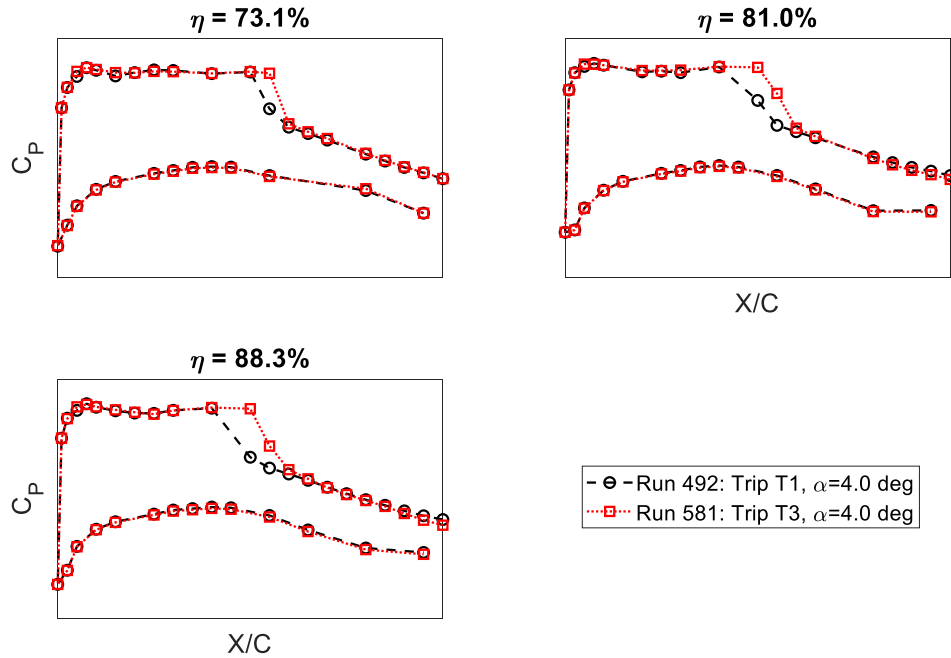


Figure 2-59. Wing Pressure Comparison: Outboard Region, T1 vs. T3 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].

2.9.7.2 Aft Trip T3 vs. Aft Trip T4

An additional aft trip location called T4 was defined to gain further insight on the sensitivity of buffet onset when the wing laminar region is extended. This alternate aft trip pattern is shown in Figure 2-33 and defined in Table 2-13. The difference between T3 and T4 is aft movement of the wing upper surface trip location from 25% to 40% of the local chord starting outboard of the nacelle. This change resulted in the expected aft shift of the shock 3% to 8%, which is similar to the shock movement measured when trip was moved from the forward to the 25% aft trip location. Figure 2-60 compares wing pressures at $Mach=0.8$ and 4° angle of attack for the mid-span region and Figure 2-61 covers the outboard wing pressure rows. The midspan stations near the wing/strut juncture region are the most sensitive to shock movement when boundary layer transition is moved aft. As with the T3 trip location, T4 aft trip allows for a thinner boundary layer at the wing shock, which is expected to delay shock-induced separation (these effects will be presented in Section 2.9.9).

Wing C_p - Config C139, $M=0.80$, $Re_{MAC}=5.18M$

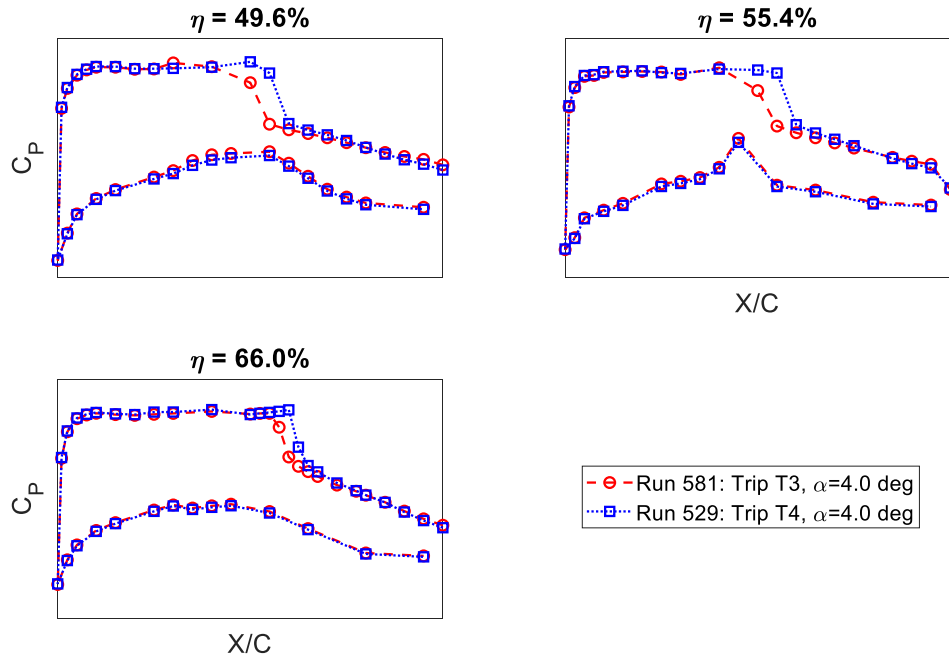


Figure 2-60. Wing Pressure Comparison: Mid-Span Region, T3 vs. T4 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].

Wing C_p - Config C139, $M=0.80$, $Re_{MAC}=5.18M$

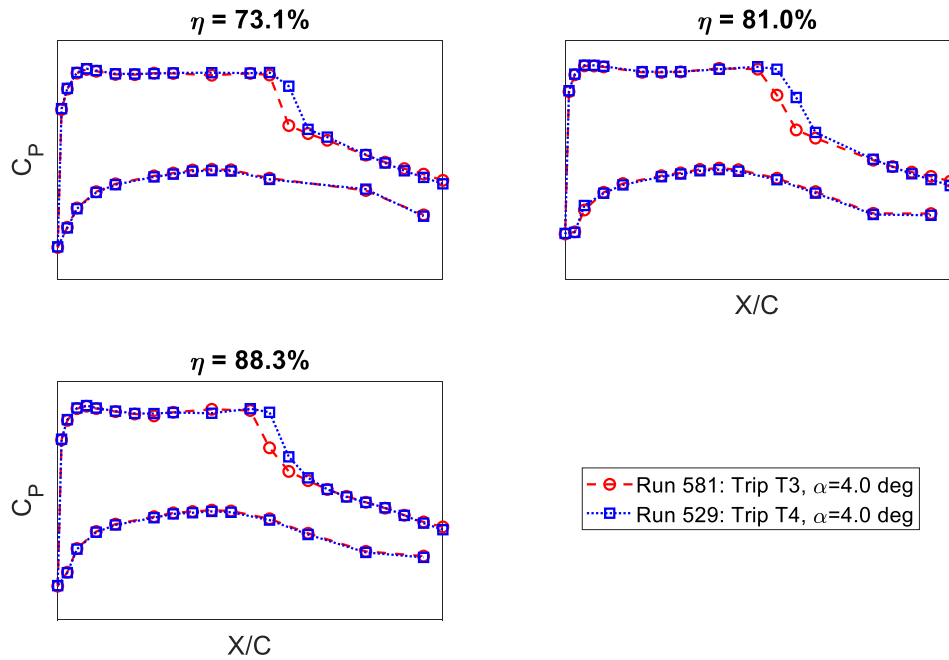


Figure 2-61. Wing Pressure Comparison: Outboard Region, T3 vs. T4 [$M=0.80$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].

2.9.7.3 Free Wing Transition

The buffet test matrix included a run series where wing upper surface boundary layer transition was allowed to occur naturally over a section of the mid-to-outboard wing. This “free” transition study provided data on the limits of laminar boundary layer behavior for the wind tunnel model. The revised trip pattern (designated T3.1) is identical to the T3 pattern except for removal of the wing upper surface trip dots between 35% and 85% span.

A drag polar comparison at Mach=0.8 is shown in Figure 2-62. By allowing the boundary layer to transition freely over a region of the wing, drag is reduced for all test points. The inset image in the figure below shows a significant drag reduction of about 10 counts at the design C_L of 0.695.

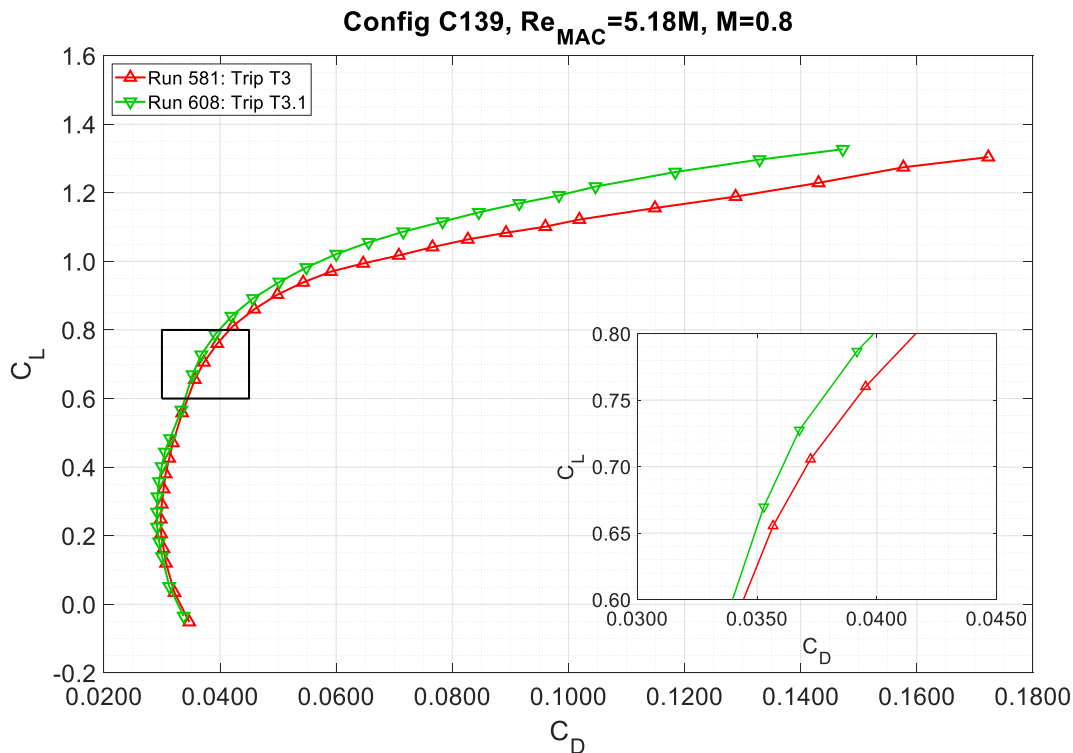


Figure 2-62. Drag Polar for Trip Patterns T3 and T3.1 [$M=0.80$, $Re_{MAC}=5.18M$].

Figure 2-63 and Figure 2-64 compare wing pressures for T3 and T3.1 at Mach=0.8 and $\alpha=4^\circ$. By removing the trip dots between semispan stations of 35% and 85%, the laminar run extends well aft, which drives the shock movement back to 70% to 75% of the local wing chord. Based on the pretest CFD transition study, allowing the boundary layer to transition naturally over most of the wing upper surface will likely result in buffet onset characteristics that do not represent the flight vehicle at full-scale Re . Wind tunnel data for the T3.1 trip pattern were gathered mainly for research purposes with the intent of having adequate data to more fully understand buffet characteristics of a TTBW configuration in the presence of laminar flow approaching the shock.

The data also highlight the configuration potential for large laminar runs associated with the high aspect-ratio (short chord) wing design.

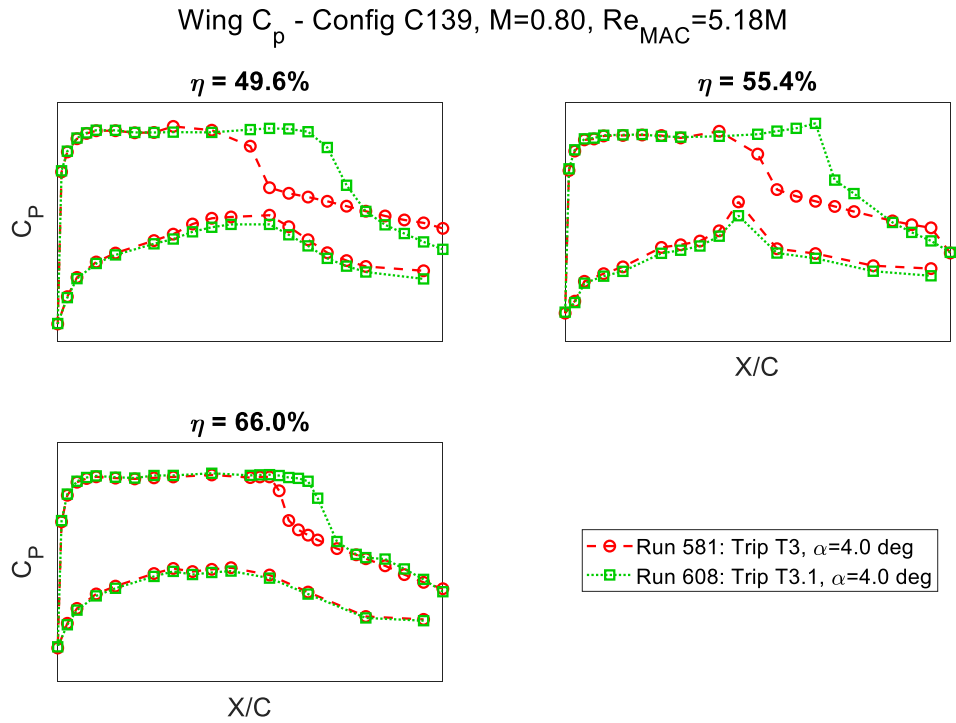


Figure 2-63. Wing Pressure Comparison: Midspan Region, T3 vs. T3.1 [$M=0.80$, $Re_{MAC}=5.18M$].

Wing C_p - Config C139, $M=0.80$, $Re_{MAC}=5.18M$

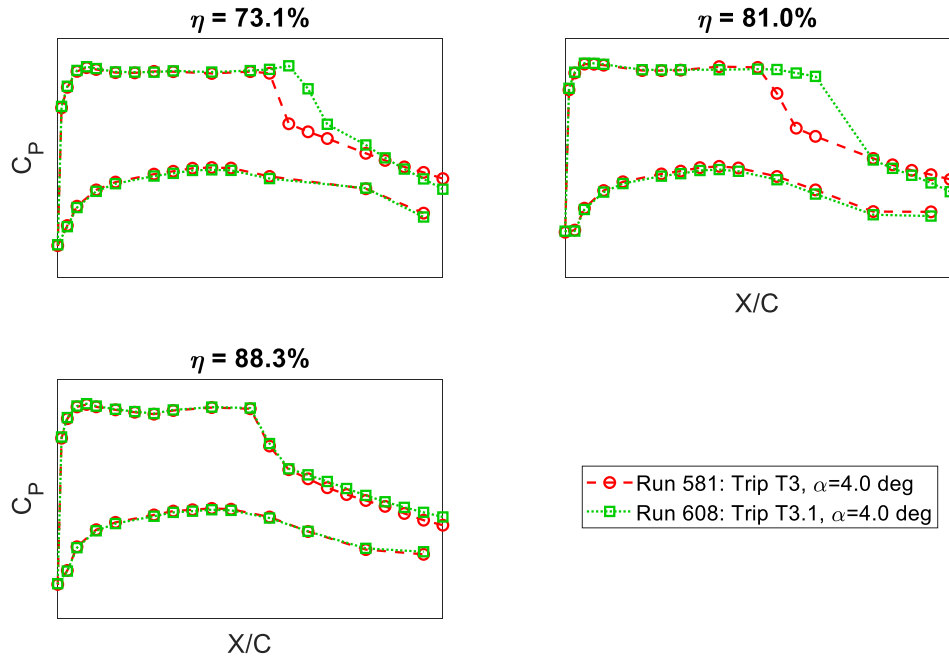


Figure 2-64. Wing Pressure Comparison: Outboard Region, T3 vs. T3.1 [$M=0.80$, $Re_{MAC}=5.18M$].

2.9.7.4 Free Strut Transition

In addition to capturing free transition data for the wing, a run series was also added to capture free transition data on the strut. The trip pattern, designated T5, removed all trip dots from the strut, allowing the strut boundary layer to transition naturally. Drag data with free transition on the strut are of interest because it gives an indication on the drag reduction potential for a natural laminar flow strut design. From a buffet perspective, this change was not expected to have a significant impact on buffet onset since the wing is designed to be buffet critical well before the strut. However, it was possible that changes to the boundary layer thickness inside the tightest confines of the wing-strut channel may affect shock formation in this region. Figure 2-65 compares drag polars at Mach=0.8 with forward trip (T1) on the wing. Note the nominal T1 trip configuration includes trip dots at 10% local chord on the strut. The polar comparison shows a drag reduction for T5 for the entire polar with a 5 count reduction at the design C_L of 0.695.

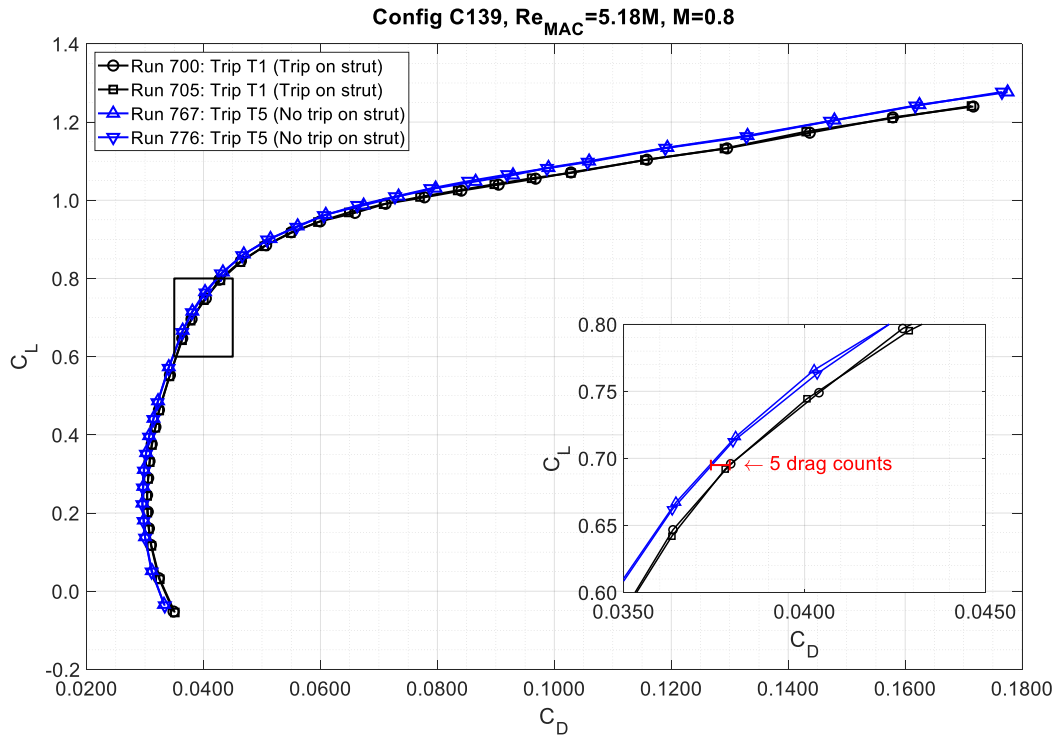


Figure 2-65. Effect of Strut Trip on Vehicle Drag Polar at $Re_{MAC}=5.18M$, $Mach=0.8$.

Figure 2-66 and Figure 2-67 show comparisons of the strut pressures near the wing-strut channel for the strut free transition configuration. For an angle of attack near the cruise design point, there is relatively little change in loading in the stations near the juncture. However, when angle of attack is increased to 4° there are more substantial changes in loading, particularly inboard.

Strut C_p - Config C139, $M=0.80$, $Re_{MAC}=5.18M$

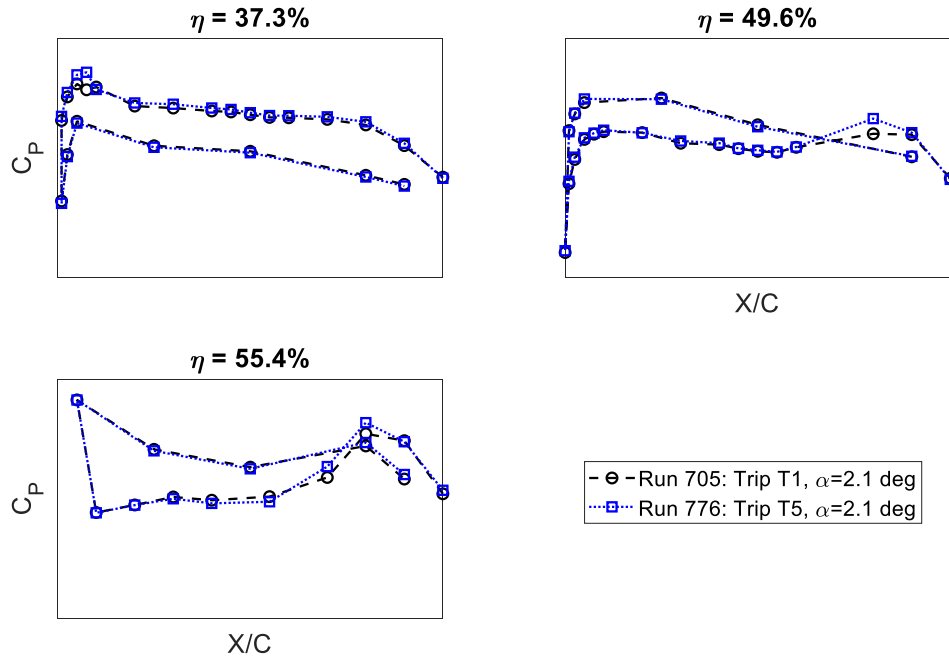


Figure 2-66. Pressure comparison in the wing-strut channel region for T1 vs. T5 [$M=0.8$, $Re_{MAC}=5.18M$, $\alpha=2.1^\circ$].

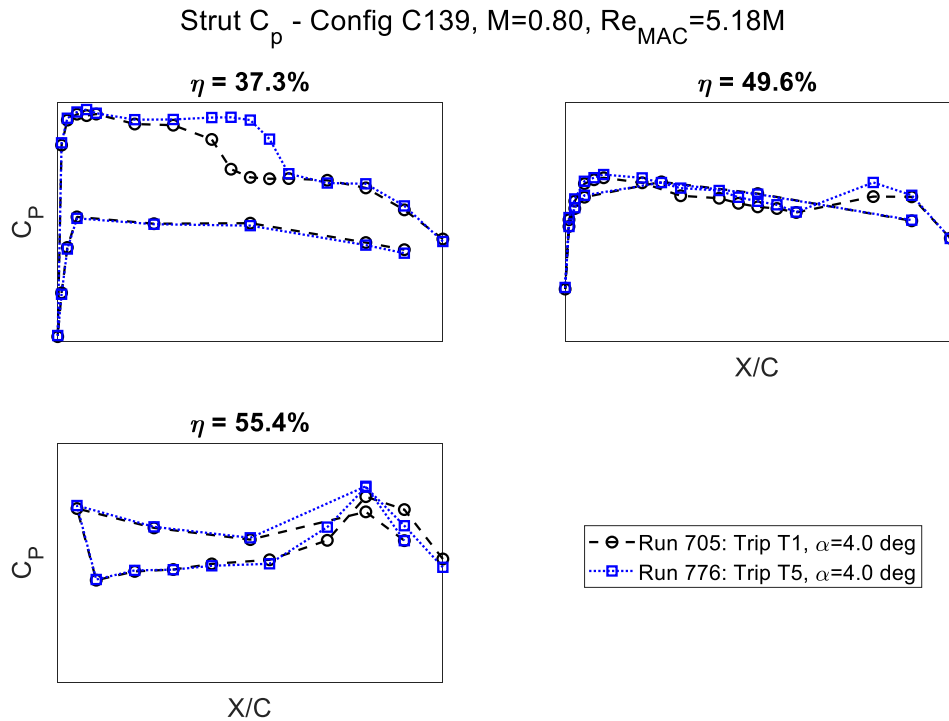


Figure 2-67. Pressure comparison in the wing-strut channel region for T1 vs. T5 [$M=0.8$, $Re_{MAC}=5.18M$, $\alpha=4.0^\circ$].

2.9.8 Wind Tunnel Component Build-Up

A component build-up was performed, starting with the wing-body-strut configuration, and then systematically adding model parts to acquire incremental data. All data presented in this section are for the forward trip T1 location only. As described in Section 2.4.4, no data could be obtained for configuration C143 due to concerns regarding the jury strut strength.

2.9.8.1 Wing-body-strut Configuration (WBS)

Lift curves for the WBS configuration (C141) are shown below (Figure 2-68) for both $Re_{MAC}=5.18M$ and $3.94M$.

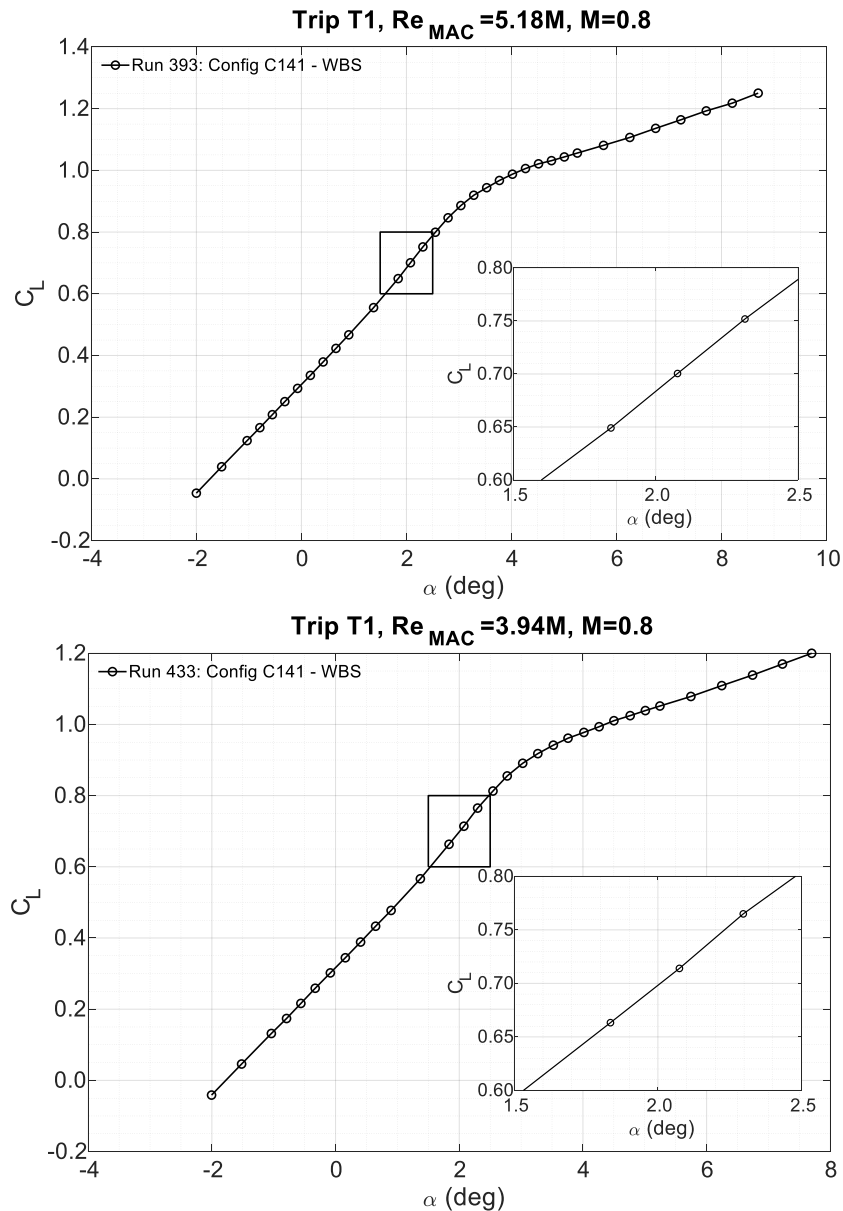


Figure 2-68. C_L vs. α for WBS (C141) configuration, Mach=0.8.

2.9.8.2 Wing-body-strut-nacelle Configuration (WBSNP)

Lift curves for the WBSNP configuration (C142) are shown below (Figure 2-69) for $Re_{MAC}=5.18M$ as compared to the C141 configuration.

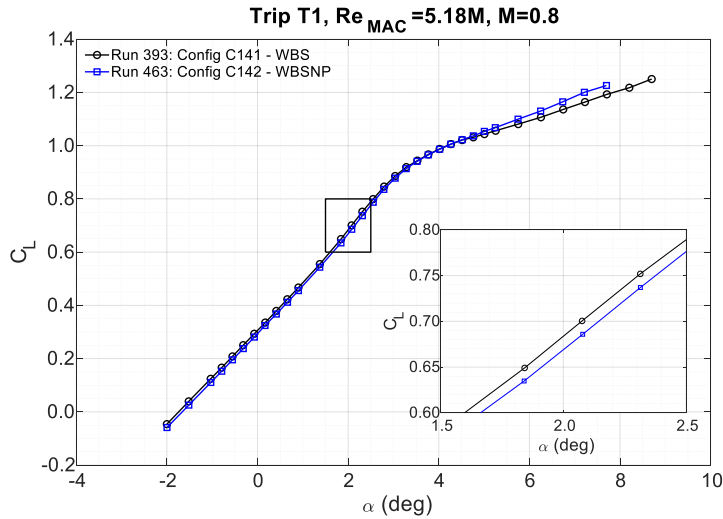


Figure 2-69. C_L vs. α for WBS (C141) and WBSNP (C142) configurations [$M=0.8$, $Re_{MAC}=5.18M$].

2.9.8.3 Wing-body-strut-nacelle-flap fairings Configuration (WBSNPF)

The final configuration in the buildup (C139) added the flap hinge fairings. Lift curves for the C139 configuration are shown below (Figure 2-70) for $Re_{MAC}=5.18M$ as compared to the C141 and C142 configurations, and for $Re_{MAC}=3.94M$ as compared to the C141 configuration.

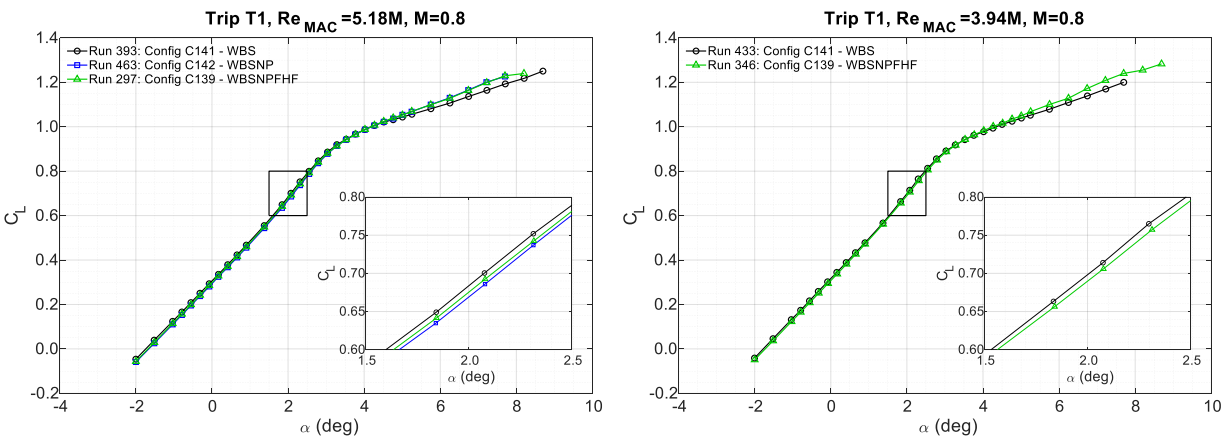


Figure 2-70. C_L vs. α for WBS (C141), WBSNP (C142) and WBSNPF (C139) configurations (note legend in figs have C139 as WBSNPFHF).

2.9.9 Wind Tunnel Buffet Assessment

The primary focus of this wind tunnel test was an assessment of buffet onset on the TTBW configuration including the identification of potentially unique buffet-onset behaviors. These potentially unique behaviors include the potential for ‘low C_L ’ buffet onset, in which the local download of the outboard strut could lead to shock-induced separation on the underside of the strut, and a potential concern that the juncture between the wing and strut might become buffet critical as the flow speeds through the tight confines of the channel at higher vehicle speeds. A localized strut flap that manipulates flow on the strut and in the channel was tested to alleviate buffet onset on the strut, if present. Finally, a determination will be made as to whether the presence of the strut could fundamentally affect ‘typical’ buffet onset for the wing.

Secondary to this effort was an assessment of whether the tools and methods typically used to predict buffet onset were valid for this new configuration. This is of critical interest as many of the computational methods used for the determination of buffet onset are rooted in experimental and/or empirical data correlated from tests on conventional cantilevered low-wing aircraft.

In this section, various heritage methods used for determining buffet onset are described and potential limitations highlighted. Section 2.9.10 will then discuss the buffet results obtained during wind tunnel testing, culminating in a comparison and assessment of these various methods.

2.9.9.1 A Discussion Regarding TTBW Vehicle Spanload

An important design feature of the TTBW configuration is the necessity of flow management through the wing/strut juncture by way of local airfoil characteristics. This feature is evident in the cruise spanload plot shown in Figure 2-71 in which strut downward lift outboard of 45% semispan is offset by the wing in order to achieve a ‘total’ vehicle spanload approaching an elliptical distribution. It is in this way that strong shocks are prevented from forming in the channel.

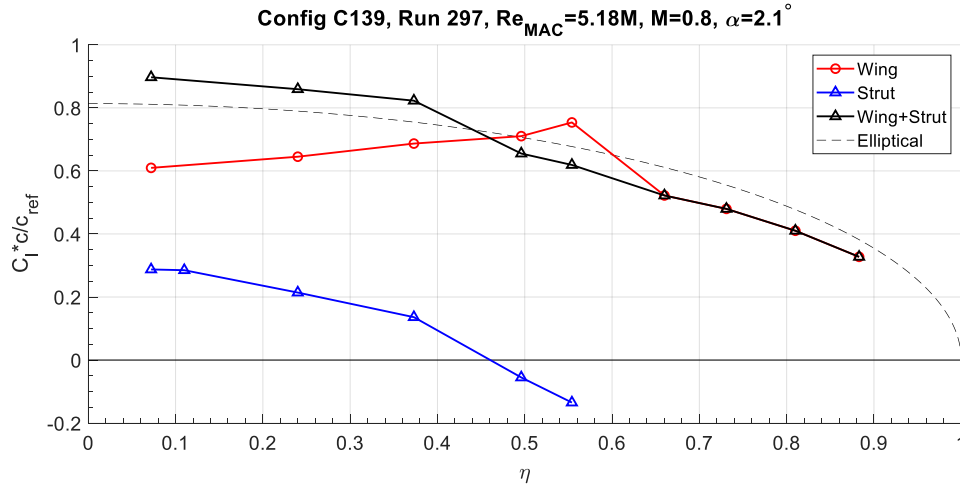


Figure 2-71. Sample Wing/Strut Spanload Plot [Config C139, Run 297, $M=0.8$, $Re_{MAC}=5.2M$, $\alpha=2.1^\circ$].

Note that this approach results in locally higher sectional lift coefficients on the midwing than a typical cantilever-wing spanload would suggest. Couple this information with the knowledge that the TTBW configuration was intentionally designed such that the wing becomes critical for buffet onset well before the strut at positive load factors, and it becomes clear that the midspan region of the wing is an area of particular interest in the determination of buffet onset. This potential midspan criticality is somewhat in contrast to cantilever-wing designs in which the combination of shorter chords and higher section lift coefficients lead designs to be buffet-critical near 70% span. The critical span section of the TTBW wing as determined by experimental data is visualized in Figure 2-72. This figure presents wing upper surface pressure contours as a function of vehicle angle of attack. The presented angles of attack represent cruise (2.1°), prebuffet onset (3.8°), and post-buffet onset (5.7° , 8.2°).

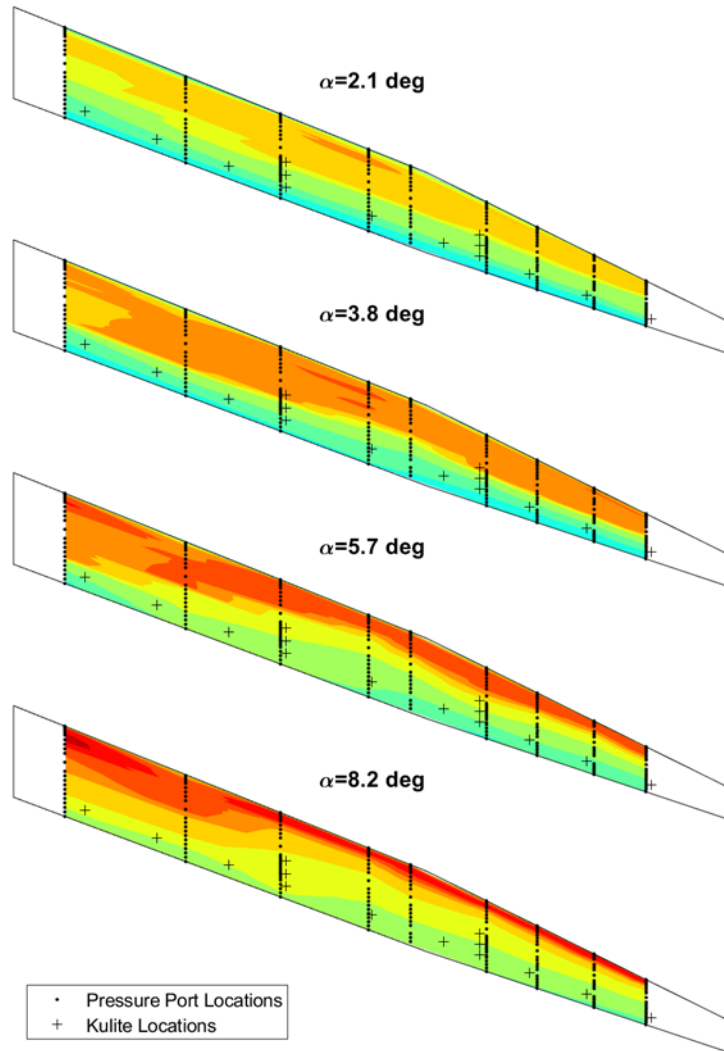


Figure 2-72. Wing Upper Surface Pressure Contours [Config C139, Run 297, $M=0.8$, $Re_{MAC}=5.18M$].

The wind tunnel static pressure data near cruise show a relatively well behaved wing shock system across the span. However, just prior to buffet onset the shock begins to move forward and strengthen around midspan suggesting reduced loading due to a weakened boundary layer potentially caused by localized shock-induced separation. At post-buffet conditions, both the midwing and outboard wing exhibit shock locations that appear further forward than neighboring wing sections, suggesting this region has the greatest criticality for buffet onset. For these reasons, the majority of the focus for buffet onset analysis will center on the wing semispan regions from 50% to 85%.

2.9.9.2 Pitching Moment Break Method

The pitch break method attempts to predict buffet onset using force and moment data for a range of Mach numbers. Nose-up pitch break in the pitching moment (C_{PM}) curve is indicative of flow separation on the wing and is treated in this method as an indication of ensuing buffet. The pitch break is often defined as the point where the C_{PM} vs α curve first deviates from the linear trend present before gross separation of the flow over the wing develops (2). For the present model, an example case of the baseline configuration at $Re_{MAC}=5.18M$ and $Mach=0.80$ is given in Figure 2-73. The pitching moment curve indicates multiple roughly linear regions before the pitch break (increasing nose-up). This leads to challenges in selecting an appropriate linear fit.

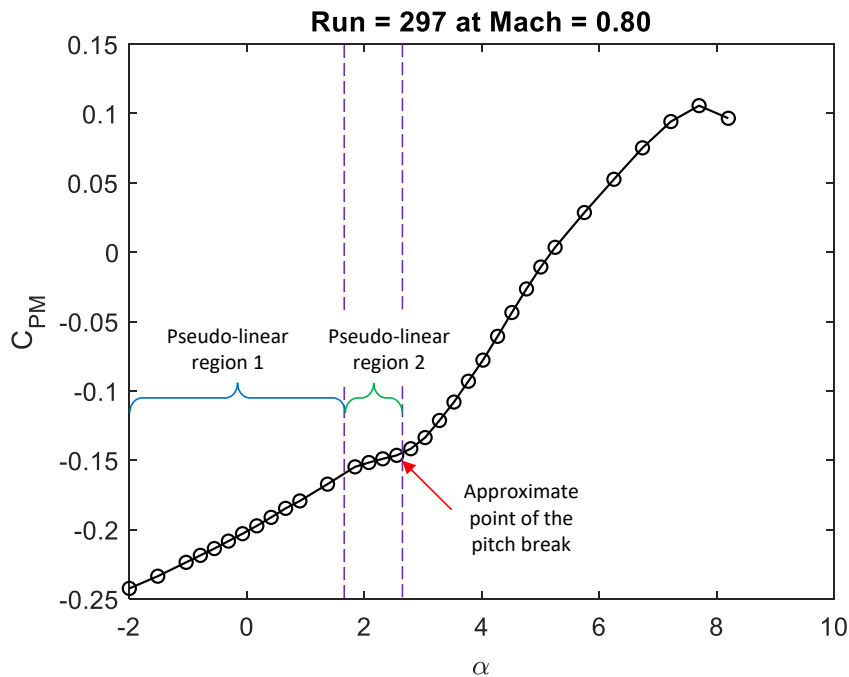


Figure 2-73. Pitching Moment Curve [M=0.8].

The resulting buffet onset boundary is shown in Figure 2-74 for the baseline configuration. A region of almost constant $C_{L,IB}$ (lift coefficient of initial buffet) can be identified for Mach numbers between $Mach=0.6$ and 0.72 , followed by a rapid decrease in predicted $C_{L,IB}$ above $Mach=0.75$. Determination of the pitch break is increasingly more difficult with increasing Mach number, as the change in pitching moment becomes more subtle, particularly at and above $Mach\ 0.85$.

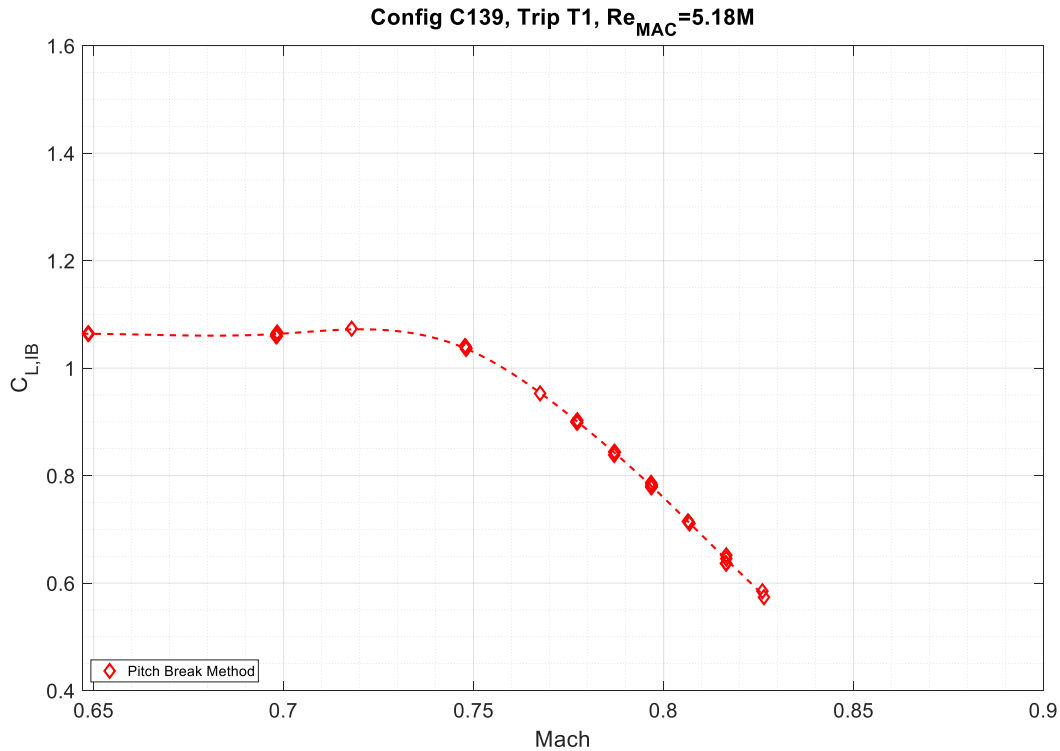


Figure 2-74. Initial Buffet Curve According to Pitch Break Method [Config C139, Trip T1, $Re_{MAC}=5.2M$].

This method treats buffet onset as a global phenomenon rather than based on sectional properties of given airfoil stations. Since the method relies on a distinct pitch-up, inferred buffet onset may be adversely affected by the TTBW's more inboard critical station (as compared to conventional cantilever wing configurations).

2.9.9.3 *Trailing Edge Pressure Divergence Method*

This method provides a prediction of the buffet onset boundary using curves of wing trailing edge pressure coefficient versus lift coefficient. These data curves are typically composed of two distinct regions. At low lift coefficient values, where the flow is attached to the wing and well-behaved, trailing edge pressure coefficient varies with lift coefficient in a linear fashion. Conversely, at higher lift coefficient values, the trailing edge pressure curve varies nonlinearly with lift coefficient. Within the nonlinear region of the data curve a rapid decrease in trailing edge pressure is indicative of flow separation on the wing and is a precursor to buffet.

A straight line is fit to the linear region of the trailing edge pressure curve and is extrapolated into the nonlinear region of the curve. Buffet onset is defined as the point where trailing edge pressure coefficient in the nonlinear region of the data curve diverges from the extrapolated linear trend by a predetermined margin (2). To increase the accuracy of the buffet onset prediction while working with coarsely sampled data, the nonlinear pressure data were interpolated with a spline fitting method. Figure 2-75 presents sample plots of trailing edge

pressure vs. C_L at Mach numbers of 0.78 and 0.85. Note that as Mach number increases, the linear region of the trailing edge pressure curve shrinks, and therefore, the uncertainty in the linear extrapolation increases.

Applying this method to each of the spanwise locations where pressure data are available at the wing trailing edge yields a set of potential initial buffet C_L predictions. The final value is taken at the critical span, which is the one with the lowest predicted initial buffet C_L . Figure 2-76 presents a sample $C_{L,IB}$ vs. wing span location plot with the critical span identified.

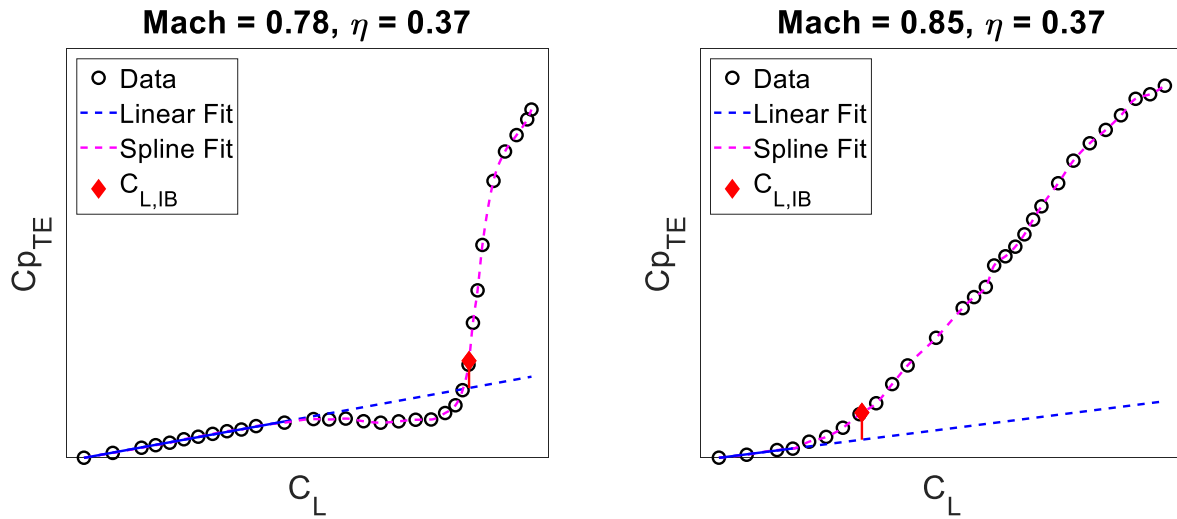


Figure 2-75. Trailing Edge Pressure Divergence Method [M=0.78 (left) and M=0.85 (right)].

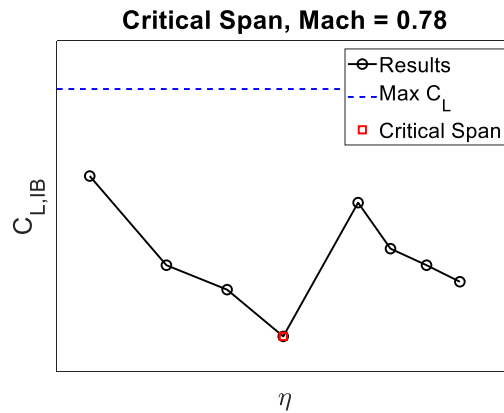


Figure 2-76. Trailing Edge Pressure Divergence Method Critical Span [M=0.78].

The buffet onset curve for the baseline configuration is shown in Figure 2-77 at $Re_{MAC}=5.18M$, indicating an expected trend of decreasing $C_{L,IB}$ with increasing Mach number for Mach numbers greater than 0.70.

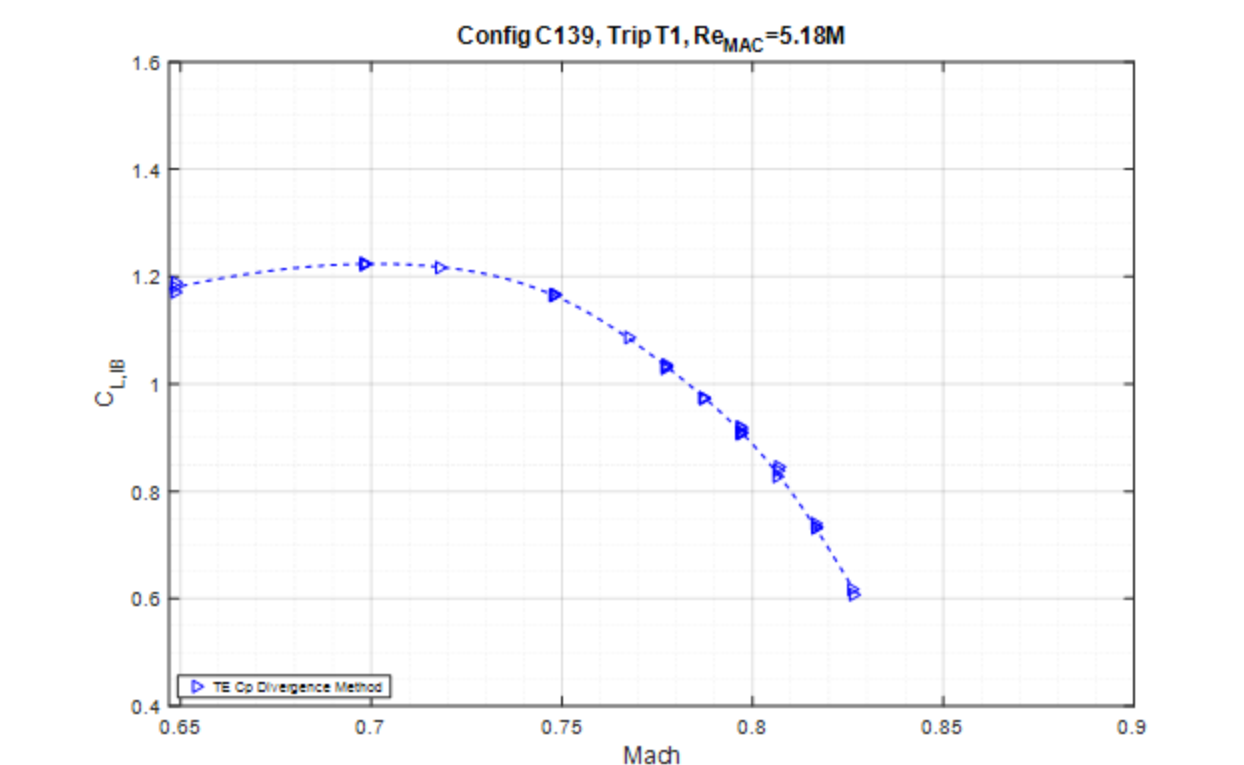


Figure 2-77. Initial Buffet Curve According to Trailing Edge Divergence Method [Config C139, Trip T1, $Re_{MAC}=5.2M$].

2.9.9.4 Axial Force Offset Method

The Axial Force Offset (AFO) method is based on the correlation of total airplane forces to flight test data for existing tube-and-wing aircraft. An envelope of curves for axial force as a function of angle of attack are evaluated over a range of Mach numbers (left side of Figure 2-78). The data are plotted to form a locus of points that make-up a common trend, described as the attached flow curve in the plot on the right side of Figure 2-78. Deviation of the axial force from this common trend is indicative of flow separation. This attached flow curve is then offset to intersect the axial force curves at points that represent buffet onset (2).

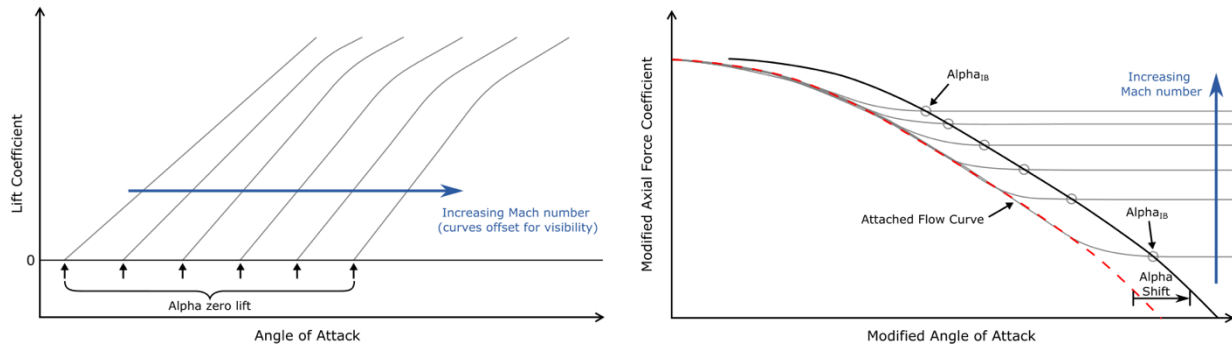


Figure 2-78. Axial Force Offset Method.

The AFO method predicts a consistent buffet boundary for repeated baseline runs in the current test (Figure 2-79). This indicates robustness of the AFO method in predicting the buffet onset as well as adequate repeatability in model build/installation and tunnel conditions during the test campaign.

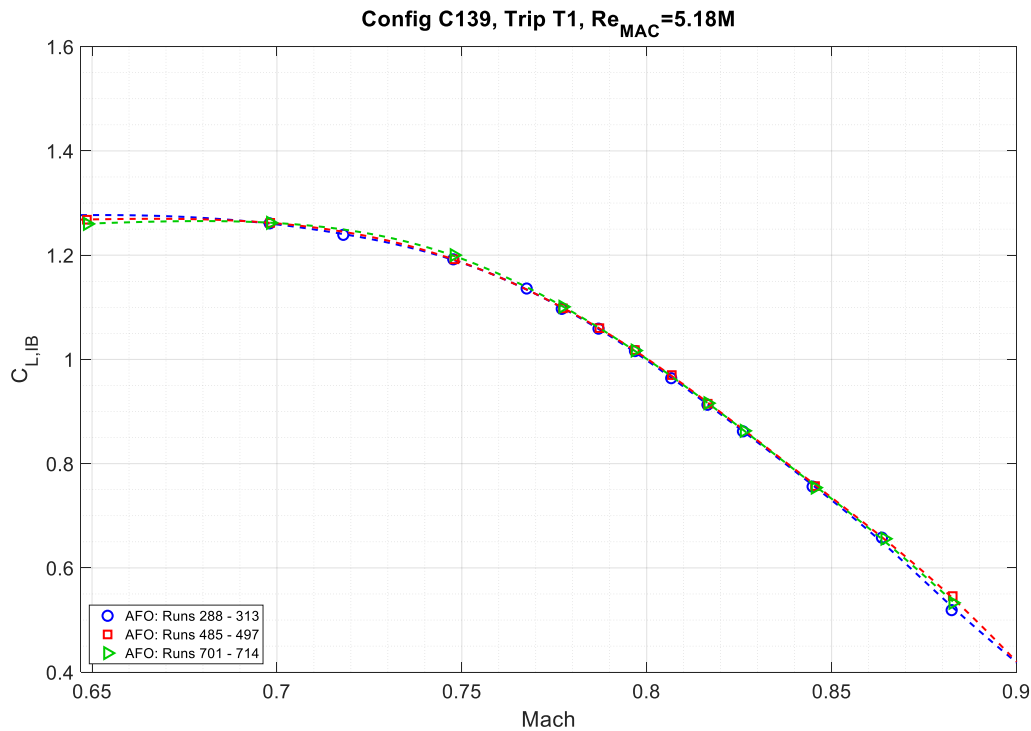


Figure 2-79. AFO: Baseline Repeatability [Config C139, Trip T1, $Re_{MAC}=5.2M$].

The AFO method uses global balance forces on the model to determine buffet onset, rather than relying on sectional measurements. However, the accuracy of the method is dependent on the

selected offset angle, which is typically determined via flight test. Since a TTBW has not yet been flown, the exact value of the offset is therefore subject to future flight-test validation.

2.9.9.5 Wing Bending Strain-Gauge Method

The wing bending strain method utilizes dynamic data from the model's structural response to infer the onset and development of shock-induced (unsteady) flow separation. Deflections in the wing were measured during testing using three strain gauges (gauge locations specified in Section 2.5.2). Dynamic data from the strain gauges was recorded during continuous pitch runs and processed post-test to extract the signal RMS. The method identifies the angle of attack at which the strain gauge RMS underwent rapid growth as angle of attack was increased. An example strain gauge RMS vs alpha curve is presented in Figure 2-80. Initially, while the model is at a low angle of attack, the strain gauge signal RMS is low and remains relatively flat with increasing angle of attack. However, once the model pitch passes a critical angle of attack, the RMS of the signal increases rapidly. The dashed red line in Figure 2-80 indicates the initial buffet point identified from the dynamic data.

The buffet onset boundaries extracted from all three wing strain gauges for the C139 configuration with the T1 trip pattern at $Re_{MAC}=5.18M$ are presented in Figure 2-81. Strain gauges WBM1 and WBM2 were positioned next to each other at 60% wing span, and therefore, recorded almost identical fluctuations in strain. Conversely, strain gauge WBM3 was attached at 10% wing span. Buffet onset boundary predictions from WBM3 tend to follow WBM1 and 2 closely for Mach 0.7 to 0.8. Above Mach 0.8, the RMS signal from WBM3 becomes hard to interpret because a clear initiation point for the ramp up in the strain gauge RMS is no longer present. Similar difficulties develop in WBM1 and WBM2 above Mach 0.83.

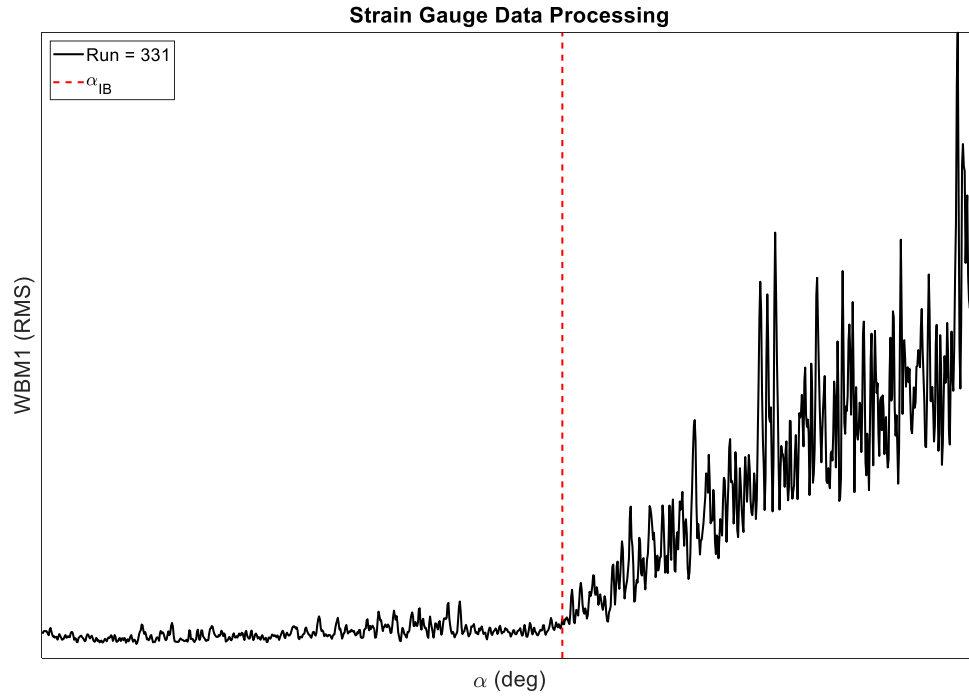


Figure 2-80. Example Wing Strain Gauge RMS Data.

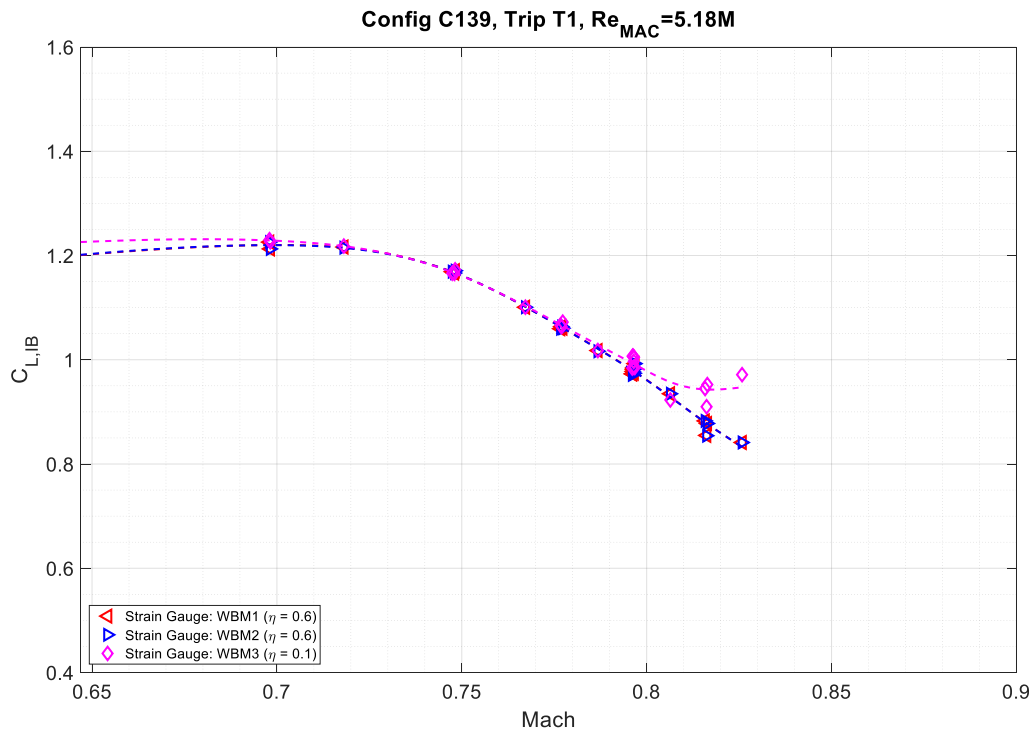


Figure 2-81. Buffet Onset Boundary Based on Strain Gauge Data [Config C139, Trip T1, $Re_{MAC}=5.2M$].

The wing strain method is based on rapid growth in wing bending moments at the start of buffet onset. While the outboard wing behaves in a similar way to a traditional cantilever-wing design, the model's nonlinear structural response inboard of the wing-strut join is more complicated. It is thus not surprising that the gauge inboard of this join does not follow traditional relationships for structural response.

2.9.9.6 Model Accelerometer Method

The three accelerometers attached to the wing provided an alternate method for quantifying wing structural response during buffet onset. Like the strain gauge data, the dynamic accelerometer data were processed post-test to compute the signal RMS, from which the point of initial buffet was extracted by finding the angle of attack at which the accelerometer RMS began increasing rapidly. An example RMS curve is presented in Figure 2-82. Identifying the point of initial buffet from the accelerometer data was more difficult than it was in the strain gauge data because the accelerometer RMS tended to increase somewhat more smoothly and continuously (compare Figure 2-80 and Figure 2-82). In Figure 2-82, the initial buffet point is indicated with a dashed red line.

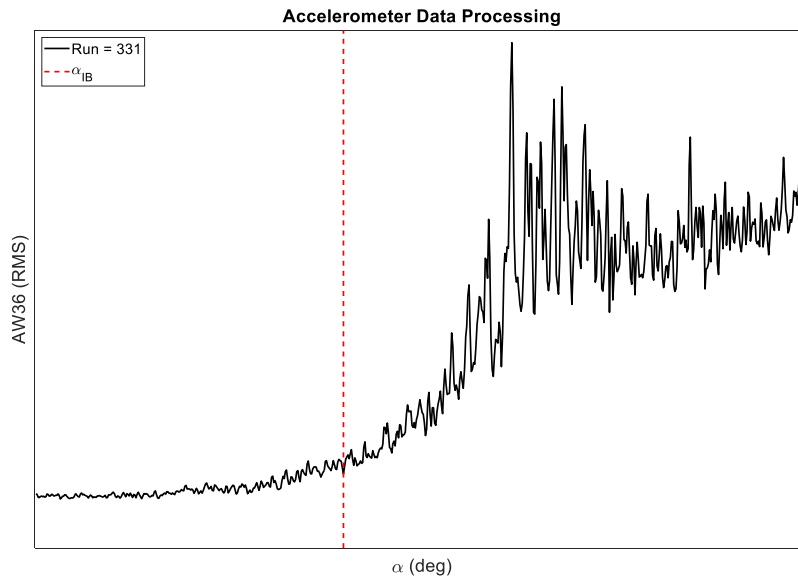


Figure 2-82. Example Wing Accelerometer RMS Data.

The buffet onset boundaries extracted from the three wing accelerometers for the C139 configuration with the T1 trip pattern at $Re_{MAC}=5.18M$ are presented in Figure 2-83. Accelerometers AW63 and AW89 were installed at 63% and 89% span, respectively, and buffet onset boundaries from those accelerometers, which were both mounted outboard of the wing/strut junction, are similar. As anticipated, the buffet onset boundary extracted from the third accelerometer, AW36, which was installed at 36% span (inboard of the wing/strut junction), does not exhibit the same magnitude of structural response, and erroneously suggests a higher buffet margin than is projected by the outboard wing gauges at higher Mach numbers.

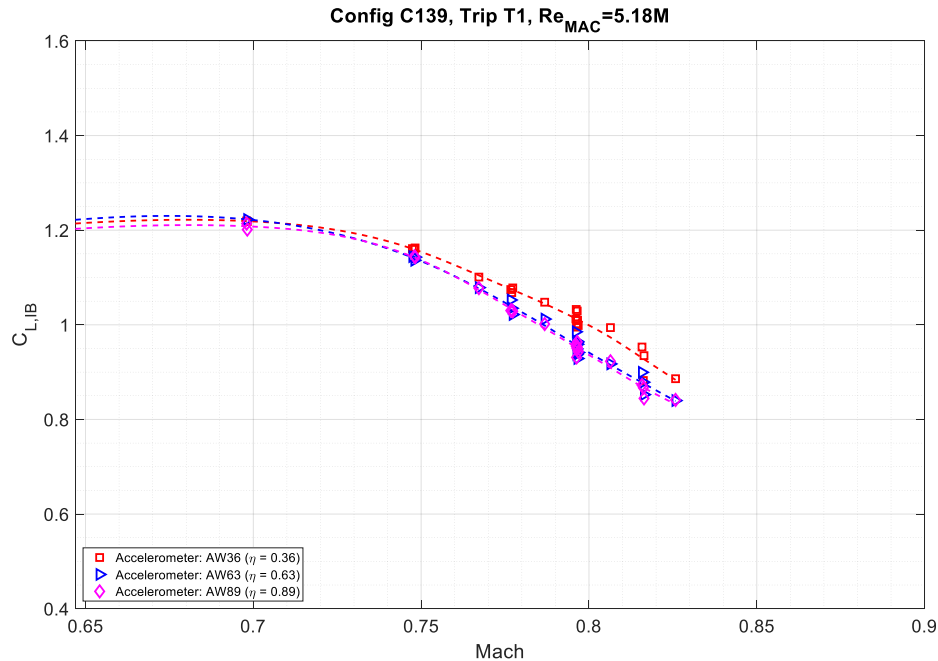


Figure 2-83. Buffet Onset Boundary Based on Accelerometer Data [Config C139, Trip T1, $Re_{MAC}=5.2M$].

2.9.9.7 Dynamic Pressure Data Method

The dynamic pressure data obtained using the model Kulites® provided an additional method for buffet boundary estimation. In this method, the critical span station was first identified through an examination of wing spanload, similar to that presented in Figure 2-71. After identifying a critical wing span station (or spanwise range of interest) from the spanloads, a range of transducers of interest could be determined. (Note that a significant number of the original Kulites® were damaged in model transit from the manufacturer to the wind tunnel. Fortunately, many of these were repaired prior to testing, and so were able to provide key data during testing. However, since not all of the sensors were able to be repaired, Kulite® data had to be examined at the remaining functional stations.) The optimal sensor location for studying buffet onset is located immediately aft of the shock. This position provides the best visibility of the global mode structure over a range of model pitch angles (3), and also can provide insight into the underlying buffet flow physics. For locating precise shock location for unsteady data runs, the span stations with an array of three chordwise sensor locations were particularly useful. Once a specific sensor location downstream of the shock was identified, the data could be examined for a variety of different parameters.

The signals from individual sensors were examined for both RMS pressure fluctuations as well as for spectral content. The RMS pressure fluctuations provide an effective approach for monitoring the development of the flow unsteadiness as the aircraft angle of attack is increased. This can be done during a continuous pitch sweep of the model, to provide a continuous nonstationary time series. Using a sliding window to sample and analyze this time series, an RMS pressure can be calculated as a function of time (or angle of attack). Figure 2-84 shows an example of an RMS

Kulite® unsteady pressure signal. The Kulite® data shown [KW60U80] are for a sensor located at 60% span and 80% chord, and are presented for the conditions $M=0.8$, $Re_{MAC}=5.18M$, using the T1 (5%) trip, without aileron or strut flap deflections.

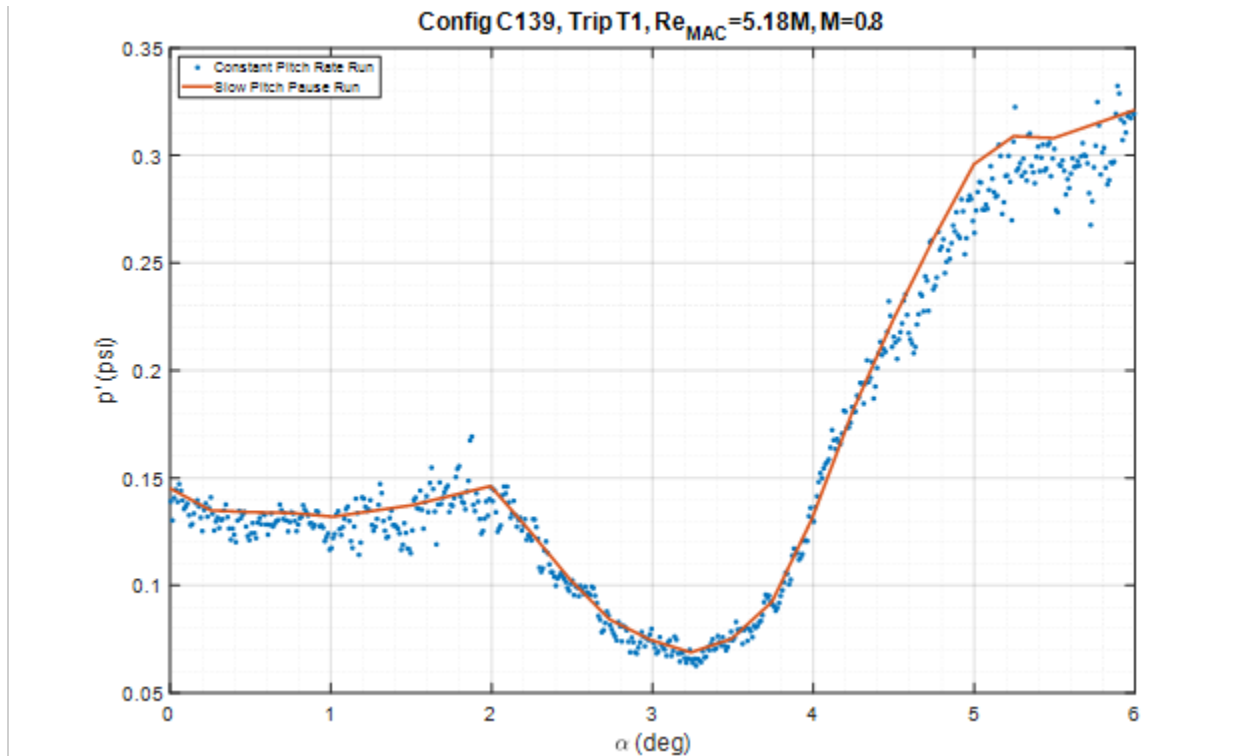


Figure 2-84. Representative Kulite RMS p' Signal [Config C139, $M=0.8$, Trip T1, $Re_{MAC}=5.2M$].

Typical of these RMS plots, there is an initial range (in this case $\alpha < 3^\circ$) where the pressure signature is moderately low and the dynamic pressure fluctuation is typically the result of forced flow oscillations. Beyond a critical angle of attack, the RMS rises monotonically with increasing angle of attack. After an increase of approximately one order of magnitude, the RMS level reaches a maximum or gradually plateaus, depending on the Mach number. This region is generally associated with buffet onset.

The RMS characteristics presented are consistent with airfoil buffeting flow phenomena (4), (5)), which have been linked to a global flow instability (6), (3). Subsequent investigations have shown similar global instability modes for infinite swept wings (7), (8) and finite-span tapered wings (9). These unstable modes are in good agreement with earlier experimental observations of Dandois (10).

The dynamic pressure power spectrum provides additional insight into the flow structure underlying the observed RMS rise. Figure 2-85 shows the spectrogram from a slow pitch pause run corresponding to the RMS plot ($\eta=0.6$) of Figure 2-84. The spectral peak around 400 Hz, and

the harmonic tone at 800Hz are known tunnel tones generated by the model support arc sector (11).

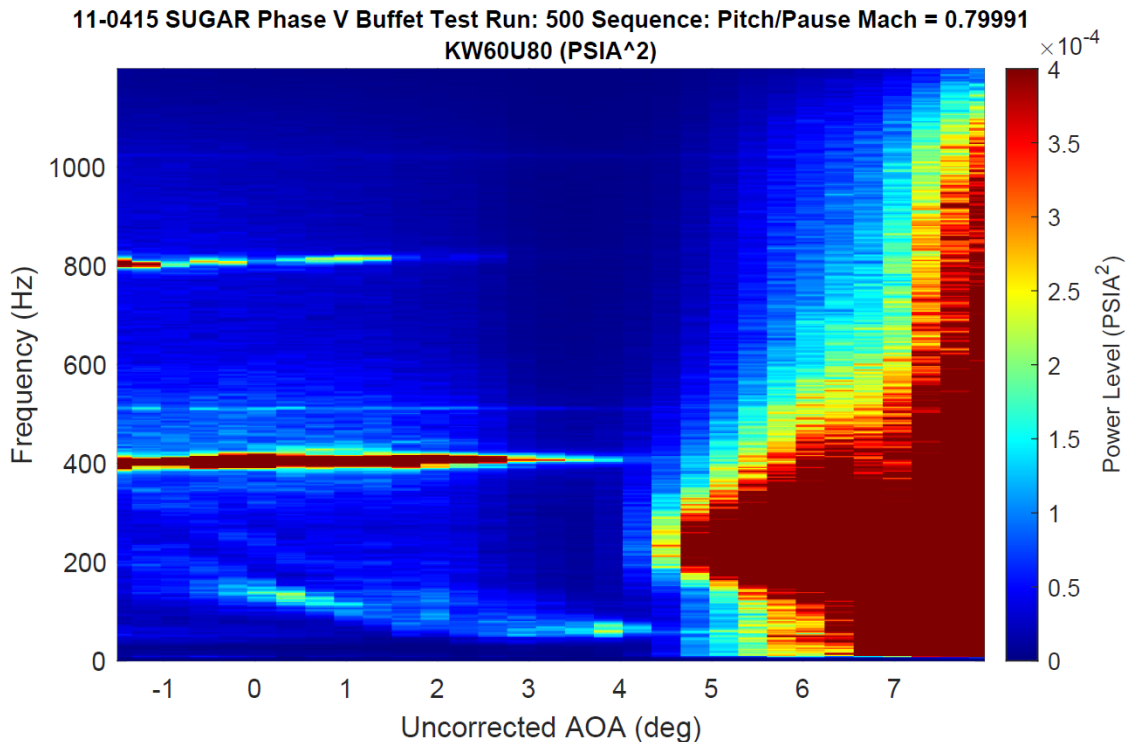


Figure 2-85. Power Spectral Density (PSD) [Config C139, M=0.8, Trip T1, $Re_{MAC}=5.2M$].

A comparison of the p' and Power Spectral Density (PSD) plots shows that the rapid rise in p' RMS is associated with a narrow frequency band around 210 Hz. This corresponds to a scaled frequency of $\omega=2\pi fc/U \approx 1.53$, where ' f ' represents frequency, ' c ' represents unit chord length, and ' U ' represents freestream velocity. Between $\alpha=4.5^\circ$ and 5.5° , the spectral plots show the rise of an additional peak around 50 Hz. This corresponds to a scaled frequency of $\omega \approx 0.36$. These frequencies are in general agreement with the predicted frequencies for a 20° leading-edge sweep airfoil (calculated based on the OAT15A airfoil section) (12). The stability results show two distinct instability modes, a 3D traveling mode at frequency $\omega \approx 1.5$ and a nominally-2D oscillatory mode at $\omega \approx 0.35$. This suggests that the observed rise in the dynamic pressure on the TTBW configuration is linked to global flow instabilities, similar to more canonical flows.

Based on the data obtained with the unsteady Kulite® pressures, a sample buffet boundary curve is shown in Figure 2-86 for the nominal test condition with forward trip T1.

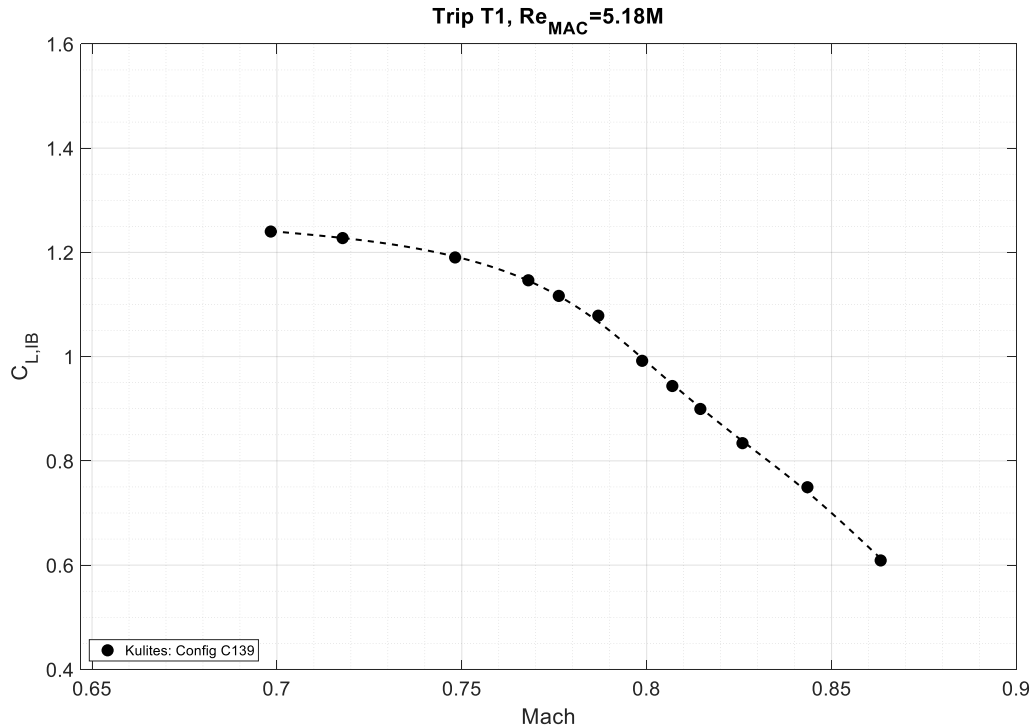


Figure 2-86. Buffet Onset Comparison [Config C139, Trip T1, $Re_{MAC}=5.2M$].

Note: Kulite® data availability was limited for several runs due to broken sensors near the critical span stations of $\eta=65\%$ and 72% . For consistency, the Kulite® buffet boundary is reported for all cases as an average of two buffet boundaries, determined at $\eta=50\%$ and 60% . This is consistent with the most critical span station located at $\eta=55\%$ for most cases. The interpolated averaging introduces some uncertainty in the Kulite®-based results.

Buffet boundary data collected from the methods presented above will next be compared for configurations and conditions of interest for the TTBW $M=0.80$ vehicle.

2.9.10 Buffet Methods Comparison on a TTBW

In this section, a comparison between the various buffet onset prediction methods as applied to the current TTBW configuration are presented.

The legacy pitching moment break and trailing edge pressure divergence methods introduced in Sections 2.9.9.2 and 2.9.9.3 are compared to the AFO and Kulite® methods in Figure 2-87 for the baseline configuration with the T1 (forward) trip. Between $M=0.70$ and $M=0.80$, the trailing edge pressure divergence method agrees fairly well with both the AFO and Kulite® buffet onset predictions. At the higher Mach numbers, the AFO method overpredicts the buffet margin relative to Kulite® measurements, while the trailing edge pressure divergence method predicts a more conservative buffet boundary than the Kulite® method. As discussed in Section 2.9.9.3, increasing uncertainty in the trailing edge pressure divergence method was observed toward

higher Mach numbers. This observation, taken together with the close agreement between AFO and Kulite® buffet onset predictions, casts doubt on the conservative (low) buffet boundary predicted by the sectional assessment of surface pressures with the trailing edge pressure divergence method at higher Mach numbers.

The buffet onset curve predicted by the pitching moment break method has even less margin than the buffet curve from the trailing edge pressure divergence method. However, the trend (shape) of the buffet curve does more closely resemble the trend of both the AFO and Kulite® buffet curves. This suggests that the pitching moment break could potentially provide useful information about buffet onset but an empirical offset would be needed to obtain more accurate estimates of the C_L level where buffet will occur for the present TTBW model.

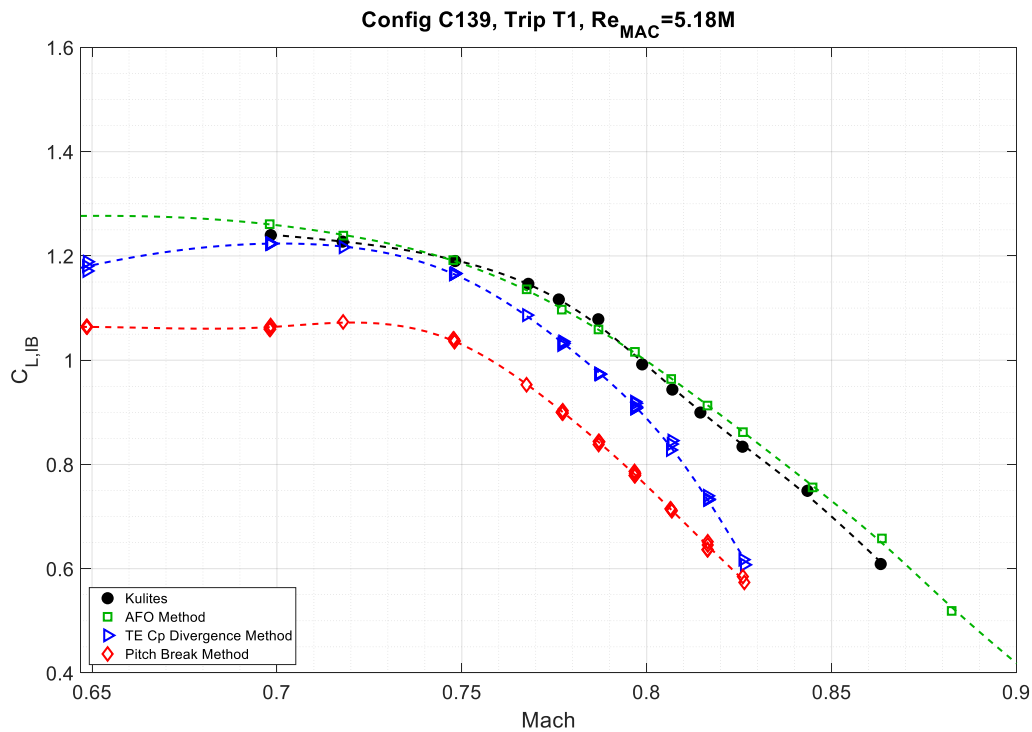


Figure 2-87. Buffet Method Comparison: Legacy Methods [Config C139, Trip T1, $Re_{MAC}=5.2M$].

The buffet onset curves from the Kulites® and the strain gauges are compared in Figure 2-88 for the baseline configuration with T1 trip. Good agreement is generally observed between these methods. However, difficulty in determining the exact level of vibration that constitutes buffet provides a potential lack of precision. In particular, previously described difficulties in interpreting the RMS signal of WBM3 above $M=0.80$ suggest that this sensor is less reliable for the determination of buffet onset at higher Mach numbers. This lack of reliability may also explain the upward turn in the WBM3 buffet curve, whereas strain gauges WBM1 and WBM2 agree well with the curve predicted by the Kulite® method up to $M=0.83$. However, since the

strain gauges directly measure the structural response of the model, the detection of unsteadiness in internal loads is considered a strong indicator of buffet. Therefore, the good agreement between the presented data gives confidence that the buffet onset predicted with both the Kulite® and the AFO method are successfully capturing the global flow unsteadiness.

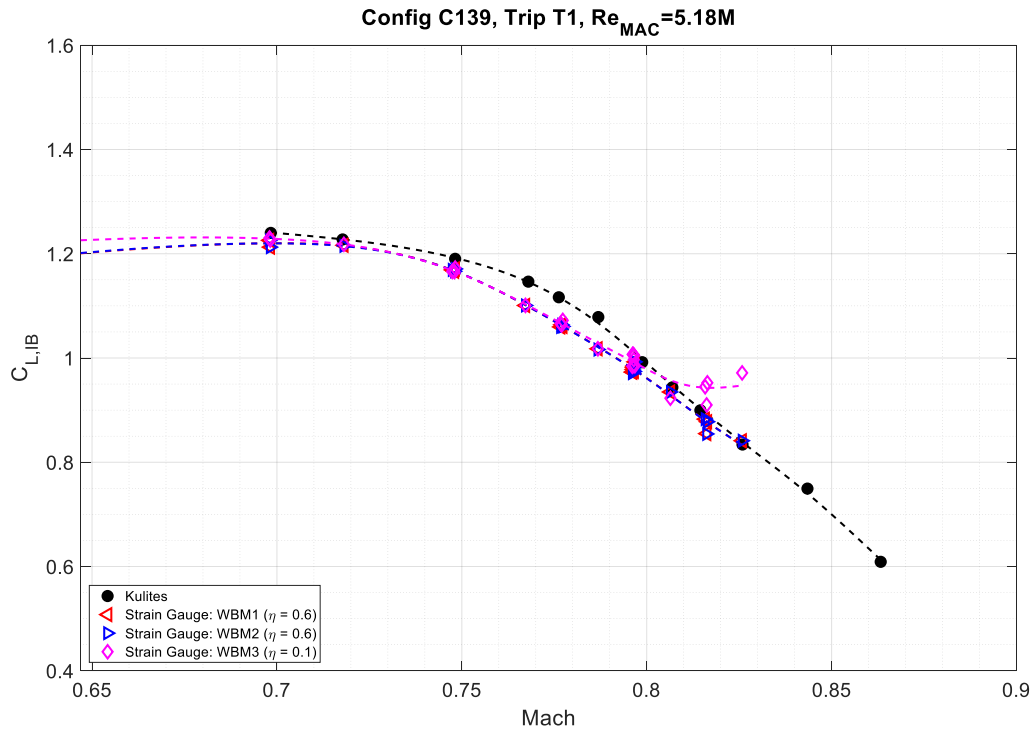


Figure 2-88. Buffet Method Comparison: Strain Gauges and Kulites® [Config C139, Trip T1, $Re_{MAC}=5.2M$].

The buffet boundary extracted from the accelerometer data is compared to the Kulite® buffet boundary in Figure 2-89 for the baseline configuration. Similar to the prediction from the strain gauge data, the accelerometer method predicts a slightly lower buffet boundary in comparison to the Kulite® method, with the exception of the region above $M=0.8$ in the AW36 curve. The agreement between the Kulite® and strain gauge methods is closest at the ends of the strain gauge-derived curves (i.e., at $M=0.7$ and $M=0.82$) and most different around $M=0.78$.

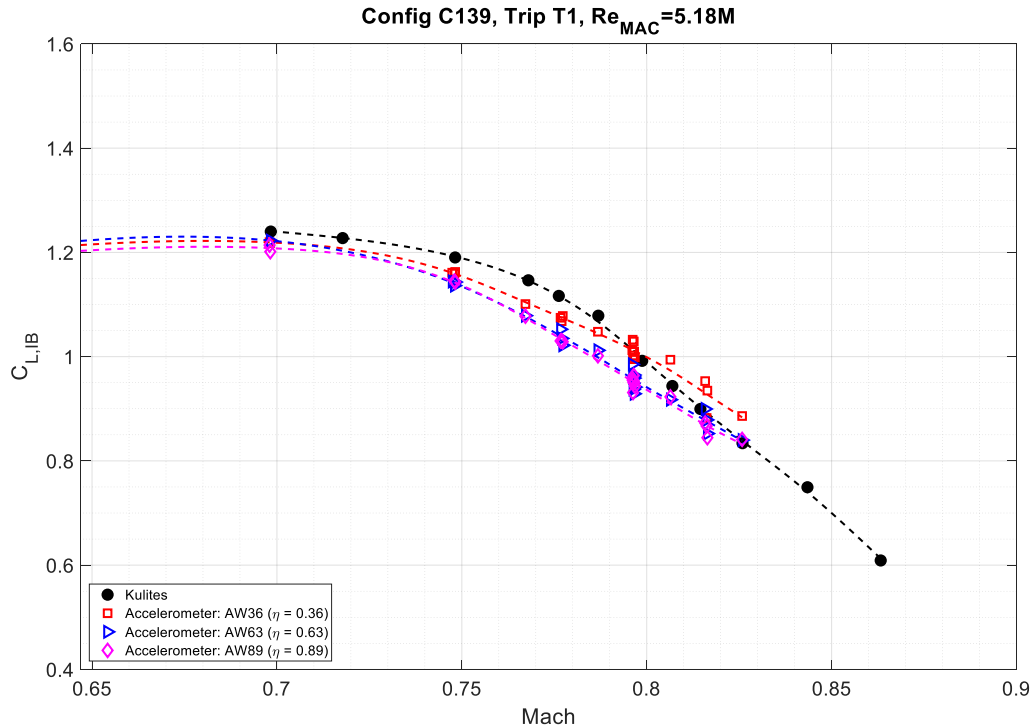


Figure 2-89. Buffet Method Comparison: Accelerometers and Kulites® [Config C139, Trip T1, $Re_{MAC}=5.2M$].

In summary, for the baseline configuration with undeflected control surfaces and T1 trip at $Re_{MAC}=5.18M$, the predicted buffet boundaries are fairly consistent between the AFO, Kulite®, strain gauge, and accelerometer methods. These methods (in general) measure global effects to determine the buffet boundary. Conversely, the pitching moment break and trailing edge pressure divergence methods did not agree particularly well with the Kulite® data. These methods are based on sectional properties that seem less suited for quantifying buffet onset on this configuration. These methods will therefore not be included in subsequent discussion.

Encouragingly, the concern of buffet at low C_L was not observed for the baseline configuration – the buffet predictions for the TTBW resemble those of a conventional wing. However, in contrast to a conventional wing, the critical span station for the TTBW is predicted in the midboard region, rather than farther outboard. This change would suggest that the TTBW may have a reduced propensity for pitch-up at buffet as compared to conventional configurations.

2.9.10.1 Spanload Modification Effects

To gain improved understanding of critical span stations, a series of runs in which the ailerons and outboard strut flap were deflected to alter wing spanload were examined. The results of these investigations are compared in Figure 2-90, Figure 2-91, and Figure 2-92 for different combined aileron deflection angles at $Re_{MAC}=5.18M$. Figure 2-96 presents data for the same conditions but with the strut flap deflected.

Figure 2-90 presents data for the 0° aileron deflection case, comparing Kulite®, AFO, and strain gauge measurements. As previously discussed, good agreement is observed between these methods for undeflected ailerons. Of the three methods, the strain gauge data yielded the most conservative buffet boundary prediction. Due to differences in the shapes of the buffet boundary curves, however, the gap between the strain gauge buffet curve and the Kulite® buffet curve diminishes above $M=0.80$.

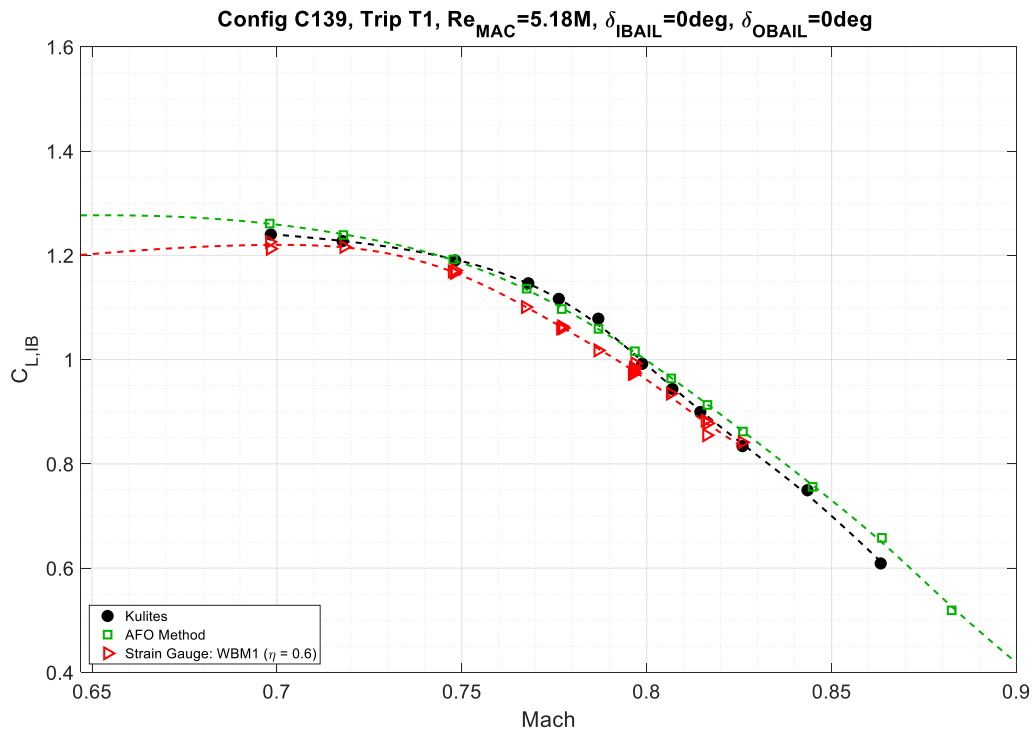


Figure 2-90. Buffet Method Comparison: 0° Aileron Deflection [Config C139, Trip T1, $Re_{MAC}=5.2M$, $\delta_{IBAIL}=\delta_{OBAIL}=0^\circ$].

For negative aileron deflection angles (Figure 2-91), the AFO method predicts a shift in the buffet boundary towards lower C_L . This trend is also seen in the Kulite® and strain gauge buffet onset curves in Figure 2-91. At $M=0.70$ and $M=0.87$, the Kulite® and AFO method predictions deviate more for the -5° aileron deflection case than they did for the undeflected aileron case, while the strain gauge data still skews slightly more conservative than the other methods but matches the Kulite® data fairly closely at $Mach=0.80$.

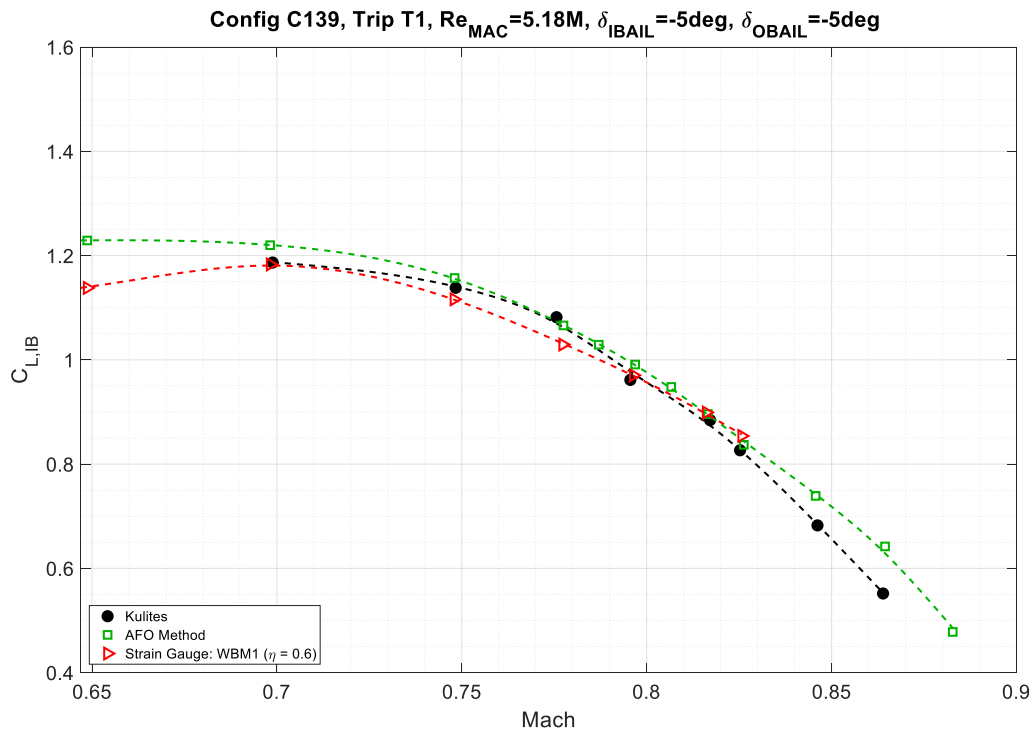


Figure 2-91. Buffet Method Comparison: -5° Aileron Deflection [Config C139, Trip T1, $Re_{MAC}=5.2M$, $\delta_{IBAIL}=\delta_{OBAIL}=-5^\circ$].

The buffet predictions for a positive aileron deflection angle of 5° are compared in Figure 2-92. A higher buffet boundary is typically not observed when the load on the outboard wing is increased. While Kulite® and AFO buffet onset predictions agree well for the positive aileron deflection angle case, the strain gauge again predicts a slightly lower buffet boundary up to M=0.82.

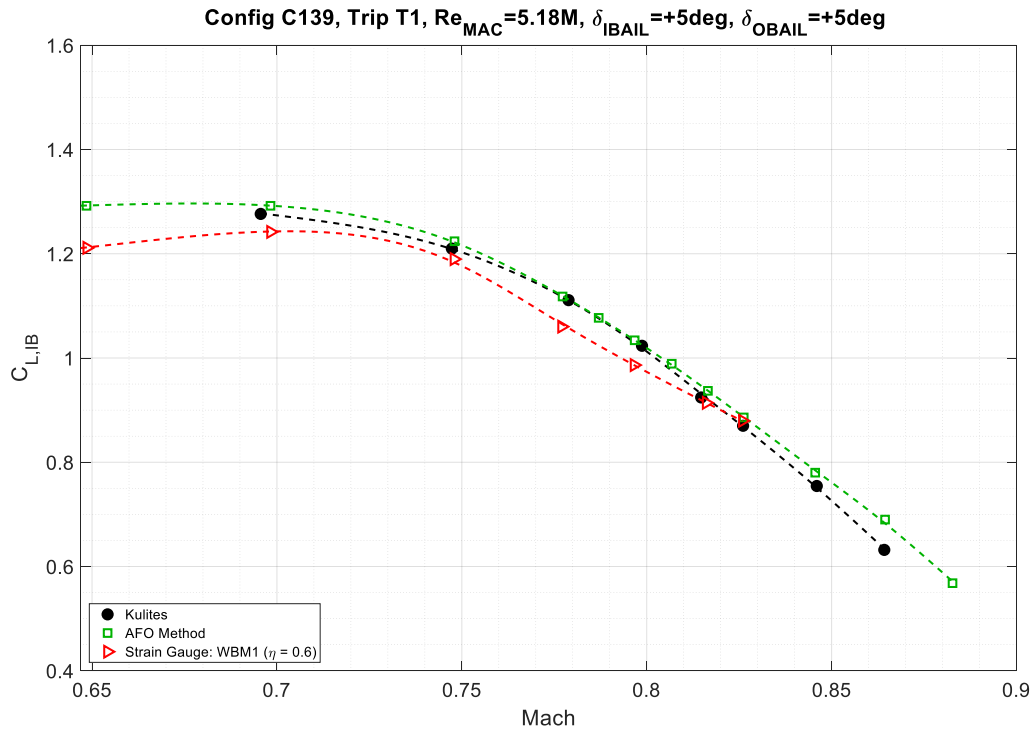


Figure 2-92. Buffet Method Comparison: +5° Aileron Deflection [Config C139, Trip T1, $Re_{MAC}=5.2M$, $\delta_{IBAIL}=\delta_{OBAIL}=5^\circ$].

The effect of aileron deflection is shown for the AFO data in Figure 2-93. Synchronous deflection of both inboard and outboard ailerons shifts the buffet onset curve relative to the undeflected baseline case. While negative aileron deflection angles reduce $C_{L,IB}$ for any given Mach number, positive aileron deflection angles increase $C_{L,IB}$.

The changes in the buffet boundary due to aileron deflections coincide with the changes in the shock location observed in Figure 2-94 at M=0.75 and $\alpha=5.0$ deg. For positive aileron deflection angles, the shock locations move in the downstream direction at $\eta=81.0\%$, increasing the spanload on the outboard wing. The buffet boundary is increased relative to the undeflected aileron case in Figure 2-93. Contrarily, for negative aileron deflection angles, the shock location moves in the upstream direction over a broader section of the outboard wing ($\eta=73.1\%$ to 88.3% in Figure 2-94) and thereby reducing the spanload. The buffet boundary is decreased relative to the undeflected aileron case in Figure 2-93.

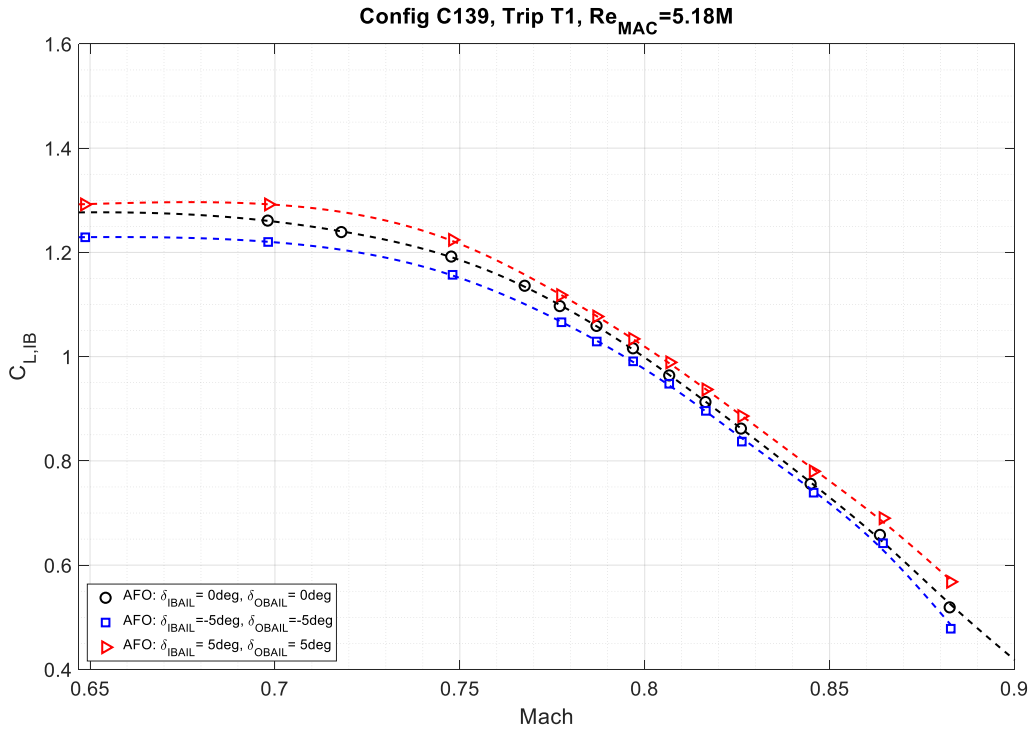


Figure 2-93. AFO: Aileron Effect [Config C139, Trip T1, $Re_{MAC}=5.2M$].

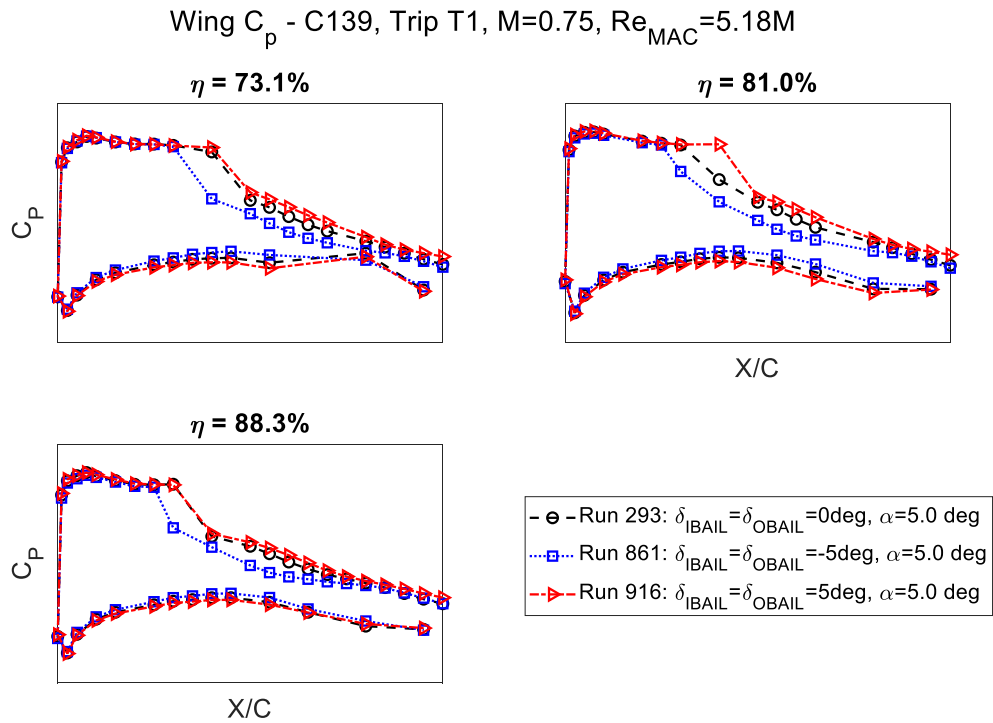


Figure 2-94. Pressure Distribution: Aileron Effect [Config C139, Trip T1, $M=0.75$, $Re_{MAC}=5.2M$].

It is perhaps important to note based on the data in Figure 2-95 that although spanload was effectively changed through aileron deflections, the spanload was never sufficiently altered such that the critical station moved in spanwise location as is typically common with cantilevered wings. Recall those wings typically have critical sections at ~70% span and as such would be more affected by changes in aileron deflection. When viewed through this lens, the data presented in Figure 2-93 could be interpreted to mean that total lift is varied through deflection of the aileron but the section of the wing that is buffet critical becomes critical at roughly the same point.

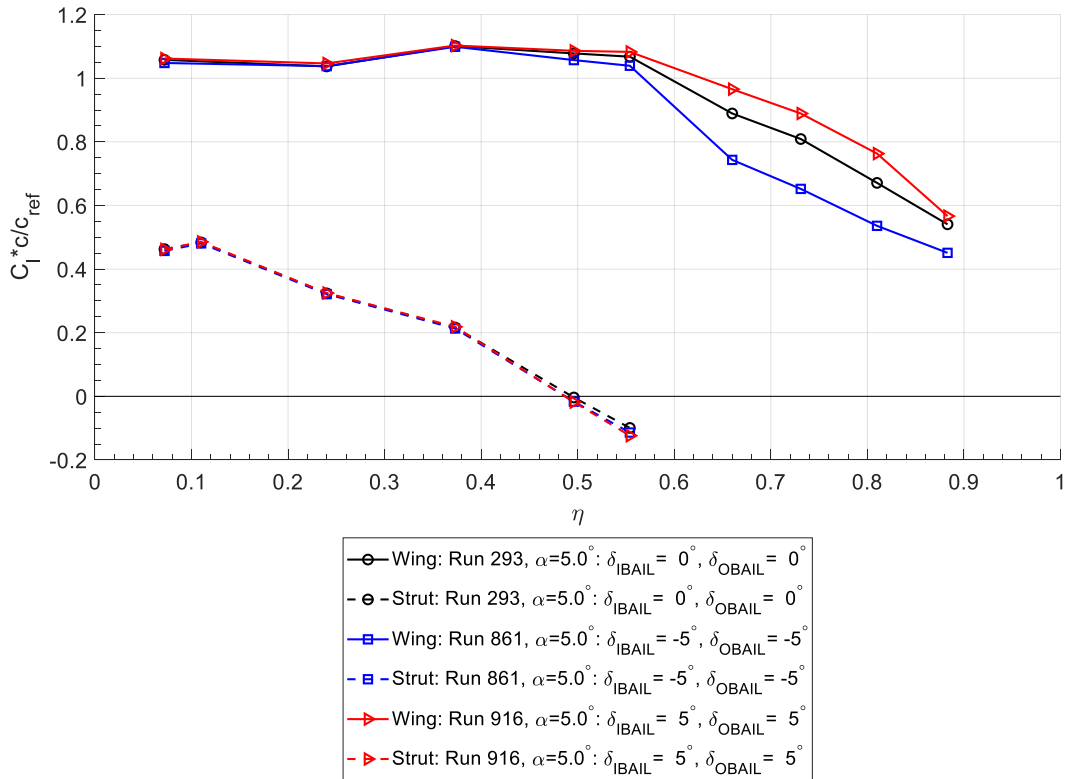


Figure 2-95. Aileron Deflection Effect on Spanloads [Config C139, Trip T1, M=0.75, Re_{MAC}=5.2M].

Outboard strut flap deflections were investigated as a potential buffet mitigation path for a situation in which the channel is buffet critical. Results presented in Figure 2-96 show the effect of outboard strut flap deflection for the maximum and minimum deflection angles of $\pm 4^\circ$. (For clarity, tested strut flap deflection angles of ± 2 deg are omitted in the plot.) For the larger strut flap deflection angles (± 4 deg), no significant impact on the buffet boundary is observed for configuration C139 at $Re_{MAC} = 5.18M$. This indicates that although the local strut download in the wing-strut channel moves the critical buffet span station inboard, the channel flow itself is not critical for the determination of buffet boundary. This finding alleviates concerns raised prior to this test and strengthens the confidence in the observation that the buffet behavior of the TTBW is driven by the wing – similar to a conventional wing.

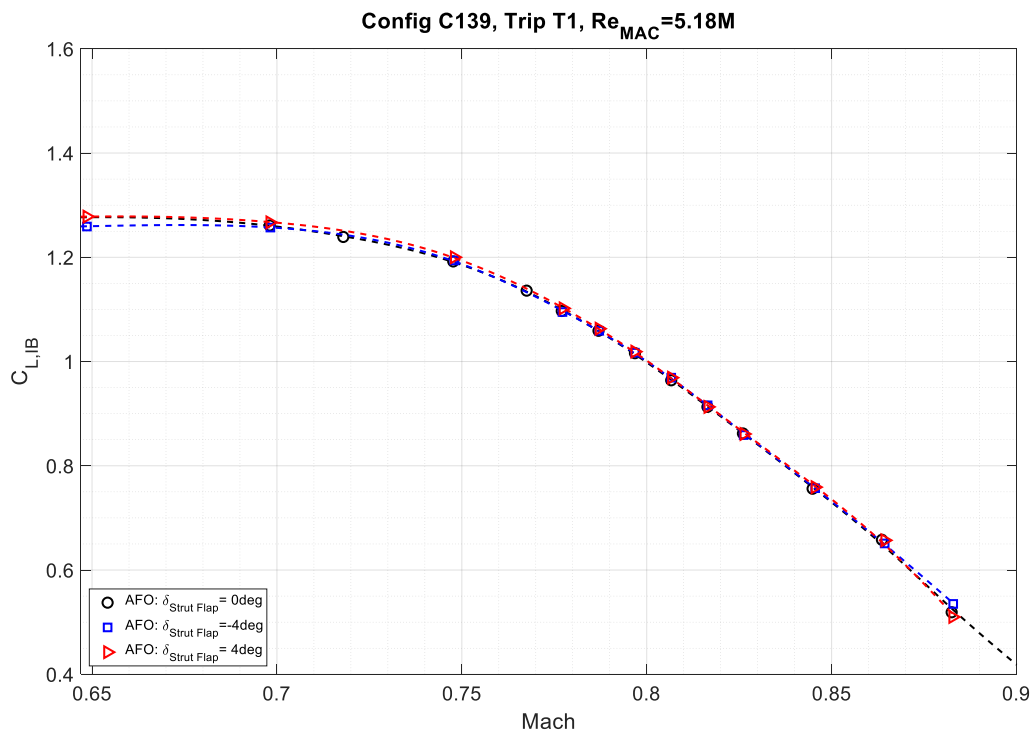


Figure 2-96. AFO: Strut Flap Effect [Config C139, Trip T1, $Re_{MAC}=5.2M$].

2.9.10.2 Trip Location Effects

In this section, the effect of boundary layer (BL) trip location on the baseline configuration buffet onset is considered. Figure 2-97 presents initial buffet curves computed using the AFO method at $Re_{MAC}=5.18M$. $C_{L,IB}$ is nearly identical for all trip configurations at Mach 0.65. As Mach number increases, significant deviation in $C_{L,IB}$ is observed depending on the trip location. Up to Mach=0.75, the smallest $C_{L,IB}$ is predicted for both the T1 (5% chord wing trip and 10% chord strut trip) and T5 (5% wing trip and strut transition free) configurations. For larger Mach numbers ($M \geq 0.8$), free transition on the strut moves the buffet boundary to larger $C_{L,IB}$. This sensitivity to the state of the strut BL is likely due to the fact that the strut lifts more with free transition (thinner BL), which unloads the wing allowing for a slight increase in margin to buffet onset. Moving the wing trip location downstream to 25% chord (i.e., T3 and T6) significantly increases $C_{L,IB}$ specifically for Mach numbers between 0.7 and 0.8. At Mach numbers greater than 0.8, the $C_{L,IB}$ increase relative to the forward trip configurations (T1 and T5) diminishes. The same trend of increased $C_{L,IB}$ is observed, if the trip location is moved further downstream to 40% chord (T4) and even more so if no tripping is employed on the midboard wing (T3.1).

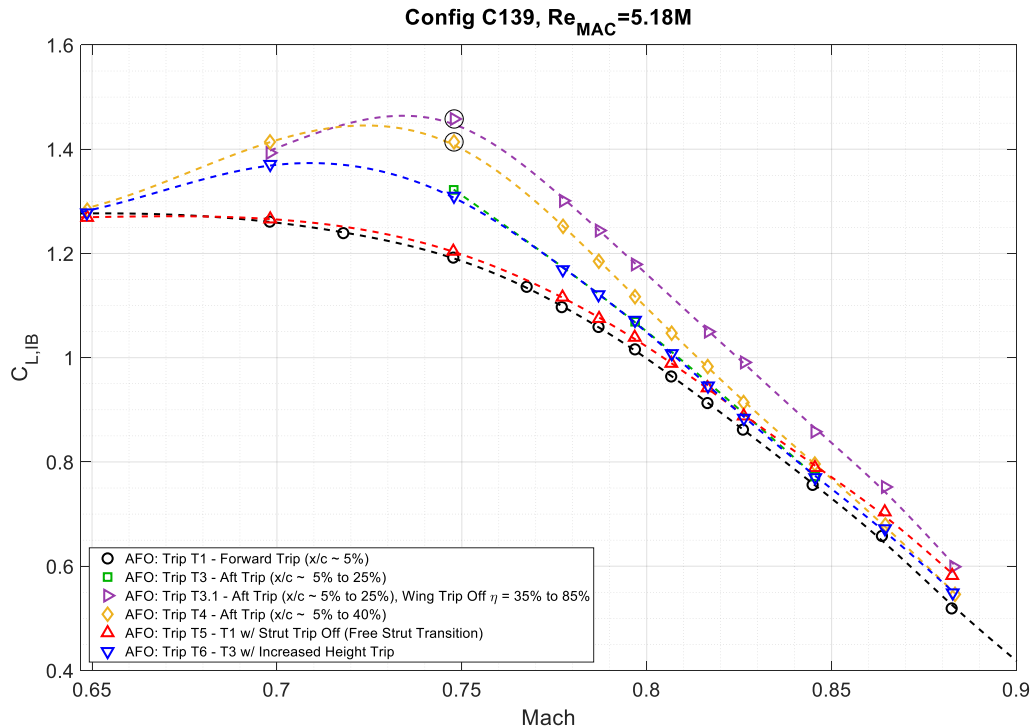


Figure 2-97. AFO: Wing Trip Location Effect [Config C139, $Re_{MAC}=5.2M$].

The influence of trip location on wing pressure distributions was shown previously in Figure 2-58 at $M=0.8$ and $\alpha=4.0^\circ$, slightly below the buffet boundary. As the wing trip location is moved downstream (T1 to T3 in Figure 2-58 and Figure 2-59, and T3 to T4 in Figure 2-60 and Figure 2-61), the shock location moves downstream as well. The aft shock movement is driven by increased

effective airfoil camber from a thinner BL. This BL is healthier and less susceptible to shock-induced separation at a given angle of attack. Despite the aft shock position and increased strength, which can contribute to separation, the healthier BL is considered the likely reason for the increase in $C_{L,IB}$ for the aft trip AFO results. With these flow physics established, the increase in $C_{L,IB}$ with aft trip data is larger than anticipated based on pretest predictions. Furthermore, it should be mentioned that the AFO $C_{L,IB}$ predictions for $M=0.75$ with T3.1 and T4 is calculated based on extrapolated C_L data due to a limited angle of attack range caused by wind tunnel model structural limitations. Here, the extrapolated C_L data predict a monotonously increasing trend with increasing α , which may lead to an overestimate in $C_{L,IB}$ at $M=0.75$ for T3.1 and T4. These data points are highlighted with circles in Figure 2-97 and Figure 2-98.

Figure 2-98 compares C139 buffet boundaries for three wing trip patterns computed using the AFO method and Kulite® data. This comparison indicates that the Kulite®-derived $C_{L,IB}$ levels do not change nearly as much with aft trip movement as the AFO results indicate. On the contrary, the Kulite® buffet boundaries for forward (T1) and aft (T4) BL transition are fairly similar in level and shape. So, while the two methods agree well for forward tripping (T1) below $M=0.8$, they deviate significantly in the same Mach range for the aft trip (T4). As discussed before, limited data availability and thus extrapolation weakens the trustworthiness of the AFO buffet margin.

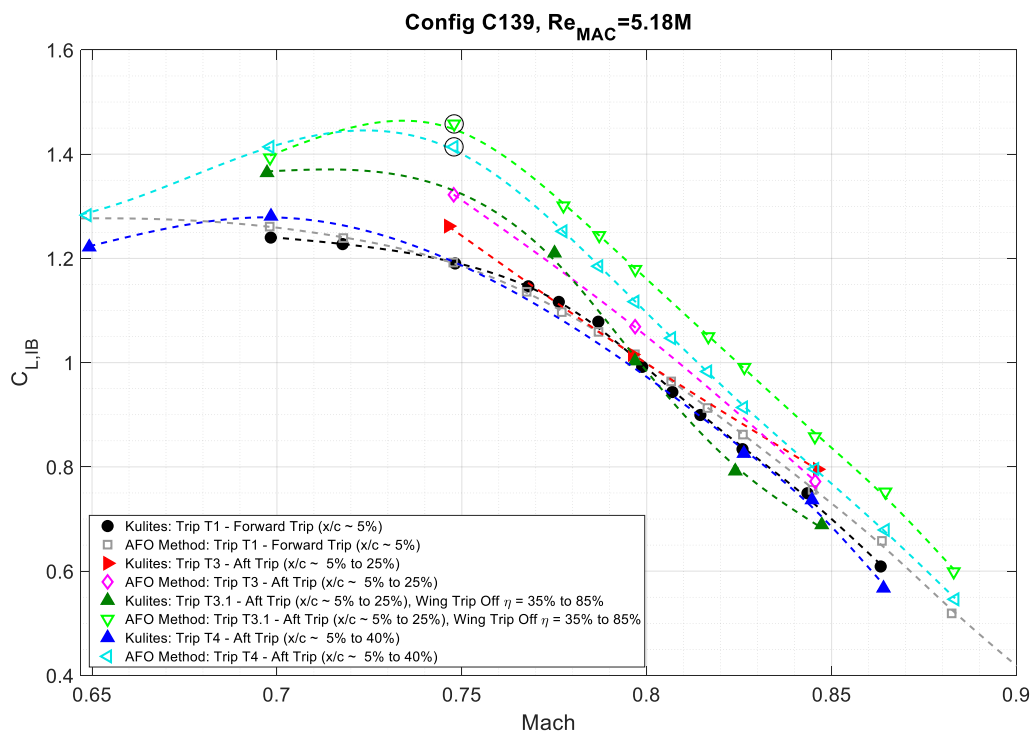


Figure 2-98. Buffet Method Comparison: Effect of Tripping [Config C139, $Re_{MAC}=5.2M$].

With the wing trip dots installed at 25% chord (T3), the Kulite® data indicates an increase in the buffet boundary for $M=0.75$ and $M=0.85$ relative to T1. To an even greater degree, the AFO method also predicts an increase in buffet margin when going from T1 to T3 for this Mach range. However, given the limited amount of data available with the T3 trip pattern and the fact that the Kulite® data indicates similar buffet onset boundaries for T1, T3, and T4 at $M=0.8$ (directly in between $M=0.75$ and $M=0.85$), no clear conclusion can be drawn regarding buffet onset for higher Mach number conditions.

2.9.10.3 Reynolds Number Effect

The effect of Reynolds number on initial buffet boundary curves is shown in Figure 2-99. For the AFO method, a general trend of increased $C_{L,IB}$ at a given Mach number with increased Reynolds number is observed. However, the highest MAC Reynolds number of 6.58M does not follow this trend except for the $M=0.78$ data. Limited data availability due to structural limits of the wind tunnel model introduced high levels of uncertainty for the AFO analysis. For $M=0.75$, 0.78, and 0.80, $C_{L,IB}$ was calculated based on extrapolated C_L data for the highest Reynolds number.

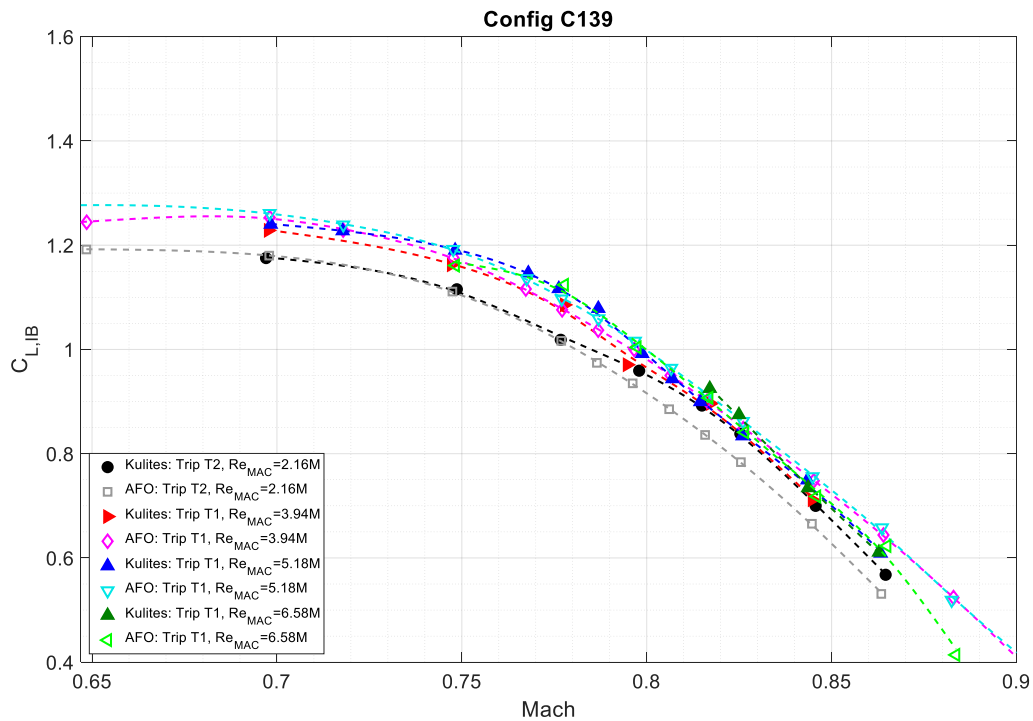


Figure 2-99. Buffet Method Comparison: Effect of Reynolds Number [Config C139].

Wing surface pressure distributions for all Reynolds numbers are plotted at $\alpha=4.0^\circ$ and $M=0.80$ in the Reynolds Number Effects section of the report (see 2.9.6). The chordwise shock location moves in the downstream direction with increasing Reynolds number, which is the same trend seen when moving boundary layer transition aft. Increasing Reynolds number and moving the

trip dots aft both result in a thinner boundary layer, which delays shock-induced separation and drives $C_{L,IB}$ higher.

Very good agreement between the AFO and Kulite® methods is observed for both $Re_{MAC}=2.16M$ and $3.94M$ over the entire Mach number range, strengthening the confidence in the predictions. The agreement between the methods is similarly good for $Re_{MAC}=5.18M$ and $Re_{MAC}=6.58M$ up to $M=0.85$. Beyond that, the buffet boundary prediction diverges with the Kulite® method predicting a slightly more conservative boundary. This results in the buffet boundary curves collapsing for the Kulite® data above $M=0.80$, indicating no significant effect of Reynolds number is present for higher Mach numbers, contrary to the predictions of the AFO method.

2.9.10.4 Configuration Effect

The effect of model configuration on buffet onset is shown in Figure 2-100 for the baseline configuration at $Re_{MAC}=5.18M$. Overall, the effect of the various model configurations is small with $\Delta C_{L,IB} < 0.1$ over the tested range. The initial buffet curve is shifted to smaller $C_{L,IB}$ if nacelle and flap hinge fairings are removed from the model (C141) compared to the baseline configuration (C139). The deviations are generally small but more pronounced for small Mach numbers ($0.6 < M < 0.77$) and large Mach numbers ($M > 0.85$). The effect of removing the flap hinge fairings from the model (C142) on the buffet boundary is negligible compared to the baseline configuration (C139). Some deviations are observed toward larger Mach numbers ($M > 0.87$), where the absence of the flap hinge fairing (C142) slightly increases $C_{L,IB}$ relative to the baseline configuration (C139). The buffet boundary predicted using Kulite® data is in good agreement with the AFO method. For the Kulite®-derived curves, a similar trend of decreased buffet margin is predicted for C141 compared to C139, while the deviations are more pronounced for Mach number between $M=0.75$ and 0.80 .

Pressure distributions for the midspan wing region at $M=0.80$ are given in Figure 2-101 at $\alpha=4.0^\circ$, which is close to buffet onset. Changes in the model configuration do not have a significant impact on wing shock location. With the flap fairings removed, there are differences in some of the lower surface pressures, particularly in the wing-strut channel. The lack of changes to the buffet boundary predictions for these cases once again confirms the channel flow is not buffet critical.

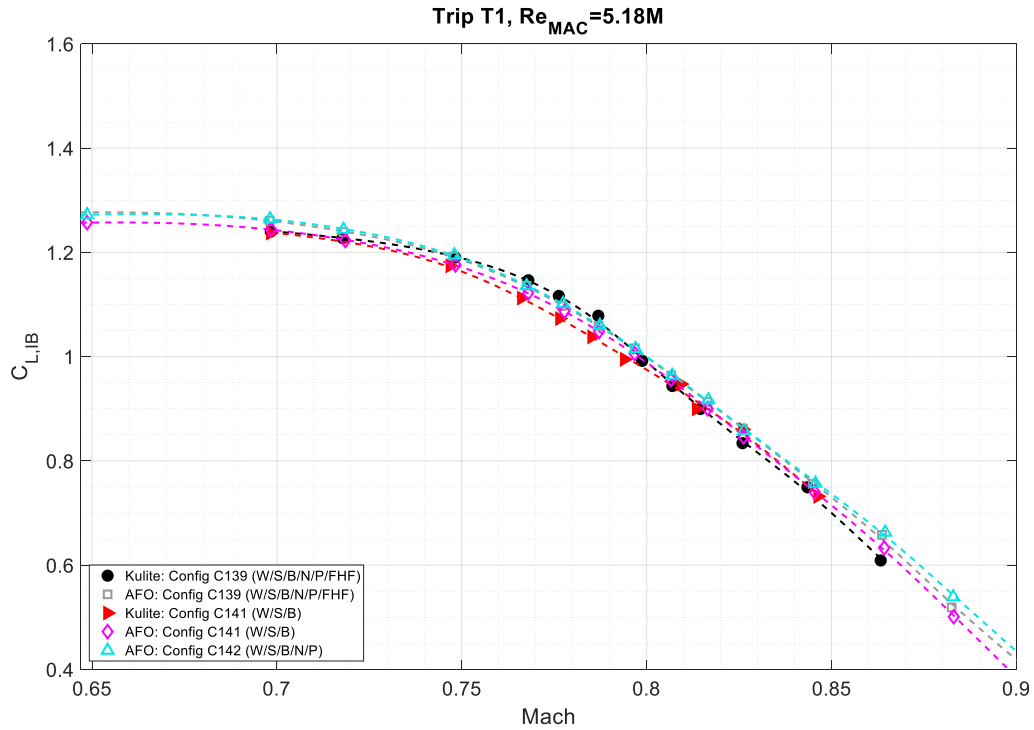


Figure 2-100. Buffet Method Comparison: Model Configuration Effect [Trip T1, $Re_{MAC}=5.2M$].

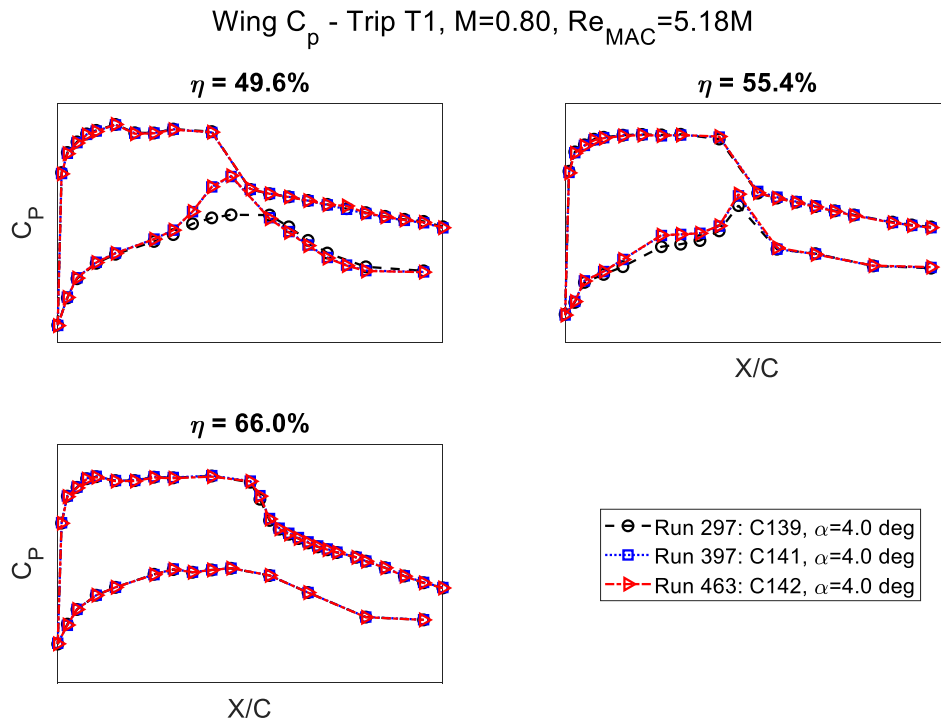


Figure 2-101. Pressure Distribution: Model Configuration Effect [$M=0.8$, Trip T1, $Re_{MAC}=5.2M$].

2.10 CFD Data Comparisons

In this section, the results of the buffet wind tunnel test are compared to pretest CFD predictions. The CFD simulation is based on the right side of the TTBW airplane and includes all model components tested for the C139 configuration. The CFD model includes the jury strut but this will not have a strong influence on the data comparisons as the jury strut is known to have a small effect on pressures, wing loading, and drag. All CFD data discussed here were generated using the OVERFLOW flow solver run on the structured overset mesh shown in Figure 2-102.

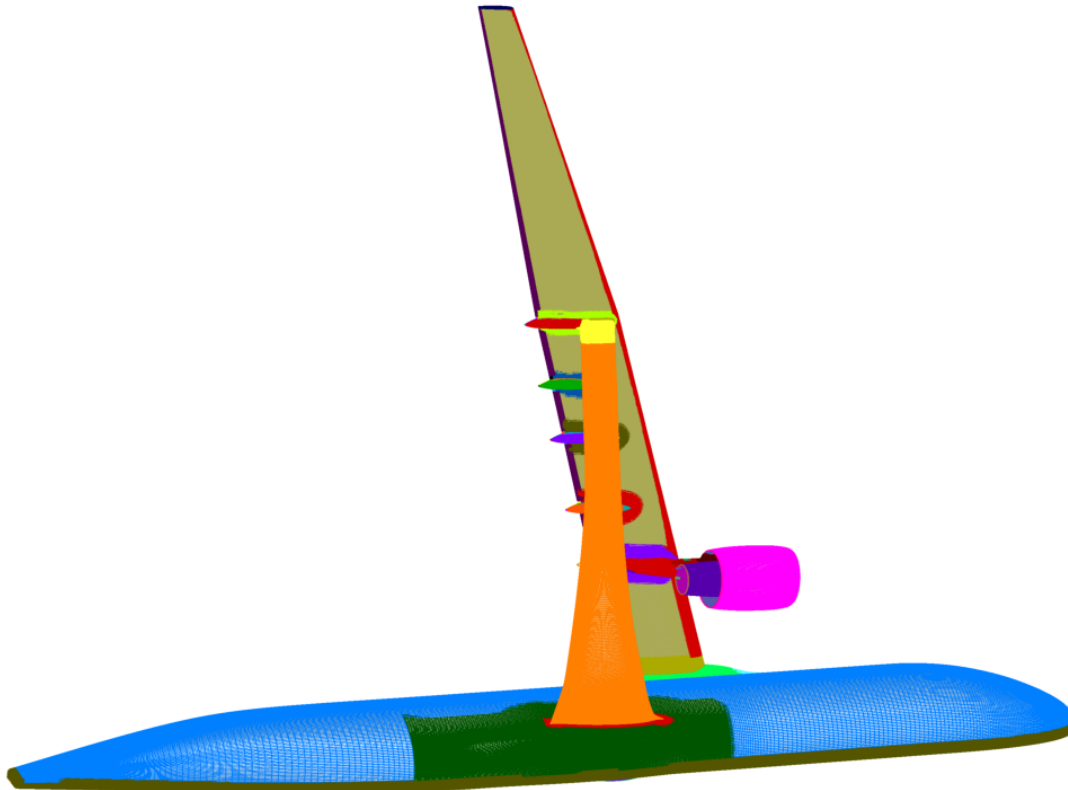


Figure 2-102. Buffet Semispan CFD Model.

The grid system is comprised of 80 individual zones with a total of 81.9 million points. The surface grid shown in red covering the wing leading edge is used to force the boundary layer to transition from laminar to turbulent at the forward trip location of 5%. A different grid defines the aft trip location. The brown grid located at the bottom of the fuselage is used to model the 0.7" profile plate that raises the model away from the test section floor. In addition to the profile plate, the CFD model includes three strategically placed keel dams used to minimize gap effects, and a circular adapter plate used to mount the model to the balance through a hole in the floor. These details in the CFD model can be seen in Figure 2-103.

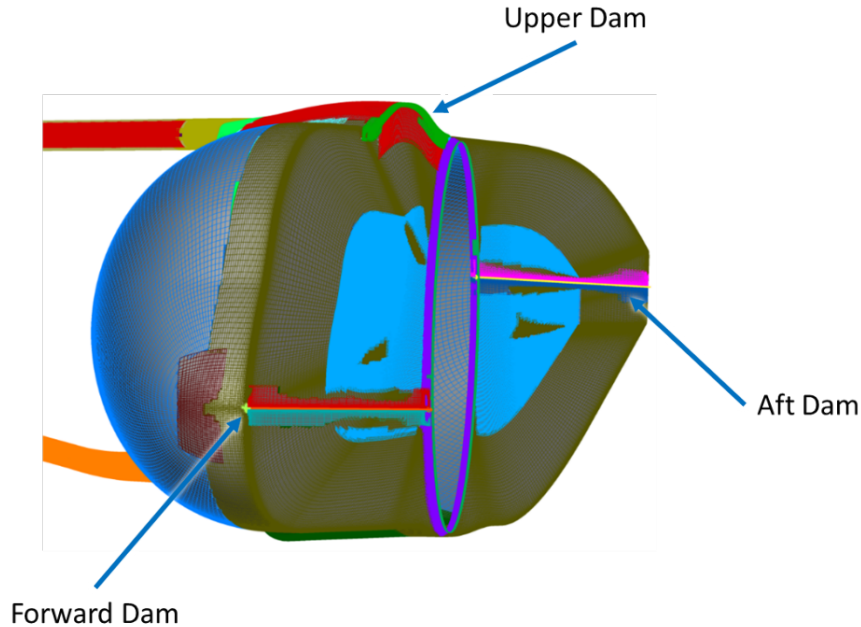


Figure 2-103. CFD Model Details Showing Keel Dams and Adapter Plate.

The pretest CFD simulations capture the effect of the test section floor with a no slip boundary condition set on a solid wall grid plane. More details on the development of the floor boundary layer will be discussed later in this section. The cut-away image shown in Figure 2-104 illustrates the relative size of the gap between the test section floor and the body backing plate (0.3"). This image does not include the keel dams and adapter plate for clarity. Figure 2-105 is another front view of the model correctly positioned above the floor. In this figure, the body profile plate and keel dams are shown to illustrate how the model-to-floor gap is reduced from 0.3" (from bottom edge of profile plate) to approximately 0.1" (from bottom edge of keel dams). It is interesting to note in this last figure how the wing/body fairing (WBF) was not simply extruded to define the profile plate like the rest of the fuselage. Instead, the profile plate is a designed extension of the WBF that improves the inboard wing loading making it similar to that of the full airplane model in free air.

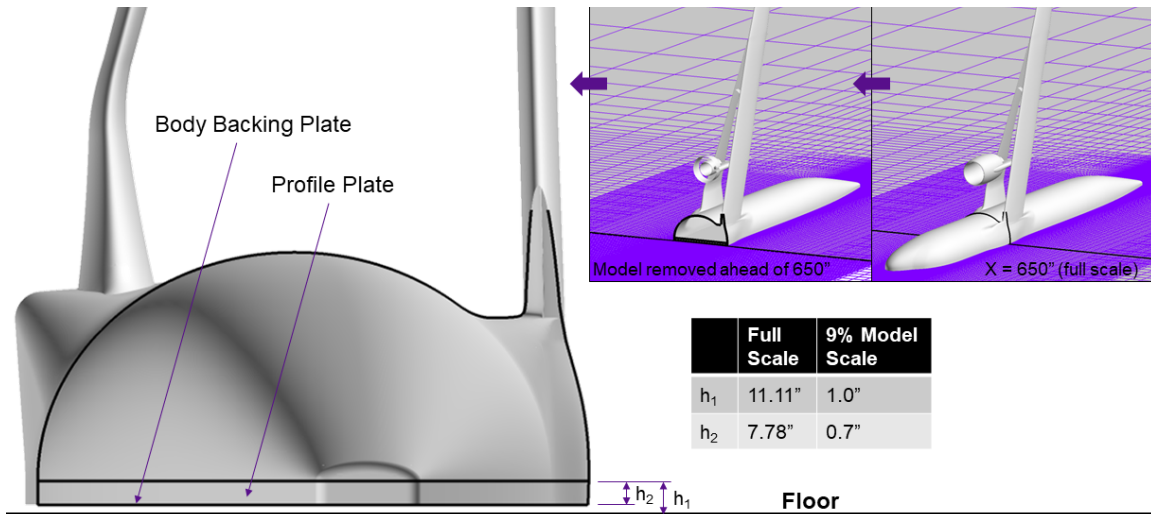


Figure 2-104. CFD Model in Proximity of Test Section Floor.

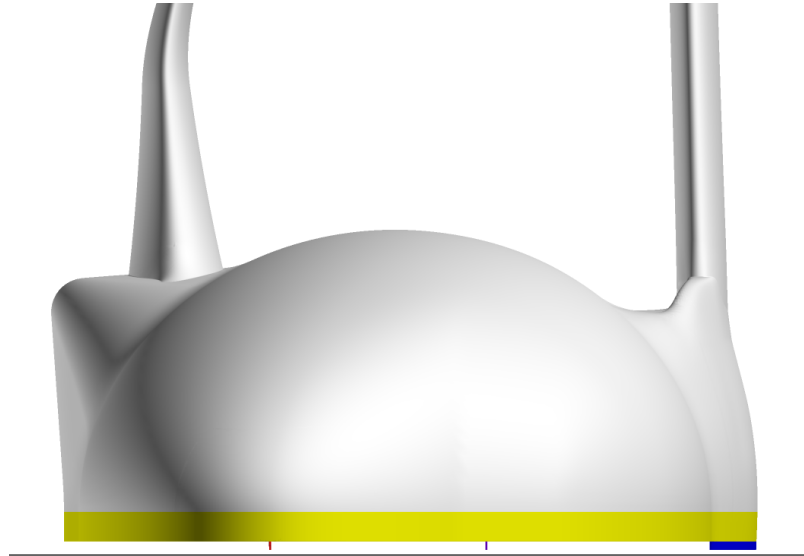


Figure 2-105. CFD Model with Profile Plate (yellow) and Keel Dams (blue, purple, red) Shown in Proximity of Test Section Floor.

A summary of OVERFLOW runs completed prior to the wind tunnel test is provided in Table 2-15. This table includes the type of run made and a brief geometry description of each configuration analyzed as well as key information associated with the simulation such as boundary layer trip location, the turbulence model used, and which freestream quantities were applied. The run type is provided in the matrix to give an indication of how the results are intended to be used. ‘Rigid’ runs utilize the 1G design twist distribution (not accounting for additional aeroelastic differences such as shear/bending), while ‘elastic’ refers to runs where the 1G model was aeroelastically twisted to represent the expected model twist under the given load and at the applied condition.

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Table 2-15. OVERFLOW Run Matrix.

Run Info				Configuration				Trip	Turb Model	CL / α	Mach Number	Re/ft (x10 ⁶)	Re _{mac} (x10 ⁶)	Temp (R)
#	Priority	Type	Aeroelastics	Description	Code	δ_{ail}	δ_{SF}							
Build Up														
1	1	cruise	rigid	WBS	C141	0	0	T1	SA	0.695	0.8	6.3	5.2	486
2	1	cruise	rigid	WBSNP	C142	0	0	T1	SA	0.695	0.8	6.3	5.2	486
3	1	cruise	rigid	WBSNPF	C139	0	0	T1	SA	0.695	0.8	6.3	5.2	486
4	1	cruise	rigid	WBSNPFJ	C143	0	0	T1	SA	0.695	0.8	6.3	5.2	486
Baseline														
5	1	polar	rigid	WBSNPFJ	C143	0	0	T1	SA	CL1	0.8	6.3	5.2	486
6	1	polar	rigid	WBSNPFJ	C143	0	0	T3	SA	CL1	0.8	6.3	5.2	486
7	1	1.3g	rigid	WBSNPFJ	C143	0	0	T3	SA	0.91	0.8	6.3	5.2	486
8	1	M _{MO}	rigid	WBSNPFJ	C143	0	0	T3	SA	0.616	0.85	6.3	5.2	486
9	1	1.3g	elastic	WBSNPFJ	C143	0	0	T3	SA	0.91	0.8	6.3	5.2	486
10	1	M _{MO}	elastic	WBSNPFJ	C143	0	0	T3	SA	0.616	0.85	6.3	5.2	486
11	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.4	6.3	5.2	486
12	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.5	6.3	5.2	486
13	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A2	0.65	6.3	5.2	486
14	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.7	6.3	5.2	486
15	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.72	6.3	5.2	486
16	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.75	6.3	5.2	486
17	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.77	6.3	5.2	486
18	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.8	6.3	5.2	486
19	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.82	6.3	5.2	486
20	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.84	6.3	5.2	486
21	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.85	6.3	5.2	486
22	1	AFO	rigid	WBSNPFJ	C143	0	0	T3	SA	A1	0.87	6.3	5.2	486
23	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.4	6.3	5.2	486
24	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.5	6.3	5.2	486
25	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A2	0.65	6.3	5.2	486
26	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.7	6.3	5.2	486
27	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.72	6.3	5.2	486
28	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.75	6.3	5.2	486
29	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.77	6.3	5.2	486
30	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.8	6.3	5.2	486
31	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.82	6.3	5.2	486
32	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.84	6.3	5.2	486
33	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.85	6.3	5.2	486
34	2	AFO	rigid	WBSNPFJ	C143	0	0	T1	SA	A1	0.87	6.3	5.2	486

OVERFLOW was run using two turbulence models to help quantify the uncertainty in the computed data: the Spalart-Allmaras (SA) 1-equation model (with the rotation and curvature corrections enabled), and the Shear Stress Transport (SST) 2-equation model. Other key solver information is provided below.

- OVERFLOW version 2.2g
- HLLC++ upwind scheme for diffusion terms
- SSOR implicit solver for convection terms
- Quadratic Constitutive Relation (QCR) turned on

Unless otherwise noted, the default turbulence model used for all CFD analyses was the SA model.

2.10.1 CFD Drag Component Increments

The “Build-Up” block of OVERFLOW runs shown in Table 2-15 were made to compare force and moment increments between CFD and test as well as between test entries. This build-up analysis was intended to ensure quality data were being measured for the new semispan model. The effect of each component was analyzed at a Reynolds number based on the Mean Aerodynamic Chord (MAC) of 5.2 million and the cruise design condition of Mach = 0.8 and $C_L = 0.695$. This condition corresponds to the tunnel condition of 6.3M/ft for which the model jig twist was designed. The four configurations analyzed for the build-up study are labeled using the letter designation shown in Table 2-11.

2.10.2 Floor Only

Wind tunnel installation effects have been quantified with OVERFLOW analyses of the semispan model in the presence of the floor only as well as a complete in-tunnel simulation (not discussed in this paper).

During positive load factor maneuvers (e.g., a 1g+ turn), high speed buffet onset for a well-designed TTBW will be driven by wing upper surface shock characteristics such as chordwise location and strength. Accurate buffet prediction methods must be able to capture and resolve shocks reasonably well, so an attempt is made to document and understand differences between computed and measured pressure data at three key conditions: 1g cruise, 1.3g cruise, and M_{MO} . The floor only OVERFLOW data created during the SUGAR Phase V contract will be compared directly with buffet test data for these three select conditions. This comparison will then be evaluated to account for the effects of turbulence model, model-to-floor sealing, and tunnel floor boundary layer height. General observations regarding shock location and strength will be made as a function of span.

2.10.2.1 Static Pressure Comparison at Mach = 0.8, $C_L = 0.695$

Wing and strut static pressures are compared at the midcruise design condition of $Re_{MAC} = 5.2M$, Mach = 0.8, and $C_L = 0.695$ for the forward trip location and the WBSNPFJ CFD configuration (note that the jury strut was not tested). The wind tunnel data selected for this comparison are from Run 297. Wing pressure comparisons are provided in three separate figures to keep plots legible. Figure 2-106 compares inboard wing pressures covering semispan stations of 7% to 37%. This comparison shows the floor-only CFD simulation using the SA turbulence model predicts the shock location to be roughly 5% to 10% aft of the test data. Upper surface CFD pressures forward of the shock are less negative and slightly more negative aft of the shock. Results using the SST turbulence model show better agreement with the experiment where the shock location is closer by a few percent of chord for the first two pressure rows.

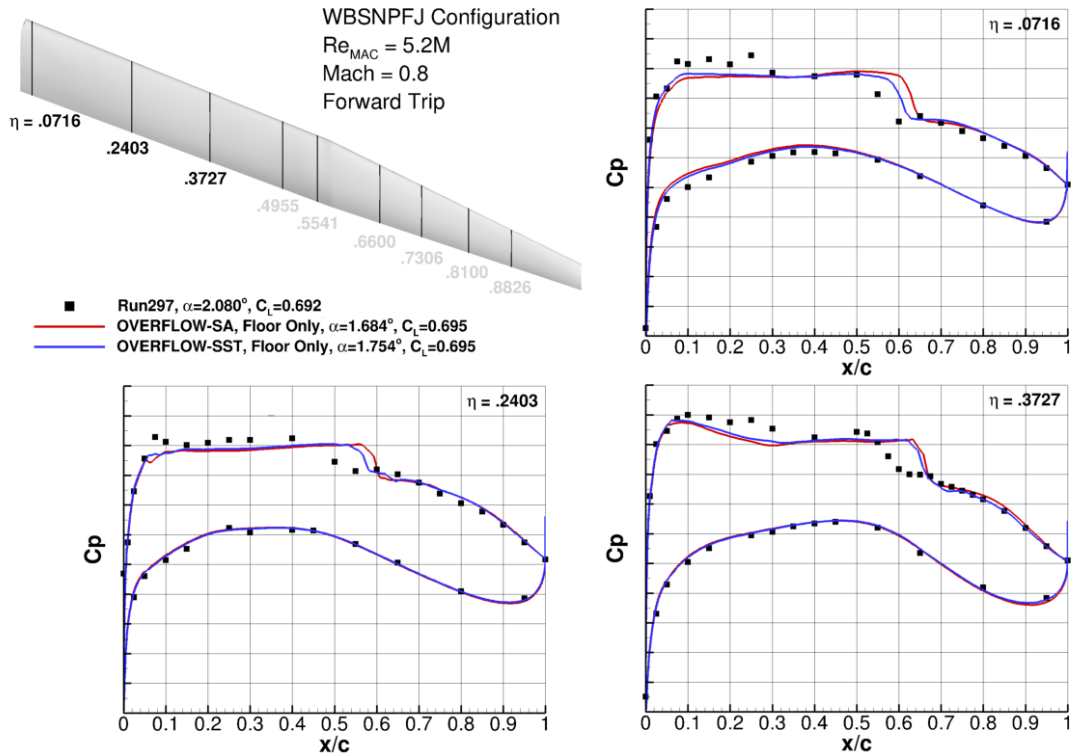


Figure 2-106. Forward Trip Wing Pressure Comparison at Design Condition: Inboard Wing [$M=0.8$, $Re_{MAC}=5.2M$, Fwd Trip].

Figure 2-107 compares midboard wing pressures covering semispan stations of 50% to 66%. Similar to the inboard comparison, the computed shock location is aft of the measured data by roughly 7% of chord for the SA model and a closer to 5% for the SST model. The juncture shock seen on the lower wing surface at 55.4% semispan agrees reasonably well for both turbulence models. Finally, the local suction peak in the buffet test pressures at 66% semispan is related to the forward trip dots applied to the model. This feature is not present in the aft trip data.

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

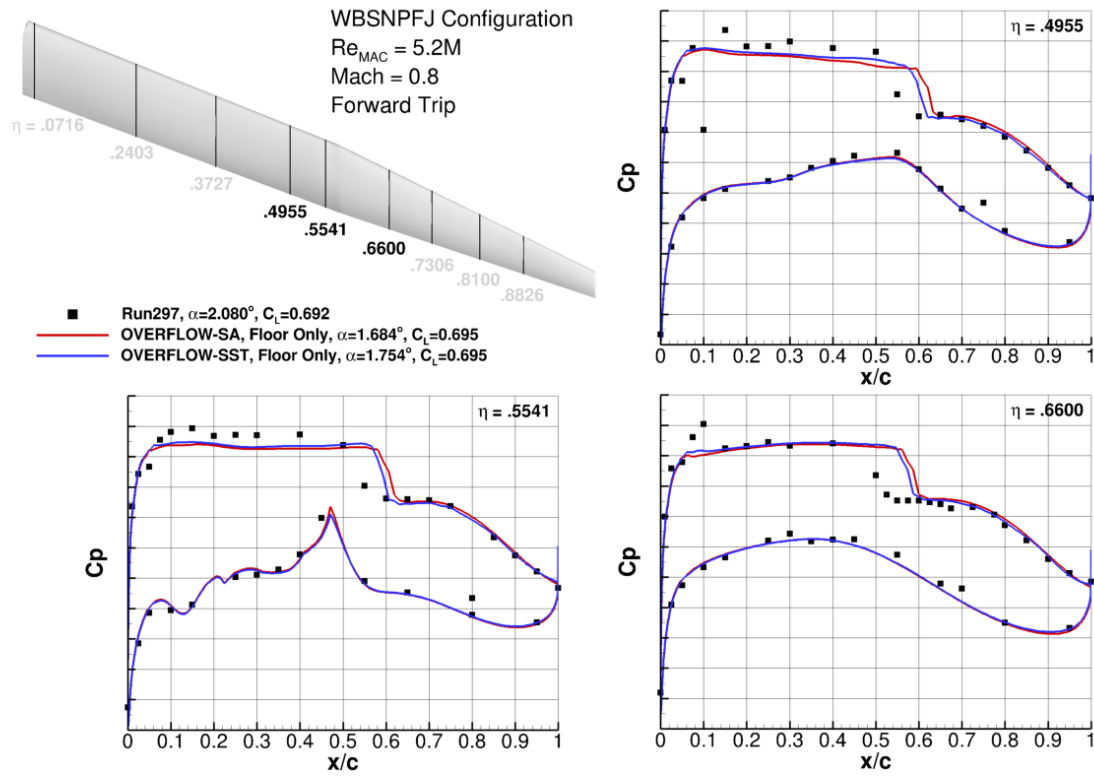


Figure 2-107. Forward Trip Wing Pressure Comparison at Design Condition: Midboard Wing [$M=0.8$, $Re_{MAC}=5.2M$, Fwd Trip].

Figure 2-108 compares outboard wing pressures covering semispan stations of 73% to 88%. It is more difficult to accurately quantify shock location from the test due to sparse pressure tap locations for the midcruise condition. It is clear that the difference between CFD and wind tunnel is no better on the outboard wing in terms of shock position. OVERFLOW predicts the shock to be 5% to 10% further aft relative to experiment with only a marginal difference between turbulence models. There is some improvement in upper surface pressure comparisons, particularly at 88.3% semispan.

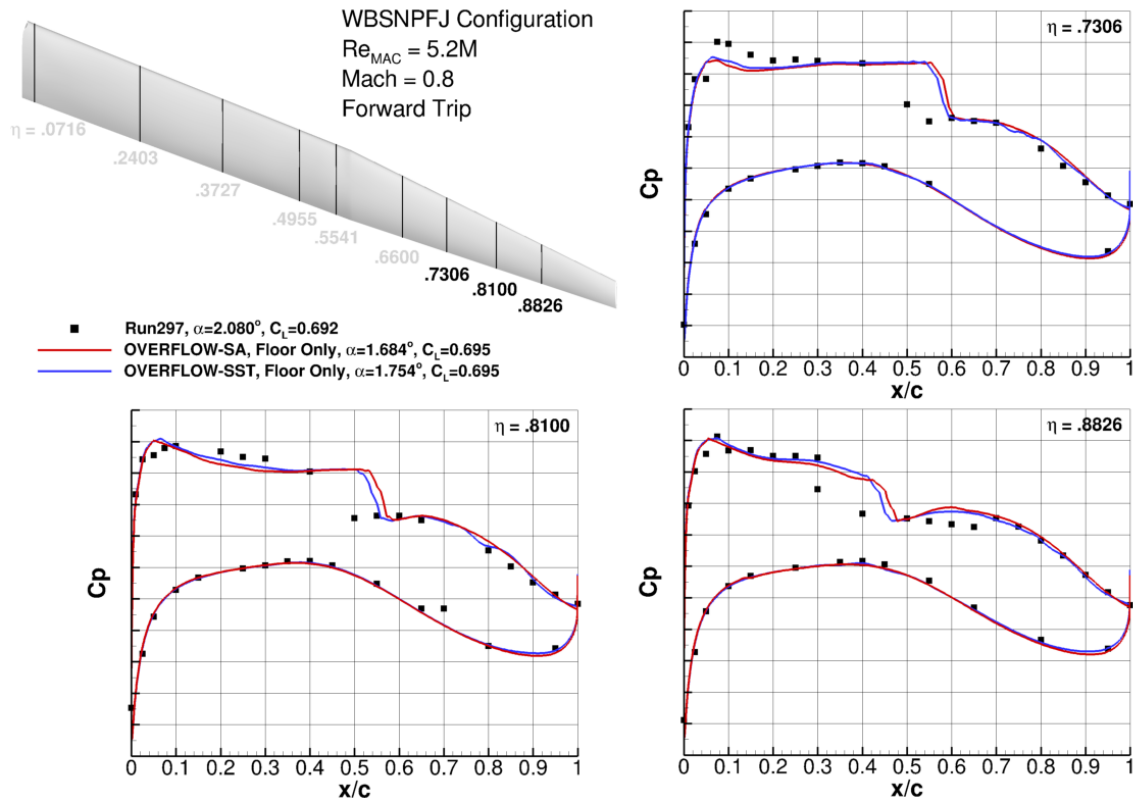


Figure 2-108. Forward Trip Wing Pressure Comparison at Design Condition: Outboard Wing [$M=0.8$, $Re_{MAC}=5.2M$, Fwd Trip].

Strut pressures are compared in Figure 2-109 and Figure 2-110 for the midcruise design condition. There are small differences in the computed pressures for the two turbulence models under study, but both sets of data are in good agreement with test data except near the leading edge on the upper surface. It is unclear whether there is a possibility of laminar flow in this region or if the trips are having a larger effect than expected. Unfortunately, the limited amount of mid-span upper surface pressure data from the experiment makes it difficult to draw firm conclusions.

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

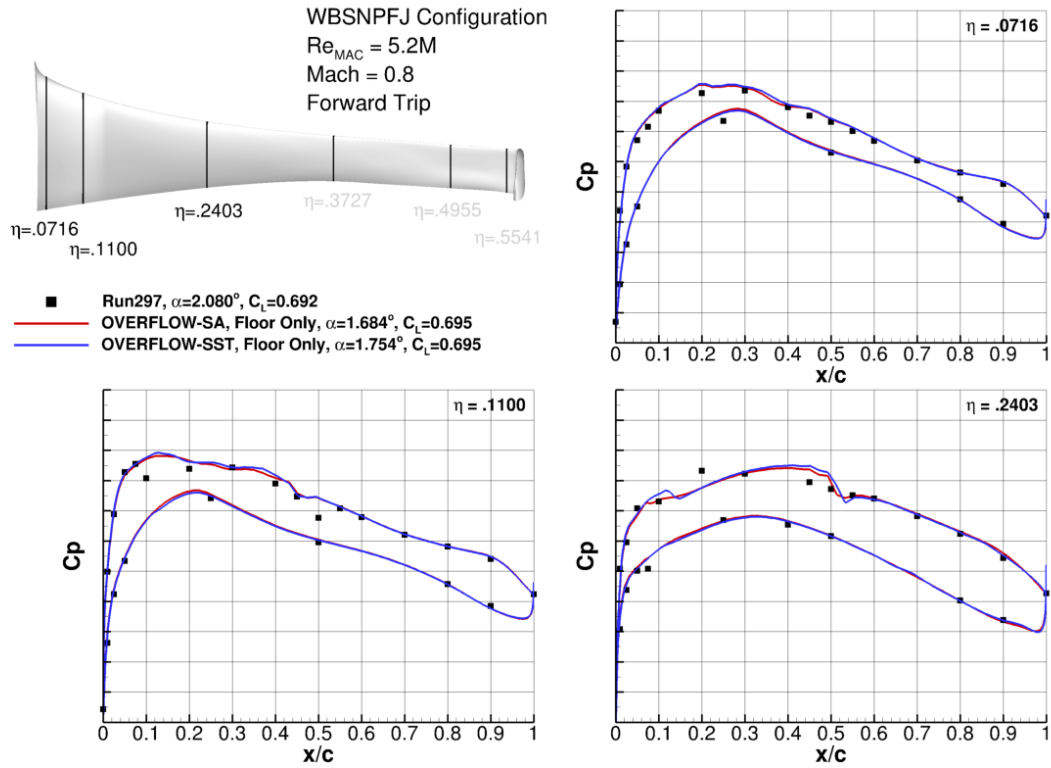


Figure 2-109. Forward Trip Strut Pressure Comparison at Design Condition: Inboard Strut [$M=0.8$, $Re_{MAC}=5.2M$, Fwd Trip].

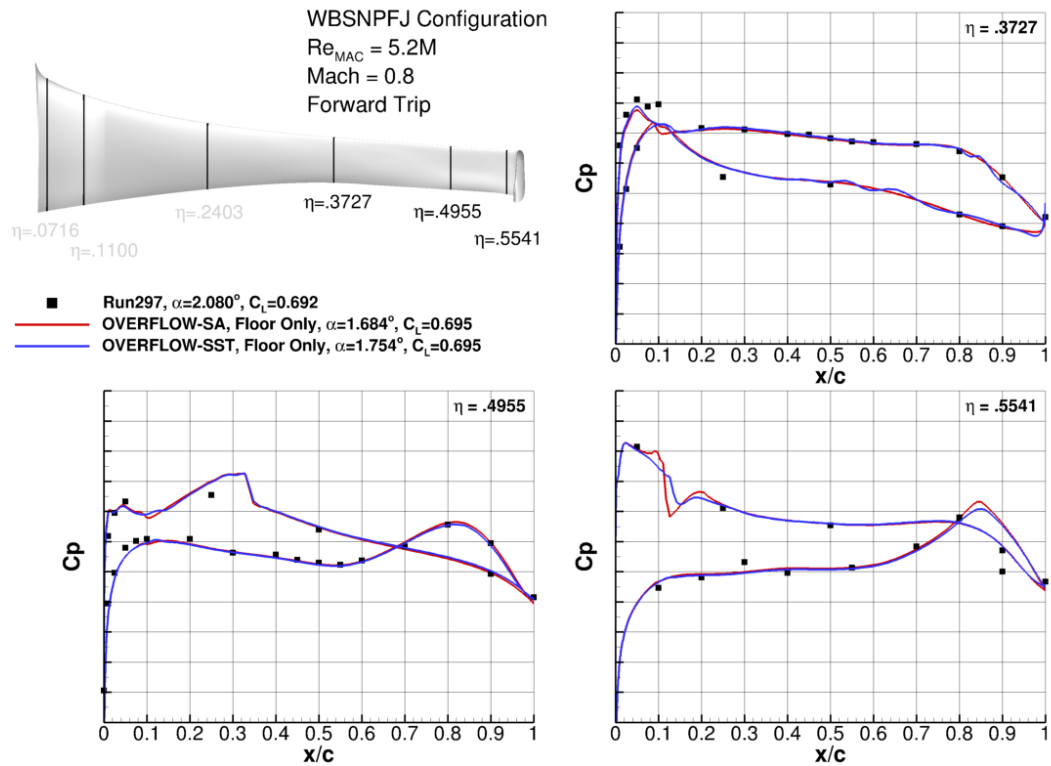


Figure 2-110. Forward Trip Strut Pressure Comparison at Design Condition: Outboard Strut [$M=0.8$, $Re_{MAC}=5.2M$, Fwd Trip].

2.10.2.2 Static Pressure Comparison at Mach = 0.8, $C_L = 0.91$

Figure 2-111, Figure 2-112, and Figure 2-113 compare wing pressures for the 1.3g condition at $Re_{MAC} = 5.2M$ and Mach = 0.8. The higher positive load factor is represented by data at $C_L = 0.91$, which is 1.3 times the midcruise C_L of 0.695 (rounded-up to 0.7 to get 0.91). The higher wing loading at this condition represents the required margin for buffet-free flight per FAR 25.251.

The inboard wing comparison given in Figure 2-111 tells a similar story as the comparison made at the design C_L of 0.695 where results from the OVERFLOW-SA analysis show the shock position is aft of the test data. However, the difference in position is considerably less at the 1.3g condition. Switching to the SST turbulence model nearly closes the gap between CFD and experiment altogether. This is encouraging because it is more important to see good agreement at conditions closer to the expected buffet boundary as opposed to the midcruise condition.

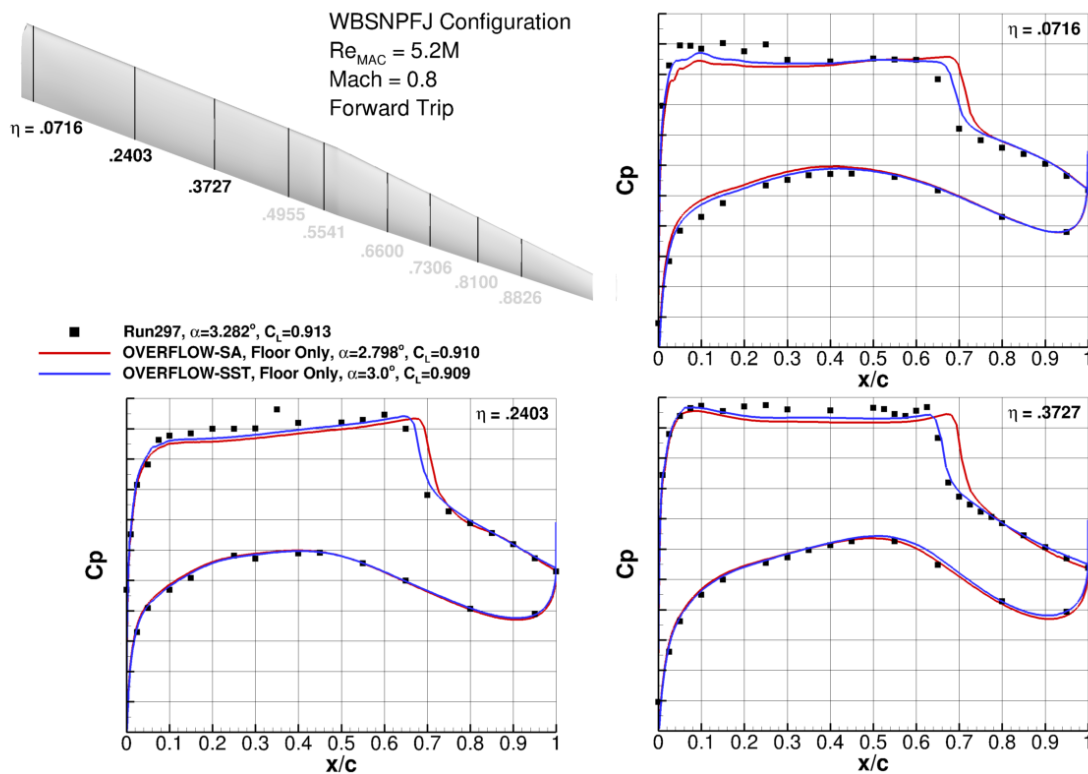


Figure 2-111. Forward Trip Wing Pressure Comparison at 1.3g Condition: Inboard Wing [M=0.8, $Re_{MAC}=5.2M$, Fwd Trip].

Figure 2-112 compares the midboard wing pressures at the 1.3g condition. Similar to the inboard comparison, OVERFLOW predicts nearly the same shock location and strength as test data with the SST turbulence model. This is an improved correlation of pressures when looking back at the design C_L plots shown in Figure 2-107. The midboard and outboard portions of the wing are considered buffet critical in terms of loading and shock position, so good agreement in these regions builds confidence in CFD-based buffet onset prediction methods.

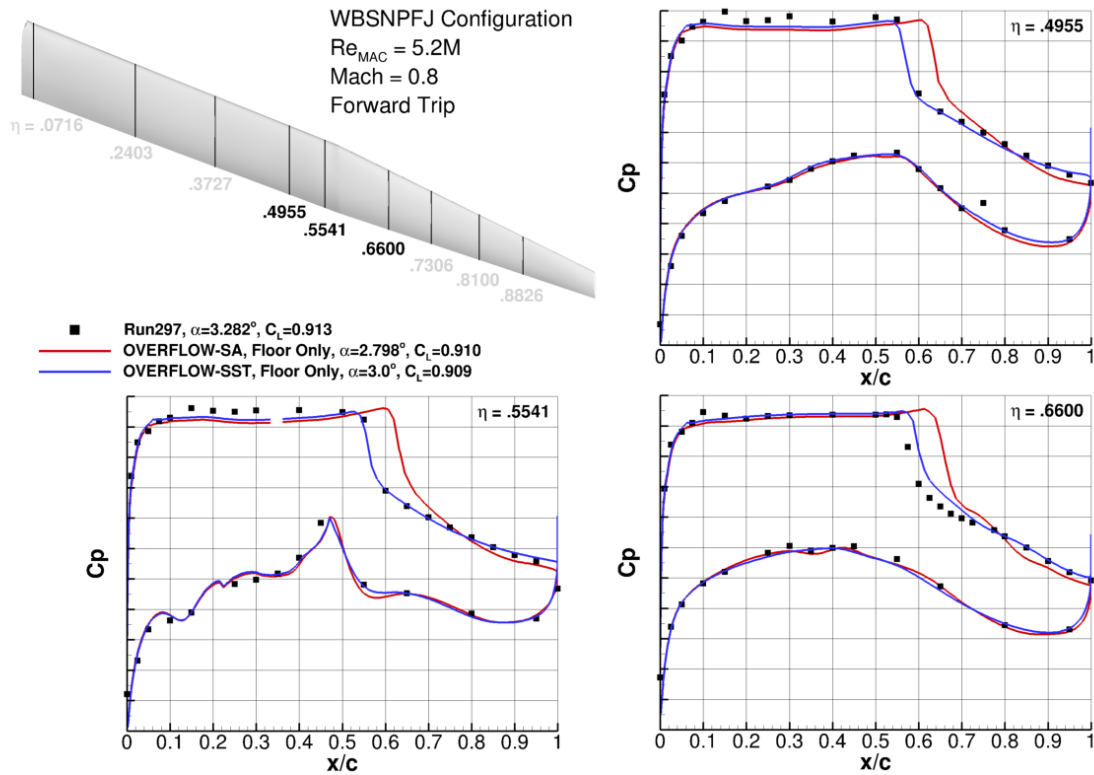


Figure 2-112. Forward Trip Wing Pressure Comparison at 1.3g Condition: Midboard Wing [M=0.8, Re_{MAC} =5.2M, Fwd Trip].

Figure 2-113 shows the outboard wing pressure comparison is also improved at $C_L = 0.91$. Here even the suction pressure level forward of the shock is in good agreement (compare data at 73% semispan between Figure 2-108 and Figure 2-113). The improved correlation of pressures at the critical buffet condition representing 1.3g flight in key regions of the wing suggests the simplified floor only OVERFLOW model may be adequate for buffet studies.

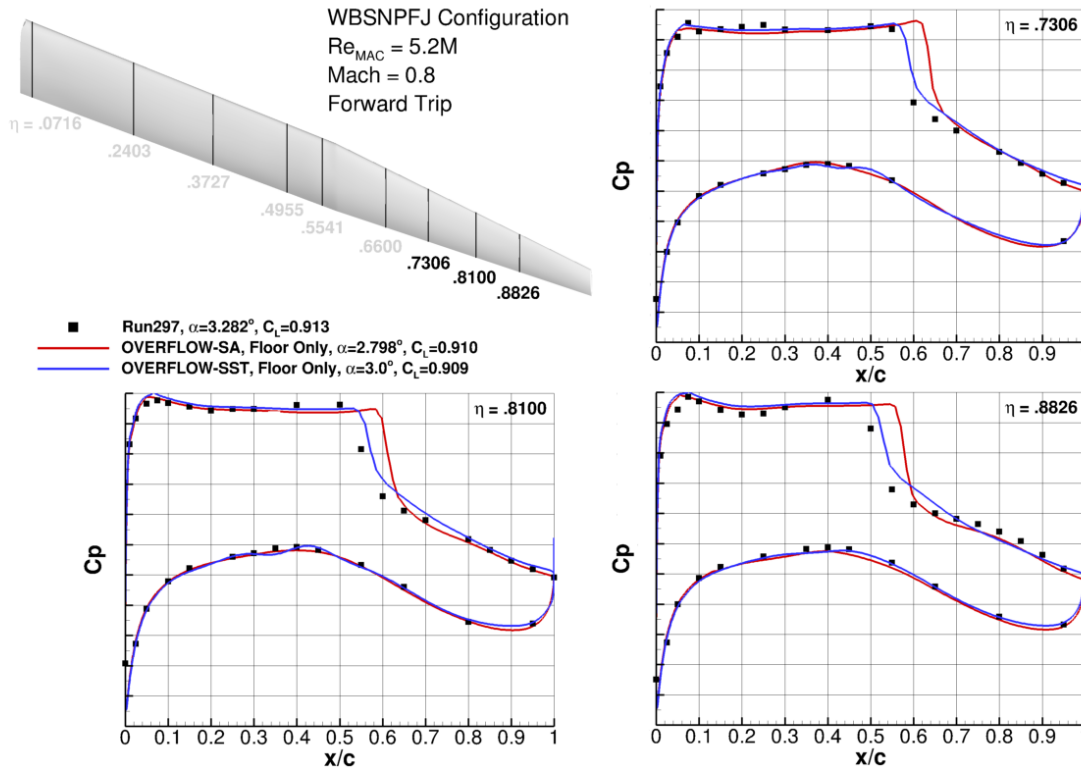


Figure 2-113. Forward Trip Wing Pressure Comparison at 1.3g Condition: Outboard Wing [$M=0.8$, $Re_{MAC}=5.2M$, Fwd Trip].

2.10.2.3 Static Pressure Comparison at Mach = 0.85, $C_L = 0.63$

Figure 2-114, Figure 2-115, and Figure 2-116 compare wing pressures for the maximum operating Mach (M_{MO}) condition at $Re_{MAC} = 5.2M$ and $C_L = 0.63$. M_{MO} for the SUGAR Mach 0.8 design is 0.85, which is cruise Mach + 0.05. This condition is called-out in FAR 25.251(d), which states “there may be no perceptible buffeting condition in the cruise configuration in straight flight at any speed up to V_{MO}/M_{MO} .”

The pressure comparison at M_{MO} tells a similar story as the 1.3g Mach 0.8 comparison. The SST turbulence model provides improved correlation with test data across the span of the wing when compared to the SA model. The SST shock position is aft of the measured data but only by a few percent chord, which can be partially explained by not analyzing the model fully installed in the test section. The outboard wing lower surface pressures from the SST solution exhibit local

irregularities caused by unidentified numerical issues. This will not impact the conclusions made here regarding upper surface shock characteristics.

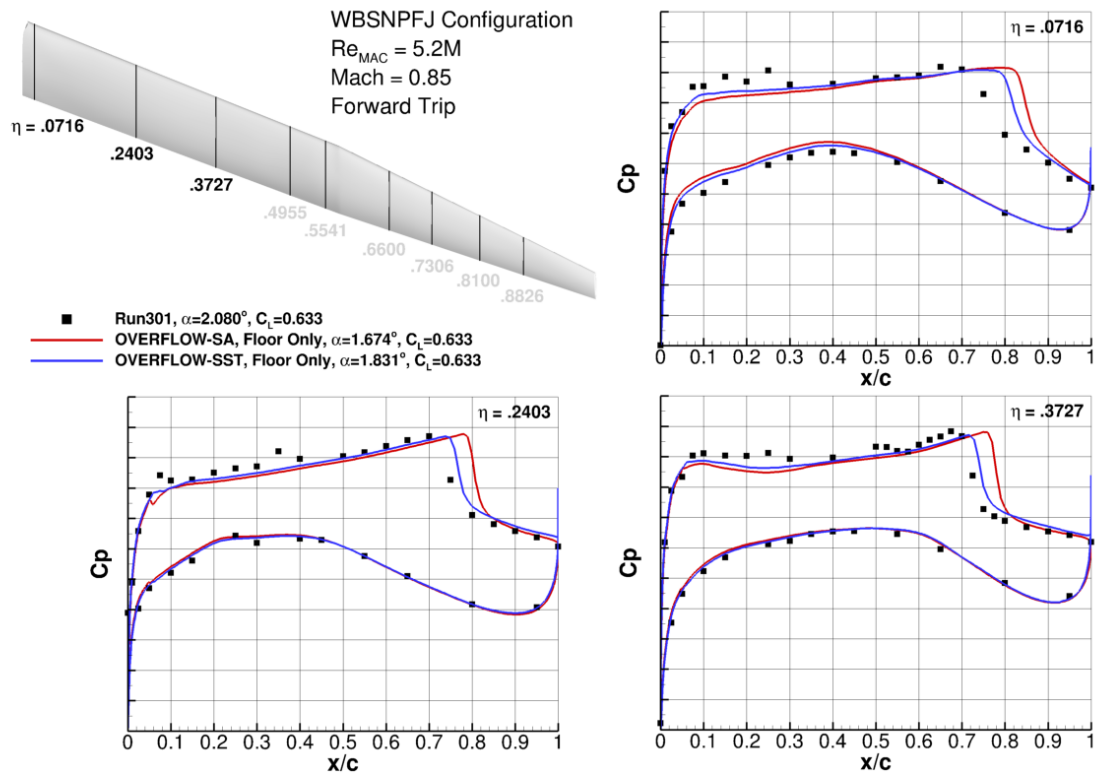


Figure 2-114. Forward Trip Wing Pressure Comparison at MMO Condition: Inboard Wing [M=0.85, $Re_{MAC}=5.2M$, Fwd Trip].

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

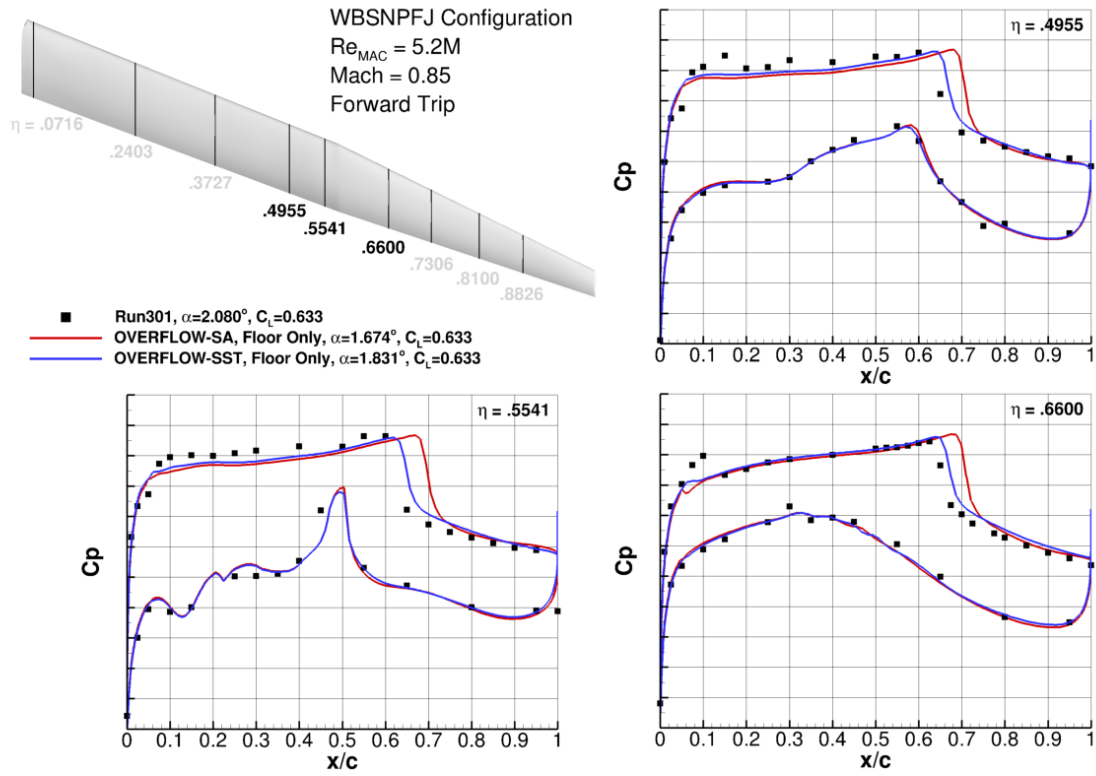


Figure 2-115. Forward Trip Wing Pressure Comparison at MMO Condition: Midboard Wing [M=0.85, $Re_{MAC}=5.2M$, Fwd Trip].

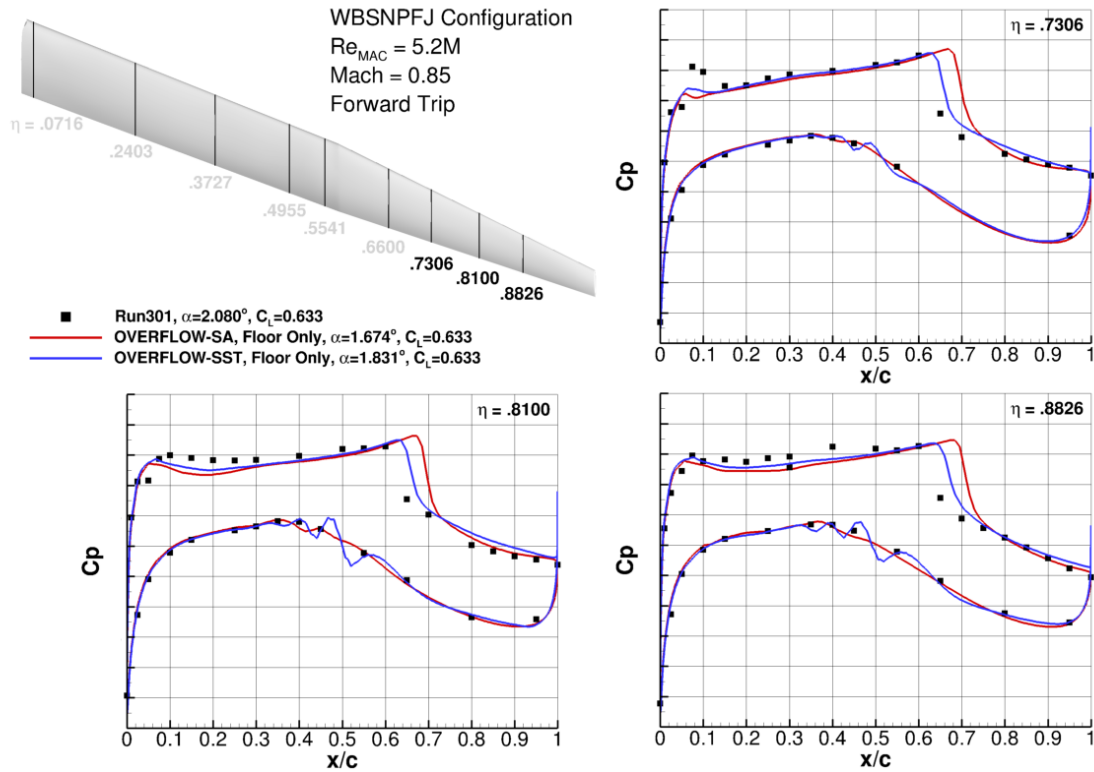


Figure 2-116. Forward Trip Wing Pressure Comparison at MMO Condition: Outboard Wing [$M=0.85$, $Re_{MAC}=5.2M$, Fwd Trip].

2.10.2.4 Effect of Boundary Layer Height

Information provided by NASA during preliminary test planning set the floor boundary layer (BL) thickness at 3 inches just ahead of the model. During the buffet test entry, NASA provided additional BL information in the form of an AIAA paper (11), which gives displacement thickness as a function of tunnel station, Mach number, and slots open/closed (see Figure 2-117). These data were used to perform a BL height sensitivity study in OVERFLOW.

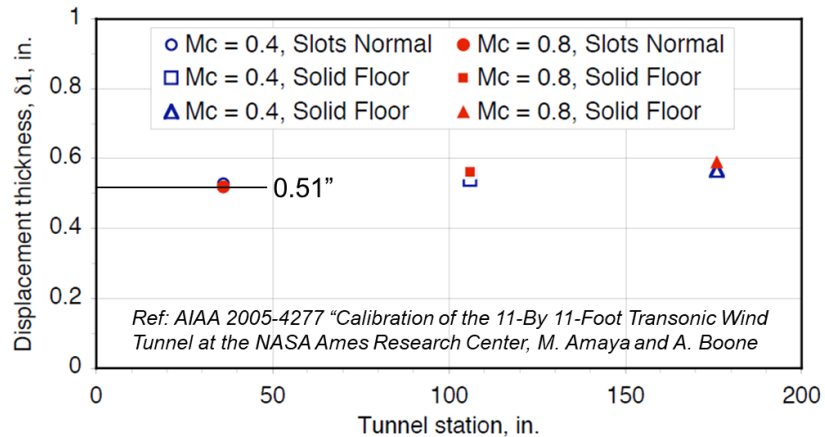


Figure 2-117. Boundary Layer Displacement Thickness (δ_1) in the Ames 11-Ft Test Section (11).

According to the data plotted in Figure 2-117, the displacement thickness at a tunnel station near the fuselage nose should be 0.51" without the model installed. The floor only OVERFLOW simulation has been calibrated to a 3" BL thickness at the fuselage nose by switching to a viscous wall boundary condition along a particular grid line. This approach is illustrated in the top half of Figure 2-118. The grid line used to initialize the turbulent BL was moved forward by 69" to match the displacement thickness of 0.51" at a tunnel station near the fuselage nose. The location where displacement thickness was evaluated in the solution is shown by the pink X symbols in the color contour images shown in the lower half of Figure 2-118. The baseline solution has a displacement thickness of 0.47".

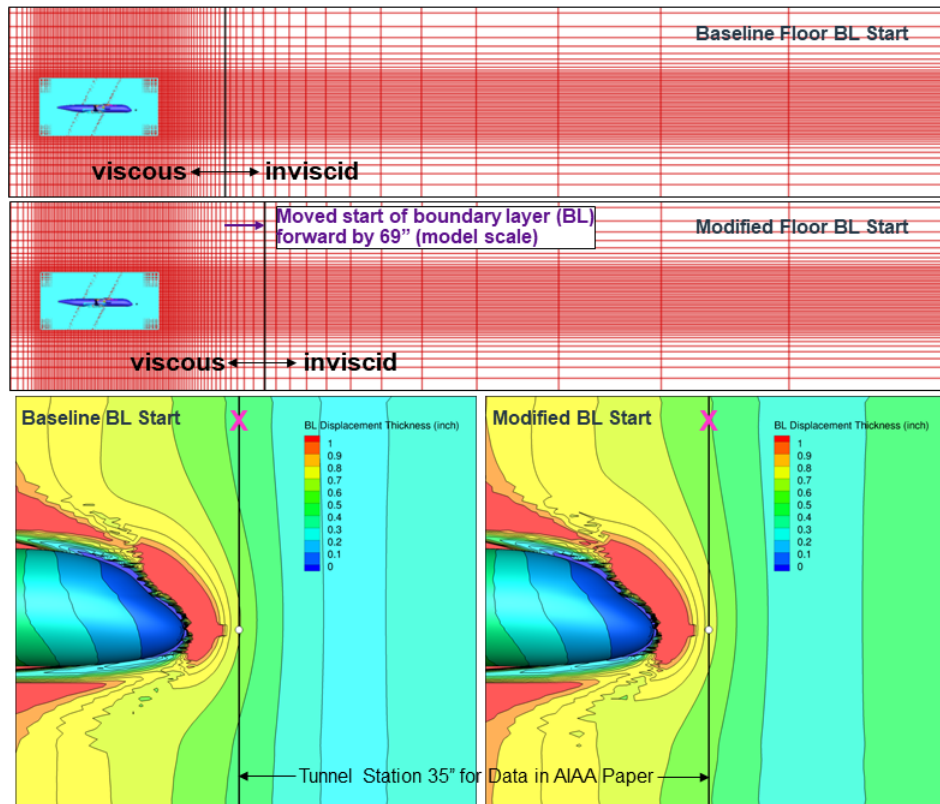


Figure 2-118. OVERFLOW Boundary Layer (BL) Approximation on the Test Section Floor at Mach 0.8.

Increasing the displacement thickness of the test section floor boundary layer by 0.04" had no significant effect on nose or wing pressures. The angle of attack was increased by 0.003° to hold $C_L = 0.695$ and there was a very slight nose-down C_{PM} shift of -0.0005. The results of this sensitivity study show the floor only OVERFLOW model has a reasonably accurate boundary layer thickness at the fuselage nose.

2.10.3 CFD Buffet Predictions

Computational studies focused on quantifying buffet characteristics of the TTBW configuration were conducted prior to the wind tunnel test. The primary objective was to predict the initial buffet boundary using different methods and quantify effects of boundary layer transition location, strut flap deflection, and turbulence modeling. Three different buffet prediction methods were applied to the CFD data:

- Axial Force Offset (see Section 2.9.9.4),
- Trailing Edge Pressure Divergence (see Section 2.9.9.3), and
- BUFFET (see Section 2.10.3.1)

The AFO and BUFFET methods are based on empirical data established for conventional configurations – the AFO method is based on global forces, while BUFFET is based on sectional flow properties. The trailing edge pressure divergence method utilizes computed data for the configuration under study. A brief description of the BUFFET method is given below.

2.10.3.1 BUFFET Code Assessment

The BUFFET code estimates a configuration sensitivity to buffet by computing shock strength and position and comparing it against a critical normal Mach number database as determined by 2D high Reynolds number data from conventional and supercritical airfoil tests. The method provides an indication of when shock-induced separation leads to buffet onset. The BUFFET program has been historically shown to be accurate for predicting buffet onset for T-tailed twinjet transport designs and was used to assess buffet characteristics for the TTBW wing and strut throughout the design process. Figure 2-119 shows a typical graphic produced by the program, which is used to infer whether the computed normal Mach number of the airfoil has exceeded the critical normal Mach, thereby inferring that buffet onset has been reached.

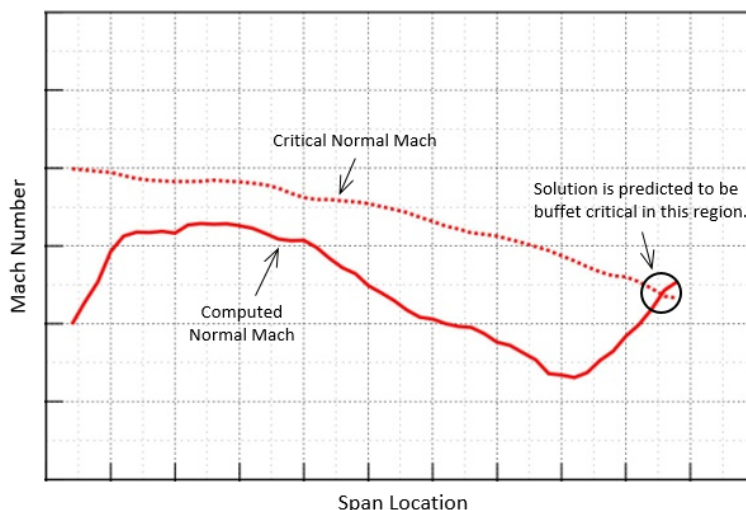


Figure 2-119. BUFFET code output indicating whether buffet has been reached.

2.10.3.2 Computational Buffet Predictions Results Comparison

After applying the three buffet prediction methods discussed in section 2.10.3, the data are summarized in Figure 2-120, which depicts several comparisons that should be noted. These comparisons are:

- The forward (5% chord) trip and aft (25% chord) trip locations
- The CFD processed data against the data collected from the test
- Various buffet prediction methods relative to each other, and
- How the CFD turbulence modeling can affect the buffet prediction at various Mach numbers.

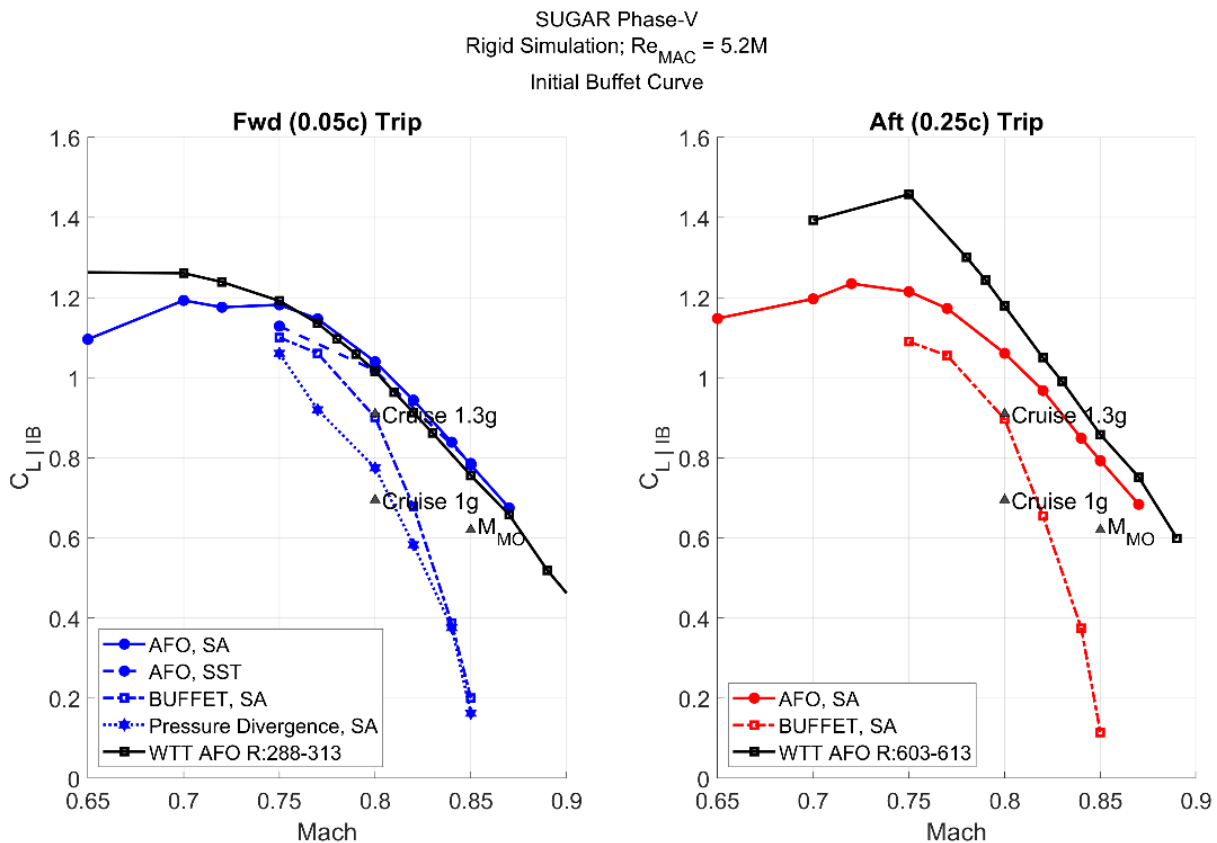


Figure 2-120. Buffet Prediction Comparisons for Forward Trip Location (5% Chord, Left) & Aft Trip Locations (25% Chord, Right) [$Re_{MAC}=5.2M$].

It can generally be seen that the AFO method, particularly for the forward trip data, agrees very well between CFD and test. Speaking to the forward trip plots, the ability of the SST turbulence model to predict wing pressure at cruise and M_{MO} can also be extended to AFO initial buffet prediction, but SA tends to better match the trend at Mach 0.75. It's at these lower Mach numbers that the prediction of C_{Lmax} and its shape becomes increasingly important, and accounts for much of the deviation from the test data. For the aft trip configuration, it can be seen that

the CFD-generated AFO prediction is conservative, when compared with wind tunnel data processed in a similar manner. It is observed that the AFO-processed CFD data indicate a much lower sensitivity to trip location than the AFO-processed wind tunnel data, but the Kulite® data collected from the test would suggest a much lower sensitivity, more in-line with the CFD-based prediction (refer to Section 2.9.10.2). It can also be observed that both the BUFFET and Trailing Edge Pressure Divergence methods used to predict initial buffet are even more conservative, and diverge significantly from the test data processed using the AFO method.

Finally, a CFD analysis examined the predicted effect that the outboard strut flap had on the buffet boundary. As was verified in the wind tunnel data in Section 2.9.10.1, the computed AFO-based initial buffet curve is insensitive to the strut flap position. These data, shown in Figure 2-121, once again verify that the wing-strut channel is not buffet critical for the TTBW.

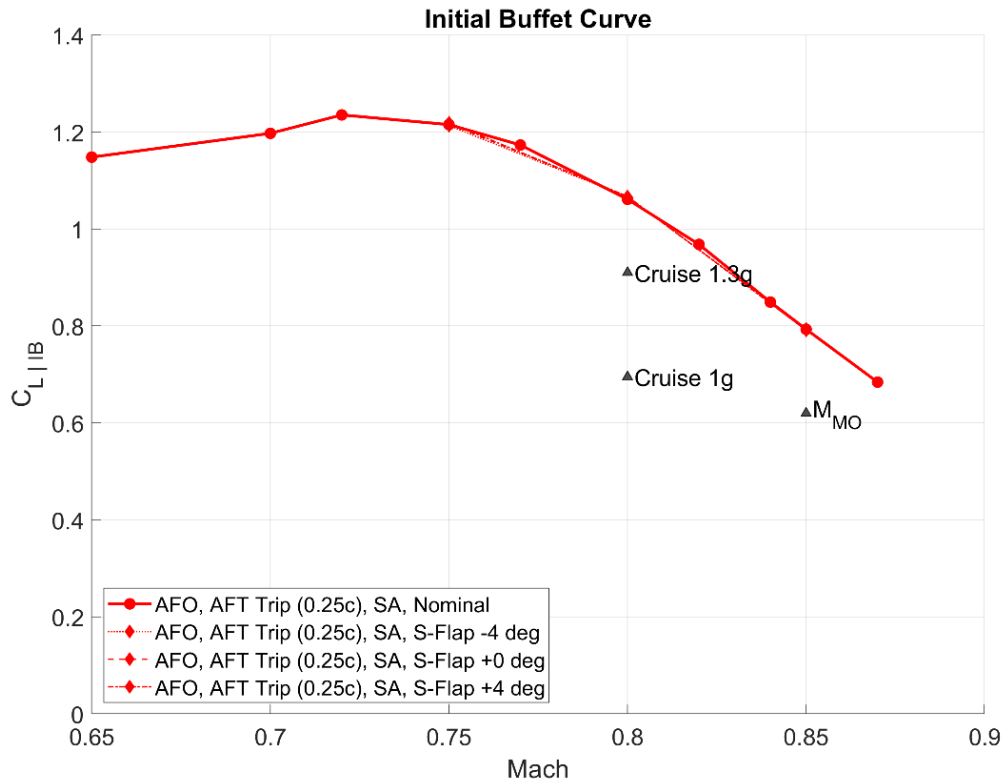


Figure 2-121. Effect of Strut Flap Position on Buffet Prediction Using AFO Method [Config C139, Aft Trip T3, $Re_{MAC}=5.2M$].

2.11 Assessment of Buffet TTBW Buffet Prediction

During the buffet wind tunnel test, a wide variety of methods were used to predict buffet onset. Data were measured in the tunnel using an extensive suite of instrumentation and computational methods (CFD) exercised. These methods examined changes in buffet onset for a series of vehicle configurations, flow conditions, and boundary layer trip patterns. Steady and unsteady data were acquired using pressure transducers, accelerometers, strain gauges, and a five-component balance.

In general, the most successful methods were based on global (whole vehicle) measurements or predictions. This makes sense since the various instability modes that lead to buffet onset manifest as whole-vehicle flow instabilities. Of the results measured, the most successful predictions were made when a forward trip location was used. As the amount of laminar flow grew on the wing, the more disagreement existed between the predicted values and inferred buffet onset as measured by the model array of Kulites®. That is not to say that section-based methods do not have a place in the modern computational and design framework, since these methods are in general simple to compute as well as conservative in their estimate of buffet onset.

As pertaining specifically to the TTBW configuration, the data obtained in the current wind tunnel test strongly suggest that (at the scale and Reynolds number of the test) buffet onset is for all intents and purposes – conventional (driven by wing upper surface initiated global instability). No data measured during the test suggested that the lower side of the strut nor the interior of the wing-strut channel were ever buffet critical. However, it is clear that the typical spanwise station where buffet often initiates for a conventional configuration is further inboard on the TTBW – located in the span region of the wing-strut juncture. This discovery is strongly supported by measurements of the TTBW spanload, with lift contributions coming from both the wing and strut. Where these surfaces join together, the airfoil designs are shaped to control flow accelerations into the channel, naturally resulting in a wing that has a higher local spanload contribution than for conventional cantilevered-wing designs.

2.12 Stability and Control Testing

Upon completion of the buffet boundary determinations, additional data collection was made regarding control surface effectiveness. The tested deflection ranges and conditions (Reynolds number and Mach ranges) were expanded from the full-span test matrix due to the model increased strength and physical size.

2.13.1.1 IB Aileron Effectiveness

The inboard ailerons were one of the components that could not be fully tested at higher angles of attack due to load limits during the earlier entry of the full span model. In this entry, testing was conducted at the higher angles of attack. Furthermore, smaller deflections were also tested to better capture nonlinear response to small aileron deflections.

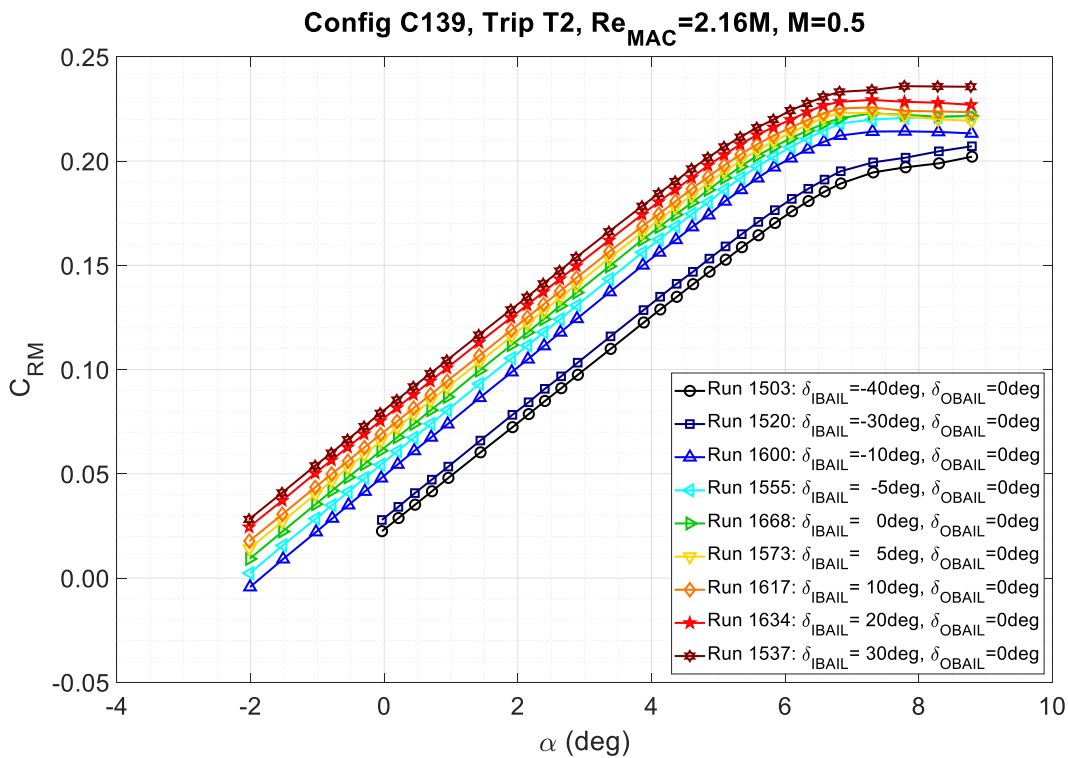


Figure 2-122. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].

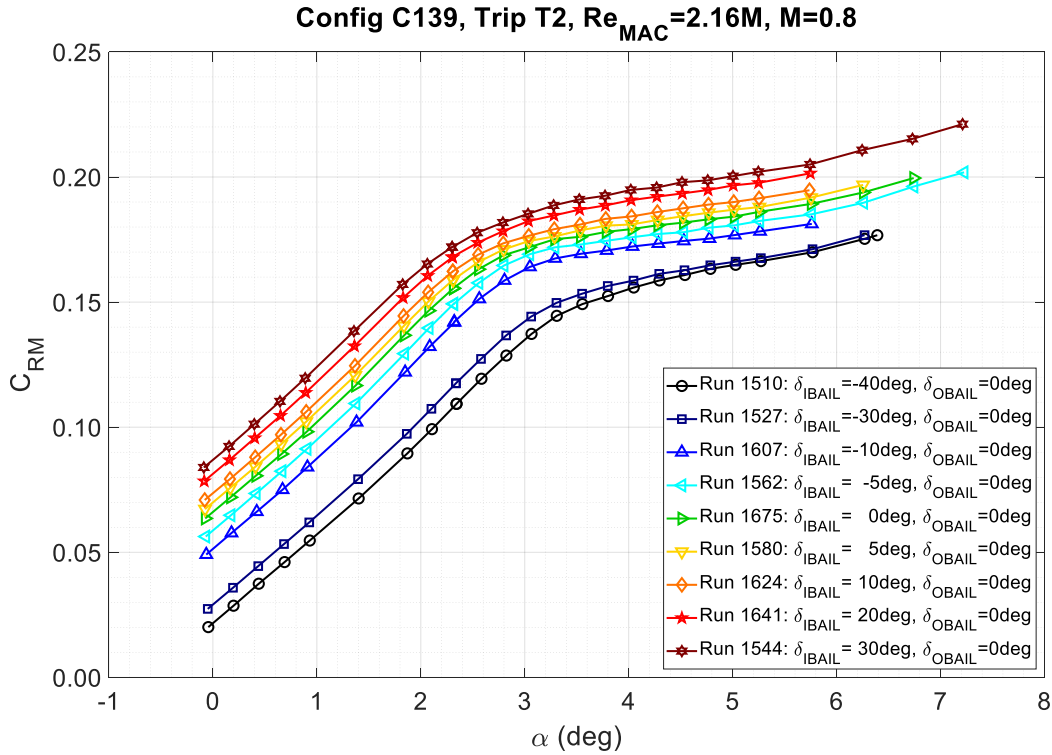


Figure 2-123. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].

As seen in Figure 2-122 (Call to figure in text should come before the figure.), at Mach=0.5, the inboard aileron behavior is very conventional and does not show any indications of sudden loss of authority exhibited at Mach=0.2 during low speed testing. As indicated in Figure 2-123 (Call to figure in text should come before the figure.), at Mach=0.80, the inboard aileron continues to be well behaved across the deflections.

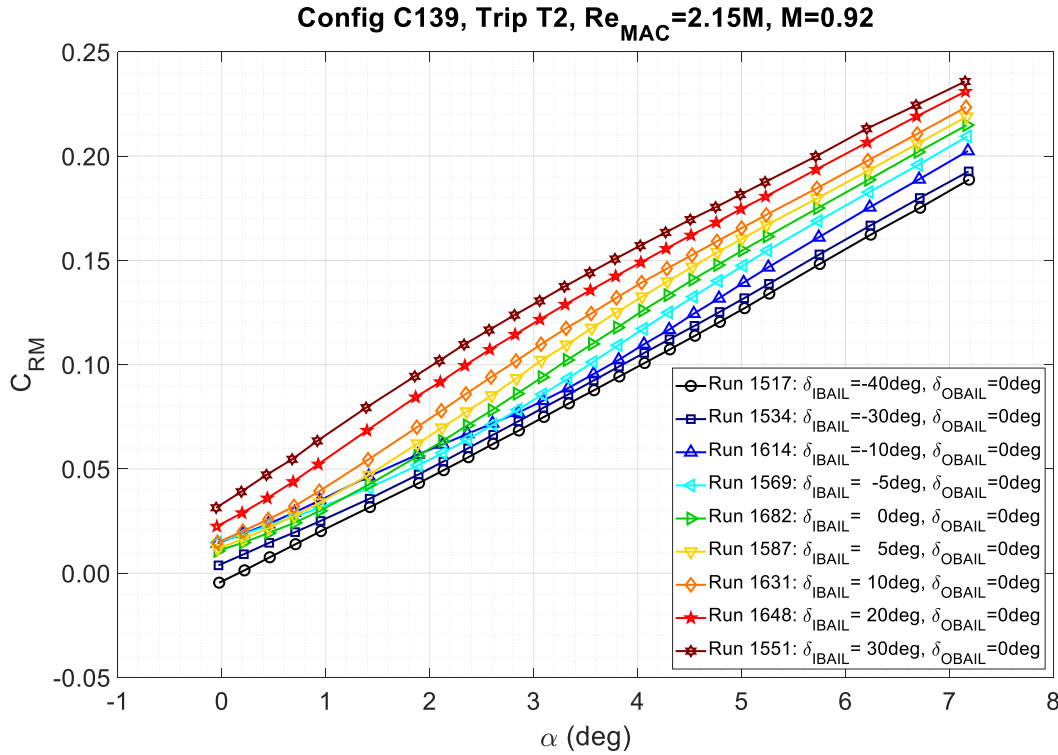


Figure 2-124. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.15M$, $M=0.92$].

At Mach=0.92 (Figure 2-124) (Call to figure in text should come before the figure.), there are clear indications of reversal at the lower angles of attack and small TEU deflections. At angles of attack higher than 3° , the magnitude of the rolling moment tends to increase with increasing deflection as is desired. However, below 3° angle of attack, deflections of up to -10° generate an opposite moment. This is consistent with results of earlier full-span model tests.

The roll reversals mentioned earlier start at Mach=0.89. Figure 2-125 shows that the reversal of -10° with -5° and -2.5° of aileron starts around 1° angle of attack. Below 0.5° angle of attack, all three TEU deflections seem to be reversing.

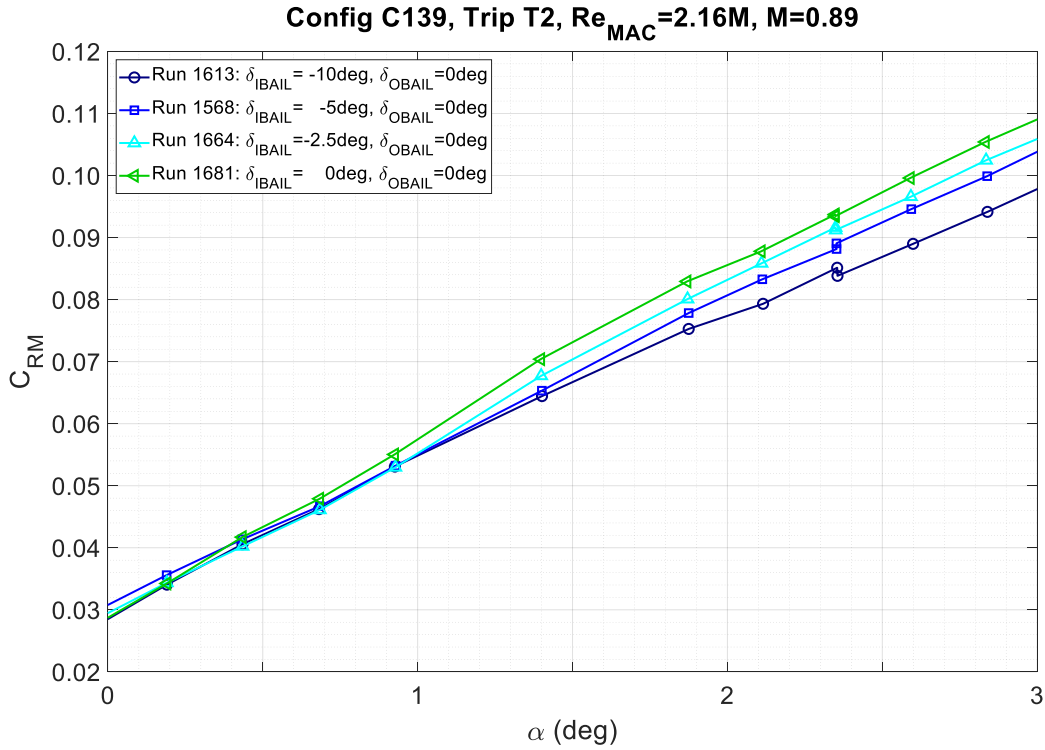


Figure 2-125. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient - zoomed in. [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.89$].

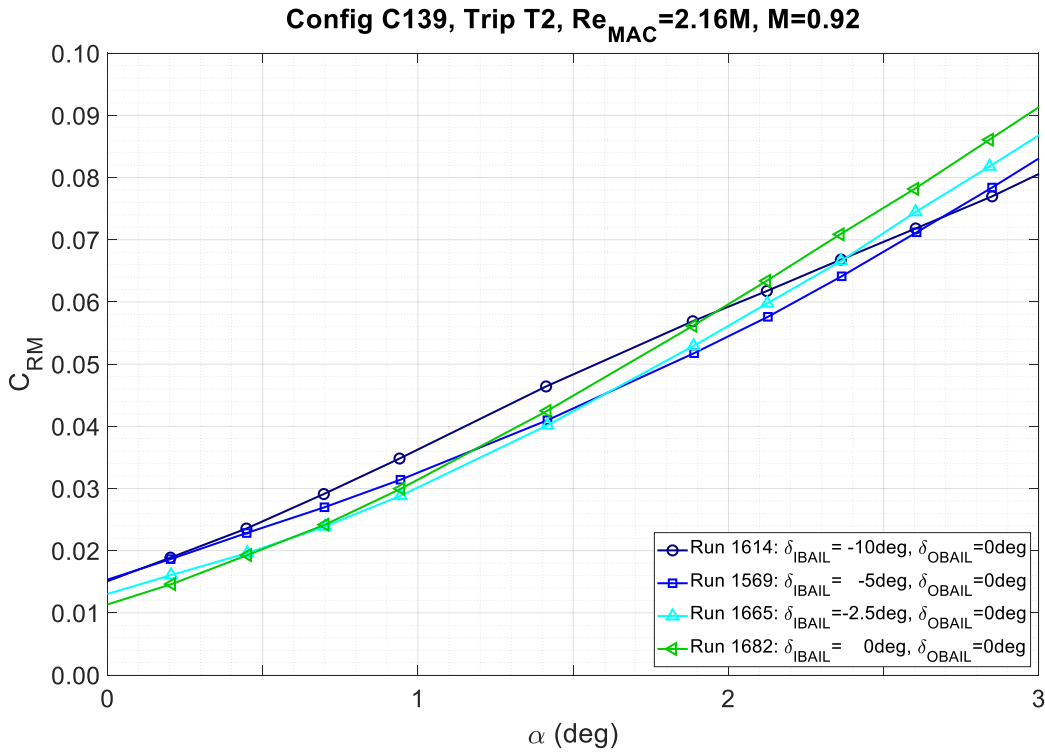


Figure 2-126. Effect of Inboard Aileron Deflection on the Rolling Moment Coefficient - zoomed in. [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].

Figure 2-126 (Call to figure in text should come before the figure.) zooms in on the region of reversal and includes the -2.5° aileron deflection, which was left off Figure 2-124 for the sake of clarity. The observations made earlier are more readily apparent and it can also be seen that -2.5° deflection reverses below 0.75° . The general trend seems to be that with increasing TEU deflection, the reversal is larger and spreads over a larger angle of attack range.

2.13.1.2 Combined Aileron Effectiveness

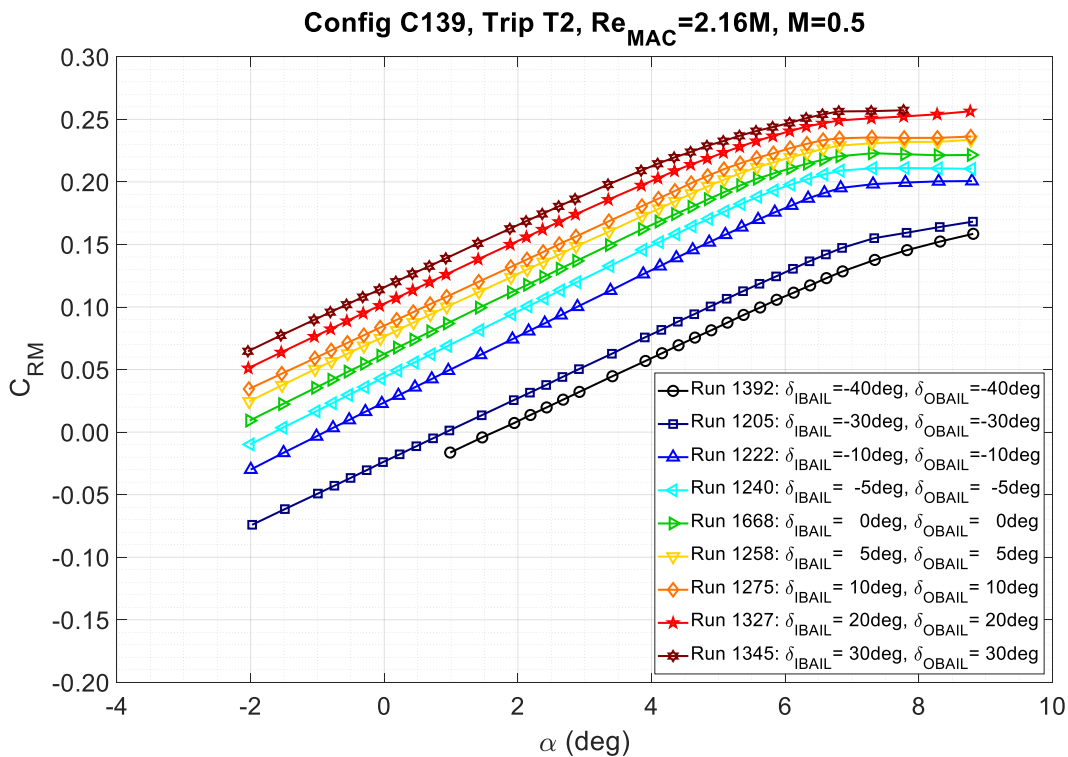


Figure 2-127. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].

As with the inboard ailerons, the combined aileron deflections at Mach=0.5 are well behaved and conventional (Figure 2-127) (also call to figure in text should come before the figure).

At cruise Mach number (Figure 2-128), the combined ailerons remain well behaved and show good authority even at the higher angles of attack.

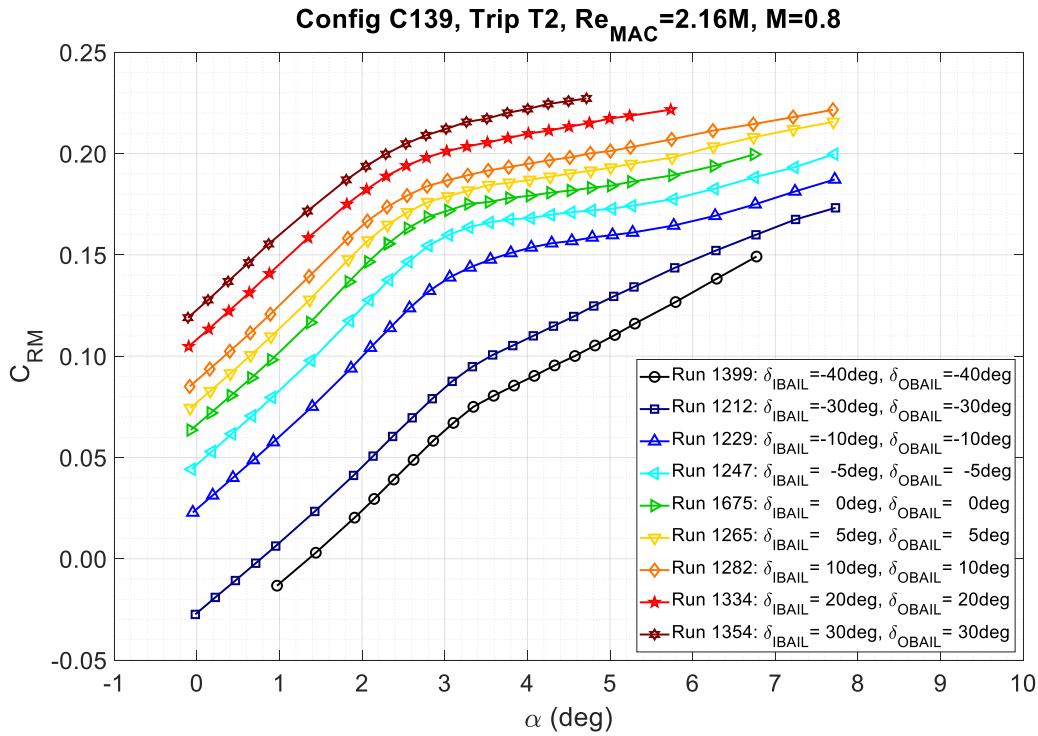


Figure 2-128. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].

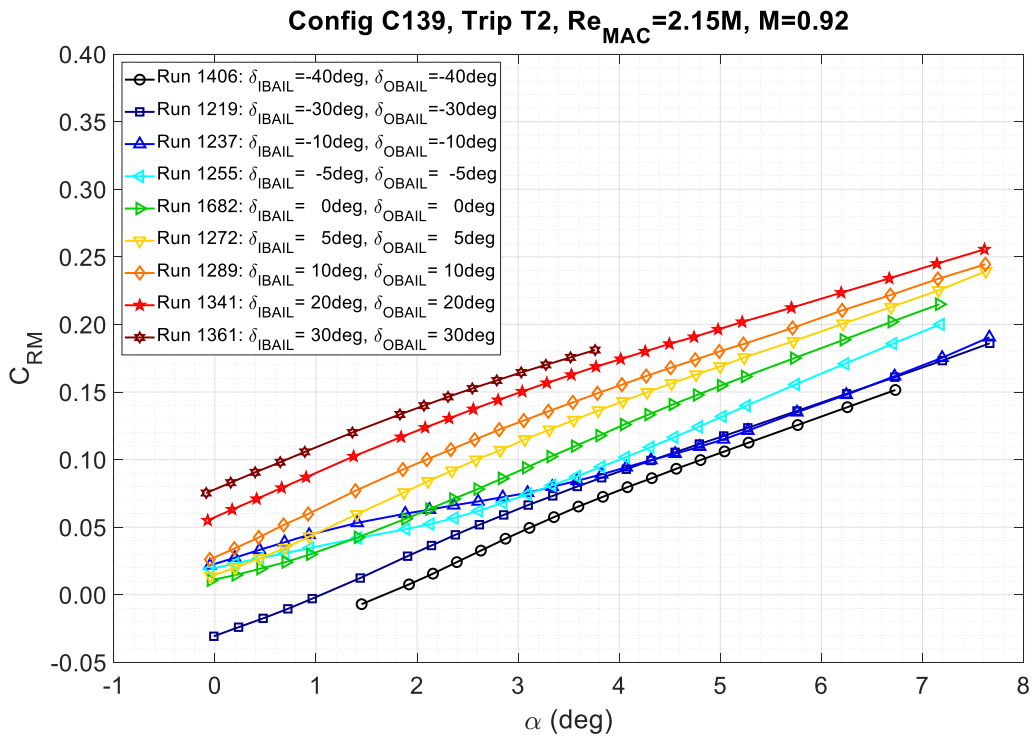


Figure 2-129. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].

At 0.92 Mach (Call to figure in text should come before the figure. (Figure 2-129), the rolling moment reversal seen with inboard ailerons get much worse. Near 3.25° angle of attack, -10° deflection reverses on the -5° deflection. Both reverse on the baseline 0° deflection around 2° and 1.5°, respectively. Furthermore, the -10° aileron is coincident with the -30° deflection above 4° angle of attack, indicating the possibility of a dead band of 20° in roll authority.

These are undesirable characteristics, which can complicate the development of the flight control system and add risk.

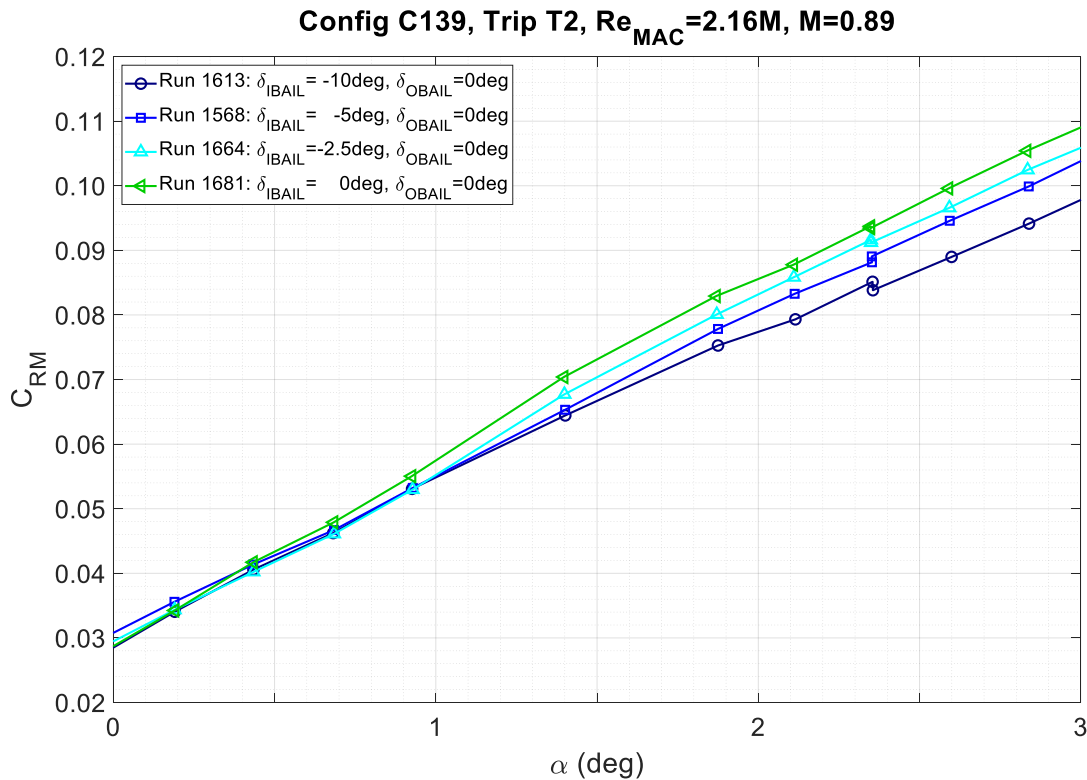


Figure 2-130. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.89$].

Figure 2-130 (Call to figure in text should come before the figure.) shows the region of reversal, which starts at Mach=0.89 and grows at Mach=0.92. At Mach=0.89, the beginning of a roll reversal are first seen. Below 0.5° angle of attack, the -5° deflection is either very slightly reversing or coincident with the -2.5° deflection.

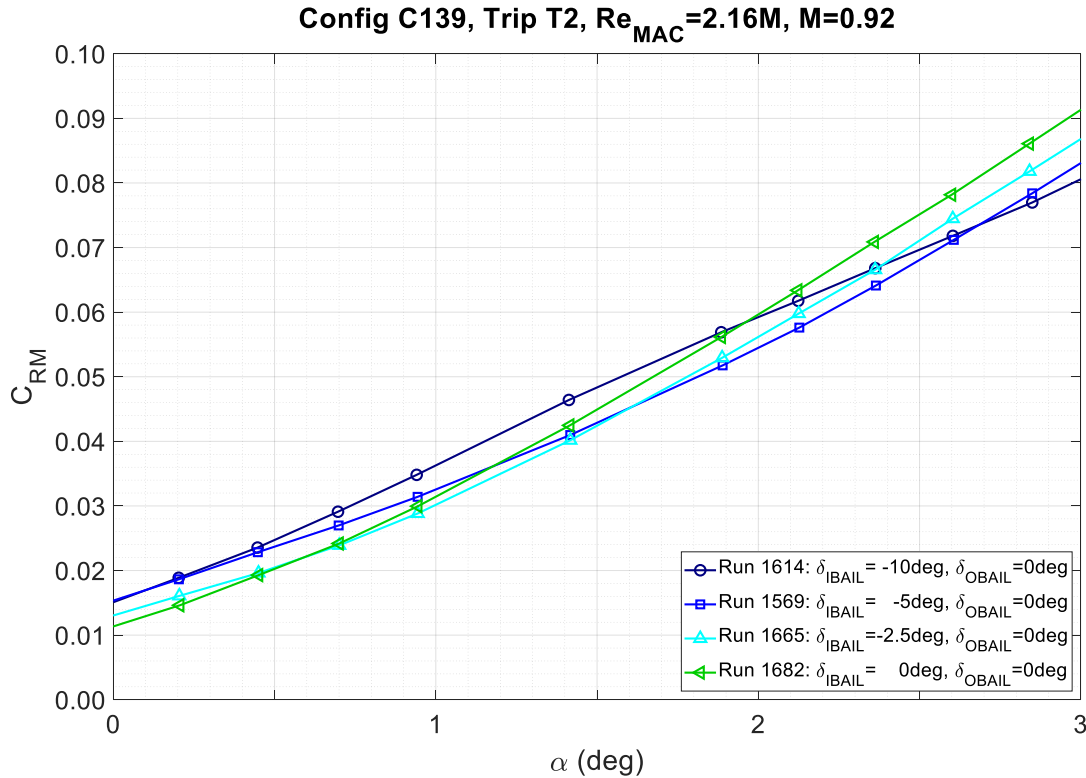


Figure 2-131. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.92$].

Figure 2-131 (Call to figure in text should come before the figure.) zooms in on the low angle of attack range to better show the region of reversal. It also includes the -2.5° deflection left off the other plot for sake of clarity. The rolling moment reversal makes a discernable trend across deflection and angle of attack. The TED deflections are fairly linear down to 0° angle of attack with a slight nonlinear behavior below 0.5° .

The effect of Reynolds number on the aileron deflections tends to be small with deflection and hard to pinpoint without accounting for the wind tunnel model aeroelastics. Since the dynamic pressure can vary dramatically to attain the desired Reynolds number, any effect of the latter on the aileron effectiveness can be lost due to effects of the former.

As show in Figure 2-132 to Figure 2-134, varying Reynolds numbers from 2.16 million to 5.18 million, the effect on rolling moment reversal is hard to discern. While the region of reversal does not change very much, there are small changes in magnitude of the rolling moment coefficients. However, these could have more to do with model aeroelastics than with Reynolds number.

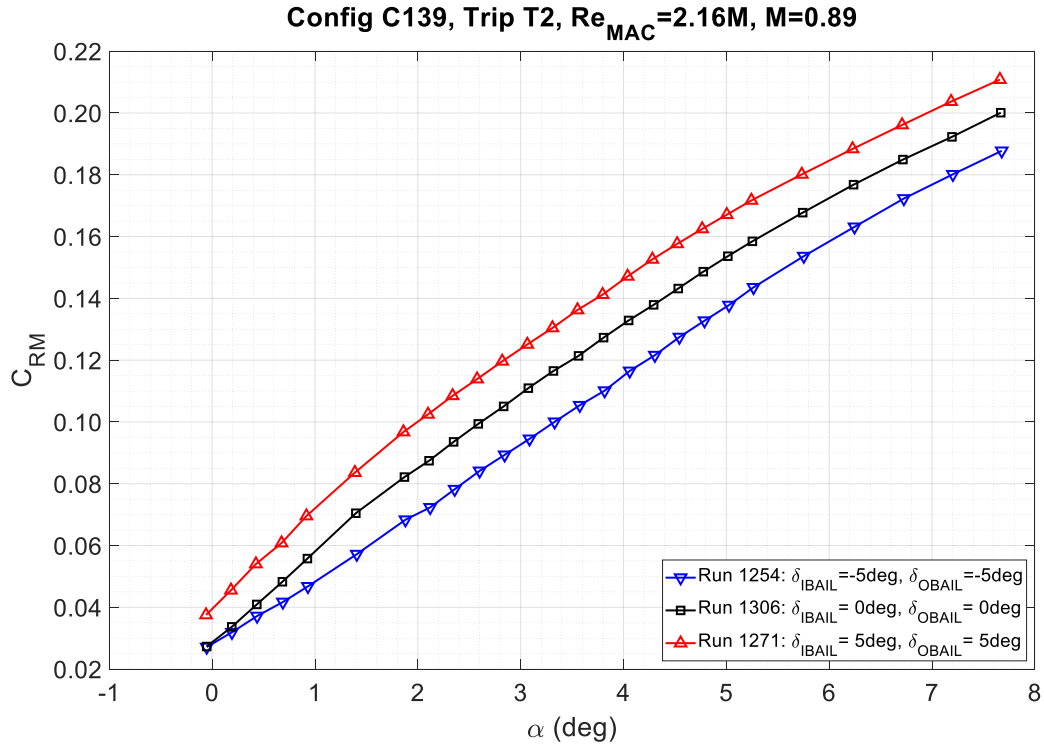


Figure 2-132. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.89$].

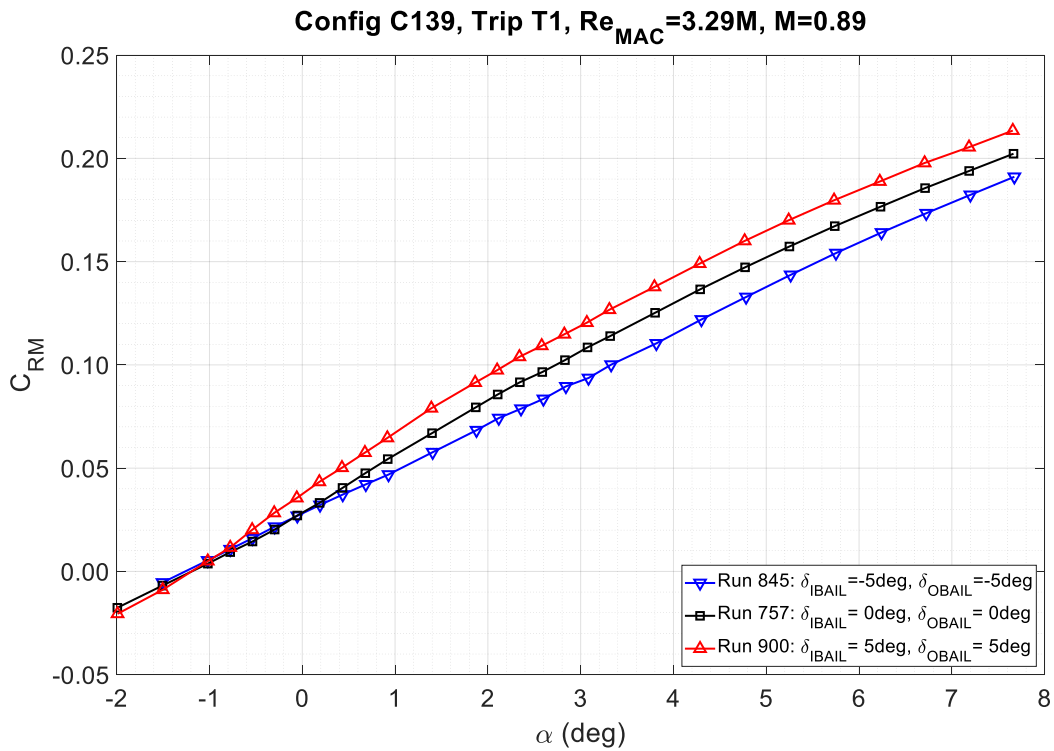


Figure 2-133. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=3.29M$, $M=0.89$].

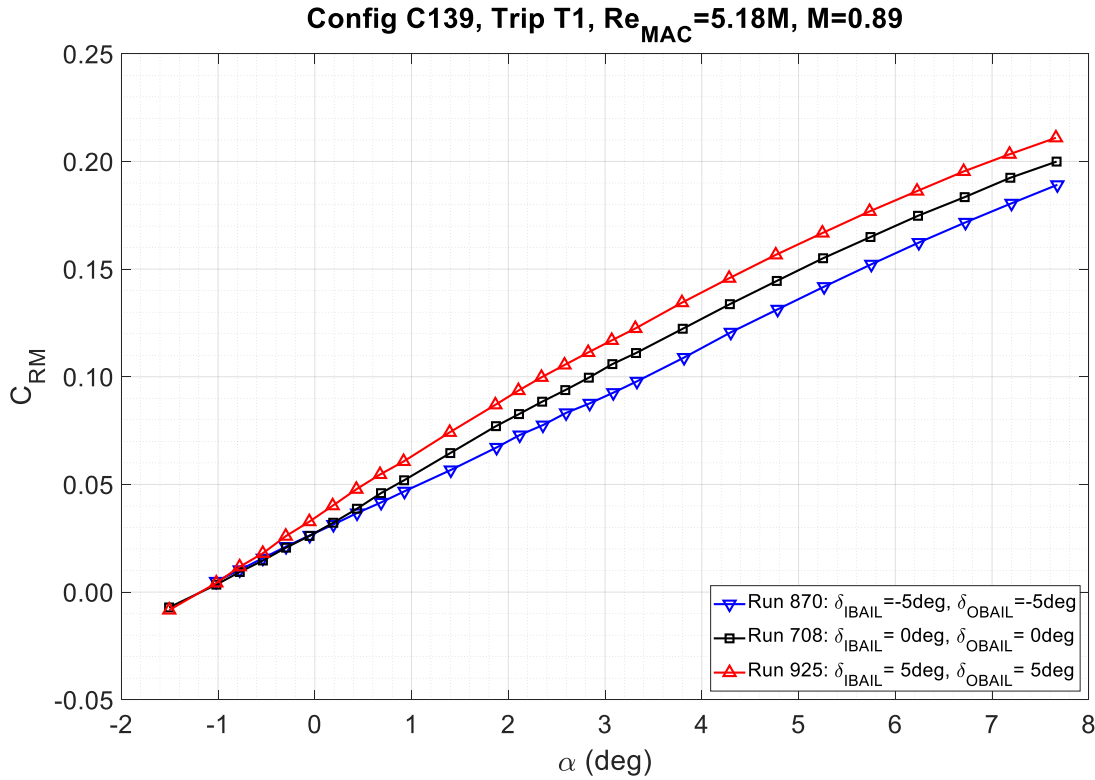


Figure 2-134. Effect of Combined Aileron Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.89$].

2.13.1.3 Spoiler Effectiveness

Testing of control surfaces was carried out during the test to fill out gaps in the test matrix of the earlier full-span model entry in 2019. The data collected for spoilers and ailerons deflected were often limited to low angles of attack due to the load limits and possible areas of concern at the higher angles of attack remained uninvestigated until this entry. A better range of deflections – small, midrange, and large – for the spoilers was available and tested enabling capture of the characteristics across deflection, Mach, and angle of attack with sufficient granularity to identify problem areas. (Do not see call to figures 2-135 and 2-136.)

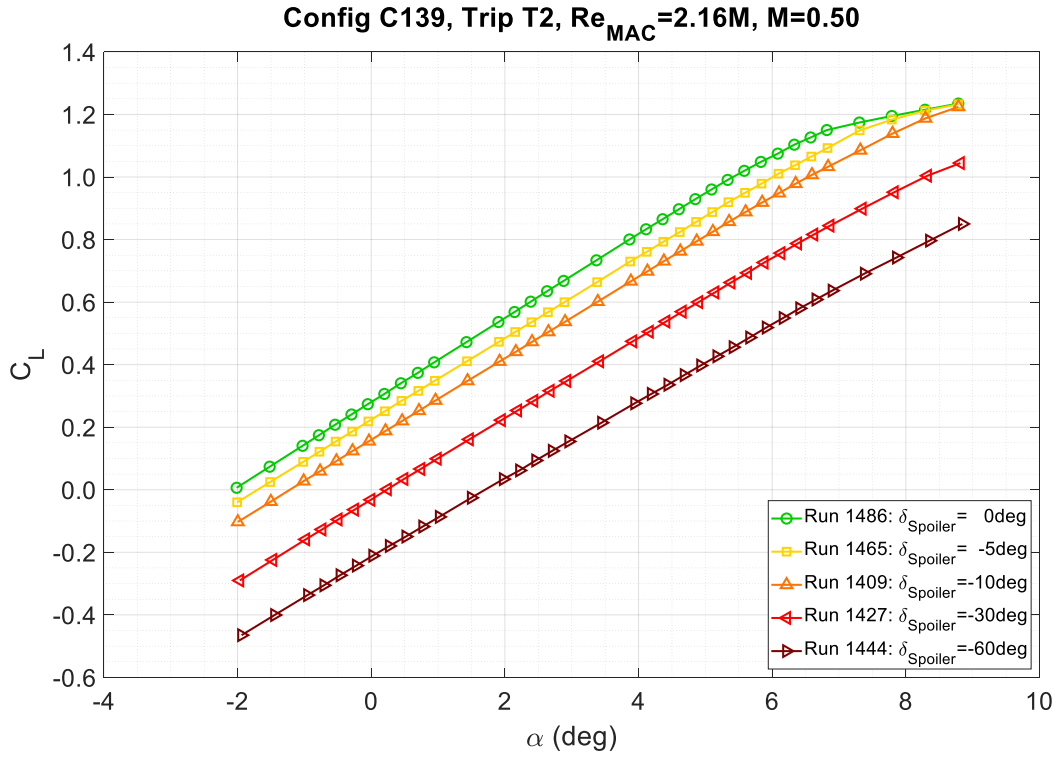


Figure 2-135. Effect of Spoilers on the Lift Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].

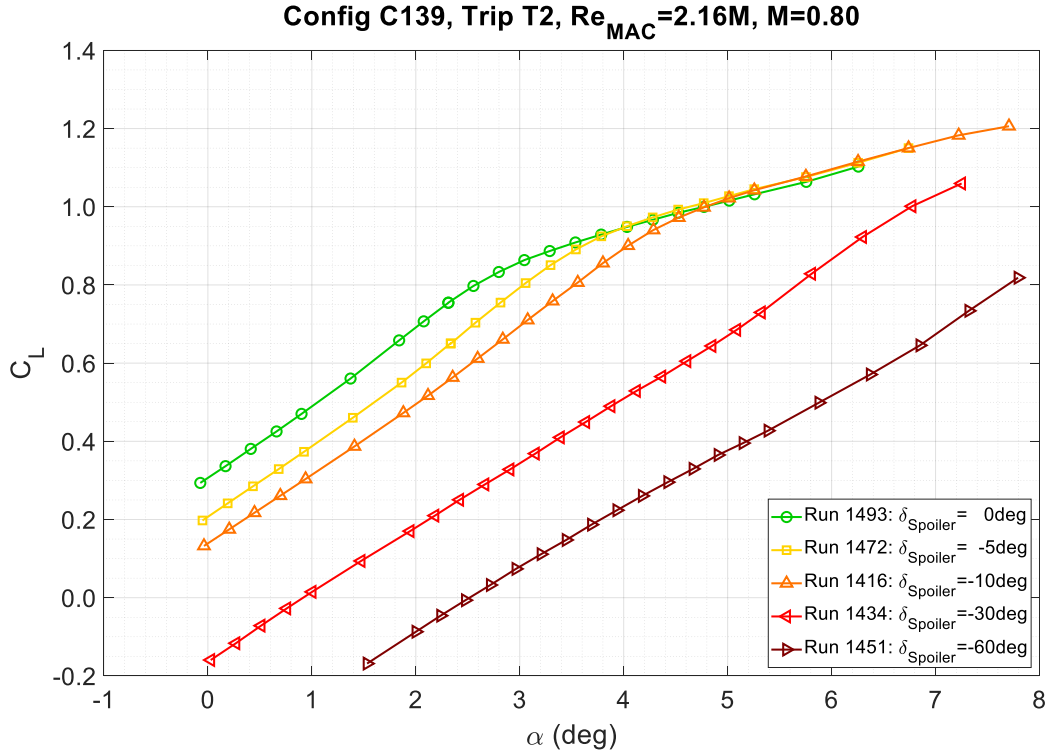


Figure 2-136. Effect of Spoilers on the Lift Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].

Lift is reversing above 4.5° angle of attack for -5° and -10° of spoiler deflections. The magnitude of the reversal is small but it remains an undesirable characteristic.

While the baseline wing and those small deflections show a decline in lift curve slope at the higher angles of attack, the larger deflections are highly separated from the beginning and exhibit a linear trend across the range of angles of attack.

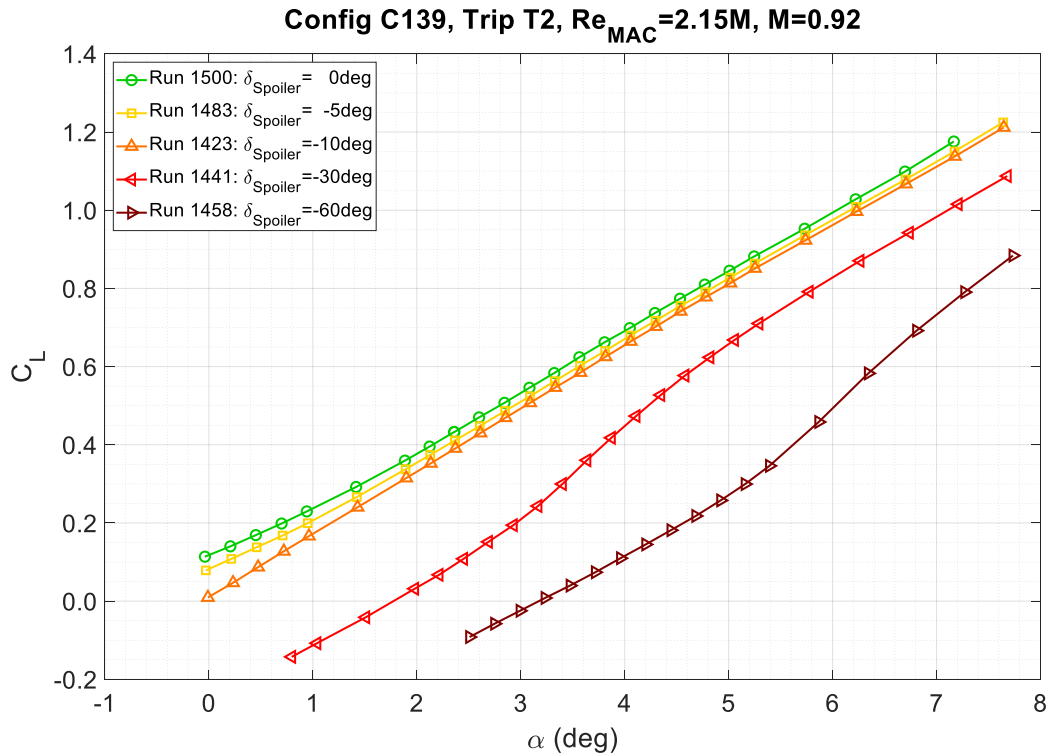


Figure 2-137. Effect of Spoilers on the Lift Coefficient [Config C139, Trip T2, $Re_{MAC}=2.15M$, $M=0.92$].

At Mach=0.92 (Call to figure in text should come before the figure. (Figure 2-137), with the presence of strong shocks, the effects of small deflections are linear with angle of attack in lift coefficient. The baseline curve also follows this trend. Larger deflections, however, are now nonlinear but no reversals are observed anywhere in the angle of attack range.

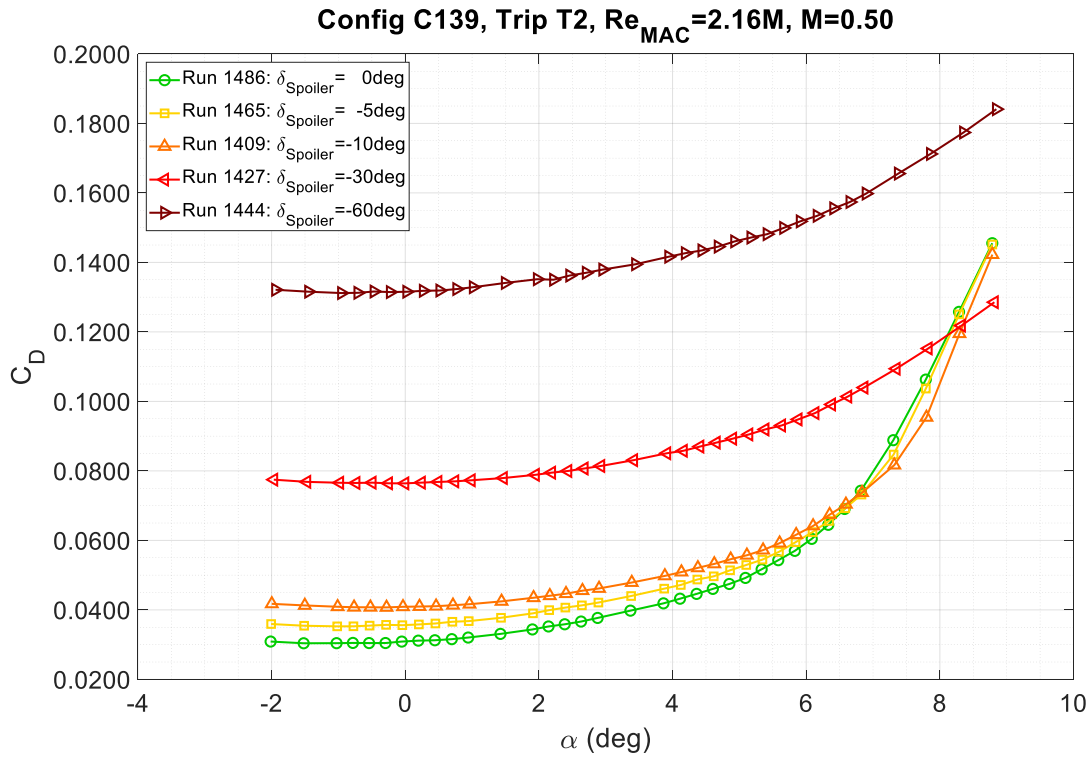


Figure 2-138. Effect of Spoilers on the Drag Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].

The use of spoilers for speed brakes show good overall results across angle of attack, Mach, and deflection. However, at Mach=0.92, the smaller deflections show relatively small increases in drag. The presence of stronger shocks and separated flow tends to dominate the flow field and small deflections of the spoiler do not affect it very much. Larger deflections are required to create significant increases in drag from the baseline configuration. (Don't see call to Figs 2-138 through 2-140.)

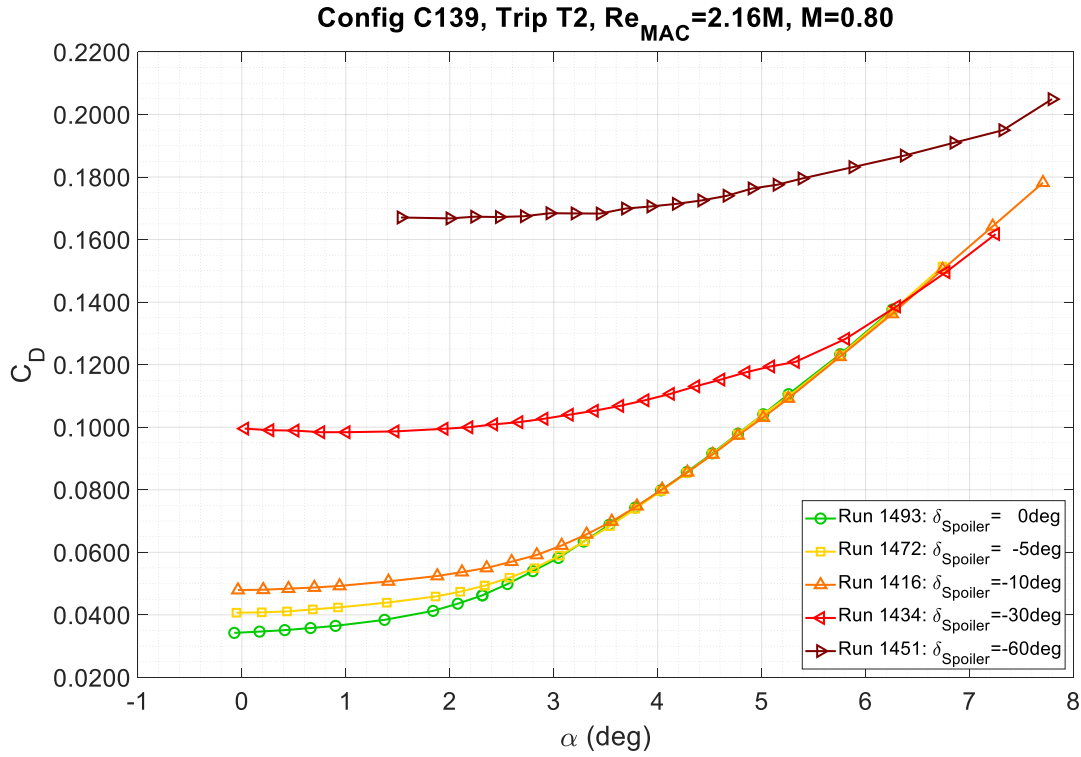


Figure 2-139. Effect of Spoilers on the Drag Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].

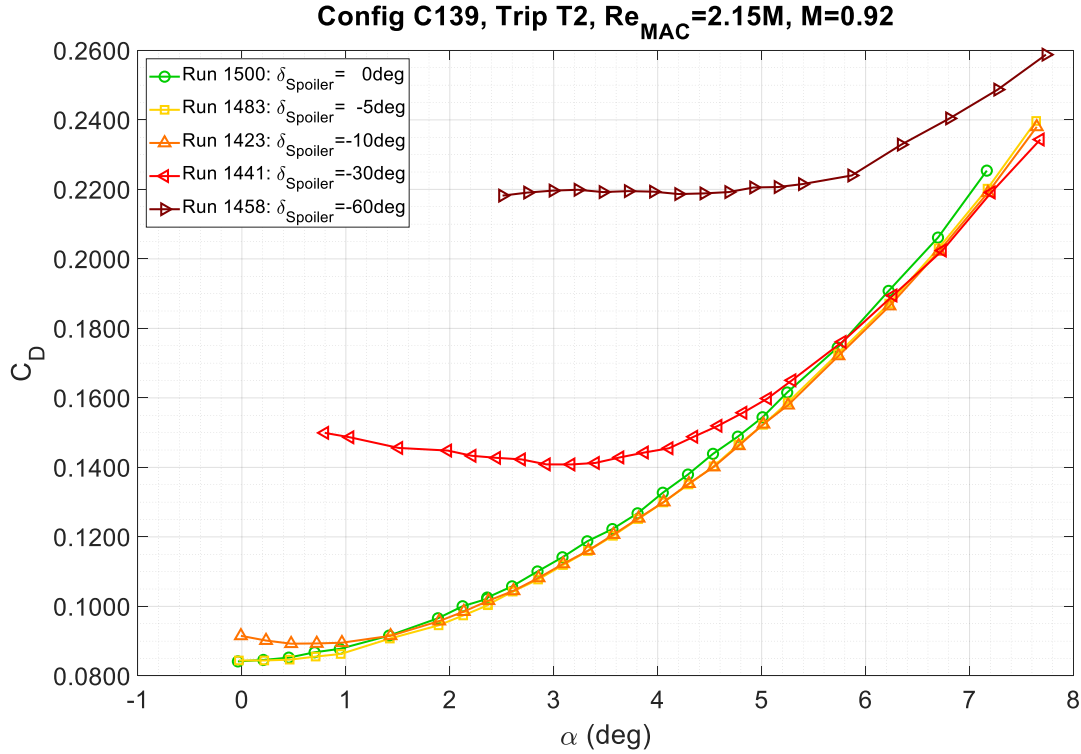


Figure 2-140. Effect of Spoilers on the Drag Coefficient [Config C139, Trip T2, $Re_{MAC}=2.15M$, $M=0.92$].

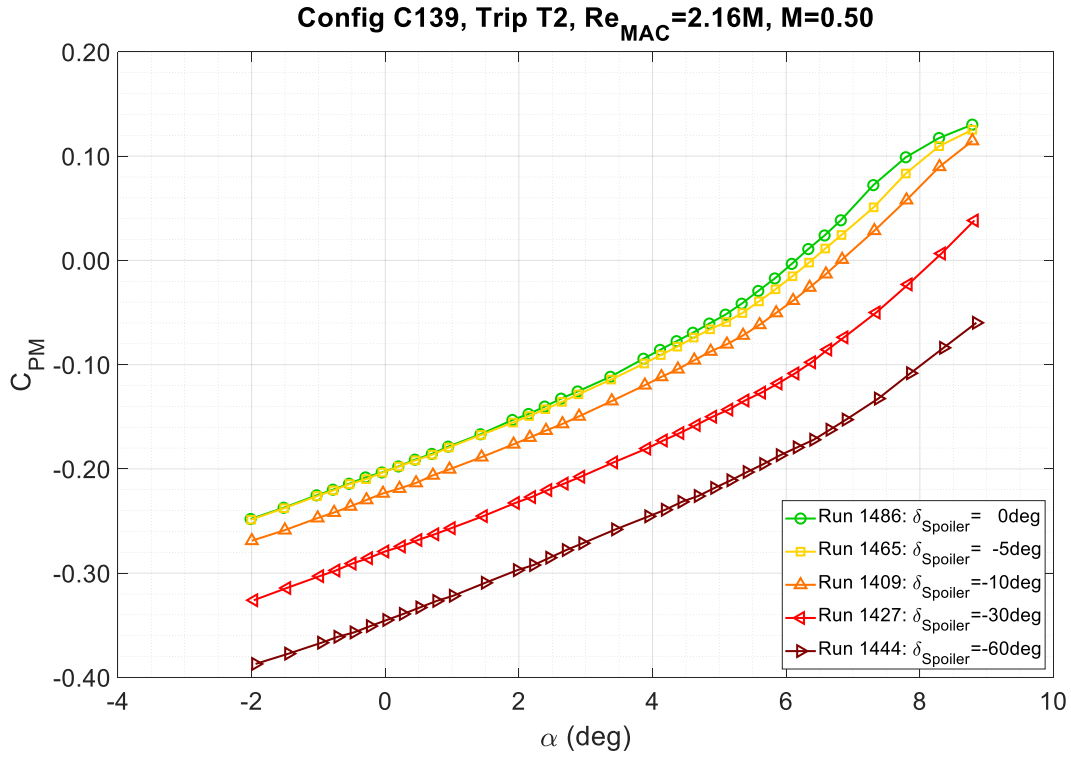


Figure 2-141. Effect of Spoilers on the Pitching Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].

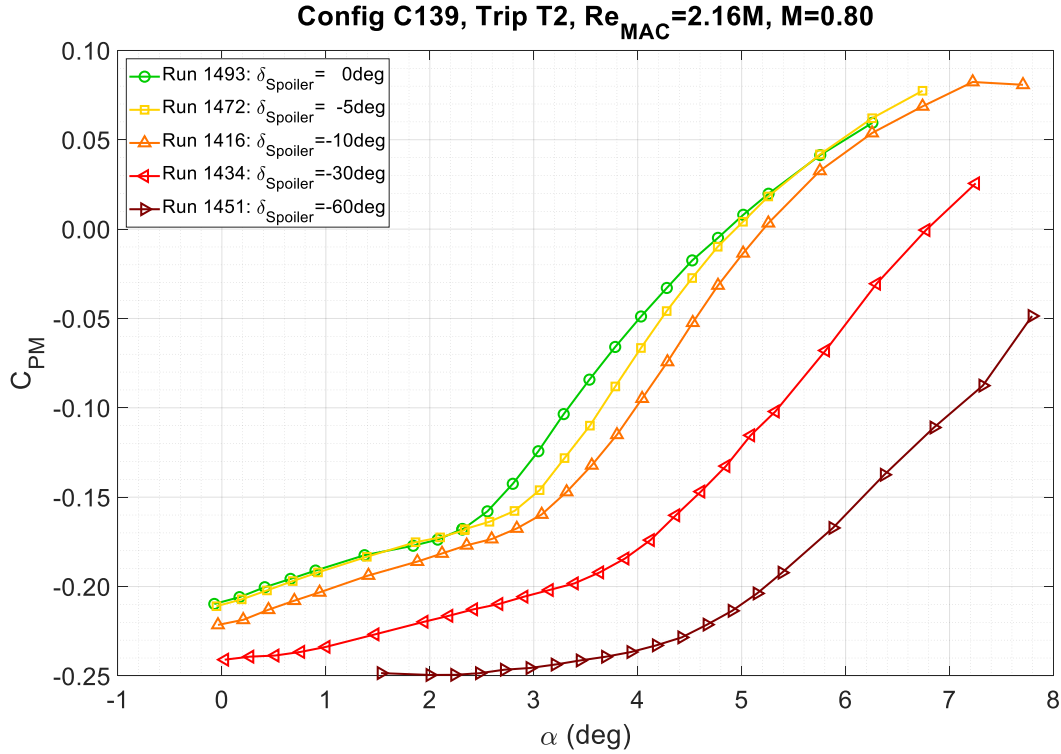


Figure 2-142. Effect of Spoilers on the Pitching Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].

Pitching moment shows reasonable response across Mach, angle of attack, and deflection. Magnitude of pitching moment changes due to the spoilers are well within the tail pitch limits mapped earlier during the full span entry and presumable elevator authority for this type of tail. (Don't see call to Figs 2-141 through 2-143. Also call to figures in text should come before the figures).

While the magnitudes remain small, the baseline level of instability increases with increasing Mach number.

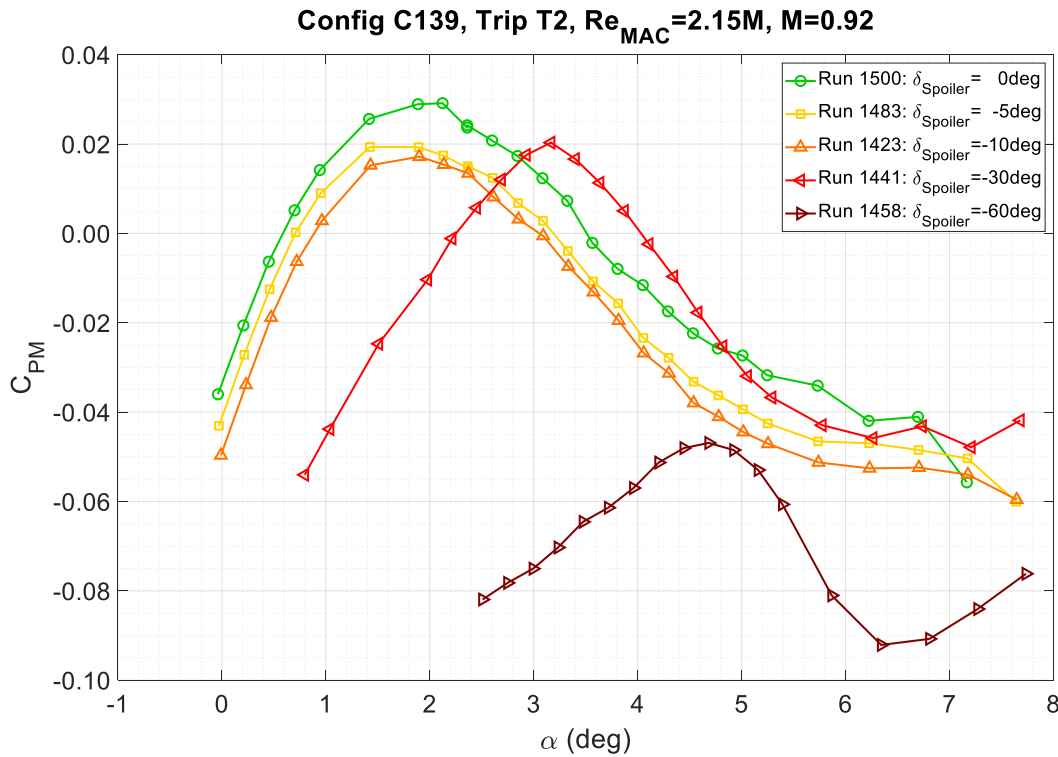


Figure 2-143. Effect of Spoilers on the Pitching Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.15M$, $M=0.92$].

The pitching moment characteristics at Mach=0.92 (Figure 2-143) are highly nonlinear but still well within tail pitch limits.

Rolling moment characteristics follow lift generally and changes due to deflection are linear at low Mach numbers (Figure 2-144). At Mach=0.80 (Figure 2-145), there are signs of reversal at the higher angles of attack and smaller deflection angles. The reversal follows the same patterns as seen in lift coefficient.

At the higher Mach numbers (Figure 2-146), there are no indications of reversal of rolling moment control authority. However, the smaller deflections of spoilers are not very effective. This is not surprising as previous testing on swept wing transports has shown similar characteristics. Small deflections do not alter the flow field which is dominated by strong shocks and separated flow.

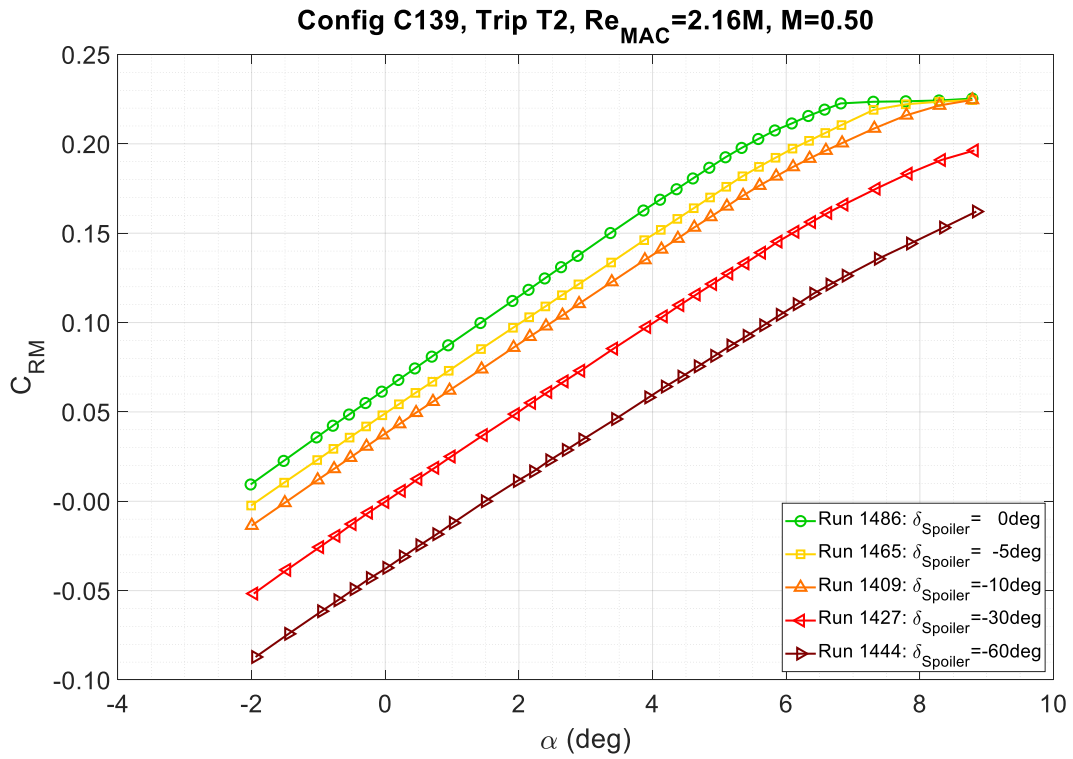


Figure 2-144. Effect of Spoilers on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.5$].

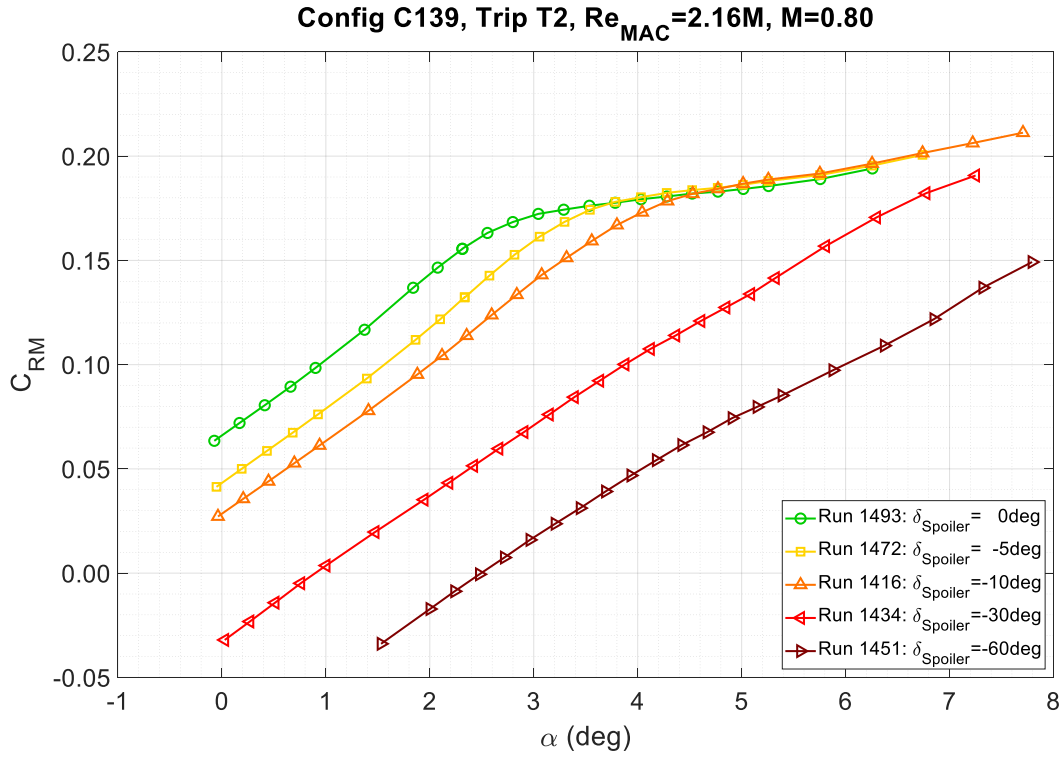


Figure 2-145. Effect of Spoilers on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.16M$, $M=0.8$].

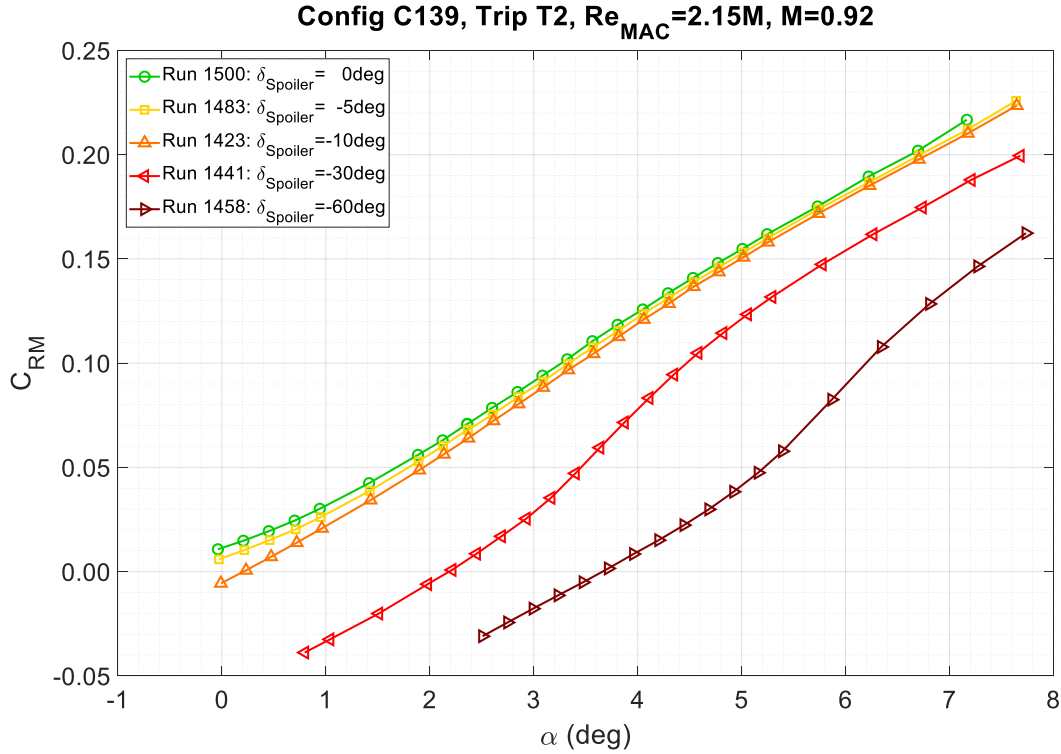


Figure 2-146. Effect of Spoilers on the Rolling Moment Coefficient [Config C139, Trip T2, $Re_{MAC}=2.15M$, $M=0.92$].

2.13.1.4 Outboard Strut Flap Effects

Small deflections of the strut flap were tested to assess levels of additional roll control. At a Reynolds number of 5.18 million, four small deflections, -4° , -2° , $+2^\circ$, and $+4^\circ$, were tested. A summary of the rolling and pitching moment coefficients is presented below.

As expected, changes in pitching moment are small at the lower Mach numbers and miniscule at the highest Mach numbers. TED deflections at the lower Mach numbers do not cause significant changes in pitching moment. Only the -4° deflection seems to affect the baseline pitching moment by a small but discernible airplane nose up moment.

With increasing Mach, the effect of the -4° deflection becomes smaller (see Figure 2-147 to Figure 2-149).

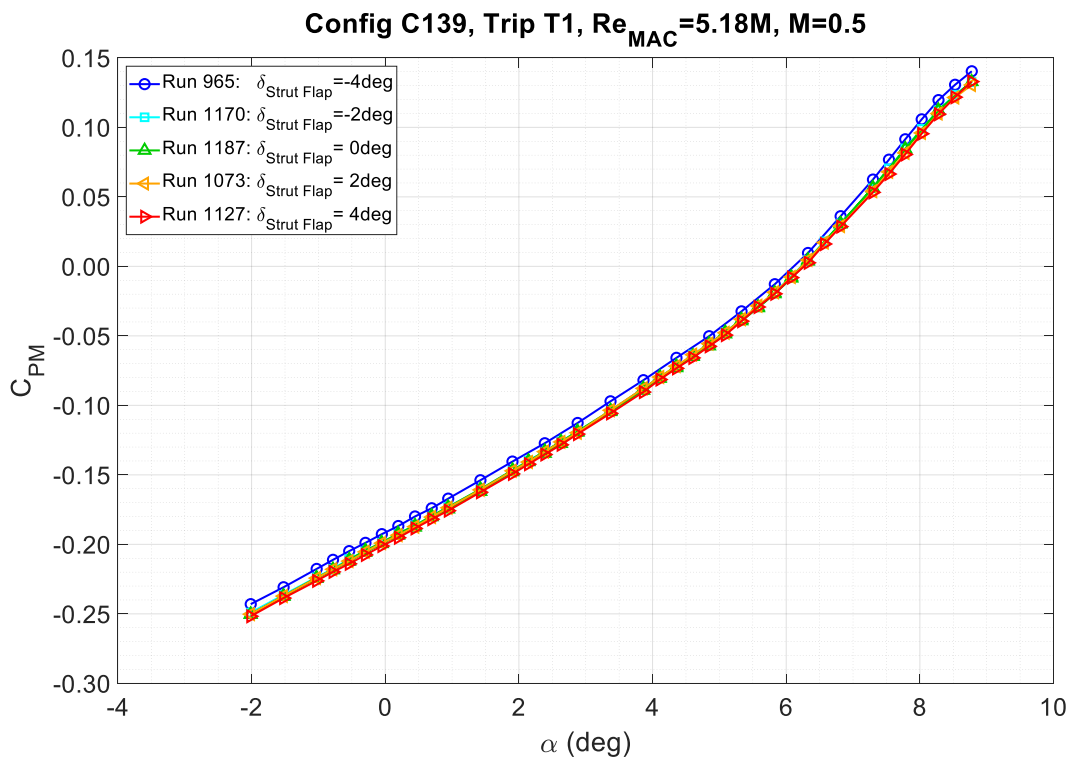


Figure 2-147. Effect of Strut Flap Deflection on the Pitching Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.5$].

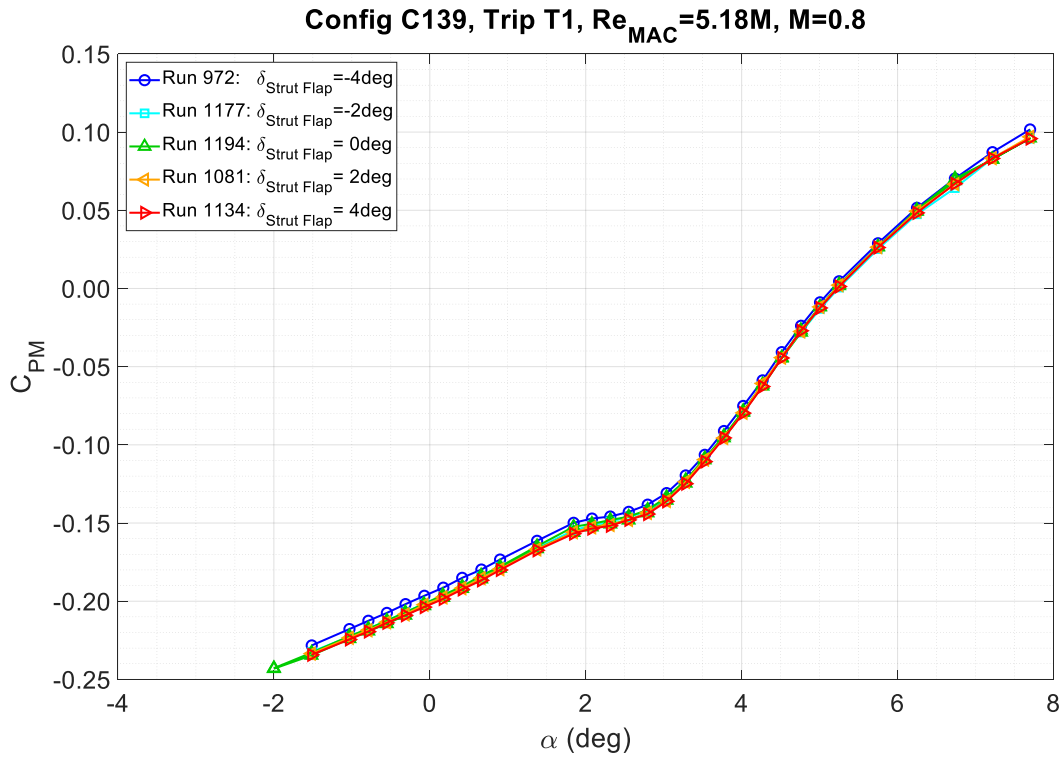


Figure 2-148. Effect of Strut Flap Deflection on the Pitching Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.8$].

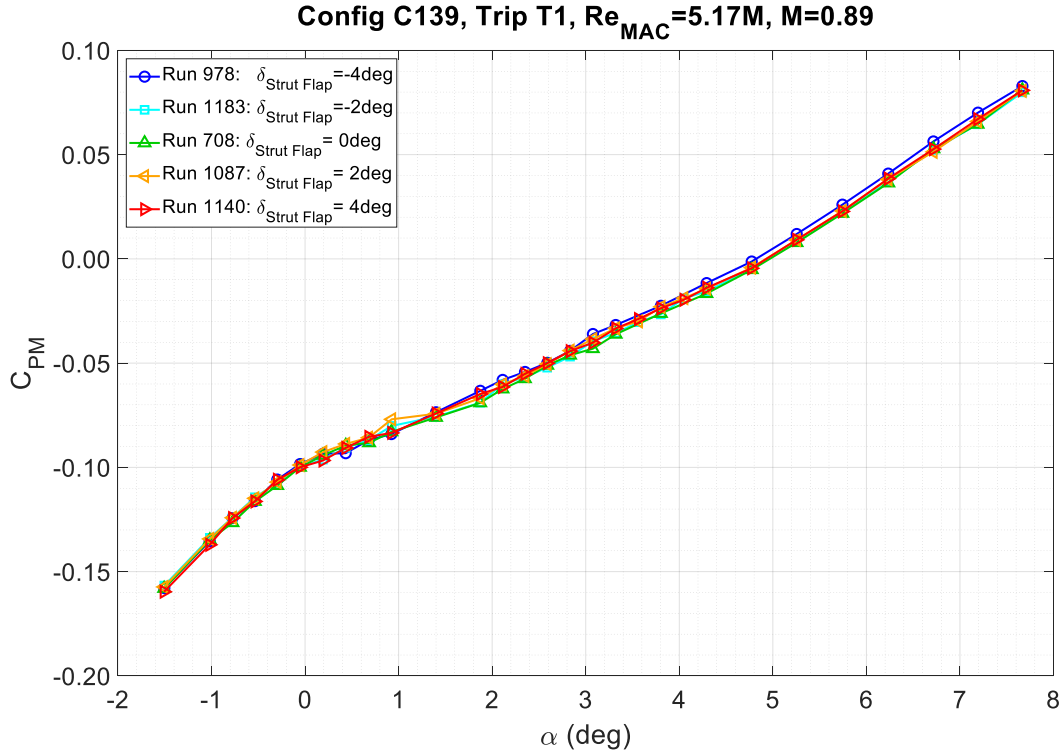


Figure 2-149. Effect of Strut Flap Deflection on the Pitching Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.89$].

The TED deflections add no significant changes to the rolling moment at lower Mach numbers (see Figure 2-150). TEU deflections are more effective but changes in rolling moment are an order of magnitude smaller than what the inboard aileron alone can generate.

At cruise Mach (Figure 2-151), both TEU and TED deflection alter the rolling moment minimally while at Mach=0.89 (Figure 2-152), the effect essentially is collapsed and no significant changes in rolling moment can be observed.

Due to the semispan installation, the ability to test the effects of the strut flap as a yaw effector were not possible to test. However, the potential of this surface to be used as a potential yaw control or speed brake will be assessed in the future.

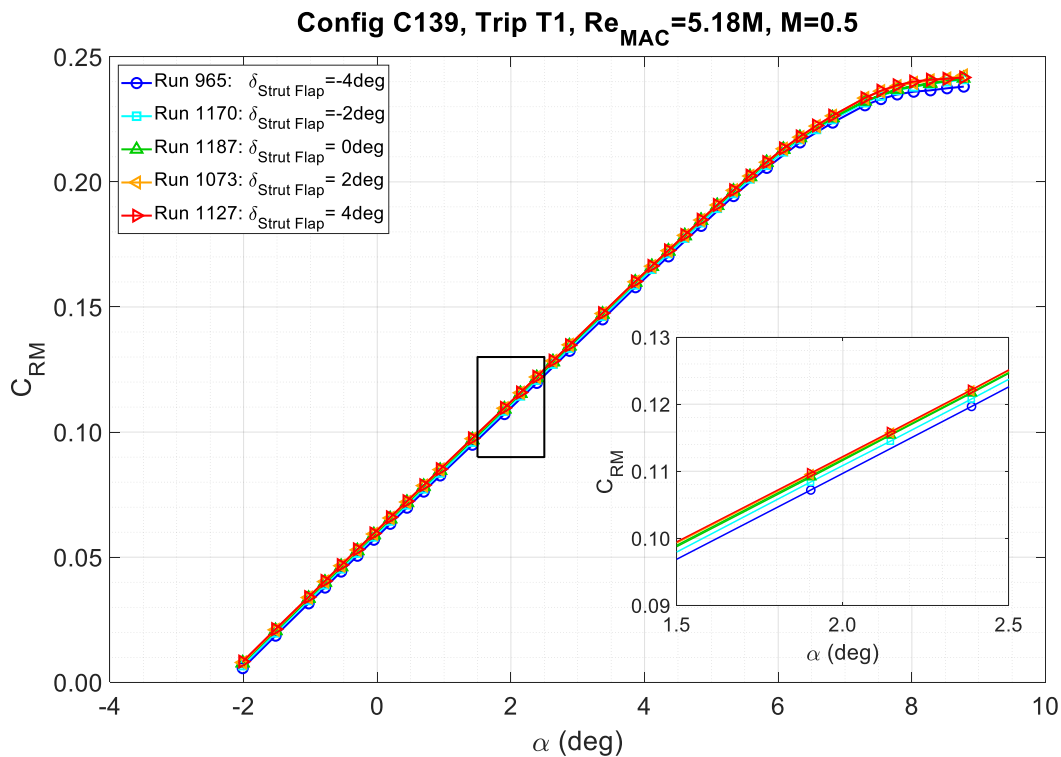


Figure 2-150. Effect of Strut Flap Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.5$].

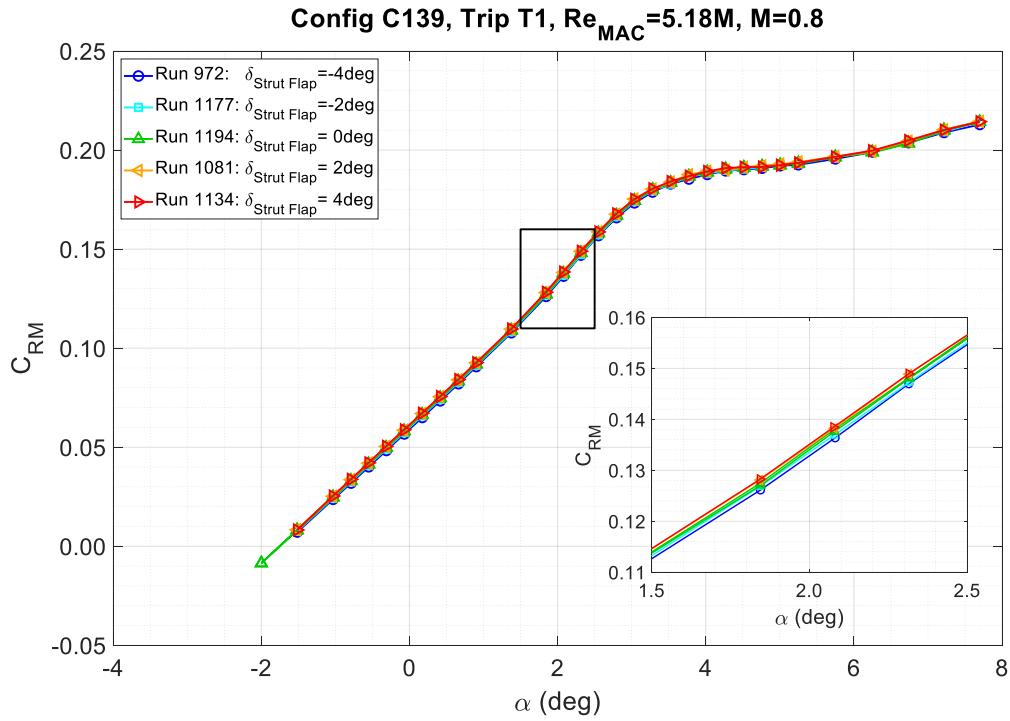


Figure 2-151. Effect of Strut Flap Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.8$].

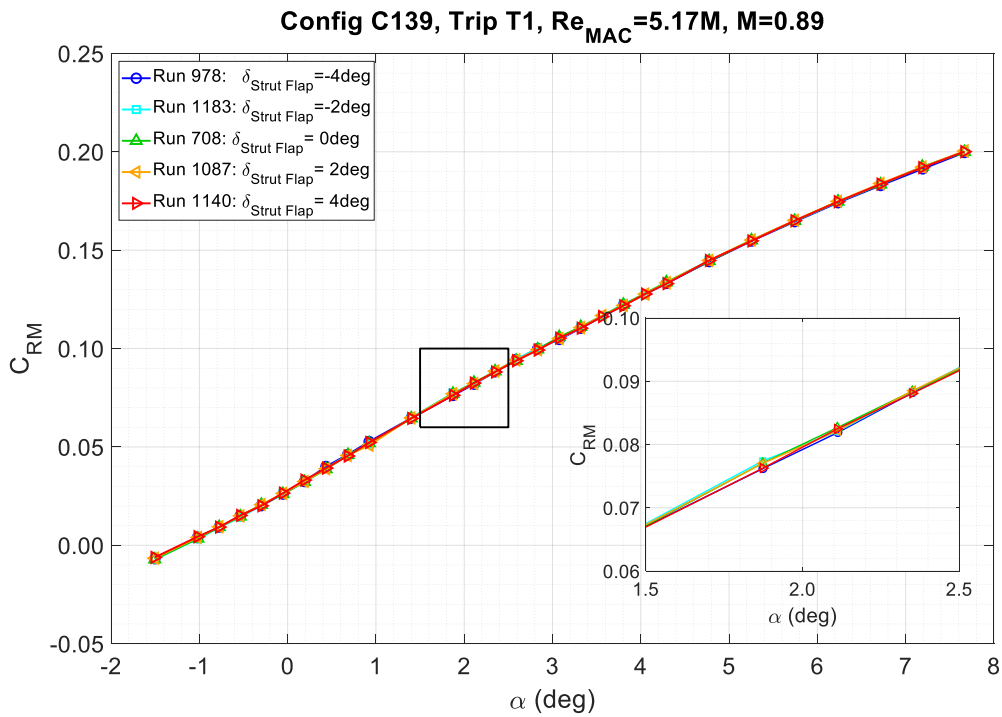


Figure 2-152. Effect of Strut Flap Deflection on the Rolling Moment Coefficient [Config C139, Trip T1, $Re_{MAC}=5.2M$, $M=0.89$].

2.13.1.5 General Assessment of Vehicle Control

During the early phases of wind tunnel testing a new airplane, primary concern is on general characteristics, levels of control authority, and any indications of problems areas. The full span model entry included testing of the horizontal tail. The angle of attack range was highly limited but, in general, showed good stability and pitch authority from the horizontal. However, lack of higher angle-of-attack data and elevator testing precluded a more complete assessment of the stability and control in the pitch axis. Testing during this entry, with a semispan model, added no further information toward a more conclusive evaluation.

In the lateral axis, investigation of rolling moment characteristics during the previous test was generally limited to lower angles of attack due to load limits. However, indications of roll reversal with aileron deflections were uncovered at the higher end of the Mach range and small deflections. During this entry, a wider range of deflections and at higher angles of attack were tested and the rolling moment reversal was confirmed and more thoroughly mapped. While the reversals are only present with TEU deflections, they remain an undesirable characteristic that complicates development of the flight control system and carries risk.

With spoiler deflections, the single indication of roll reversal during the previous entry was with the deployment of the outboard spoilers. Midboard and inboard spoilers did not show this characteristic. During this entry, only the combined inboard, midboard, and outboard spoilers were tested and, as a combined element, show no indication of reversal, which is as expected. Also, as is consistent with previous swept wing transport configurations, small deflections are ineffective at the high end of the Mach range. This is observed both in rolling moment and drag. However, the larger deflections of the spoilers remain effective and do not generate severe changes in pitching moment and remain well within the pitch limits of the horizontal. Since elevator authority was not defined, the horizontal pitch limits were used to make a rough assessment.

3.0 Final High-Speed Test Conclusions

The transonic buffet test successfully investigated buffet onset on a TTBW, and gathered important data for the validation of existing tools and processes. A series of heritage tools for buffet boundary prediction were compared against unsteady pressure measurements taken with a new, 9% scale semispan wind tunnel model tested in the NASA ARC 11-Ft Transonic Wind Tunnel. With the exception of the pitching moment break and trailing edge pressure divergence methods, reasonably good agreement in buffet boundary predictions was found for the axial force offset, accelerometer, and strain gauge methods, when using the wing forward trip configuration. However, buffet boundaries for configurations that tested more significant laminar runs using a series of aft trips were found to have disagreement with unsteady pressure measurements taken during testing, particularly for higher Mach flows. In these cases, resolution of buffet prediction methods still requires additional work to understand and resolve differences. Changes to vehicle configuration and changes in flow conditions were also well predicted when using the forward trip. Alterations in vehicle spanload did not have a strong effect on buffet critical station.

CFD analysis of the vehicle was compared to acquired test data. While good agreement was found in incremental changes based on changes to configuration and flow conditions, the analysis highlighted a disconnect between the predicted and measured vehicle surface pressures. In particular, the cruise design condition shock location was significantly further forward in test than in analysis. A review of previous in-tunnel CFD predictions highlighted the need for full-tunnel modeling (floor, walls, and ceiling) to achieve improved matching between CFD and test. Nevertheless, for the conditions of interest in the buffet test, floor-only CFD of the wind tunnel model provided a good match to test, giving confidence that the desired buffet-onset flow characteristics in the tunnel were suitable for investigations of buffet boundary.

For the TTBW configuration, this test has successfully mitigated concerns regarding potential alternate buffet onset mechanisms. Measured data confirm that low- C_L and wing-strut-channel induced buffet onset are no longer a primary concern. Rather, the TTBW configuration has a fairly conventional wing-upper-surface-based buffet onset, where the only difference from a standard cantilever wing buffet is an inward movement of the critical wing section from ~70% span to the wing-strut spanwise attachment location.

The testing also expanded the range of stability and control investigations begun in the last high-speed wind tunnel test campaign. Data for an expanded range of deflections, Mach and angle of attack for wing-mounted control surfaces were collected. These data identified a region of rolling moment reversal with greater definition across a range of control surface deflections, Mach, and angle of attack.

4.0 Recommendations for Future High-Speed Testing

Completion of the transonic buffet test marks the conclusion of the latest high-speed risk reduction effort for the SUGAR Mach=0.80 TTBW configuration. In this test, it was shown that buffet onset flow physics for the TTBW are similar to conventional cantilevered wing aircraft, with the primary buffet instabilities occurring on the wing, and not on the strut or in the wing-strut channel. Despite this determination, there are several elements of the test that could be improved on to provide more complete information regarding buffet onset on the TTBW. In particular, the loss of unsteady pressure transducers (Kulites®) before and during testing in the key spanwise region provided some limitations to the results of the test. Replacement of these sensors and revisitation/addition of key test points could provide more complete information regarding buffet onset. In addition, since the buffet boundary was determined through a post-test analysis process (and not in real time), load limitations on the model occasionally cut testing short at some conditions of interest. This directly resulted in the need for some calculated buffet boundaries to use more significant extrapolation. These extrapolations occasionally led to increased uncertainty in predicted buffet boundaries. Therefore, revisiting of these conditions at slightly lower dynamic pressures may provide additional data to complement available buffet estimates.

In addition, the buffet wind tunnel model is fairly stiff and is not representative of anticipated flight vehicle aeroelastics. Since significant structural maturation of the TTBW has occurred in the last few years, interest has increased in revisiting aeroelastic testing with an updated configuration structural and aerodynamic design. This test could leverage the learnings from the last decade of TTBW development (both M=0.80 aero design with EI/GJ distributions from new structural designs), and provide the most accurate insight into TTBW aeroelastic behaviors to date. The creation of a new test asset would provide the potential for future studies of gust load alleviation benefits and exploration of aeroservoelasticity effects that may be used for control law development.

It is noted that for future testing of any configuration in the 11-Ft transonic tunnel in which unsteady pressure measurements are collected, a fairing applied to the tunnel arc sector might reduce background noise, increasing dynamic data quality.

High speed (transonic) testing to date has been completed in the wind tunnel. These tests have provided critical technology maturation. However, in order to best match vehicle aeroelastics and Reynolds number, the next step in maturation would be best accomplished using a full-scale flying test article. This article could be used to substantiate the high aerodynamic efficiency of the configuration, and further calibrate both buffet prediction and flutter prediction methods.

5.0 References

1. *Investigation of Seal-to-Floor Effects on Semi-Span Transonic Model*. **Sleppy, Mark A., et al.** Orlando : AIAA, 2009. 47th AIAA Aerospace Sciences Meeting Including The New Horizons Forum and Aerospace Exposition.
2. *Characterisation of Buffet on a Civil Aircraft Wing*. **Lawson, Simon G, Greenwell, Doug and Quinn, Mark Kenneth** . San Diego : 54th AIAA Aerospace Sciences Meeting, 2016.
3. *Global Structure of Buffeting Flow on Transonic Airfoils*. **Crouch, Jeffrey D, et al.** Dordrecht : Springer, 2009. IUTAM Symposium on Unsteady Separated Flows and Their Control.
4. **McDevitt, John B and Okuno, Arthur F.** *Static and Dynamic Pressure Measurements on a NACA 0012 Airfoil in the Ames High Reynolds Number Facility*. Moffet Field : NASA Technical Paper 2485, 1985.
5. *Experimental Study of Shock Oscillation over a Transonic Supercritical Profile*. **Jacquin, L, et al.** 9, 2009, AIAA Journal, Vol. 47.
6. *Origin of Transonic Buffet on Aerofoils*. **Crouch, Jeffrey D, et al.** June 2009, Journal of Fluid Mechanics, Vol. 628, pp. 357–369.
7. *Global Instability in the Onset of Transonic-Wing Buffet*. **Crouch, Jeffrey D, Garbaruk, A and Strelets, M.** 2019, Journal of Fluid Mechanics, Vol. 881, pp. 3-22.
8. *Analysis and Comparison of Transonic Buffet Phenomenon over Several Three Dimensional Wings*. **Paladini, E, et al.** 1, 2019, AIAA Journal, Vol. 57, pp. 379-396.
9. *Global Instability of Wing Shock-Buffet Onset*. **Timme, S.** February 2020, Journal of Fluid Mechanics, Vol. 885.
10. *Experimental Study of Transonic Buffet Phenomenon on a 3D Swept Wing*. **Dandois, Julien.** 1, 2016, Physics of Fluids, Vol. 28.
11. *Flow Quality Survey of the NASA Ames 11-by 11-Ft Transonic Wind Tunnel*. **Amaya, Max A.** Tokyo and Nagoya : s.n., 2011. 114th Meeting of the Supersonic Tunnel Association.
12. **Rodde, A M and Archambaud, J P.** *A Selection of Experimental Test Cases* . Neuilly-Sur-Seine : Advisory Group for Aerospace Research & Development, 1994.
13. **Droney, C., Sclafani, A. and Grash, A.** *Subsonic Ultra-Green Aircraft Research Phase III: Mach 0.745 Aerodynamic Design*. s.l. : NASA, 2015.

14. **Harrison, Neal A, Droney, Christopher K and Beyar, Michael D.** *SUGAR Phase III: 4.5% Scale Transonic Truss-Braced Wing (TTBW) LB-649A Transonic Wind Tunnel Test - Final Report [Limited Rights Data]*. 2016. Contract Number: NNL10AA05B, Task Order: NNL14AB51T.

15. **Braslow, Albert L and Knox, Eugene C.** *Simplified Method for Determination of Critical Height of Distributed Roughness Particles for Boundary Layer Transition at Mach numbers from 0 to 5*. Washington, D.C. : NACA, 1958. Technical Note 4363.

16. **Harrison, Neal A, et al.** *SUGAR Phase IV Final Report - Volume I: Transonic Truss-Braced Wing High-Speed Design Report*. 2020. Contract number: NNL16AA04B, Task order: NNL17AA46T.

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Appendix A – Buffet Test Run Matrix

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			ReMAC	Mach
									IB	OB	IB	MB	OB		
Reynolds Number Study for Safety of Flight/Tunnel Cleanliness Check															
108	1/26/22	1	PP	C139	LE tape on	T1	0	0	0	0	0	0	0	0.00	0.00
109	1/26/22	1	SLO	C139		T1	0	0	0	0	0	0	0	0.00	0.00
110	1/26/22	1	SLO	C139		T1	0	0	0	0	0	0	0	0.00	0.00
111	1/26/22	1	SLO	C139		T1	0	0	0	0	0	0	0	0.00	0.00
112	1/26/22	1	SLO	C139		T1	0	0	0	0	0	0	0	0.00	0.00
113	1/26/22	1	PP	C139		T1	-4 to +6	0	0	0	0	0	0	2.16	0.80
117	1/27/22	1	PP	C139		T1	-4 to +10	0	0	0	0	0	0	2.16	0.20
Forward Trip															
118	1/27/22	1	PP	C139		T1	-4 to +16	0	0	0	0	0	0	2.16	0.20
119	1/27/22	1	PP	C139		T1	-4 to +9.5	0	0	0	0	0	0	2.16	0.50
120	1/27/22	1	PP	C139		T1	-4 to +7.5	0	0	0	0	0	0	2.16	0.70
121	1/27/22	1	PP	C139		T1	-4 to +6	0	0	0	0	0	0	2.16	0.80
122	1/27/22	1	PP	C139		T1	-4 to +5	0	0	0	0	0	0	2.16	0.85
123	1/27/22	1	PP	C139		T1	-3 to +5	0	0	0	0	0	0	2.16	0.89
124	1/27/22	1	PP	C139		T1	-3 to +5	0	0	0	0	0	0	2.16	0.92
128	1/27/22	2	PP	C139	LE tape on	T1	-2 to +9.5	0	0	0	0	0	0	3.29	0.50
129	1/27/22	2	PP	C139		T1	-2 to +7.5	0	0	0	0	0	0	3.29	0.70
130	1/27/22	2	PP	C139		T1	-2 to +7	0	0	0	0	0	0	3.29	0.75
131	1/27/22	2	PP	C139		T1	-2 to +6	0	0	0	0	0	0	3.29	0.80
132	1/27/22	2	PP	C139		T1	-2 to +5	0	0	0	0	0	0	3.29	0.85
133	1/27/22	2	PP	C139		T1	-2 to +5	0	0	0	0	0	0	3.29	0.89
135	1/27/22	2	PP	C139		T1	-2 to +5	0	0	0	0	0	0	3.29	0.92
136	1/27/22	3	PP	C139		T1	-2 to +9.5	0	0	0	0	0	0	5.18	0.50
137	1/27/22	3	SLO	C139	LE tape on	T1	-2 to +9.5	0	0	0	0	0	0	5.18	0.50
138	1/27/22	3	PP	C139		T1	-2 to +7.5	0	0	0	0	0	0	5.18	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
139	1/27/22	3	SLO	C139		T1	-2 to +6.25	0	0	0	0	0	0	5.18	0.70
140	1/27/22	3	SLO	C139		T1	-2 to +7.5	0	0	0	0	0	0	5.18	0.70
141	1/27/22	3	PP	C139		T1	-2 to +7	0	0	0	0	0	0	5.18	0.75
142	1/27/22	3	SLO	C139		T1	-2 to +7	0	0	0	0	0	0	5.18	0.75
143	1/27/22	3	PP	C139		T1	-2 to +6	0	0	0	0	0	0	5.18	0.80
144	1/27/22	3	SLO	C139		T1	-2 to +6	0	0	0	0	0	0	5.18	0.80
145	1/27/22	3	PP	C139		T1	-2 to +5	0	0	0	0	0	0	5.18	0.85
146	1/27/22	3	SLO	C139		T1	-2 to +5	0	0	0	0	0	0	5.18	0.85
147	1/27/22	3	PP	C139		T1	-1.5 to +5	0	0	0	0	0	0	5.18	0.89
148	1/27/22	3	PP	C139		T1	-1.5 to +5	0	0	0	0	0	0	5.18	0.89
149	1/27/22	3	SLO	C139		T1	-1.5 to +5	0	0	0	0	0	0	5.18	0.89
150	1/27/22	3	PP	C139		T1	-1.5 to +5	0	0	0	0	0	0	5.18	0.92
151	1/27/22	3	SLO	C139		T1	-1.5 to +5	0	0	0	0	0	0	5.18	0.92
158	1/27/22	4	PP	C139	LE tape on	T1	0. to +5	0	0	0	0	0	0	6.58	0.70
159	1/27/22	4	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.75
160	1/27/22	4	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.80
161	1/27/22	4	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.82
162	1/27/22	4	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.85
165	1/27/22	5	PP	C139	LE tape off	T1	0. to +5	0	0	0	0	0	0	6.58	0.70
166	1/27/22	5	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.75
167	1/27/22	5	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.80
168	1/27/22	5	SLO	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.80
169	1/27/22	5	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.82
170	1/27/22	5	PP	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.85
171	1/27/22	5	SLO	C139		T1	0. to +5	0	0	0	0	0	0	6.58	0.85
174	1/27/22	6	PP	C139	LE tape off	T1	-2. to 10	0	0	0	0	0	0	5.18	0.50
175	1/27/22	6	PP	C139		T1	-2. to 7.5	0	0	0	0	0	0	5.18	0.70
176	1/27/22	6	PP	C139		T1	-2. to 7	0	0	0	0	0	0	5.18	0.75
177	1/27/22	6	PP	C139		T1	-2. to 7	0	0	0	0	0	0	5.18	0.78

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
178	1/27/22	6	PP	C139		T1	-2. to 6	0	0	0	0	0	0	5.18	0.80
179	1/27/22	6	PP	C139		T1	-2. to 5.5	0	0	0	0	0	0	5.18	0.82
181	1/27/22	6	PP	C139		T1	-2. to 5	0	0	0	0	0	0	5.18	0.85
182	1/27/22	6	PP	C139		T1	-2. to 5	0	0	0	0	0	0	5.18	0.87
183	1/27/22	6	PP	C139		T1	-2. to 5	0	0	0	0	0	0	5.18	0.89
184	1/27/22	6	PP	C139		T1	-2. to 5	0	0	0	0	0	0	5.18	0.92
188	1/27/22	7	CPR	C139		T1	-2. to 6	0	0	0	0	0	0	5.18	0.80
189	1/27/22	7	CPR	C139		T1	-2. to 5	0	0	0	0	0	0	5.18	0.85
190	1/27/22	7	CPR	C139		T1	-2. to 5	0	0	0	0	0	0	5.18	0.92
191	1/27/22	7	CPR	C139		T1	-2. to 7	0	0	0	0	0	0	5.18	0.92
192	1/27/22	7	CPR	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.85
193	1/27/22	7	CPR	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.80
194	1/27/22	9	CPR	C139		T1	-2 to 10	0	0	0	0	0	0	5.18	0.80
195	1/27/22	9	CPR	C139		T1	-2 to 11	0	0	0	0	0	0	5.18	0.85
196	1/27/22	9	CPR	C139		T1	-1.5 to 8.4	0	0	0	0	0	0	5.18	0.92
197	1/27/22	10	CPR	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.92
198	1/27/22	10	CPR	C139		T1	-2. to 8.8	0	0	0	0	0	0	5.18	0.85
199	1/27/22	10	CPR	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.80
200	1/27/22	11	SLO	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.80
201	1/27/22	11	SLO	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.85
204	1/28/22	12	CPR	C139		T1	-2. to 14	0	0	0	0	0	0	5.18	0.78
205	1/28/22	12	CPR	C139		T1	-2. to 14	0	0	0	0	0	0	5.18	0.82
206	1/28/22	12	CPR	C139		T1	-2. to 14	0	0	0	0	0	0	5.18	0.78
207	1/28/22	12	CPR	C139		T1	-2. to 14	0	0	0	0	0	0	5.18	0.82
208	1/28/22	12	CPR	C139		T1	-2. to 12.4	0	0	0	0	0	0	5.18	0.87
217	1/28/22	12	PP	C139		T1	-2. to 11	0	0	0	0	0	0	5.18	0.78
218	1/28/22	12	PP	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.80
219	1/28/22	12	PP	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.82

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
220	1/28/22	12	PP	C139		T1	-2. to 10	0	0	0	0	0	0	5.18	0.85
221	1/28/22	12	PP	C139		T1	-1.5 to 9	0	0	0	0	0	0	5.18	0.87
222	1/28/22	12	PP	C139		T1	-1.5 to 9	0	0	0	0	0	0	5.18	0.92
223	1/28/22	13	CPR	C139		T1	-2. to 13	0	0	0	0	0	0	3.95	0.78
224	1/28/22	13	CPR	C139		T1	-2. to 12	0	0	0	0	0	0	3.95	0.80
225	1/28/22	13	CPR	C139		T1	-2. to 12	0	0	0	0	0	0	3.95	0.82
226	1/28/22	13	CPR	C139		T1	-2. to 12	0	0	0	0	0	0	3.95	0.85
227	1/28/22	13	CPR	C139		T1	-1.5 to 10	0	0	0	0	0	0	3.95	0.92
228	1/28/22	13	PP	C139		T1	-2. to 12	0	0	0	0	0	0	3.95	0.78
229	1/28/22	13	PP	C139		T1	-2. to 9.5	0	0	0	0	0	0	3.95	0.80
230	1/28/22	13	PP	C139		T1	-2. to 9	0	0	0	0	0	0	3.95	0.82
231	1/28/22	13	PP	C139		T1	-2. to 9	0	0	0	0	0	0	3.95	0.85
232	1/28/22	13	PP	C139		T1	-1.5 to 8.5	0	0	0	0	0	0	3.95	0.92
Forward Trip, Inboard Aileron +5deg															
235	1/28/22	14	CPR	C139	+ Inbd Ail	T1	-2 to 9	0	5	0	0	0	0	3.95	0.80
238	1/28/22	14	CPR	C139		T1	-2 to 9	0	5	0	0	0	0	3.95	0.85
239	1/28/22	14	CPR	C139		T1	-2 to 9	0	5	0	0	0	0	3.95	0.80
240	1/28/22	14	CPR	C139		T1	-1.5 to 8	0	5	0	0	0	0	3.95	0.92
242	1/28/22	14	PP	C139		T1	-2 to 9	0	5	0	0	0	0	3.95	0.80
243	1/28/22	14	PP	C139		T1	-2 to 9	0	5	0	0	0	0	3.95	0.85
244	1/28/22	14	PP	C139		T1	-1.5 to 8	0	5	0	0	0	0	3.95	0.92
245	1/28/22	14	PP	C139		T1	-2.0 to 9.5	0	5	0	0	0	0	5.18	0.80
246	1/28/22	14	PP	C139		T1	-2 to 9	0	5	0	0	0	0	5.18	0.85
247	1/28/22	14	PP	C139		T1	-1.5 to 8	0	5	0	0	0	0	5.18	0.92
248	1/28/22	14	CPR	C139		T1	-2.0 to 9.5	0	5	0	0	0	0	5.18	0.92
249	1/28/22	14	CPR	C139		T1	-2 to 8	0	5	0	0	0	0	5.18	0.85
250	1/28/22	14	CPR	C139		T1	-1.5 to 8	0	5	0	0	0	0	5.18	0.80
256	1/28/22	15	SLO	C139		T1	-2.0 to 9.5	0	5	0	0	0	0	5.18	0.80

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
257	1/28/22	15	SLO	C139		T1	-2 to 9	0	5	0	0	0	0	5.18	0.85
258	1/28/22	15	SLO	C139		T1	-2 to 9	0	5	0	0	0	0	3.95	0.80
259	1/28/22	15	SLO	C139		T1	-2 to 9	0	5	0	0	0	0	3.95	0.85
260	1/28/22	16	CPR	C139		T1	-2 to 10	0	5	0	0	0	0	5.18	0.80
261	1/28/22	16	CPR	C139		T1	-2 to 10	0	5	0	0	0	0	5.18	0.85
262	1/28/22	16	CPR	C139		T1	-2 to 10	0	5	0	0	0	0	3.95	0.80
263	1/28/22	16	CPR	C139		T1	-2 to 10	0	5	0	0	0	0	3.95	0.85
264	1/28/22	17	CPR	C139		T1	+2 to 8	0	5	0	0	0	0	3.95	0.85
265	1/28/22	17	CPR	C139		T1	+2 to 8	0	5	0	0	0	0	3.95	0.80
266	1/28/22	17	CPR	C139		T1	+2 to 8	0	5	0	0	0	0	5.18	0.80
267	1/28/22	17	CPR	C139		T1	+2 to 8	0	5	0	0	0	0	5.18	0.85
Forward Trip, Inboard Aileron 0deg															
270	1/28/22	18	CPR	C139		T1	+2 to 8	0	0	0	0	0	0	5.18	0.80
271	1/28/22	18	CPR	C139		T1	+2 to 8.9	0	0	0	0	0	0	5.18	0.85
272	1/28/22	18	CPR	C139		T1	+2 to 8	0	0	0	0	0	0	3.95	0.80
273	1/28/22	18	CPR	C139		T1	+2 to 8	0	0	0	0	0	0	3.95	0.85
274	1/28/22	19	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.85
275	1/28/22	19	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
276	1/28/22	20	SLO	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
277	1/28/22	20	SLO	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.85
278	1/28/22	21	CPR	C139		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.75
279	1/28/22	21	CPR	C139		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.78
280	1/28/22	21	CPR	C139		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.80
281	1/28/22	21	CPR	C139		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.82
282	1/28/22	21	CPR	C139		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.85
283	1/28/22	21	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.87
284	1/28/22	21	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.50
287	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.80

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
288	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.50
289	1/30/22	22	PP	C139		T1	-2 to 0.75	0	0	0	0	0	0	5.18	0.50
290	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.60
291	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.70
292	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.72
293	1/30/22	22	PP	C139		T1	-2 to 9.5	0	0	0	0	0	0	5.18	0.75
294	1/30/22	22	PP	C139		T1	-2 to 8.	0	0	0	0	0	0	5.18	0.77
295	1/30/22	22	PP	C139		T1	-2 to 8.5.	0	0	0	0	0	0	5.18	0.78
296	1/30/22	22	PP	C139		T1	-2 to 8.5.	0	0	0	0	0	0	5.18	0.79
297	1/30/22	22	PP	C139		T1	-2 to 8.5.	0	0	0	0	0	0	5.18	0.80
298	1/30/22	22	PP	C139		T1	-2 to 9.	0	0	0	0	0	0	5.18	0.81
299	1/30/22	22	PP	C139		T1	-2 to 9.	0	0	0	0	0	0	5.18	0.82
300	1/30/22	22	PP	C139		T1	-2 to 9.5	0	0	0	0	0	0	5.18	0.83
301	1/30/22	22	PP	C139		T1	-2 to 4.5	0	0	0	0	0	0	5.18	0.85
310	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.85
311	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.87
312	1/30/22	22	PP	C139		T1	-2 to 8.5	0	0	0	0	0	0	5.18	0.89
313	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.92
314	1/30/22	22	PP	C139		T1	-2 to 8.5.	0	0	0	0	0	0	5.18	0.92
315	1/30/22	22	PP	C139		T1	-2 to 9.	0	0	0	0	0	0	5.18	0.80
316	1/30/22	22	PP	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.65
319	1/30/22	23	CPR	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.80
320	1/30/22	23	CPR	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.80
321	1/30/22	23	CPR	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.85
322	1/30/22	23	CPR	C139		T1	-2 to 9.6	0	0	0	0	0	0	5.18	0.85
324	1/30/22	24	Static Tap Test	C139		T1	N/A	0	0	0	0	0	0	0.00	0.00
326	1/31/22	25	CPR	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.60
327	1/31/22	25	CPR	C139		T1	-2 to 10.	0	0	0	0	0	0	5.18	0.70
328	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.72

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
329	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.77
330	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.79
331	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
332	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.81
333	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.83
334	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.87
335	2/1/22	25	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.89
336	2/1/22	26	PP	C139		T1	-2 to 10	0	0	0	0	0	0	3.95	0.80
337	2/1/22	26	PP	C139		T1	-2 to 10	0	0	0	0	0	0	3.95	0.50
338	2/1/22	26	PP	C139		T1	-2 to 10	0	0	0	0	0	0	3.95	0.60
339	2/1/22	26	PP	C139		T1	-2 to 10	0	0	0	0	0	0	3.95	0.65
340	2/1/22	26	PP	C139		T1	-2 to 10	0	0	0	0	0	0	3.95	0.70
341	2/1/22	26	PP	C139		T1	-2 to 10	0	0	0	0	0	0	3.95	0.72
342	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.75
343	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.77
344	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.78
345	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.79
346	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.80
347	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.81
348	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.82
349	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.83
350	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.85
351	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.87
352	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.89
353	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.92
354	2/1/22	26	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.80
355	2/1/22	27	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.75
356	2/1/22	27	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.78
357	2/1/22	27	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.80

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
358	2/1/22	27	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.82
359	2/1/22	27	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.85
360	2/1/22	27	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.89
Forward Trip, Add missing trip dots on Outboard Strut Upper Surface															
363	2/1/22	28	PP	C139	add strut trip dots	T1	-2 to 10	0	0	0	0	0	0	5.18	0.70
364	2/1/22	28	PP	C139		T1	-2 to 7	0	0	0	0	0	0	5.18	0.75
365	2/1/22	28	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.78
366	2/1/22	28	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.79
367	2/1/22	28	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
368	2/1/22	28	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.81
369	2/1/22	28	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.82
370	2/1/22	28	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.85
371	2/1/22	28	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.87
372	2/1/22	28	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.89
373	2/1/22	29	CPR	C139		T1	-2 to 7	0	0	0	0	0	0	5.18	0.75
374	2/1/22	29	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.78
375	2/1/22	29	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
376	2/1/22	29	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.82
377	2/1/22	29	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.85
378	2/1/22	29	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.89
Forward Trip, Build Up. Removed added Strut US trip dots in juncture															
380	2/1/22	30	PP	C139		T1	0	0	0	0	0	0	0	0.00	0.00
381	2/1/22	30	PP	C139		T1	0	0	0	0	0	0	0	0.00	0.00
382	2/1/22	30	PP	C139		T1	0	0	0	0	0	0	0	0.00	0.00
383	2/1/22	31	PP	C141	-NPFHF	T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
384	2/1/22	31	PP	C141		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.50
385	2/1/22	31	PP	C141		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.60
386	2/1/22	31	PP	C141		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.65

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
387	2/1/22	31	PP	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.70
388	2/1/22	31	PP	C141		T1	-2 to 7	0	0	0	0	0	0	5.18	0.72
389	2/1/22	31	PP	C141		T1	-2 to 6.25	0	0	0	0	0	0	5.18	0.75
390	2/1/22	31	PP	C141		T1	-2 to 6	0	0	0	0	0	0	5.18	0.77
391	2/1/22	31	PP	C141		T1	-2 to 6.0	0	0	0	0	0	0	5.18	0.78
392	2/1/22	31	PP	C141		T1	-2 to 9.	0	0	0	0	0	0	5.18	0.79
393	2/1/22	31	PP	C141		T1	-2 to 9.9	0	0	0	0	0	0	5.18	0.80
394	2/1/22	31	PP	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.81
397	2/1/22	31	PP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
398	2/1/22	31	PP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.81
399	2/1/22	31	PP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.82
400	2/1/22	31	PP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.83
401	2/1/22	31	PP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.85
402	2/1/22	31	PP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.87
403	2/1/22	31	PP	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.89
404	2/1/22	31	PP	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.92
405	2/1/22	31	PP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
406	2/1/22	31	PP	C141		T1	-2 to 7	0	0	0	0	0	0	5.18	0.70
407	2/1/22	32	SPP	C141		T1	-2 to 6.25	0	0	0	0	0	0	5.18	0.75
408	2/1/22	32	SPP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.78
409	2/1/22	32	SPP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
410	2/1/22	32	SPP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.82
411	2/1/22	32	SPP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.85
412	2/1/22	33	CP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.80
413	2/1/22	33	CP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.85
414	2/1/22	33	CP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.78
415	2/1/22	33	CP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.82
416	2/1/22	33	CP	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.89
417	2/1/22	33	wind off zero	C141		T1	0	0	0	0	0	0	0	0.00	0.00

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
418	2/1/22	33	wind off zero	C141		T1	0	0	0	0	0	0	0	0.00	0.00
421	2/1/22	33	CPR	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.60
422	2/1/22	33	CPR	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.65
423	2/1/22	33	CPR	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.70
424	2/1/22	33	CPR	C141		T1	-2 to 9	0	0	0	0	0	0	5.18	0.75
425	2/1/22	33	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.77
426	2/1/22	33	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.79
427	2/1/22	33	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
428	2/2/22	33	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.81
429	2/2/22	33	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.83
430	2/2/22	33	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	5.18	0.87
433	2/2/22	34	PP	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
434	2/2/22	34	PP	C141		T1	-2 to 9	0	0	0	0	0	0	3.95	0.50
435	2/2/22	34	PP	C141		T1	-2 to 9	0	0	0	0	0	0	3.95	0.65
436	2/2/22	34	PP	C141		T1	-2 to 9	0	0	0	0	0	0	3.95	0.70
437	2/2/22	34	PP	C141		T1	-2 to 9	0	0	0	0	0	0	3.95	0.75
438	2/2/22	34	PP	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.78
439	2/2/22	34	PP	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
440	2/2/22	34	PP	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.82
441	2/2/22	34	PP	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.83
442	2/2/22	34	PP	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.85
443	2/2/22	34	PP	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.89
444	2/2/22	35	CPR	C141		T1	-2 to 9	0	0	0	0	0	0	3.95	0.65
445	2/2/22	35	CPR	C141		T1	-2 to 9	0	0	0	0	0	0	3.95	0.70
446	2/2/22	35	CPR	C141		T1	-2 to 9	0	0	0	0	0	0	3.95	0.75
447	2/2/22	35	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.78
448	2/2/22	35	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
449	2/2/22	35	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.82
450	2/2/22	35	CPR	C141		T1	-2 to 8	0	0	0	0	0	0	3.95	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
453	2/2/22	36	PP	C142	+NP	T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
454	2/2/22	36	PP	C142		T1	-2 to 9	0	0	0	0	0	0	5.18	0.50
455	2/2/22	36	PP	C142		T1	-2 to 9	0	0	0	0	0	0	5.18	0.60
456	2/2/22	36	PP	C142		T1	-2 to 9	0	0	0	0	0	0	5.18	0.65
457	2/2/22	36	PP	C142		T1	-2 to 9	0	0	0	0	0	0	5.18	0.70
458	2/2/22	36	PP	C142		T1	-2 to 9	0	0	0	0	0	0	5.18	0.72
459	2/2/22	36	PP	C142		T1	-2 to 9	0	0	0	0	0	0	5.18	0.75
460	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.77
461	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.78
462	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.79
463	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
464	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.81
465	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.82
466	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.83
467	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.85
468	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.87
469	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.89
470	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.92
471	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
472	2/2/22	36	PP	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.70
473	2/2/22	37	CPR	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
474	2/2/22	37	CPR	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.65
475	2/2/22	37	CPR	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.70
476	2/2/22	37	CPR	C142		T1	-2 to 7.5	0	0	0	0	0	0	5.18	0.75
477	2/2/22	37	CPR	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.78
478	2/2/22	37	CPR	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
479	2/2/22	37	CPR	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.82
480	2/2/22	37	CPR	C142		T1	-2 to 8	0	0	0	0	0	0	5.18	0.85
485	2/2/22	38	PP	C139	+FHF	T1	-2 to 9	0	0	0	0	0	0	5.18	0.50

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
486	2/2/22	38	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.60
487	2/2/22	38	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.65
488	2/2/22	38	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.70
489	2/2/22	38	PP	C139		T1	-2 to 7	0	0	0	0	0	0	5.18	0.75
490	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.78
491	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.79
492	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
493	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.81
494	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.82
495	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.85
496	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.89
497	2/2/22	38	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.92
498	2/2/22	39	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.80
499	2/2/22	39	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.85
500	2/2/22	40	SPP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.80
501	2/2/22	40	SPP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.85
Aft Trip Wing 0.40c															
504	2/2/22	41	SPP	C139	Aft trip 2	T4	-2 to 8	0	0	0	0	0	0	5.18	0.80
505	2/2/22	41	SPP	C139		T4	-2 to 7.5	0	0	0	0	0	0	5.18	0.75
506	2/2/22	41	SPP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.85
512	2/2/22	42	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.65
513	2/3/22	42	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.70
514	2/3/22	42	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.75
515	2/3/22	42	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.78
516	2/3/22	42	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.80
517	2/3/22	42	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.82
518	2/3/22	42	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.83
519	2/3/22	42	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
520	2/3/22	42	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.87
521	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.80
522	2/3/22	43	PP	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.50
523	2/3/22	43	PP	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.60
524	2/3/22	43	PP	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.65
525	2/3/22	43	PP	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.70
526	2/3/22	43	PP	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.75
527	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.78
528	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.79
529	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.80
530	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.81
531	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.82
532	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.83
533	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.85
534	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.87
535	2/3/22	43	PP	C139		T4	-2 to 8	0	0	0	0	0	0	5.18	0.89
537	2/3/22	43	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.70
538	2/3/22	43	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	5.18	0.70
541	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.80
542	2/3/22	44	PP	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.50
543	2/3/22	44	PP	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.60
544	2/3/22	44	PP	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.65
545	2/3/22	44	PP	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.70
546	2/3/22	44	PP	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.75
547	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.78
548	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.79
549	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.80
550	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.81
551	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.82

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
552	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.83
553	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.85
554	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.87
555	2/3/22	44	PP	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.89
556	2/3/22	45	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.65
558	2/3/22	45	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.70
560	2/3/22	45	CPR	C139		T4	-2 to 9	0	0	0	0	0	0	3.95	0.75
561	2/3/22	45	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.78
562	2/3/22	45	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.80
563	2/3/22	45	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.82
564	2/3/22	45	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.83
565	2/3/22	45	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.85
566	2/3/22	45	CPR	C139		T4	-2 to 8	0	0	0	0	0	0	3.95	0.87
Aft Trip Wing 0.25c															
569	2/3/22	46	CPR	C139	Aft trip 1	T3	-2 to 9	0	0	0	0	0	0	5.18	0.50
572	2/3/22	46	CPR	C139		T3	-2 to 9	0	0	0	0	0	0	5.18	0.65
573	2/3/22	46	CPR	C139		T3	-2 to 9	0	0	0	0	0	0	5.18	0.70
574	2/3/22	46	CPR	C139		T3	-2 to 9	0	0	0	0	0	0	5.18	0.75
575	2/3/22	46	CPR	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.78
576	2/3/22	46	CPR	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.80
577	2/3/22	46	CPR	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.82
578	2/3/22	46	CPR	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.85
579	2/3/22	47	PP	C139		T3	-2 to 9	0	0	0	0	0	0	5.18	0.50
580	2/3/22	47	PP	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.75
581	2/3/22	47	PP	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.80
582	2/3/22	47	PP	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.85
583	2/3/22	48	SPP	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.85
584	2/3/22	48	SPP	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.80

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
585	2/3/22	48	SPP	C139		T3	-2 to 8	0	0	0	0	0	0	5.18	0.75
Aft Trip Wing 0.25c/Mod															
588	2/3/22	49	SPP	C139	mod aft trip 1	T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.80
589	2/3/22	49	SPP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.85
592	2/3/22	50	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.50
593	2/3/22	50	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.60
594	2/3/22	50	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.65
595	2/3/22	50	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.70
596	2/3/22	50	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.75
597	2/4/22	50	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.78
598	2/4/22	50	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.80
599	2/4/22	50	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.82
600	2/4/22	50	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.83
601	2/4/22	50	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.85
602	2/4/22	50	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.87
603	2/4/22	51	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.50
604	2/4/22	51	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.70
605	2/4/22	51	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.75
606	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.78
607	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.79
608	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.80
609	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.82
610	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.83
611	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.85
612	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.87
613	2/4/22	51	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	5.18	0.89
614	2/4/22	51	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	5.18	0.50
615	2/4/22	52	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.50

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
616	2/4/22	52	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.60
617	2/4/22	52	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.65
618	2/4/22	52	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.70
619	2/4/22	52	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.75
620	2/4/22	52	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.78
621	2/4/22	52	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.80
622	2/4/22	52	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.82
623	2/4/22	52	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.83
624	2/4/22	52	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.85
625	2/4/22	52	CPR	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.87
626	2/4/22	52	CPR	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.50
627	2/4/22	53	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.50
628	2/4/22	53	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.50
629	2/4/22	53	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.70
630	2/4/22	53	PP	C139		T3.1	-2 to 9	0	0	0	0	0	0	3.95	0.75
631	2/4/22	53	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.78
632	2/4/22	53	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.79
633	2/4/22	53	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.80
634	2/4/22	53	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.82
635	2/4/22	53	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.85
636	2/4/22	53	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.87
637	2/4/22	53	PP	C139		T3.1	-2 to 8	0	0	0	0	0	0	3.95	0.89
Aft Trip Wing 0.25c															
639	2/4/22	54	PP	C139	Aft trip 1	T6	-2 to 8	0	0	0	0	0	0	5.18	0.80
640	2/4/22	54	PP	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.50
641	2/4/22	54	PP	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.60
642	2/4/22	54	PP	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.65
643	2/4/22	54	PP	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
644	2/4/22	54	PP	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.75
645	2/4/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.78
646	2/4/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.79
647	2/4/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.80
648	2/4/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.81
649	2/4/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.82
650	2/7/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.83
651	2/7/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.85
652	2/7/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.87
653	2/7/22	54	PP	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.89
654	2/7/22	55	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.87
655	2/7/22	55	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.85
656	2/7/22	55	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.83
657	2/7/22	55	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.82
658	2/7/22	55	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.80
659	2/7/22	55	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	5.18	0.78
660	2/7/22	55	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.75
661	2/7/22	55	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.70
662	2/7/22	55	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.65
663	2/7/22	55	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	5.18	0.50
664	2/7/22	56	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.50
665	2/7/22	56	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.65
666	2/7/22	56	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.70
667	2/7/22	56	CPR	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.75
668	2/7/22	56	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.78
669	2/7/22	56	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.80
670	2/7/22	56	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.82
671	2/7/22	56	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.83
672	2/7/22	56	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
673	2/7/22	56	CPR	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.87
674	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.80
675	2/7/22	57	PP	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.50
676	2/7/22	57	PP	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.60
677	2/7/22	57	PP	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.65
678	2/7/22	57	PP	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.70
679	2/7/22	57	PP	C139		T6	-2 to 9	0	0	0	0	0	0	3.95	0.75
680	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.78
681	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.79
682	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.80
683	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.81
684	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.82
685	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.83
686	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.85
687	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.87
688	2/7/22	57	PP	C139		T6	-2 to 8	0	0	0	0	0	0	3.95	0.89
691	2/7/22	58	PP	C139		T6	0 to 5.9	0	0	0	0	0	0	6.58	0.70
692	2/7/22	58	PP	C139		T6	0 to 5	0	0	0	0	0	0	6.58	0.75
693	2/7/22	58	PP	C139		T6	0 to 4.5	0	0	0	0	0	0	6.58	0.78
694	2/7/22	58	PP	C139		T6	0 to 4.5	0	0	0	0	0	0	6.58	0.80
695	2/7/22	58	PP	C139		T6	0 to 5.3	0	0	0	0	0	0	6.58	0.82
696	2/7/22	58	PP	C139		T6	0 to 5	0	0	0	0	0	0	6.58	0.85
697	2/7/22	58	PP	C139		T6	0 to 5	0	0	0	0	0	0	6.58	0.89
Return to T1 - Repeatability Series.															
700	2/7/22	59	PP	C139	Fwd Trip, tape gaps	T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
701	2/7/22	59	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.50
702	2/7/22	59	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.70
703	2/7/22	59	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.75

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
704	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.78
705	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
706	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.82
707	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.85
708	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.89
711	2/7/22	59	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.65
712	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
713	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.83
714	2/7/22	59	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.87
715	2/7/22	60	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.50
716	2/7/22	60	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.70
717	2/7/22	60	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.75
718	2/7/22	60	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.78
719	2/7/22	60	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
720	2/7/22	60	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.82
721	2/7/22	60	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.85
722	2/7/22	60	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.89
723	2/7/22	61	PP	C139		T1	-1.5 to 4.5	0	0	0	0	0	0	6.58	0.80
724	2/7/22	61	PP	C139		T1	0 to 5.5	0	0	0	0	0	0	6.58	0.70
725	2/7/22	61	PP	C139		T1	0 to 4.8	0	0	0	0	0	0	6.58	0.75
726	2/7/22	61	PP	C139		T1	0 to 4.5	0	0	0	0	0	0	6.58	0.78
727	2/7/22	61	PP	C139		T1	0 to 4.3	0	0	0	0	0	0	6.58	0.80
728	2/7/22	61	PP	C139		T1	0 to 5.3	0	0	0	0	0	0	6.58	0.82
729	2/7/22	61	PP	C139		T1	0 to 5.5	0	0	0	0	0	0	6.58	0.83
730	2/7/22	61	PP	C139		T1	0 to 5	0	0	0	0	0	0	6.58	0.85
731	2/7/22	61	PP	C139		T1	-1.5 to 5	0	0	0	0	0	0	6.58	0.87
732	2/7/22	61	PP	C139		T1	0 to 5	0	0	0	0	0	0	6.58	0.89
733	2/7/22	62	CPR	C139		T1	0 to 5	0	0	0	0	0	0	6.58	0.87
734	2/7/22	62	CPR	C139		T1	0 to 5	0	0	0	0	0	0	6.58	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
735	2/7/22	62	CPR	C139		T1	0 to 5.5	0	0	0	0	0	0	6.58	0.83
736	2/7/22	62	CPR	C139		T1	0 to 5.5	0	0	0	0	0	0	6.58	0.83
737	2/7/22	62	CPR	C139		T1	0 to 5	0	0	0	0	0	0	6.58	0.85
738	2/7/22	62	CPR	C139		T1	0 to 5	0	0	0	0	0	0	6.58	0.87
739	2/7/22	62	CPR	C139		T1	0 to 5.3	0	0	0	0	0	0	6.58	0.82
740	2/7/22	62	CPR	C139		T1	0 to 4.7	0	0	0	0	0	0	6.58	0.80
741	2/7/22	62	CPR	C139		T1	0 to 4.5	0	0	0	0	0	0	6.58	0.78
742	2/7/22	62	CPR	C139		T1	0 to 4.8	0	0	0	0	0	0	6.58	0.75
743	2/7/22	62	CPR	C139		T1	0 to 5.8	0	0	0	0	0	0	6.58	0.70
746	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
747	2/7/22	63	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.50
748	2/7/22	63	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.65
749	2/7/22	63	PP	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.70
750	2/7/22	63	PP	C139		T1	-2 to 7	0	0	0	0	0	0	3.95	0.75
751	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.78
752	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
753	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.82
754	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.83
755	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.85
756	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.87
757	2/7/22	63	PP	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.89
758	2/7/22	64	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.89
759	2/7/22	64	CPR	C139		T1	-2 to 9	0	0	0	0	0	0	3.95	0.85
760	2/7/22	64	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.82
761	2/7/22	64	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.80
762	2/7/22	64	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.78
763	2/7/22	64	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.75
764	2/7/22	64	CPR	C139		T1	-2 to 8	0	0	0	0	0	0	3.95	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
Forward Trip, No Trip on Strut (US + LS)															
767	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.80
768	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.50
769	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.60
770	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.65
771	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.70
772	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.75
773	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.78
775	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.79
776	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.80
777	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.81
778	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.82
779	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.83
780	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.85
781	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.87
782	2/7/22	65	PP	C139		T5	-2 to 8	0	0	0	0	0	0	5.18	0.89
792	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.80
794	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.50
795	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.60
796	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.65
797	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.70
798	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.75
799	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.78
800	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.79
801	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.80
802	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.81
803	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.82
804	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.83
805	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
806	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.87
807	2/7/22	67	PP	C139		T5	-2 to 8	0	0	0	0	0	0	3.95	0.89
Tape Fuselage to Floor, replace strut trips (return to T1)															
811	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.50
812	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.65
813	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.70
814	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.75
815	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.78
816	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.80
817	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.82
818	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.85
819	2/7/22	68	fixed	C139		T1	2	0	0	0	0	0	0	5.18	0.89
821	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.50
822	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.65
823	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.70
824	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.75
825	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.78
826	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.80
827	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.82
828	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.85
829	2/7/22	69	fixed	C139		T1	3.5	0	0	0	0	0	0	5.18	0.89
Fwd Trip, Both Ailerons - 5deg															
832	2/7/22	70	PP	C139	Fwd Trip, Aileron - 5deg	T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.50
833	2/7/22	70	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.60
834	2/7/22	70	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.65
835	2/7/22	70	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.70
836	2/7/22	70	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.75
837	2/7/22	70	PP	C139		T1	-2 to 8	0	-5	-5	0	0	0	3.95	0.78

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
838	2/8/22	70	PP	C139		T1	-2 to 8	0	-5	-5	0	0	0	3.95	0.79
839	2/8/22	70	PP	C139		T1	-2 to 8	0	-5	-5	0	0	0	3.95	0.80
840	2/8/22	70	PP	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.81
841	2/8/22	70	PP	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.82
842	2/8/22	70	PP	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.83
843	2/8/22	70	PP	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.85
844	2/8/22	70	PP	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.87
845	2/8/22	70	PP	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.89
846	2/8/22	70	PP	C139		T1	-2 to 8	0	-5	-5	0	0	0	3.95	0.80
847	2/8/22	71	CPR	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.50
848	2/8/22	71	CPR	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.65
849	2/8/22	71	CPR	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.70
850	2/8/22	71	CPR	C139		T1	-2 to 9	0	-5	-5	0	0	0	3.95	0.75
851	2/8/22	71	CPR	C139		T1	-2 to 8	0	-5	-5	0	0	0	3.95	0.78
852	2/8/22	71	CPR	C139		T1	-2 to 8	0	-5	-5	0	0	0	3.95	0.80
853	2/8/22	71	CPR	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.82
854	2/8/22	71	CPR	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.83
855	2/8/22	71	CPR	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.85
856	2/8/22	71	CPR	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	3.95	0.87
857	2/8/22	72	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.50
858	2/8/22	72	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.60
859	2/8/22	72	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.65
860	2/8/22	72	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.70
861	2/8/22	72	PP	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.75
862	2/8/22	72	PP	C139		T1	-2 to 8	0	-5	-5	0	0	0	5.18	0.78
863	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.79
864	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.80
865	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.81
866	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.82

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
867	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.83
868	2/8/22	72	PP	C139		T1	-1.5 to 8	0	-5	-5	0	0	0	5.18	0.85
869	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.87
870	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.89
871	2/8/22	72	PP	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.80
874	2/8/22	73	CPR	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.50
875	2/8/22	73	CPR	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.65
876	2/8/22	73	CPR	C139		T1	-2 to 9	0	-5	-5	0	0	0	5.18	0.70
877	2/8/22	73	CPR	C139		T1	-1 to 7.5	0	-5	-5	0	0	0	5.18	0.75
878	2/8/22	73	CPR	C139		T1	-1 to 7	0	-5	-5	0	0	0	5.18	0.78
879	2/8/22	73	CPR	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.80
880	2/8/22	73	CPR	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.82
881	2/8/22	73	CPR	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.83
882	2/8/22	73	CPR	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.85
883	2/8/22	73	CPR	C139		T1	-1 to 8	0	-5	-5	0	0	0	5.18	0.87
Fwd Trip, Both Ailerons +5deg															
886	2/8/22	74	PP	C139	Aileron +5deg	T1	-2 to 9	0	5	5	0	0	0	3.95	0.50
887	2/8/22	74	PP	C139		T1	-2 to 9	0	5	5	0	0	0	3.95	0.60
888	2/8/22	74	PP	C139		T1	-2 to 9	0	5	5	0	0	0	3.95	0.65
889	2/8/22	74	PP	C139		T1	-2 to 9	0	5	5	0	0	0	3.95	0.70
890	2/8/22	74	PP	C139		T1	-2 to 7.5	0	5	5	0	0	0	3.95	0.75
891	2/8/22	74	PP	C139		T1	-2 to 7	0	5	5	0	0	0	3.95	0.78
892	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.79
893	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.80
894	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.81
896	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.82
897	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.83
898	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
899	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.87
900	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.89
901	2/8/22	74	PP	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.80
902	2/8/22	75	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.50
903	2/8/22	75	CPR	C139		T1	-2 to 9	0	5	5	0	0	0	3.95	0.65
904	2/8/22	75	CPR	C139		T1	-2 to 9	0	5	5	0	0	0	3.95	0.70
905	2/8/22	75	CPR	C139		T1	-2 to 7.5	0	5	5	0	0	0	3.95	0.75
906	2/8/22	75	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.78
907	2/8/22	75	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.80
908	2/8/22	75	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.82
909	2/8/22	75	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.83
910	2/8/22	75	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.85
911	2/8/22	75	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	3.95	0.87
912	2/8/22	76	PP	C139	PP at 6.3M/ft	T1	-2 to 9	0	5	5	0	0	0	5.18	0.50
913	2/8/22	76	PP	C139		T1	-2 to 9	0	5	5	0	0	0	5.18	0.60
914	2/8/22	76	PP	C139		T1	-2 to 9	0	5	5	0	0	0	5.18	0.65
915	2/8/22	76	PP	C139		T1	-2 to 7.5	0	5	5	0	0	0	5.18	0.70
916	2/8/22	76	PP	C139		T1	-2 to 7	0	5	5	0	0	0	5.18	0.75
917	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.78
918	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.79
919	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.80
920	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.81
921	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.82
922	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.83
923	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.85
924	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.87
925	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.89
926	2/8/22	76	PP	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.80
928	2/8/22	77	CPR	C139	CPR at 6.3M/ft	T1	-2 to 9	0	5	5	0	0	0	5.18	0.50

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
929	2/8/22	77	CPR	C139		T1	-2 to 9	0	5	5	0	0	0	5.18	0.65
930	2/8/22	77	CPR	C139		T1	-2 to 7.5	0	5	5	0	0	0	5.18	0.70
931	2/8/22	77	CPR	C139		T1	-2 to 7.25	0	5	5	0	0	0	5.18	0.75
932	2/8/22	77	CPR	C139		T1	-2 to 7.8	0	5	5	0	0	0	5.18	0.78
933	2/8/22	77	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.80
934	2/8/22	77	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.82
935	2/8/22	77	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.83
936	2/8/22	77	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.85
937	2/8/22	77	CPR	C139		T1	-2 to 8	0	5	5	0	0	0	5.18	0.87
Fwd Trip, Ailerons 0deg, Strut Flap -4deg															
940	2/8/22	78	PP	C139	Strut Flap -4 deg	T1	-2 to 8.75	-4	0	0	0	0	0	3.95	0.50
941	2/8/22	78	PP	C139		T1	-2 to 8.75	-4	0	0	0	0	0	3.95	0.60
942	2/8/22	78	PP	C139		T1	-2 to 8.75	-4	0	0	0	0	0	3.95	0.65
943	2/8/22	78	PP	C139		T1	-2 to 8.75	-4	0	0	0	0	0	3.95	0.70
944	2/9/22	78	PP	C139		T1	-2 to 6.75	-4	0	0	0	0	0	3.95	0.75
945	2/9/22	78	PP	C139		T1	-2 to 6.75	-4	0	0	0	0	0	3.95	0.78
946	2/9/22	78	PP	C139		T1	-2 to 6.75	-4	0	0	0	0	0	3.95	0.79
947	2/9/22	78	PP	C139		T1	-2 to 6.75	-4	0	0	0	0	0	3.95	0.80
948	2/9/22	78	PP	C139		T1	-2 to 7.75	-4	0	0	0	0	0	3.95	0.81
949	2/9/22	78	PP	C139		T1	-2 to 7.75	-4	0	0	0	0	0	3.95	0.82
950	2/9/22	78	PP	C139		T1	-2 to 7.75	-4	0	0	0	0	0	3.95	0.83
951	2/9/22	78	PP	C139		T1	-2 to 7.75	-4	0	0	0	0	0	3.95	0.85
952	2/9/22	78	PP	C139		T1	-2 to 7.75	-4	0	0	0	0	0	3.95	0.87
953	2/9/22	78	PP	C139		T1	-1.5 to 7.75	-4	0	0	0	0	0	3.95	0.89
954	2/9/22	78	PP	C139		T1	-2 to 6.75	-4	0	0	0	0	0	3.95	0.80
955	2/9/22	79	CPR	C139	CPR at 4.8M/ft	T1	-2 to 9	-4	0	0	0	0	0	3.95	0.50
956	2/9/22	79	CPR	C139		T1	-2 to 9	-4	0	0	0	0	0	3.95	0.65
957	2/9/22	79	CPR	C139		T1	-2 to 9	-4	0	0	0	0	0	3.95	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
958	2/9/22	79	CPR	C139		T1	-2 to 7	-4	0	0	0	0	0	3.95	0.75
959	2/9/22	79	CPR	C139		T1	-2 to 6.5	-4	0	0	0	0	0	3.95	0.78
960	2/9/22	79	CPR	C139		T1	-2 to 7	-4	0	0	0	0	0	3.95	0.80
961	2/9/22	79	CPR	C139		T1	-2 to 8	-4	0	0	0	0	0	3.95	0.82
962	2/9/22	79	CPR	C139		T1	-2 to 8	-4	0	0	0	0	0	3.95	0.83
963	2/9/22	79	CPR	C139		T1	-2 to 8	-4	0	0	0	0	0	3.95	0.85
964	2/9/22	79	CPR	C139		T1	-1.5 to 8	-4	0	0	0	0	0	3.95	0.87
965	2/9/22	80	PP	C139		T1	-2 to 9	-4	0	0	0	0	0	5.18	0.50
966	2/9/22	80	PP	C139		T1	-2 to 9	-4	0	0	0	0	0	5.18	0.60
967	2/9/22	80	PP	C139		T1	-2 to 9	-4	0	0	0	0	0	5.18	0.65
968	2/9/22	80	PP	C139		T1	-2 to 9	-4	0	0	0	0	0	5.18	0.70
969	2/9/22	80	PP	C139		T1	-2 to 7	-4	0	0	0	0	0	5.18	0.75
970	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.78
971	2/9/22	80	PP	C139		T1	-1.5 to 7.5	-4	0	0	0	0	0	5.18	0.79
972	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.80
973	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.81
974	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.82
975	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.83
976	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.85
977	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.87
978	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.89
979	2/9/22	80	PP	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.80
982	2/9/22	81	CPR	C139		T1	-2 to 9	-4	0	0	0	0	0	5.18	0.50
983	2/9/22	81	CPR	C139		T1	-2 to 9	-4	0	0	0	0	0	5.18	0.65
984	2/9/22	81	CPR	C139		T1	-2 to 7.75	-4	0	0	0	0	0	5.18	0.70
985	2/9/22	81	CPR	C139		T1	-2 to 7	-4	0	0	0	0	0	5.18	0.75
986	2/9/22	81	CPR	C139		T1	-1.5 to 7	-4	0	0	0	0	0	5.18	0.78
987	2/9/22	81	CPR	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.80
988	2/9/22	81	CPR	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.82

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
989	2/9/22	81	CPR	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.83
990	2/9/22	81	CPR	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.85
991	2/9/22	81	CPR	C139		T1	-1.5 to 8	-4	0	0	0	0	0	5.18	0.87
Fwd Trip, Strut Flap -2deg															
994	2/9/22	82	PP	C139	Strut Flap -2 deg	T1	-2 to 9	-2	0	0	0	0	0	3.95	0.50
995	2/9/22	82	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.60
996	2/9/22	82	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.65
997	2/9/22	82	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.70
998	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.75
999	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.78
1000	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.79
1001	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.80
1002	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.81
1003	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.82
1004	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.83
1005	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.85
1006	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.87
1007	2/9/22	82	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	3.95	0.89
1008	2/9/22	82	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.80
1009	2/9/22	83	CPR	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.50
1010	2/9/22	83	CPR	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.65
1011	2/9/22	83	CPR	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.70
1012	2/9/22	83	CPR	C139		T1	-2 to 7.5	-2	0	0	0	0	0	3.95	0.75
1013	2/9/22	83	CPR	C139		T1	-2 to 6.7	-2	0	0	0	0	0	3.95	0.78
1014	2/9/22	83	CPR	C139		T1	-2 to 7	-2	0	0	0	0	0	3.95	0.80
1015	2/9/22	83	CPR	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.82
1016	2/9/22	83	CPR	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.83
1017	2/9/22	83	CPR	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1018	2/9/22	83	CPR	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.87
1019	2/9/22	84	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.50
1020	2/9/22	84	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.60
1021	2/9/22	84	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.65
1022	2/9/22	84	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.70
1023	2/9/22	84	PP	C139		T1	-2 to 7	-2	0	0	0	0	0	5.18	0.75
1024	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.78
1025	2/9/22	84	PP	C139		T1	-1.5 to 7.5	-2	0	0	0	0	0	5.18	0.79
1026	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.80
1027	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.81
1028	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.82
1029	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.83
1030	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.85
1031	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.87
1032	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.89
1033	2/9/22	84	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.80
1034	2/9/22	85	CPR	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.50
1035	2/9/22	85	CPR	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.65
1036	2/9/22	85	CPR	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.70
1037	2/9/22	85	CPR	C139		T1	-1.5 to 7	-2	0	0	0	0	0	5.18	0.75
1038	2/9/22	85	CPR	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.78
1039	2/9/22	85	CPR	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.80
1040	2/9/22	85	CPR	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.82
1041	2/9/22	85	CPR	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.83
1042	2/9/22	85	CPR	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.85
1043	2/9/22	85	CPR	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.87
Fwd Trip, Strut Flap +2deg															
1046	2/9/22	86	PP	C139	Strut Flap +2 deg	T1	-2 to 9	2	0	0	0	0	0	3.95	0.50

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1047	2/9/22	86	PP	C139		T1	-2 to 9	2	0	0	0	0	0	3.95	0.60
1048	2/9/22	86	PP	C139		T1	-2 to 9	2	0	0	0	0	0	3.95	0.65
1049	2/9/22	86	PP	C139		T1	-2 to 9	2	0	0	0	0	0	3.95	0.70
1050	2/9/22	86	PP	C139		T1	-2 to 7.5	2	0	0	0	0	0	3.95	0.75
1051	2/10/22	86	PP	C139		T1	-2 to 7	2	0	0	0	0	0	3.95	0.78
1052	2/10/22	86	PP	C139		T1	-2 to 7	2	0	0	0	0	0	3.95	0.79
1053	2/10/22	86	PP	C139		T1	-2 to 7	2	0	0	0	0	0	3.95	0.80
1054	2/10/22	86	PP	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.81
1055	2/10/22	86	PP	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.82
1056	2/10/22	86	PP	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.83
1057	2/10/22	86	PP	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.85
1058	2/10/22	86	PP	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.87
1059	2/10/22	86	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	3.95	0.89
1060	2/10/22	86	PP	C139		T1	-2 to 7	2	0	0	0	0	0	3.95	0.80
1063	2/10/22	87	CPR	C139		T1	-2 to 9	2	0	0	0	0	0	3.95	0.50
1064	2/10/22	87	CPR	C139		T1	-2 to 9	2	0	0	0	0	0	3.95	0.65
1065	2/10/22	87	CPR	C139		T1	-2 to 9	2	0	0	0	0	0	3.95	0.70
1066	2/10/22	87	CPR	C139		T1	-2 to 7.5	2	0	0	0	0	0	3.95	0.75
1067	2/10/22	87	CPR	C139		T1	-2 to 7	2	0	0	0	0	0	3.95	0.78
1068	2/10/22	87	CPR	C139		T1	-2 to 7	2	0	0	0	0	0	3.95	0.80
1069	2/10/22	87	CPR	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.82
1070	2/10/22	87	CPR	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.83
1071	2/10/22	87	CPR	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.85
1072	2/10/22	87	CPR	C139		T1	-2 to 8	2	0	0	0	0	0	3.95	0.87
1073	2/10/22	88	PP	C139		T1	-2 to 9	2	0	0	0	0	0	5.18	0.50
1074	2/10/22	88	PP	C139		T1	-2 to 9	2	0	0	0	0	0	5.18	0.60
1075	2/10/22	88	PP	C139		T1	-2 to 9	2	0	0	0	0	0	5.18	0.65
1076	2/10/22	88	PP	C139		T1	-2 to 9	2	0	0	0	0	0	5.18	0.70
1077	2/10/22	88	PP	C139		T1	-1.5 to 7	2	0	0	0	0	0	5.18	0.75

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1078	2/10/22	88	PP	C139		T1	-1.5 to 7	2	0	0	0	0	0	5.18	0.78
1079	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.79
1081	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.80
1082	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.81
1083	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.82
1084	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.83
1085	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.85
1086	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.87
1087	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.89
1088	2/10/22	88	PP	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.80
1089	2/10/22	89	CPR	C139		T1	-2 to 9	2	0	0	0	0	0	5.18	0.50
1090	2/10/22	89	CPR	C139		T1	-2 to 9	2	0	0	0	0	0	5.18	0.65
1091	2/10/22	89	CPR	C139		T1	-2 to 9	2	0	0	0	0	0	5.18	0.70
1092	2/10/22	89	CPR	C139		T1	-1.5 to 7	2	0	0	0	0	0	5.18	0.75
1093	2/10/22	89	CPR	C139		T1	-1.5 to 7	2	0	0	0	0	0	5.18	0.78
1094	2/10/22	89	CPR	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.80
1095	2/10/22	89	CPR	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.82
1096	2/10/22	89	CPR	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.83
1097	2/10/22	89	CPR	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.85
1098	2/10/22	89	CPR	C139		T1	-1.5 to 8	2	0	0	0	0	0	5.18	0.87
Fwd Trip, Strut Flap +4deg															
1101	2/10/22	90	PP	C139	Strut Flap +4 deg	T1	-2 to 9	4	0	0	0	0	0	3.95	0.50
1102	2/10/22	90	PP	C139		T1	-2 to 9	4	0	0	0	0	0	3.95	0.60
1103	2/10/22	90	PP	C139		T1	-2 to 9	4	0	0	0	0	0	3.95	0.65
1104	2/10/22	90	PP	C139		T1	-2 to 9	4	0	0	0	0	0	3.95	0.70
1105	2/10/22	90	PP	C139		T1	-2 to 6.5	4	0	0	0	0	0	3.95	0.75
1106	2/10/22	90	PP	C139		T1	-2 to 6.5	4	0	0	0	0	0	3.95	0.78
1107	2/10/22	90	PP	C139		T1	-2 to 7	4	0	0	0	0	0	3.95	0.79

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1108	2/10/22	90	PP	C139		T1	-2 to 7.5	4	0	0	0	0	0	3.95	0.80
1109	2/10/22	90	PP	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.81
1110	2/10/22	90	PP	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.82
1111	2/10/22	90	PP	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.83
1112	2/10/22	90	PP	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.85
1113	2/10/22	90	PP	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.87
1114	2/10/22	90	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	3.95	0.89
1115	2/10/22	90	PP	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.80
1117	2/10/22	91	CPR	C139		T1	-2 to 9	4	0	0	0	0	0	3.95	0.50
1118	2/10/22	91	CPR	C139		T1	-2 to 9	4	0	0	0	0	0	3.95	0.65
1119	2/10/22	91	CPR	C139		T1	-2 to 9	4	0	0	0	0	0	3.95	0.70
1120	2/10/22	91	CPR	C139		T1	-2 to 7.25	4	0	0	0	0	0	3.95	0.75
1121	2/10/22	91	CPR	C139		T1	-2 to 6.7	4	0	0	0	0	0	3.95	0.78
1122	2/10/22	91	CPR	C139		T1	-2 to 7.25	4	0	0	0	0	0	3.95	0.80
1123	2/10/22	91	CPR	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.82
1124	2/10/22	91	CPR	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.83
1125	2/10/22	91	CPR	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.85
1126	2/10/22	91	CPR	C139		T1	-2 to 8	4	0	0	0	0	0	3.95	0.87
1127	2/10/22	92	PP	C139		T1	-2 to 9	4	0	0	0	0	0	5.18	0.50
1128	2/10/22	92	PP	C139		T1	-2 to 9	4	0	0	0	0	0	5.18	0.60
1129	2/10/22	92	PP	C139		T1	-2 to 9	4	0	0	0	0	0	5.18	0.65
1130	2/10/22	92	PP	C139		T1	-2 to 9	4	0	0	0	0	0	5.18	0.70
1131	2/10/22	92	PP	C139		T1	-1.5 to 7	4	0	0	0	0	0	5.18	0.75
1132	2/10/22	92	PP	C139		T1	-1.5 to 7	4	0	0	0	0	0	5.18	0.78
1133	2/10/22	92	PP	C139		T1	-1.5 to 7	4	0	0	0	0	0	5.18	0.79
1134	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.80
1135	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.81
1136	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.82
1137	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.83

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1138	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.85
1139	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.87
1140	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.89
1141	2/10/22	92	PP	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.80
1142	2/10/22	93	CPR	C139		T1	-2 to 9	4	0	0	0	0	0	5.18	0.50
1143	2/10/22	93	CPR	C139		T1	-2 to 9	4	0	0	0	0	0	5.18	0.65
1144	2/10/22	93	CPR	C139		T1	-2 to 9	4	0	0	0	0	0	5.18	0.70
1145	2/10/22	93	CPR	C139		T1	-1.5 to 7.25	4	0	0	0	0	0	5.18	0.75
1146	2/10/22	93	CPR	C139		T1	-1.5 to 7.5	4	0	0	0	0	0	5.18	0.78
1147	2/10/22	93	CPR	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.80
1148	2/10/22	93	CPR	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.82
1149	2/10/22	93	CPR	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.83
1150	2/10/22	93	CPR	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.85
1151	2/10/22	93	CPR	C139		T1	-1.5 to 8	4	0	0	0	0	0	5.18	0.87
Fwd Trip, Strut Flap -2deg PP Repeat															
1153	2/10/22	94	PP	C139	Strut Flap -2 deg	T1	-2 to 9	-2	0	0	0	0	0	3.95	0.50
1154	2/10/22	94	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.60
1155	2/10/22	94	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.65
1156	2/10/22	94	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	3.95	0.70
1157	2/10/22	94	PP	C139		T1	-2 to 7.5	-2	0	0	0	0	0	3.95	0.75
1158	2/10/22	94	PP	C139		T1	-2 to 6.5	-2	0	0	0	0	0	3.95	0.78
1159	2/10/22	94	PP	C139		T1	-2 to 6.5	-2	0	0	0	0	0	3.95	0.79
1160	2/10/22	94	PP	C139		T1	-2 to 6.5	-2	0	0	0	0	0	3.95	0.80
1161	2/10/22	94	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.81
1162	2/10/22	94	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.82
1165	2/10/22	94	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.83
1166	2/10/22	94	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.85
1167	2/10/22	94	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.87
1168	2/10/22	94	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	3.95	0.89

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1169	2/10/22	94	PP	C139		T1	-2 to 8	-2	0	0	0	0	0	3.95	0.80
1170	2/10/22	95	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.50
1171	2/11/22	95	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.60
1172	2/11/22	95	PP	C139		T1	-2 to 9	-2	0	0	0	0	0	5.18	0.65
1173	2/11/22	95	PP	C139		T1	-2 to 8.5	-2	0	0	0	0	0	5.18	0.70
1174	2/11/22	95	PP	C139		T1	-1.5 to 7	-2	0	0	0	0	0	5.18	0.75
1175	2/11/22	95	PP	C139		T1	-1.5 to 7	-2	0	0	0	0	0	5.18	0.78
1176	2/11/22	95	PP	C139		T1	-1.5 to 7.5	-2	0	0	0	0	0	5.18	0.79
1177	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.80
1178	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.81
1179	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.82
1180	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.83
1181	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.85
1182	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.87
1183	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.89
1184	2/11/22	95	PP	C139		T1	-1.5 to 8	-2	0	0	0	0	0	5.18	0.80
STABILITY & CONTROL SECTION															
Hysteresis Runs															
1187	2/11/22	96	PP	C139	strut flap 0deg	T1	-2 to 9	0	0	0	0	0	0	5.18	0.50
1188	2/11/22	96	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.60
1189	2/11/22	96	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.65
1190	2/11/22	96	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.70
1191	2/11/22	96	PP	C139		T1	-2 to 9	0	0	0	0	0	0	5.18	0.72
1193	2/11/22	96	PP	C139		T1	-2 to 7	0	0	0	0	0	0	5.18	0.75
1194	2/11/22	96	PP	C139		T1	-2 to 8	0	0	0	0	0	0	5.18	0.80
S&C Envelope Expansion															
1197	2/11/22	97	PP	C139	Both Ailerons = -30	T1	-2 to 9	0	-30	-30	0	0	0	2.16	0.50
1198	2/11/22	97	PP	C139		T1	0 to 9	0	-30	-30	0	0	0	2.16	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1199	2/11/22	97	PP	C139		T1	0 to 8	0	-30	-30	0	0	0	2.16	0.80
1200	2/11/22	97	PP	C139		T1	0 to 8	0	-30	-30	0	0	0	2.16	0.85
1201	2/11/22	97	PP	C139		T1	0 to 8	0	-30	-30	0	0	0	2.16	0.89
1202	2/11/22	97	PP	C139		T1	0 to 8	0	-30	-30	0	0	0	2.16	0.92
Combined Aileron Effectiveness															
1205	2/11/22	98	PP	C139	Both Ailerons -30deg	T2	-2 to 9	0	-30	-30	0	0	0	2.16	0.50
1206	2/11/22	98	PP	C139		T2	0 to 9	0	-30	-30	0	0	0	2.16	0.60
1207	2/11/22	98	PP	C139		T2	0 to 9	0	-30	-30	0	0	0	2.16	0.65
1208	2/11/22	98	PP	C139		T2	0 to 9	0	-30	-30	0	0	0	2.16	0.70
1209	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.75
1210	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.78
1211	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.79
1212	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.80
1213	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.81
1214	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.82
1215	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.83
1216	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.85
1217	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.87
1218	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.89
1219	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.92
1220	2/11/22	98	PP	C139		T2	0 to 8	0	-30	-30	0	0	0	2.16	0.80
1222	2/11/22	99	PP	C139	Both Ailerons -10deg	T2	-2 to 9	0	-10	-10	0	0	0	2.16	0.50
1223	2/11/22	99	PP	C139		T2	0 to 9	0	-10	-10	0	0	0	2.16	0.60
1224	2/11/22	99	PP	C139		T2	0 to 9	0	-10	-10	0	0	0	2.16	0.65
1225	2/11/22	99	PP	C139		T2	0 to 9	0	-10	-10	0	0	0	2.16	0.70
1226	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.75
1227	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.78
1228	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.79

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1229	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.80
1231	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.81
1232	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.82
1233	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.83
1234	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.85
1235	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.87
1236	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.89
1237	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.92
1238	2/11/22	99	PP	C139		T2	0 to 8	0	-10	-10	0	0	0	2.16	0.80
1240	2/11/22	100	PP	C139	Both Ailerons -5deg	T2	-2 to 9	0	-5	-5	0	0	0	2.16	0.50
1241	2/11/22	100	PP	C139		T2	0 to 9	0	-5	-5	0	0	0	2.16	0.60
1242	2/11/22	100	PP	C139		T2	0 to 9	0	-5	-5	0	0	0	2.16	0.65
1243	2/11/22	100	PP	C139		T2	0 to 9	0	-5	-5	0	0	0	2.16	0.70
1244	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.75
1245	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.78
1246	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.79
1247	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.80
1248	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.81
1249	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.82
1250	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.83
1251	2/11/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.85
1253	2/14/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.87
1254	2/14/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.89
1255	2/14/22	100	PP	C139		T2	0 to 7.5	0	-5	-5	0	0	0	2.16	0.92
1256	2/14/22	100	PP	C139		T2	0 to 8	0	-5	-5	0	0	0	2.16	0.80
1258	2/14/22	101	PP	C139	Aileron +5deg	T2	-2 to 9	0	+5	+5	0	0	0	2.16	0.50
1259	2/14/22	101	PP	C139		T2	0 to 9	0	+5	+5	0	0	0	2.16	0.60
1260	2/14/22	101	PP	C139		T2	0 to 9	0	+5	+5	0	0	0	2.16	0.65
1261	2/14/22	101	PP	C139		T2	0 to 9	0	+5	+5	0	0	0	2.16	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1262	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.75
1263	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.78
1264	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.79
1265	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.80
1266	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.81
1267	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.82
1268	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.83
1269	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.85
1270	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.87
1271	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.89
1272	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.92
1273	2/14/22	101	PP	C139		T2	0 to 8	0	+5	+5	0	0	0	2.16	0.80
1275	2/14/22	102	PP	C139	Both Ailerons +10deg	T2	-2 to 9	0	+10	+10	0	0	0	2.16	0.50
1276	2/14/22	102	PP	C139		T2	0 to 9	0	+10	+10	0	0	0	2.16	0.60
1277	2/14/22	102	PP	C139		T2	0 to 9	0	+10	+10	0	0	0	2.16	0.65
1278	2/14/22	102	PP	C139		T2	0 to 9	0	+10	+10	0	0	0	2.16	0.70
1279	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.75
1280	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.78
1281	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.79
1282	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.80
1283	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.81
1284	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.82
1285	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.83
1286	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.85
1287	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.87
1288	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.89
1289	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.92
1290	2/14/22	102	PP	C139		T2	0 to 8	0	+10	+10	0	0	0	2.16	0.80
1292	2/14/22	103	PP	C139	Both Ailerons 0deg	T2	-2 to 16 to -2	0	0	0	0	0	0	2.16	0.20

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1293	2/14/22	103	PP	C139		T2	-2 to 9	0	0	0	0	0	0	2.16	0.50
1294	2/14/22	103	PP	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.60
1295	2/14/22	103	PP	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.65
1296	2/14/22	103	PP	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.70
1297	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.75
1298	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.78
1299	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.79
1300	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.80
1301	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.81
1302	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.82
1303	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.83
1304	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.85
1305	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.87
1306	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.89
1307	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.92
1309	2/14/22	103	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.80
1310	2/14/22	103	PP	C139		T2	-2 to 16 to -2	0	0	0	0	0	0	2.16	0.20
1311	2/14/22	103	PP	C139		T2	-2 to 16 to -2	0	0	0	0	0	0	2.16	0.20
1312	2/14/22	104	CPR	C139		T2	-2 to 9	0	0	0	0	0	0	2.16	0.50
1313	2/14/22	104	CPR	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.65
1314	2/14/22	104	CPR	C139		T2	-2 to 9	0	0	0	0	0	0	2.16	0.50
1315	2/14/22	104	CPR	C139		T2	-2 to 9	0	0	0	0	0	0	2.16	0.65
1316	2/14/22	104	CPR	C139		T2	-2 to 9	0	0	0	0	0	0	2.16	0.70
1317	2/14/22	104	CPR	C139		T2	-2 to 8	0	0	0	0	0	0	2.16	0.75
1318	2/14/22	104	CPR	C139		T2	-2 to 8	0	0	0	0	0	0	2.16	0.78
1319	2/14/22	104	CPR	C139		T2	-2 to 8	0	0	0	0	0	0	2.16	0.80
1320	2/14/22	104	CPR	C139		T2	-2 to 8	0	0	0	0	0	0	2.16	0.82
1321	2/14/22	104	CPR	C139		T2	-2 to 8	0	0	0	0	0	0	2.16	0.83
1322	2/14/22	104	CPR	C139		T2	-2 to 8	0	0	0	0	0	0	2.16	0.85

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1323	2/14/22	104	CPR	C139		T2	-2 to 8	0	0	0	0	0	0	2.16	0.87
1325	2/14/22	105	PP	C139	Both Ailerons +20deg	T2	-2 to 9	0	+20	+20	0	0	0	2.16	0.50
1326	2/14/22	105	PP	C139		T2	-2 to 9	0	+20	+20	0	0	0	2.16	0.50
1327	2/14/22	105	PP	C139		T2	-2 to 9	0	+20	+20	0	0	0	2.16	0.50
1328	2/14/22	105	PP	C139		T2	0 to 9	0	+20	+20	0	0	0	2.16	0.60
1329	2/14/22	105	PP	C139		T2	0 to 8.5	0	+20	+20	0	0	0	2.16	0.65
1330	2/14/22	105	PP	C139		T2	0 to 9	0	+20	+20	0	0	0	2.16	0.70
1331	2/14/22	105	PP	C139		T2	0 to 5.5	0	+20	+20	0	0	0	2.16	0.75
1332	2/14/22	105	PP	C139		T2	0 to 5.5	0	+20	+20	0	0	0	2.16	0.78
1333	2/14/22	105	PP	C139		T2	0 to 5.25	0	+20	+20	0	0	0	2.16	0.79
1334	2/14/22	105	PP	C139		T2	0 to 6	0	+20	+20	0	0	0	2.16	0.80
1335	2/14/22	105	PP	C139		T2	0 to 6	0	+20	+20	0	0	0	2.16	0.81
1336	2/14/22	105	PP	C139		T2	0 to 6.5	0	+20	+20	0	0	0	2.16	0.82
1337	2/14/22	105	PP	C139		T2	0 to 6.5	0	+20	+20	0	0	0	2.16	0.83
1338	2/14/22	105	PP	C139		T2	0 to 8	0	+20	+20	0	0	0	2.16	0.85
1339	2/14/22	105	PP	C139		T2	0 to 6.5	0	+20	+20	0	0	0	2.16	0.87
1340	2/14/22	105	PP	C139		T2	0 to 8	0	+20	+20	0	0	0	2.16	0.89
1341	2/14/22	105	PP	C139		T2	0 to 8	0	+20	+20	0	0	0	2.16	0.92
1342	2/14/22	105	PP	C139		T2	0 to 5.5	0	+20	+20	0	0	0	2.16	0.80
1344	2/14/22	106	PP	C139	Both Ailerons +30deg	T2	-2 to 8	0	+30	+30	0	0	0	2.16	0.50
1345	2/14/22	106	PP	C139		T2	-2 to 8	0	+30	+30	0	0	0	2.16	0.50
1348	2/15/22	106	PP	C139		T2	0 to 5.75	0	+30	+30	0	0	0	2.16	0.60
1349	2/15/22	106	PP	C139		T2	0 to 5.5	0	+30	+30	0	0	0	2.16	0.65
1350	2/15/22	106	PP	C139		T2	0 to 5.25	0	+30	+30	0	0	0	2.16	0.70
1351	2/15/22	106	PP	C139		T2	0 to 4.5	0	+30	+30	0	0	0	2.16	0.75
1352	2/15/22	106	PP	C139		T2	0 to 4	0	+30	+30	0	0	0	2.16	0.78
1353	2/15/22	106	PP	C139		T2	0 to 3.5	0	+30	+30	0	0	0	2.16	0.79
1354	2/15/22	106	PP	C139		T2	0 to 5	0	+30	+30	0	0	0	2.16	0.80
1355	2/15/22	106	PP	C139		T2	0 to 5.25	0	+30	+30	0	0	0	2.16	0.81

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1356	2/15/22	106	PP	C139		T2	0 to 4.5	0	+30	+30	0	0	0	2.16	0.82
1357	2/15/22	106	PP	C139		T2	0 to 5.25	0	+30	+30	0	0	0	2.16	0.83
1358	2/15/22	106	PP	C139		T2	0 to 4	0	+30	+30	0	0	0	2.16	0.85
1359	2/15/22	106	PP	C139		T2	0 to 4.25	0	+30	+30	0	0	0	2.16	0.87
1360	2/15/22	106	PP	C139		T2	0 to 4.25	0	+30	+30	0	0	0	2.16	0.89
1361	2/15/22	106	PP	C139		T2	0 to 4	0	+30	+30	0	0	0	2.16	0.92
1362	2/15/22	106	PP	C139		T2	0 to 4.5	0	+30	+30	0	0	0	2.16	0.80
1364	2/15/22	107	PP	C139	Both Ailerons -2.5deg	T2	-2 to 9	0	-2.5	-2.5	0	0	0	2.16	0.50
1365	2/15/22	107	PP	C139		T2	0 to 9	0	-2.5	-2.5	0	0	0	2.16	0.60
1366	2/15/22	107	PP	C139		T2	0 to 9	0	-2.5	-2.5	0	0	0	2.16	0.65
1367	2/15/22	107	PP	C139		T2	0 to 8.5	0	-2.5	-2.5	0	0	0	2.16	0.70
1368	2/15/22	107	PP	C139		T2	0 to 7	0	-2.5	-2.5	0	0	0	2.16	0.75
1369	2/15/22	107	PP	C139		T2	0 to 6.5	0	-2.5	-2.5	0	0	0	2.16	0.78
1370	2/15/22	107	PP	C139		T2	0 to 6.5	0	-2.5	-2.5	0	0	0	2.16	0.79
1371	2/15/22	107	PP	C139		T2	0 to 6.5	0	-2.5	-2.5	0	0	0	2.16	0.80
1372	2/15/22	107	PP	C139		T2	0 to 7	0	-2.5	-2.5	0	0	0	2.16	0.81
1373	2/15/22	107	PP	C139		T2	0 to 7	0	-2.5	-2.5	0	0	0	2.16	0.82
1374	2/15/22	107	PP	C139		T2	0 to 7.5	0	-2.5	-2.5	0	0	0	2.16	0.83
1375	2/15/22	107	PP	C139		T2	0 to 7.5	0	-2.5	-2.5	0	0	0	2.16	0.85
1376	2/15/22	107	PP	C139		T2	0 to 8	0	-2.5	-2.5	0	0	0	2.16	0.87
1377	2/15/22	107	PP	C139		T2	0 to 8	0	-2.5	-2.5	0	0	0	2.16	0.89
1378	2/15/22	107	PP	C139		T2	0 to 8	0	-2.5	-2.5	0	0	0	2.16	0.92
1379	2/15/22	107	PP	C139		T2	0 to 6	0	-2.5	-2.5	0	0	0	2.16	0.80
1380	2/15/22	108	CPR	C139	Both Ailerons -2.5deg	T2	0 to 9	0	-2.5	-2.5	0	0	0	2.16	0.50
1381	2/15/22	108	CPR	C139		T2	0 to 9	0	-2.5	-2.5	0	0	0	2.16	0.50
1382	2/15/22	108	CPR	C139		T2	0 to 9	0	-2.5	-2.5	0	0	0	2.16	0.65
1383	2/15/22	108	CPR	C139		T2	0 to 8	0	-2.5	-2.5	0	0	0	2.16	0.70
1384	2/15/22	108	CPR	C139		T2	0 to 7	0	-2.5	-2.5	0	0	0	2.16	0.75
1385	2/15/22	108	CPR	C139		T2	0 to 6.5	0	-2.5	-2.5	0	0	0	2.16	0.78

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1386	2/15/22	108	CPR	C139		T2	0 to 6.5	0	-2.5	-2.5	0	0	0	2.16	0.80
1387	2/15/22	108	CPR	C139		T2	0 to 7	0	-2.5	-2.5	0	0	0	2.16	0.82
1388	2/15/22	108	CPR	C139		T2	0 to 7.5	0	-2.5	-2.5	0	0	0	2.16	0.83
1389	2/15/22	108	CPR	C139		T2	0 to 7.5	0	-2.5	-2.5	0	0	0	2.16	0.85
1390	2/15/22	108	CPR	C139		T2	0 to 8	0	-2.5	-2.5	0	0	0	2.16	0.87
1392	2/15/22	109	PP	C139	Both Ailerons -40deg	T2	1 to 9	0	-40	-40	0	0	0	2.16	0.50
1393	2/15/22	109	PP	C139		T2	1 to 9	0	-40	-40	0	0	0	2.16	0.60
1394	2/15/22	109	PP	C139		T2	1 to 9	0	-40	-40	0	0	0	2.16	0.65
1395	2/15/22	109	PP	C139		T2	1 to 9	0	-40	-40	0	0	0	2.16	0.70
1396	2/15/22	109	PP	C139		T2	1 to 8	0	-40	-40	0	0	0	2.16	0.75
1397	2/15/22	109	PP	C139		T2	1 to 8	0	-40	-40	0	0	0	2.16	0.78
1398	2/15/22	109	PP	C139		T2	1 to 7	0	-40	-40	0	0	0	2.16	0.79
1399	2/15/22	109	PP	C139		T2	1 to 7	0	-40	-40	0	0	0	2.16	0.80
1400	2/15/22	109	PP	C139		T2	1 to 3	0	-40	-40	0	0	0	2.16	0.81
1401	2/15/22	109	PP	C139		T2	2 to 7	0	-40	-40	0	0	0	2.16	0.82
1402	2/15/22	109	PP	C139		T2	1 to 7	0	-40	-40	0	0	0	2.16	0.83
1403	2/15/22	109	PP	C139		T2	1 to 7	0	-40	-40	0	0	0	2.16	0.85
1404	2/15/22	109	PP	C139		T2	1.5 to 7	0	-40	-40	0	0	0	2.16	0.87
1405	2/15/22	109	PP	C139		T2	1.5 to 7	0	-40	-40	0	0	0	2.16	0.89
1406	2/15/22	109	PP	C139		T2	1 to 7	0	-40	-40	0	0	0	2.16	0.92
1407	2/15/22	109	PP	C139		T2	1.5 to 7	0	-40	-40	0	0	0	2.16	0.80
Combined Spoiler Effectiveness															
1409	2/15/22	110	PP	C139	All Spoilers -10deg	T2	-2 to 8.75	0	0	0	-10	-10	-10	2.16	0.50
1410	2/15/22	110	PP	C139		T2	0 to 8.75	0	0	0	-10	-10	-10	2.16	0.60
1411	2/15/22	110	PP	C139		T2	0 to 8.75	0	0	0	-10	-10	-10	2.16	0.65
1412	2/15/22	110	PP	C139		T2	0 to 8.75	0	0	0	-10	-10	-10	2.16	0.70
1413	2/15/22	110	PP	C139		T2	0 to 6.75	0	0	0	-10	-10	-10	2.16	0.75
1414	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.78

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1415	2/15/22	110	PP	C139		T2	0 to 6.75	0	0	0	-10	-10	-10	2.16	0.79
1416	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.80
1417	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.81
1418	2/15/22	110	PP	C139		T2	0 to 7.25	0	0	0	-10	-10	-10	2.16	0.82
1419	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.83
1420	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.85
1421	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.87
1422	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.89
1423	2/15/22	110	PP	C139		T2	0 to 7.75	0	0	0	-10	-10	-10	2.16	0.92
1424	2/15/22	110	PP	C139		T2	0 to 7	0	0	0	-10	-10	-10	2.16	0.80
1427	2/15/22	111	PP	C139	All Spoilers -30deg	T2	-2 to 9	0	0	0	-30	-30	-30	2.16	0.50
1428	2/15/22	111	PP	C139		T2	0 to 9	0	0	0	-30	-30	-30	2.16	0.60
1429	2/15/22	111	PP	C139		T2	0 to 9	0	0	0	-30	-30	-30	2.16	0.65
1430	2/15/22	111	PP	C139		T2	0 to 8.5	0	0	0	-30	-30	-30	2.16	0.70
1431	2/15/22	111	PP	C139		T2	0 to 7.5	0	0	0	-30	-30	-30	2.16	0.75
1432	2/15/22	111	PP	C139		T2	0 to 7	0	0	0	-30	-30	-30	2.16	0.78
1433	2/15/22	111	PP	C139		T2	0 to 7.5	0	0	0	-30	-30	-30	2.16	0.79
1434	2/15/22	111	PP	C139		T2	0 to 7.5	0	0	0	-30	-30	-30	2.16	0.80
1435	2/15/22	111	PP	C139		T2	0 to 8	0	0	0	-30	-30	-30	2.16	0.81
1436	2/15/22	111	PP	C139		T2	0 to 8	0	0	0	-30	-30	-30	2.16	0.82
1437	2/15/22	111	PP	C139		T2	0 to 7.5	0	0	0	-30	-30	-30	2.16	0.83
1438	2/15/22	111	PP	C139		T2	0 to 8	0	0	0	-30	-30	-30	2.16	0.85
1439	2/15/22	111	PP	C139		T2	0.25 to 8	0	0	0	-30	-30	-30	2.16	0.87
1440	2/15/22	111	PP	C139		T2	0.75 to 8	0	0	0	-30	-30	-30	2.16	0.89
1441	2/15/22	111	PP	C139		T2	0.75 to 8	0	0	0	-30	-30	-30	2.16	0.92
1442	2/15/22	111	PP	C139		T2	0 to 7.5	0	0	0	-30	-30	-30	2.16	0.80
1444	2/15/22	112	PP	C139	All Spoilers -60deg	T2	-2 to 9	0	0	0	-60	-60	-60	2.16	0.50
1445	2/15/22	112	PP	C139		T2	0 to 9	0	0	0	-60	-60	-60	2.16	0.60
1446	2/15/22	112	PP	C139		T2	1.5 to 9	0	0	0	-60	-60	-60	2.16	0.65

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1447	2/15/22	112	PP	C139		T2	1 to 8.5	0	0	0	-60	-60	-60	2.16	0.70
1448	2/15/22	112	PP	C139		T2	1 to 8	0	0	0	-60	-60	-60	2.16	0.75
1449	2/15/22	112	PP	C139		T2	1 to 8	0	0	0	-60	-60	-60	2.16	0.78
1450	2/15/22	112	PP	C139		T2	1.5 to 8	0	0	0	-60	-60	-60	2.16	0.79
1451	2/15/22	112	PP	C139		T2	1.5 to 8	0	0	0	-60	-60	-60	2.16	0.80
1452	2/15/22	112	PP	C139		T2	1.5 to 8	0	0	0	-60	-60	-60	2.16	0.81
1453	2/15/22	112	PP	C139		T2	1.5 to 8	0	0	0	-60	-60	-60	2.16	0.82
1454	2/15/22	112	PP	C139		T2	0.75 to 8	0	0	0	-60	-60	-60	2.16	0.83
1455	2/15/22	112	PP	C139		T2	0.75 to 8	0	0	0	-60	-60	-60	2.16	0.85
1456	2/15/22	112	PP	C139		T2	1 to 8	0	0	0	-60	-60	-60	2.16	0.87
1457	2/15/22	112	PP	C139		T2	2 to 8	0	0	0	-60	-60	-60	2.16	0.89
1458	2/15/22	112	PP	C139		T2	2.5 to 8	0	0	0	-60	-60	-60	2.16	0.92
1459	2/15/22	112	PP	C139		T2	1.5 to 8	0	0	0	-60	-60	-60	2.16	0.80
1460	2/15/22	112	PP	C139		T2	1 to 9	0	0	0	-60	-60	-60	2.16	0.65
1461	2/15/22	112	PP	C139		T2	1 to 8.5	0	0	0	-60	-60	-60	2.16	0.70
1462	2/15/22	112	PP	C139		T2	1 to 8	0	0	0	-60	-60	-60	2.16	0.75
1465	2/15/22	113	PP	C139	All Spoilers -5deg	T2	-2 to 9	0	0	0	-5	-5	-5	2.16	0.50
1466	2/15/22	113	PP	C139		T2	0 to 9	0	0	0	-5	-5	-5	2.16	0.60
1467	2/15/22	113	PP	C139		T2	0 to 9	0	0	0	-5	-5	-5	2.16	0.65
1468	2/15/22	113	PP	C139		T2	0 to 9	0	0	0	-5	-5	-5	2.16	0.70
1469	2/15/22	113	PP	C139		T2	0 to 7.5	0	0	0	-5	-5	-5	2.16	0.75
1470	2/15/22	113	PP	C139		T2	0 to 7	0	0	0	-5	-5	-5	2.16	0.78
1471	2/15/22	113	PP	C139		T2	0 to 6.25	0	0	0	-5	-5	-5	2.16	0.79
1472	2/15/22	113	PP	C139		T2	0 to 7	0	0	0	-5	-5	-5	2.16	0.80
1473	2/15/22	113	PP	C139		T2	0 to 8	0	0	0	-5	-5	-5	2.16	0.81
1474	2/15/22	113	PP	C139		T2	0 to 8	0	0	0	-5	-5	-5	2.16	0.82
1475	2/15/22	113	PP	C139		T2	0 to 7.5	0	0	0	-5	-5	-5	2.16	0.83
1479	2/16/22	113	PP	C139		T2	0 to 8	0	0	0	-5	-5	-5	2.16	0.85
1480	2/16/22	113	PP	C139		T2	0 to 7	0	0	0	-5	-5	-5	2.16	0.83

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1481	2/16/22	113	PP	C139		T2	0 to 4.75	0	0	0	-5	-5	-5	2.16	0.87
1482	2/16/22	113	PP	C139		T2	0 to 8	0	0	0	-5	-5	-5	2.16	0.89
1483	2/16/22	113	PP	C139		T2	0 to 8	0	0	0	-5	-5	-5	2.16	0.92
1484	2/16/22	113	PP	C139		T2	0 to 6.5	0	0	0	-5	-5	-5	2.16	0.80
1486	2/16/22	114	PP	C139	All Spoilers 0deg	T2	-2 to 9	0	0	0	0	0	0	2.16	0.50
1487	2/16/22	114	PP	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.60
1488	2/16/22	114	PP	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.65
1489	2/16/22	114	PP	C139		T2	0 to 8.5	0	0	0	0	0	0	2.16	0.70
1490	2/16/22	114	PP	C139		T2	0 to 6	0	0	0	0	0	0	2.16	0.75
1491	2/16/22	114	PP	C139		T2	0 to 5.5	0	0	0	0	0	0	2.16	0.78
1492	2/16/22	114	PP	C139		T2	0 to 5.5	0	0	0	0	0	0	2.16	0.79
1493	2/16/22	114	PP	C139		T2	0 to 6.5	0	0	0	0	0	0	2.16	0.80
1494	2/16/22	114	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.81
1495	2/16/22	114	PP	C139		T2	0 to 7	0	0	0	0	0	0	2.16	0.82
1496	2/16/22	114	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.83
1497	2/16/22	114	PP	C139		T2	0 to 7.75	0	0	0	0	0	0	2.16	0.85
1498	2/16/22	114	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.87
1499	2/16/22	114	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.89
1500	2/16/22	114	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.92
1501	2/16/22	114	PP	C139		T2	0 to 6	0	0	0	0	0	0	2.16	0.80
Inboard Aileron Effectiveness															
1503	2/16/22	115	PP	C139	Inboard Aileron -40deg	T2	0 to 9	0	-40	0	0	0	0	2.16	0.50
1504	2/16/22	115	PP	C139		T2	0 to 9	0	-40	0	0	0	0	2.16	0.60
1505	2/16/22	115	PP	C139		T2	0 to 9	0	-40	0	0	0	0	2.16	0.65
1506	2/16/22	115	PP	C139		T2	0 to 8.5	0	-40	0	0	0	0	2.16	0.70
1507	2/16/22	115	PP	C139		T2	0 to 6	0	-40	0	0	0	0	2.16	0.75
1508	2/16/22	115	PP	C139		T2	0 to 6.5	0	-40	0	0	0	0	2.16	0.78
1509	2/16/22	115	PP	C139		T2	0 to 6.5	0	-40	0	0	0	0	2.16	0.79

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1510	2/16/22	115	PP	C139		T2	0 to 6.5	0	-40	0	0	0	0	2.16	0.80
1511	2/16/22	115	PP	C139		T2	0 to 7	0	-40	0	0	0	0	2.16	0.81
1512	2/16/22	115	PP	C139		T2	0 to 7	0	-40	0	0	0	0	2.16	0.82
1513	2/16/22	115	PP	C139		T2	0 to 7	0	-40	0	0	0	0	2.16	0.83
1514	2/16/22	115	PP	C139		T2	0 to 7.5	0	-40	0	0	0	0	2.16	0.85
1515	2/16/22	115	PP	C139		T2	0 to 8	0	-40	0	0	0	0	2.16	0.87
1516	2/16/22	115	PP	C139		T2	0 to 8	0	-40	0	0	0	0	2.16	0.89
1517	2/16/22	115	PP	C139		T2	0 to 6.5	0	-40	0	0	0	0	2.16	0.92
1518	2/16/22	115	PP	C139		T2	0 to 6.5	0	-40	0	0	0	0	2.16	0.80
1520	2/16/22	116	PP	C139	Inboard Aileron -30deg	T2	0 to 9	0	-30	0	0	0	0	2.16	0.50
1521	2/16/22	116	PP	C139		T2	0 to 9	0	-30	0	0	0	0	2.16	0.60
1522	2/16/22	116	PP	C139		T2	0 to 9	0	-30	0	0	0	0	2.16	0.65
1523	2/16/22	116	PP	C139		T2	0 to 8	0	-30	0	0	0	0	2.16	0.70
1524	2/16/22	116	PP	C139		T2	0 to 7	0	-30	0	0	0	0	2.16	0.75
1525	2/16/22	116	PP	C139		T2	0 to 6	0	-30	0	0	0	0	2.16	0.78
1526	2/16/22	116	PP	C139		T2	0 to 6.5	0	-30	0	0	0	0	2.16	0.79
1527	2/16/22	116	PP	C139		T2	0 to 6.5	0	-30	0	0	0	0	2.16	0.80
1528	2/16/22	116	PP	C139		T2	0 to 6.5	0	-30	0	0	0	0	2.16	0.81
1529	2/16/22	116	PP	C139		T2	0 to 7.5	0	-30	0	0	0	0	2.16	0.82
1530	2/16/22	116	PP	C139		T2	0 to 7.5	0	-30	0	0	0	0	2.16	0.83
1531	2/16/22	116	PP	C139		T2	0 to 8	0	-30	0	0	0	0	2.16	0.85
1532	2/16/22	116	PP	C139		T2	0 to 8	0	-30	0	0	0	0	2.16	0.87
1533	2/16/22	116	PP	C139		T2	0 to 8	0	-30	0	0	0	0	2.16	0.89
1534	2/16/22	116	PP	C139		T2	0 to 7.5	0	-30	0	0	0	0	2.16	0.92
1535	2/16/22	116	PP	C139		T2	0 to 6.5	0	-30	0	0	0	0	2.16	0.80
1537	2/16/22	117	PP	C139	Inboard Aileron +30deg	T2	-2 to 9	0	30	0	0	0	0	2.16	0.50
1538	2/16/22	117	PP	C139		T2	0 to 9	0	30	0	0	0	0	2.16	0.60
1539	2/16/22	117	PP	C139		T2	0 to 9	0	30	0	0	0	0	2.16	0.65
1540	2/16/22	117	PP	C139		T2	0 to 9	0	30	0	0	0	0	2.16	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1541	2/16/22	117	PP	C139		T2	0 to 7	0	30	0	0	0	0	2.16	0.75
1542	2/16/22	117	PP	C139		T2	0 to 7	0	30	0	0	0	0	2.16	0.78
1543	2/16/22	117	PP	C139		T2	0 to 7.25	0	30	0	0	0	0	2.16	0.79
1544	2/16/22	117	PP	C139		T2	0 to 7.5	0	30	0	0	0	0	2.16	0.80
1545	2/16/22	117	PP	C139		T2	0 to 7.5	0	30	0	0	0	0	2.16	0.81
1546	2/16/22	117	PP	C139		T2	0 to 7	0	30	0	0	0	0	2.16	0.82
1547	2/16/22	117	PP	C139		T2	0 to 7.5	0	30	0	0	0	0	2.16	0.83
1548	2/16/22	117	PP	C139		T2	0 to 7	0	30	0	0	0	0	2.16	0.85
1549	2/16/22	117	PP	C139		T2	0 to 8	0	30	0	0	0	0	2.16	0.87
1550	2/16/22	117	PP	C139		T2	0 to 8	0	30	0	0	0	0	2.16	0.89
1551	2/16/22	117	PP	C139		T2	0 to 7.5	0	30	0	0	0	0	2.16	0.92
1552	2/16/22	117	PP	C139		T2	0 to 7.5	0	30	0	0	0	0	2.16	0.80
1555	2/16/22	118	PP	C139	Inboard Aileron -5deg	T2	-2 to 9	0	-5	0	0	0	0	2.16	0.50
1556	2/16/22	118	PP	C139		T2	0 to 9	0	-5	0	0	0	0	2.16	0.60
1557	2/16/22	118	PP	C139		T2	0 to 9	0	-5	0	0	0	0	2.16	0.65
1558	2/16/22	118	PP	C139		T2	0 to 9	0	-5	0	0	0	0	2.16	0.70
1559	2/16/22	118	PP	C139		T2	0 to 8	0	-5	0	0	0	0	2.16	0.75
1560	2/16/22	118	PP	C139		T2	0 to 7.5	0	-5	0	0	0	0	2.16	0.78
1561	2/16/22	118	PP	C139		T2	0 to 7.5	0	-5	0	0	0	0	2.16	0.79
1562	2/16/22	118	PP	C139		T2	0 to 7.5	0	-5	0	0	0	0	2.16	0.80
1563	2/16/22	118	PP	C139		T2	0 to 8	0	-5	0	0	0	0	2.16	0.81
1564	2/16/22	118	PP	C139		T2	0 to 8	0	-5	0	0	0	0	2.16	0.82
1565	2/16/22	118	PP	C139		T2	0 to 7.5	0	-5	0	0	0	0	2.16	0.83
1566	2/16/22	118	PP	C139		T2	0 to 7.5	0	-5	0	0	0	0	2.16	0.85
1567	2/16/22	118	PP	C139		T2	0 to 8	0	-5	0	0	0	0	2.16	0.87
1568	2/16/22	118	PP	C139		T2	0 to 8	0	-5	0	0	0	0	2.16	0.89
1569	2/16/22	118	PP	C139		T2	0 to 7.5	0	-5	0	0	0	0	2.16	0.92
1570	2/16/22	118	PP	C139		T2	0 to 7.5	0	-5	0	0	0	0	2.16	0.80
1573	2/17/22	119	PP	C139	Inboard Aileron +5deg	T2	-2 to 9	0	5	0	0	0	0	2.16	0.50

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1574	2/17/22	119	PP	C139		T2	0 to 9	0	5	0	0	0	0	2.16	0.60
1575	2/17/22	119	PP	C139		T2	0 to 9	0	5	0	0	0	0	2.16	0.65
1576	2/17/22	119	PP	C139		T2	0 to 7	0	5	0	0	0	0	2.16	0.70
1577	2/17/22	119	PP	C139		T2	0 to 6.75	0	5	0	0	0	0	2.16	0.75
1578	2/17/22	119	PP	C139		T2	0 to 6.5	0	5	0	0	0	0	2.16	0.78
1579	2/17/22	119	PP	C139		T2	0 to 6.5	0	5	0	0	0	0	2.16	0.79
1580	2/17/22	119	PP	C139		T2	0 to 6.5	0	5	0	0	0	0	2.16	0.80
1581	2/17/22	119	PP	C139		T2	0 to 7	0	5	0	0	0	0	2.16	0.81
1582	2/17/22	119	PP	C139		T2	0 to 7	0	5	0	0	0	0	2.16	0.82
1583	2/17/22	119	PP	C139		T2	0 to 7.5	0	5	0	0	0	0	2.16	0.83
1584	2/17/22	119	PP	C139		T2	0 to 7.5	0	5	0	0	0	0	2.16	0.85
1585	2/17/22	119	PP	C139		T2	0 to 8	0	5	0	0	0	0	2.16	0.87
1586	2/17/22	119	PP	C139		T2	0 to 8	0	5	0	0	0	0	2.16	0.89
1587	2/17/22	119	PP	C139		T2	0 to 7.5	0	5	0	0	0	0	2.16	0.92
1588	2/17/22	119	PP	C139		T2	0 to 6.5	0	5	0	0	0	0	2.16	0.80
1589	2/17/22	120	CPR	C139	Inboard Aileron +5deg	T2	0 to 9	0	5	0	0	0	0	2.16	0.50
1590	2/17/22	120	CPR	C139		T2	0 to 9	0	5	0	0	0	0	2.16	0.65
1591	2/17/22	120	CPR	C139		T2	0 to 7	0	5	0	0	0	0	2.16	0.70
1592	2/17/22	120	CPR	C139		T2	0 to 6.5	0	5	0	0	0	0	2.16	0.75
1593	2/17/22	120	CPR	C139		T2	0 to 6.5	0	5	0	0	0	0	2.16	0.78
1594	2/17/22	120	CPR	C139		T2	0 to 6.5	0	5	0	0	0	0	2.16	0.80
1595	2/17/22	120	CPR	C139		T2	0 to 7	0	5	0	0	0	0	2.16	0.82
1596	2/17/22	120	CPR	C139		T2	0 to 7	0	5	0	0	0	0	2.16	0.83
1597	2/17/22	120	CPR	C139		T2	0 to 7	0	5	0	0	0	0	2.16	0.85
1598	2/17/22	120	CPR	C139		T2	0 to 8	0	5	0	0	0	0	2.16	0.87
1600	2/17/22	121	PP	C139	Inboard Aileron -10deg	T2	-2 to 9	0	-10	0	0	0	0	2.16	0.50
1601	2/17/22	121	PP	C139		T2	0 to 9	0	-10	0	0	0	0	2.16	0.60
1602	2/17/22	121	PP	C139		T2	0 to 9	0	-10	0	0	0	0	2.16	0.65
1603	2/17/22	121	PP	C139		T2	0 to 7.5	0	-10	0	0	0	0	2.16	0.70

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1604	2/17/22	121	PP	C139		T2	0 to 6.5	0	-10	0	0	0	0	2.16	0.75
1605	2/17/22	121	PP	C139		T2	0 to 6	0	-10	0	0	0	0	2.16	0.78
1606	2/17/22	121	PP	C139		T2	0 to 6	0	-10	0	0	0	0	2.16	0.79
1607	2/17/22	121	PP	C139		T2	0 to 6	0	-10	0	0	0	0	2.16	0.80
1608	2/17/22	121	PP	C139		T2	0 to 7.75	0	-10	0	0	0	0	2.16	0.81
1609	2/17/22	121	PP	C139		T2	0 to 7	0	-10	0	0	0	0	2.16	0.82
1610	2/17/22	121	PP	C139		T2	0 to 7	0	-10	0	0	0	0	2.16	0.83
1611	2/17/22	121	PP	C139		T2	0 to 7.5	0	-10	0	0	0	0	2.16	0.85
1612	2/17/22	121	PP	C139		T2	0 to 8	0	-10	0	0	0	0	2.16	0.87
1613	2/17/22	121	PP	C139		T2	0 to 8	0	-10	0	0	0	0	2.16	0.89
1614	2/17/22	121	PP	C139		T2	0 to 7.5	0	-10	0	0	0	0	2.16	0.92
1615	2/17/22	121	PP	C139		T2	0 to 6	0	-10	0	0	0	0	2.16	0.80
1617	2/17/22	122	PP	C139	Inboard Aileron +10deg	T2	-2 to 9	0	10	0	0	0	0	2.16	0.50
1618	2/17/22	122	PP	C139		T2	0 to 9	0	10	0	0	0	0	2.16	0.60
1619	2/17/22	122	PP	C139		T2	0 to 9	0	10	0	0	0	0	2.16	0.65
1620	2/17/22	122	PP	C139		T2	0 to 7	0	10	0	0	0	0	2.16	0.70
1621	2/17/22	122	PP	C139		T2	0 to 6	0	10	0	0	0	0	2.16	0.75
1622	2/17/22	122	PP	C139		T2	0 to 6	0	10	0	0	0	0	2.16	0.78
1623	2/17/22	122	PP	C139		T2	0 to 6	0	10	0	0	0	0	2.16	0.79
1624	2/17/22	122	PP	C139		T2	0 to 6	0	10	0	0	0	0	2.16	0.80
1625	2/17/22	122	PP	C139		T2	0 to 6.5	0	10	0	0	0	0	2.16	0.81
1626	2/17/22	122	PP	C139		T2	0 to 7	0	10	0	0	0	0	2.16	0.82
1627	2/17/22	122	PP	C139		T2	0 to 7	0	10	0	0	0	0	2.16	0.83
1628	2/17/22	122	PP	C139		T2	0 to 7.5	0	10	0	0	0	0	2.16	0.85
1629	2/17/22	122	PP	C139		T2	0 to 8	0	10	0	0	0	0	2.16	0.87
1630	2/17/22	122	PP	C139		T2	0 to 8	0	10	0	0	0	0	2.16	0.89
1631	2/17/22	122	PP	C139		T2	0 to 7.5	0	10	0	0	0	0	2.16	0.92
1632	2/17/22	122	PP	C139		T2	0 to 6	0	10	0	0	0	0	2.16	0.80
1634	2/17/22	123	PP	C139	Inboard Aileron +20deg	T2	-2 to 9	0	20	0	0	0	0	2.16	0.50

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1635	2/17/22	123	PP	C139		T2	0 to 9	0	20	0	0	0	0	2.16	0.60
1636	2/17/22	123	PP	C139		T2	0 to 7.5	0	20	0	0	0	0	2.16	0.65
1637	2/17/22	123	PP	C139		T2	0 to 7	0	20	0	0	0	0	2.16	0.70
1638	2/17/22	123	PP	C139		T2	0 to 6	0	20	0	0	0	0	2.16	0.75
1639	2/17/22	123	PP	C139		T2	0 to 5.25	0	20	0	0	0	0	2.16	0.78
1640	2/17/22	123	PP	C139		T2	0 to 5.5	0	20	0	0	0	0	2.16	0.79
1641	2/17/22	123	PP	C139		T2	0 to 6	0	20	0	0	0	0	2.16	0.80
1642	2/17/22	123	PP	C139		T2	0 to 6.5	0	20	0	0	0	0	2.16	0.81
1643	2/17/22	123	PP	C139		T2	0 to 7	0	20	0	0	0	0	2.16	0.82
1644	2/17/22	123	PP	C139		T2	0 to 6.5	0	20	0	0	0	0	2.16	0.83
1645	2/17/22	123	PP	C139		T2	0 to 7.5	0	20	0	0	0	0	2.16	0.85
1646	2/17/22	123	PP	C139		T2	0 to 8	0	20	0	0	0	0	2.16	0.87
1647	2/17/22	123	PP	C139		T2	0 to 8	0	20	0	0	0	0	2.16	0.89
1648	2/17/22	123	PP	C139		T2	0 to 7.5	0	20	0	0	0	0	2.16	0.92
1649	2/17/22	123	PP	C139		T2	0 to 6	0	20	0	0	0	0	2.16	0.80
1651	2/17/22	124	PP	C139	Inboard Aileron -2.5deg	T2	-2 to 9	0	-2.5	0	0	0	0	2.16	0.50
1652	2/17/22	124	PP	C139		T2	0 to 9	0	-2.5	0	0	0	0	2.16	0.60
1653	2/17/22	124	PP	C139		T2	0 to 9	0	-2.5	0	0	0	0	2.16	0.65
1654	2/17/22	124	PP	C139		T2	0 to 9	0	-2.5	0	0	0	0	2.16	0.70
1655	2/17/22	124	PP	C139		T2	0 to 7.5	0	-2.5	0	0	0	0	2.16	0.75
1656	2/17/22	124	PP	C139		T2	0 to 7	0	-2.5	0	0	0	0	2.16	0.78
1657	2/17/22	124	PP	C139		T2	0 to 7	0	-2.5	0	0	0	0	2.16	0.79
1658	2/17/22	124	PP	C139		T2	0 to 7.5	0	-2.5	0	0	0	0	2.16	0.80
1659	2/17/22	124	PP	C139		T2	0 to 8	0	-2.5	0	0	0	0	2.16	0.81
1660	2/17/22	124	PP	C139		T2	0 to 8	0	-2.5	0	0	0	0	2.16	0.82
1661	2/17/22	124	PP	C139		T2	0 to 8	0	-2.5	0	0	0	0	2.16	0.83
1662	2/17/22	124	PP	C139		T2	0 to 7.5	0	-2.5	0	0	0	0	2.16	0.85
1663	2/17/22	124	PP	C139		T2	0 to 8	0	-2.5	0	0	0	0	2.16	0.87
1664	2/17/22	124	PP	C139		T2	0 to 8	0	-2.5	0	0	0	0	2.16	0.89

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1665	2/17/22	124	PP	C139		T2	0 to 7.5	0	-2.5	0	0	0	0	2.16	0.92
1666	2/17/22	124	PP	C139		T2	0 to 7.75	0	-2.5	0	0	0	0	2.16	0.80
1668	2/17/22	125	PP	C139	Inboard Aileron 0deg	T2	-2 to 9	0	0	0	0	0	0	2.16	0.50
1669	2/17/22	125	PP	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.60
1670	2/17/22	125	PP	C139		T2	0 to 9	0	0	0	0	0	0	2.16	0.65
1671	2/17/22	125	PP	C139		T2	0 to 8.5	0	0	0	0	0	0	2.16	0.70
1672	2/17/22	125	PP	C139		T2	0 to 7	0	0	0	0	0	0	2.16	0.75
1673	2/17/22	125	PP	C139		T2	0 to 6.5	0	0	0	0	0	0	2.16	0.78
1674	2/17/22	125	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.79
1675	2/17/22	125	PP	C139		T2	0 to 7	0	0	0	0	0	0	2.16	0.80
1676	2/17/22	125	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.81
1677	2/17/22	125	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.82
1678	2/17/22	125	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.83
1679	2/17/22	125	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.85
1680	2/17/22	125	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.87
1681	2/17/22	125	PP	C139		T2	0 to 8	0	0	0	0	0	0	2.16	0.89
1682	2/17/22	125	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.92
1683	2/17/22	125	PP	C139		T2	0 to 7.5	0	0	0	0	0	0	2.16	0.80
Miscellaneous Runs															
1685	2/17/22	126	PP	C139	Spoilers 2.5deg	T2	-2 to 2.5	0	0	0	-2.5	-2.5	-2.5	2.16	0.50
1687	2/17/22	126	PP	C139	All Ailerons 2.5deg	T2	-2 to 9	0	2.5	2.5	0	0	0	2.16	0.50
1688	2/17/22	126	PP	C139		T2	0 to 9	0	2.5	2.5	0	0	0	2.16	0.60
1689	2/17/22	126	PP	C139		T2	0 to 9	0	2.5	2.5	0	0	0	2.16	0.65
1690	2/17/22	126	PP	C139		T2	0 to 9	0	2.5	2.5	0	0	0	2.16	0.70
1691	2/17/22	126	PP	C139		T2	0 to 7	0	2.5	2.5	0	0	0	2.16	0.75
1692	2/17/22	126	PP	C139		T2	0 to 7	0	2.5	2.5	0	0	0	2.16	0.78
1693	2/17/22	126	PP	C139		T2	0 to 7	0	2.5	2.5	0	0	0	2.16	0.79
1694	2/17/22	126	PP	C139		T2	0 to 7.5	0	2.5	2.5	0	0	0	2.16	0.80

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

Run Number	As-run Date	Run Series	Run Type	Config	Model Change	Transition Trip	Alpha	OB Strut Flap	Ailerons		Spoilers			Re _{MAC}	Mach
									IB	OB	IB	MB	OB		
1695	2/17/22	126	PP	C139		T2	0 to 8	0	2.5	2.5	0	0	0	2.16	0.81
1696	2/17/22	126	PP	C139		T2	0 to 8	0	2.5	2.5	0	0	0	2.16	0.82
1697	2/17/22	126	PP	C139		T2	0 to 7	0	2.5	2.5	0	0	0	2.16	0.83
1698	2/17/22	126	PP	C139		T2	0 to 8	0	2.5	2.5	0	0	0	2.16	0.85
1699	2/17/22	126	PP	C139		T2	0 to 8	0	2.5	2.5	0	0	0	2.16	0.87
1700	2/17/22	126	PP	C139		T2	0 to 8	0	2.5	2.5	0	0	0	2.16	0.89
1701	2/17/22	126	PP	C139		T2	0 to 7.5	0	2.5	2.5	0	0	0	2.16	0.92
1702	2/17/22	126	PP	C139		T2	0 to 7	0	2.5	2.5	0	0	0	2.16	0.80
1703	2/17/22	126	PP	C139		T2	0 to 7.5	0	2.5	2.5	0	0	0	2.16	0.80
1704	2/17/22	126	PP	C139		T2	0 to 7.5	0	2.5	2.5	0	0	0	2.16	0.80
1705	2/17/22	126	PP	C139		T2	0 to 7.5	0	2.5	2.5	0	0	0	2.16	0.80
1709	2/17/22	127	Pressure Sweep	C139	Alpha and Mach set to zero	T2	0	0	2.5	2.5	0	0	0	0.00	0.00
1710	2/17/22	127	Pressure Sweep	C139		T2	0	0	2.5	2.5	0	0	0	0.00	0.00
1711	2/17/22	127	Pressure Sweep	C139		T2	0	0	2.5	2.5	0	0	0	0.00	0.00
1712	2/17/22	127	Pressure Sweep	C139		T2	0	0	2.5	2.5	0	0	0	0.00	0.00

Appendix B – Model Instrumentation Specifications



ULTRAMINIATURE THIN LINE PRESSURE TRANSDUCERS

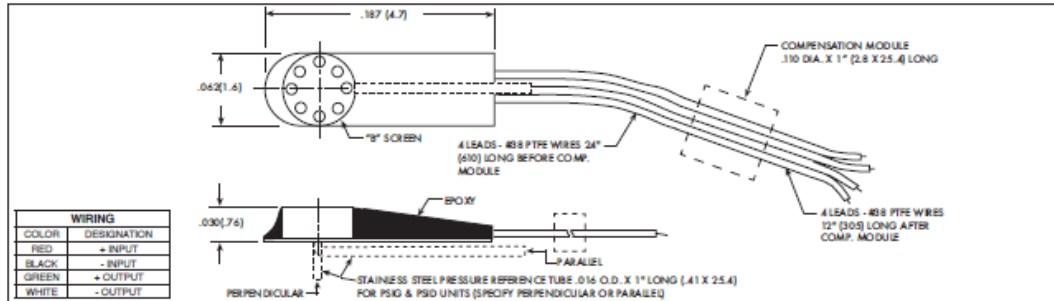
LQ-062 SERIES

- Ideal For Wind Tunnel Applications
- Excellent Static And Dynamic Performance
- High Natural Frequency
- Silicon on Silicon Integrated Sensor VIS®

The LQ-062 Series demonstrates Kulite's ability to provide pressure transducers suited for adaptation into custom packages. These devices can be integrated into various test articles such as fan blades, engine nozzles of various types, etc. The features of these transducers include small foot print, high natural frequency, extreme resistance to vibration and shock, and wide temperature range.



Kulite recommends the **KSC Series** of signal conditioners to maximize the measurement capability of the LQ-062 transducer.



INPUT	Pressure Range	0.35 5	0.7 10	1 15	1.7 25	3.5 50	7 100	17 250	35 500	70 BAR 1000 PSI
	Operational Mode	Absolute, Gage, Differential			Absolute, Gage, Sealed Gage, Differential			Absolute, Sealed Gage		
	Over Pressure	2 Times Rated Pressure								
	Burst Pressure	3 Times Rated Pressure								
	Pressure Media	All Nonconductive, Noncorrosive Liquids or Gases								
	Rated Electrical Excitation	10 VDC								
	Maximum Electrical Excitation	12 VDC								
	Input Impedance	1000 Ohms (Min.)								
OUTPUT	Output Impedance	1000 Ohms (Nom.)								
	Full Scale Output (FSO)	100 mV (Nom.)								
	Residual Unbalance	± 5 mV (Typ.)								
	Combined Non-Linearity, Hysteresis and Repeatability	± 0.1% FSO BFSL (Typ.), ± 0.5% FSO (Max.)								
	Resolution	Infinitesimal								
	Natural Frequency of Sensor Without Screen (KHz) (Typ.)	150	175	200	240	300	380	550	700	1000
	Acceleration Sensitivity % FS/g Perpendicular	1.5x10 ⁻³	1.0x10 ⁻³	6.5x10 ⁻⁴	5.0x10 ⁻⁴	3.0x10 ⁻⁴	1.5x10 ⁻⁴	1.0x10 ⁻⁴	6.0x10 ⁻⁵	4.5x10 ⁻⁵
	Insulation Resistance	100 Megohm Min. @ 50 VDC								
ENVIRONMENTAL	Operating Temperature Range	-65°F to +250°F (-55°C to +120°C)								
	Compensated Temperature Range	80°F to +180°F (25°C to +80°C) any 100°F Range Within The Operating Range on Request								
	Thermal Zero Shift	± 1% FS/100°F (Typ.)								
	Thermal Sensitivity Shift	± 1% /100°F (Typ.)								
	Linear Vibration	10-2,000 Hz Sine, 100g. (Max.)								
PHYSICAL	Mechanical Shock	20g half Sine Wave 11 msec. Duration								
	Electrical Connection	4 Leads 36 AWG 36" Long								
	Weight	.2 Gram (Nom.) Excluding Module and Leads								
	Pressure Sensing Principle	Fully Active Four Arm Wheatstone Bridge Dielectrically Isolated Silicon on Silicon								

Note: Custom pressure ranges, accuracies and mechanical configurations available. Dimensions are in inches. Dimensions in parenthesis are in millimeters. All dimensions nominal. (N) Continuous development and refinement of our products may result in specification changes without notice. Copyright © 2014 Kulite Semiconductor Products, Inc. All Rights Reserved. Kulite miniature pressure transducers are intended for use in test and research and development programs and are not necessarily designed to be used in production applications. For products designed to be used in production programs, please consult the factory.

KULITE SEMICONDUCTOR PRODUCTS, INC. • One Willow Tree Road • Leonia, New Jersey 07605 • Tel: 201 461-0900 • Fax: 201 461-0990 • <http://www.kulite.com>

Figure B-1. Kulite Specification Data Sheet.

NASA Contract NNL16AA04B, 80LARC20F0113
Subsonic Ultra-Green Aircraft Research Phase V – Buffet Test Report

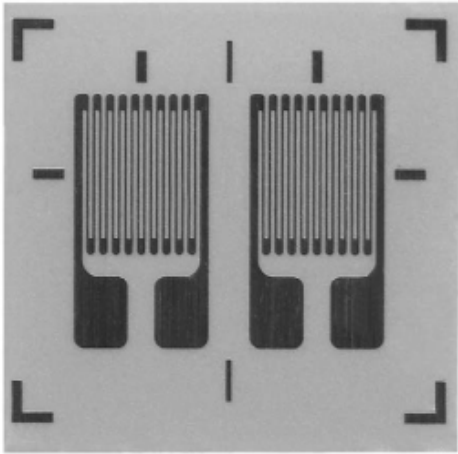
Model Number 352A71		ICP® ACCELEROMETER		Revision: D ECN #: 42399		
Performance Sensitivity(± 15 %) Measurement Range Frequency Range(± 5 %) Frequency Range(± 10 %) Frequency Range(± 3 dB) Resonant Frequency Broadband Resolution(1 to 10,000 Hz) Non-Linearity Transverse Sensitivity Environmental Overload Limit(Shock) Temperature Range(Operating) Temperature Response Electrical Excitation Voltage Constant Current Excitation Output Impedance Output Bias Voltage Discharge Time Constant Settling Time(within 10% of bias) Spectral Noise(1 Hz) Spectral Noise(10 Hz) Spectral Noise(100 Hz) Spectral Noise(1 kHz) Physical Size (Height x Length x Width) Weight(without cable) Sensing Element Sensing Geometry Housing Material Sealing Electrical Connector Electrical Connection Position Cable Termination Cable Length Mounting	ENGLISH 10 mV/g ± 500 g pk 0.5 to 10,000 Hz 0.35 to 16,000 Hz 0.2 to 25,000 Hz ≥ 65 kHz 0.003 g rms ≤ 1 % ≤ 5 % ± 10,000 g pk -65 to +200 °F See Graph 18 to 30 VDC 2 to 20 mA ≤ 200 Ohm 7 to 12 VDC 1.0 to 3.5 sec ≤ 3 sec 725 µg/√Hz 225 µg/√Hz 60 µg/√Hz 20 µg/√Hz .14 in x 0.41 in x 0.25 in 0.023 oz Ceramic Shear Titanium Hermetic Solder pins with attached cable Side 10-32 Coaxial Plug 10 ft Adhesive		SI 1.02 mV/(m/s²) ± 4900 m/s² pk 0.5 to 10,000 Hz 0.35 to 16,000 Hz 0.2 to 25,000 Hz ≥ 65 kHz 0.03 m/s² rms ≤ 1 % ≤ 5 % ± 98,000 m/s² pk -54 to +93 °C See Graph 18 to 30 VDC 2 to 20 mA ≤ 200 Ohm 7 to 12 VDC 1.0 to 3.5 sec ≤ 3 sec 7110 (µm/sec²)/√Hz 2210 (µm/sec²)/√Hz 590 (µm/sec²)/√Hz 196 (µm/sec²)/√Hz 3.6 mm x 10.4 mm x 6.4 mm 0.64 gm Ceramic Shear Titanium Hermetic Solder pins with attached cable Side 10-32 Coaxial Plug 3.05 m Adhesive			
					OPTIONAL VERSIONS Optional versions have identical specifications and accessories as listed for the standard model except where noted below. More than one option may be used. NOTES: [1] Typical. [2] Zero-based, least-squares, straight line method. [3] Cable is made up of 1 ft. of 089 cable (32 AWG twisted pair) spliced to 9 ft. of 018 cable (coaxial). [4] See PCB Declaration of Conformance PS023 for details.	
		</				

Figure B-2. Accelerometer Data Sheet.

060PB

MICRO
MEASUREMENTS
A VPG Brand

General Purpose Strain Gages—Linear Pattern

GAGE PATTERN DATA					
 actual size			GAGE DESIGNATION	RESISTANCE (OHMS)	OPTIONS AVAILABLE
			See Note 1, 3	See Note 2	See Note 3
			EA-XX-060PB-120	120 ±0.2%	W, E, L, LE
			EA-XX-060PB-350	350 ±0.2%	W, E, L, LE
			WA-XX-060PB-120	120 ±0.3%	W*
			WA-XX-060PB-350	350 ±0.3%	W*
			WK-XX-060PB-350	350 ±0.3%	W*, SP35*
			WK-XX-060PB-500	500 ±0.3%	W*, SP35*
			SA-XX-060PB-120	120 ±0.3%	
			SA-XX-060PB-350	350 ±0.3%	
			SK-XX-060PB-350	350 ±0.3%	
			SK-XX-060PB-500	500 ±0.3%	
DESCRIPTION Dual pattern for back-to-back bending sections. Longitudinal grid centerlines spaced 0.085 in (2.16 mm) apart.					
GAGE DIMENSIONS		Legend		inch millimeter	
		ES = Each Section S = Section (S1 = Section 1)		CP = Complete Pattern M = Matrix	
Gage Length	Overall Length	Grid Width	Overall Width	Matrix Length	Matrix Width
0.060 ES	0.120 CP	0.065 ES	0.150 CP	0.18	0.20
1.52 ES	3.05 CP	1.65 ES	3.81 CP	4.6	5.1

GAGE SERIES DATA — See Gage Series datasheet for complete specifications			
Series	Description	Strain Range	Temperature Range
EA	Constantan foil in combination with a tough, flexible, polyimide backing.	±3%	–100° to +350°F (–75° to +175°C)
WA	Fully encapsulated constantan gages with high-endurance leadwires.	±2%	–100° to +400°F (–75° to +205°C)
WK	Fully encapsulated K-alloy gages with high-endurance leadwires.	±1.5%	–452° to +550°F (–269° to +290°C)
SA	Fully encapsulated constantan gages with solder dots.	±2%	–100° to +400°F (–75° to +205°C)
SK	Fully encapsulated K-alloy gages with solder dots.	±1.5%	–452° to +450°F (–269° to +230°C)

Note 1: Insert desired S-T-C number in spaces marked XX.

Note 2: Tolerance is increased when Option W, E, SE, LE, P, or SP35 is specified.

Note 3: Products with designations and options shown in **bold** are not RoHS compliant.

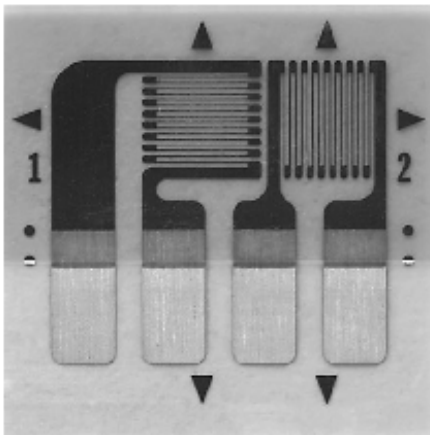
*Options available but not normally recommended. See Optional Features data sheet for details.

Figure B-3. Strain Gauge Data Sheet 1.



062UT

General Purpose Strain Gages – Tee Rosette

GAGE PATTERN DATA					
  actual size			GAGE DESIGNATION	RESISTANCE (OHMS)	OPTIONS AVAILABLE
			See Note 1		See Note 2
			CEA-XX-062UT-120 CEA-XX-062UT-350	120 ± 0.4% 350 ± 0.4%	P2 P2
			DESCRIPTION Small general-purpose two-element 90° tee rosette. Exposed solder tab area 0.07 x 0.04 in (1.8 x 1.0 mm).		
GAGE DIMENSIONS		Legend			
		ES – Each Section	CP – Complete Pattern		Inch
		S – Section (S1 – Section 1)	M – Matrix		millimeter
Gage Length	Overall Length	Grid Width	Overall Width	Matrix Length	Matrix Width
0.062 ES	0.205 CP	0.080 ES	0.225 CP	0.31	0.31
1.57 ES	5.21 CP	2.03 ES	5.72 CP	7.9	7.9

GAGE SERIES DATA — See Gage Series datasheet for complete specifications			
Series	Description	Strain Range	Temperature Range
CEA	Universal general-purpose strain gages.	±3%	–100° to +350°F (–75° to +175°C)

Note 1: Insert desired S-T-C number in spaces marked XX.

Note 2: Products with designations and options shown in bold are not RoHS compliant.

Figure B-4. Strain Gauge Data Sheet 2.