



POSITION CORRECTIONS AND STALL CHARACTERISTICS OF EPIC MODIFIED C-12C (Project Have EPIC DISCO)

JOHN STEVENSON, Capt, USAF
Project Manager/WSO

SARAH VORGERT, Capt, USAF
Project Engineer

ERIC HICKERNELL, Maj, USAF
Project Pilot

DOUG WEIDMAN, Capt, USAF
Project Pilot

W. TRAVIS JOHNSON, LT, USN
Project Pilot

RACHEL WILLIAMS, Capt USAF
Project Pilot



DECEMBER 2020

FINAL TECHNICAL INFORMATION MEMORANDUM

APPROVED FOR PUBLIC RELEASE DISTRIBUTION STATEMENT A:
DISTRIBUTION IS UNLIMITED. 412TW-PA-22229

DISCLAIMER: This report has been prepared in partial fulfillment of the graduation requirements of the Test Pilot School and the award of a Master's Degree in Flight Test Engineering by Air University. While thoroughly reviewed for technical veracity, the analysis, conclusions, and recommendations herein are not endorsed by the 412th Test Wing or the Air Force Test Center. It is intended for the sole use of the sponsoring agency of the report and the Test Pilot School Staff. It is not to be distributed beyond those agencies without the express permission of the Commandant of the Test Pilot School and the appropriate representative of the sponsoring agency.

UNITED STATES AIR FORCE TEST PILOT SCHOOL
AIR FORCE TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

U
S
A
F

T
P
S

This technical information memorandum (USAFTPS-TIM-20A-03, *Position Corrections and Stall Characterization of EPIC Modified C-12C*) was submitted under job order number MT20A300 by the Commandant, USAF Test Pilot School, Edwards AFB, California 93524-6843.

Prepared by:

This test plan has been reviewed and is approved for publication:

STEVENSON.JOHN
.ARIS.1460089103
Digitally signed by
STEVENSON.JOHN.ARIS.14600891
03
Date: 2020.12.08 08:53:34 -08'00'

JOHN A. STEVENSON
Captain, USAF
Project Manager/WSO

JURADO.JUAN.
D.1272700300
Digitally signed by
JURADO.JUAN.D.1272700300
Date: 2020.12.08 13:43:03 -08'00'

JUAN D. JURADO, PhD
Lieutenant Colonel, USAF
Project Staff Advisor
USAF Test Pilot School

VORGERT.SARAH
.ANN.1405248111
Digitally signed by
VORGERT.SARAH.ANN.1405248111
Date: 2020.12.08 10:17:20 -08'00'

SARAH A. VORGERT
Captain, USAF
Project Engineer


Digitally signed by MAJOR.KARL.B.1145510437
Date: 2020.12.08 12:17:27 -08'00'

KARL B. MAJOR
NH-04, DAF
Project Staff Advisor
USAF Test Pilot School

HICKERNELL.ERI
C.L.1297100986
Digitally signed by
HICKERNELL.ERIC.L.1297100986
Date: 2020.12.08 10:36:11 -08'00'

ERIC L. HICKERNELL
Major, USAF
Project Pilot


Digitally signed by
LEE.CHIawei.NMN.1300514088
Date: 2020.12.08 11:58:09 -08'00'

CHIAWEIN. LEE
NH-03, DAF
Test Management Program Director
USAF Test Pilot School

WEIDMAN.DOUG
LAS.J.1300924014
Digitally signed by
WEIDMAN.DOUGLAS.J.1300924014
Date: 2020.12.08 10:47:34 -08'00'

DOUG J. WEIDMAN
Captain, USAF
Project Pilot

VANHOY.DAVID.L.
1229799688
Digitally signed by
VANHOY.DAVID.L.1229799688
Date: 2021.02.01 15:49:43 -08'00'

DAVD L. VANHOY
NH-04, DAF
Technical Director
USAF Test Pilot School

JOHNSON.WILLIAM.T
RAVIS.III.1284096858
Digitally signed by
JOHNSON.WILLIAM.TRAVIS.III.128
4096858
Date: 2020.12.08 10:18:35 -08'00'

W. TRAVIS JOHNSON
Lieutenant, USN
Project Pilot

PABON.SEBRINA.L.
1015514848
Digitally signed by
PABON.SEBRINA.L.1015514848
Date: 2021.02.01 16:07:12 -08'00'

SEBRINA L. PABON
Colonel, USAF
Commandant
USAF Test Pilot School

WILLIAMS.RACHE
L.W.1388065920
Digitally signed by
WILLIAMS.RACHEL.W.1388065920
Date: 2020.12.08 08:52:35 -08'00'

RACHEL W. WILLIAMS
Captain, USAF
Project Pilot

| REPORT DOCUMENTATION PAGE | | | <i>Form Approved</i> OMB No. 0704-0188 | |
|--|-------------------------|--|---|--|
| <p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Department of Defense, Executive Service Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.</p> | | | | |
| 1. REPORT DATE (DD-MM-YYYY) 07-12-2020 | | 2. REPORT TYPE Final Technical Information | | 3. DATES COVERED (From - Through) 01 SEPT - 24 SEPT 2020 |
| 4. TITLE AND SUBTITLE Position Corrections and Stall Characteristics of EPIC Modified C-12C | | | 5A. CONTRACT NUMBER | |
| | | | 5B. GRANT NUMBER | |
| | | | 5C. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) JOHN STEVENSON, Capt, USAF Project Manager/WSO ERIC HICKERNELL, Maj, USAF Project Pilot W. TRAVIS JOHNSON, LT, USN Project Pilot SARAH VORGERT, Capt, USAF Project Engineer DOUG WEIDMAN, Capt, USAF Project Pilot RACHEL WILLIAMS, Capt USAF Project Pilot | | | 5D. PROJECT NUMBER MT20A300 | |
| | | | 5E. TASK NUMBER | |
| | | | 5F. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Test Center 412 th Test Wing USAF Test Pilot School Edwards AFB CA 93524-6485 | | | 8. PERFORMING ORGANIZATION REPORT NUMBER 412TW-PA-22229 | |
| 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) USAF Test Pilot School 220 Wolfe Ave Edwards AFB, California 93524-6843 | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION / AVAILABILITY STATEMENT See disclaimer on cover. USAFTPS-TIM-20A-03 | | | | |
| 13. SUPPLEMENTARY NOTES SC: 012100 CA: 412th Test Wing Edwards AFB CA Print this document in COLOR . | | | | |
| 14. ABSTRACT This report documents results of the C-12C EPIC-modified aircraft. Testing was requested by the USAF Test Pilot School, Edwards AFB, California. The lead developmental test organization was the Air Force Test Center, Edwards AFB, California. The executing test organization was Class 20A of the USAF Test Pilot School, Edwards AFB. Testing was conducted from 01 to 24 September 2020 and comprised of 4.8 ground test hours and 14 sorties totaling 21.2 flight test hours. The overall test objective was to determine the flight idle stall speeds and the effects of AOA and Mach on static position error of the C-12C EPIC-modified aircraft. All test objectives were met. | | | | |
| 15. SUBJECT TERMS C-12C stall speeds, SPE (Static Position Error), AOA (Angle of Attack), Mach, JMOSS (Jurado-McGehee Online Self-Survey Method), EPIC (Enhanced Performance Increased Capability) | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT Same as Report | 18. NUMBER OF PAGES 72 |
| a. REPORT U | b. ABSTRACT U | c. THIS PAGE U | | |
| | | | 19B. TELEPHONE NUMBER (INCLUDE AREA CODE) 661-277-8892 | |

This page was intentionally left blank.

EXECUTIVE SUMMARY

This report presents the results of the position corrections and stall characteristics of the Enhanced Performance Increased Capability (EPIC) modified C-12C under the project name Have EPIC DISCO. Testing was requested by the United States Air Force (USAF) Test Pilot School (TPS), and the lead developmental test organization was the Air Force Test Center, Edwards AFB, California. The executing test organization was USAF TPS Class 20A, Edwards AFB. Testing was conducted at Edwards AFB from 01 to 24 September 2020 and comprised of 4.8 ground test hours and 14 sorties totaling 21.2 flight test hours.

In 2015, the C-12C fleet was modified with the EPIC Platinum Performance Package, which included the addition of swept blade turbofan propellers and modification of the inboard leading edges. The published stall data for the modified C-12C showed lower stall speeds than unmodified C-12C. Initial flight tests to determine the new stall speeds of modified C-12C used a zero-thrust power setting instead of the flight idle setting specified by the American Society for Testing and Materials Standard F3179, which was used for FAA certification. Since the C-12C had more drag in flight idle compared to the zero thrust power setting, the published stall data in the flight manual was not the most conservative. Higher stall speeds at idle thrust could have affected calculation of safe maneuvering, takeoff, and landing speeds.

Static Position Error (SPE), which is used in air data system calibration, had traditionally been determined using the tower flyby, survey, or pacer methods, which each required additional calibrated assets or infrastructure that may not be available for a program. Tower flyby and pacer were also generally limited to steady-state conditions, which restricted the data collection capabilities at very slow airspeeds, such as near the stall speed of the aircraft. For this reason, tower flyby and pacer methods required extrapolation to determine SPE at stall speeds. To calculate SPE directly, the staff at Test Pilot School had been independently investigating the use of a quasi-steady flight test technique; the Jurado-McGehee Online Self Survey (JMOSS) method. This project applied the JMOSS method across different weights and pressure altitudes to calculate SPE and to model the individual contributions of Mach and angle of attack.

This program had two general test objectives. The first was to determine the stall speeds of an EPIC-modified C-12C and the second was to determine the independent effects of Angle of Attack (AOA) and Mach number on static position error.

A C-12C equipped with Data Acquisition System (DAS) and a nose boom was used for the majority of the test program. Stalls were accomplished at idle power with wings level in flaps up and gear up, flaps 40% and gear down, and flaps 100% and gear down configurations. Aircraft gross weight was between 10,550 and 12,250 pounds and aircraft center of gravity was held between 0 and 20 % of the forward limit. Testing occurred between 8,000 and 20,000 feet pressure altitude. Stall speeds in all configurations were spot checked in a non-DAS, fleet representative C-12C.

Overall, both objectives were met. The wings level stall speeds of EPIC-modified C-12C were as much as seven knots higher than the stall speeds currently published in the aircraft flight manual. Stall testing in the fleet representative C-12C also revealed few statistically significant differences between the stall speeds of DAS and non-DAS aircraft, with all stall speeds higher than EPIC numbers. This meant that the flight test boom did not significantly alter the stall speed and that the collected DAS stall speeds could be considered fleet-representative. Additionally, the JMOSS method successfully determined the static position error of the C-12C and revealed the relationship of static position error to Mach and angle of attack. Although both variables exhibited a statistically significant relationship, AOA was not found to have a strong effect on the SPE variance and was not a good predictor of SPE in the C-12C. The test team recommends that the stall speeds in the C-12C flight manual should be updated to reflect the higher stall speeds discovered during this test program.

This page was intentionally left blank.

TABLE OF CONTENTS

| | <u>Page No.</u> |
|--|-----------------|
| EXECUTIVE SUMMARY | v |
| TABLE OF CONTENTS | vii |
| INTRODUCTION | 1 |
| BACKGROUND..... | 1 |
| TEST ITEM DESCRIPTION..... | 3 |
| TEST OBJECTIVES..... | 6 |
| TEST AND EVALUATION | 9 |
| OVERALL TEST METHODS AND CONDITIONS..... | 9 |
| DETERMINATION OF C-12C FLIGHT IDLE STALL SPEEDS..... | 12 |
| DETERMINATION OF SPE AS A FUNCTION OF AOA AND MACH | 19 |
| TEST RESULTS SUMMARY..... | 22 |
| REFERENCES | 23 |
| APPENDIX A – ADC GROUND CALIBRATION..... | A-1 |
| DAS CONFIGURED GROUND CALIBRATION..... | A-1 |
| NON-DAS CONFIGURED GROUND CALIBRATION..... | A-5 |
| APPENDIX B – DETAILED TEST ITEM DESCRIPTION..... | B-1 |
| PROPELLERS..... | B-2 |
| PRODUCTION PITOT STATIC SYSTEM..... | B-2 |
| STALL WARNING SYSTEM | B-2 |
| PRIMARY FLIGHT DISPLAY | B-2 |
| DATA ACQUISITION SYSTEM | B-3 |
| STALL AND RECOVERY PROCEDURES | B-4 |
| APPENDIX C – DATA ANALYSIS..... | C-1 |
| DATA REQUIREMENTS..... | C-1 |
| AIRSPEED DATA ANALYSIS..... | C-2 |
| STATIC POSITION ERROR DETERMINATION | C-5 |
| STATISTICAL ANALYSIS | C-7 |
| APPENDIX D – SUPPLEMENTAL DATA | D-1 |
| APPENDIX E – TEST CONDITION MATRIX | E-1 |
| APPENDIX F – LESSONS LEARNED | F-1 |
| APPENDIX G – DIGITAL DATA | G-1 |
| APPENDIX H – ABBREVIATIONS, ACRONYMS, AND SYMBOLS | H-1 |
| APPENDIX I – DISTRIBUTION LIST..... | I-1 |

This page was intentionally left blank

INTRODUCTION

This report presents the results of the position corrections and stall characteristics of the Enhanced Performance Increased Capability (EPIC) modified C-12C under the project name Have EPIC DISCO. Testing was requested by the United States Air Force (USAF) Test Pilot School (TPS), and the lead developmental test organization was the Air Force Test Center, Edwards AFB, California. The executing test organization was USAF TPS Class 20A, Edwards AFB. Testing was conducted at Edwards AFB from 01 to 24 September 2020 and comprised of 4.8 ground test hours and 14 sorties totaling 21.2 flight test hours.

BACKGROUND

Air data system position corrections were required to calculate calibrated stall speed. This project employed a quasi-steady method to directly calculate Static Position Error (SPE) at a wide range of airspeeds to include stall speed. This method also gathered data to determine possible predictor factors for SPE. Stall speeds and SPE predictor factors were determined using the same platform and a combined flight test technique (FTT). Testing was conducted by the Have EPIC DISCO Test Team in accordance with the test plan, *Position Corrections and Stall Characteristics of EPIC Modified C-12C* (reference 1).

Determination of Stall Speeds

Aircraft stall speeds were defined in MIL-STD-1797B (reference 2) as the highest of the speed for steady straight flight at C_{Lmax} , the speed at which uncommanded pitching, rolling, or yawing occurs, or the speed at which intolerable buffet or structural vibration are encountered. The Federal Aviation Administration (FAA) defined stall speeds in American Society for Testing and Materials (ASTM) Compliance Standard F3180, paragraph 4.2.2.2 (reference 3). The FAA Advisory Circular 23-8C (reference 4) provided further guidance on both stall conditions and test procedures, defining stall as the first of the following conditions to occur: “uncontrollable downward pitching motion”, “downward pitching motion resulting from the activation of a device (for example, stick pusher)” or, “the control reaches the stop”. Based on ASTM Compliance Standard F3179, paragraph 5.1.1 (reference 5), for turboprop engine aircraft, stall testing should be conducted at “the propulsive thrust not greater than zero at the stalling speed, or, if the resultant thrust has no appreciable effect on the stalling speed, with engine(s) idling and throttle(s) closed”. The Circular clarified this statement saying stall speed should be obtained at either flight idle (defined as “propellers in the takeoff position and the engines idling with throttles closed”) or at zero thrust (defined as “sufficient power to produce zero propeller thrust”) “if idle thrust has no appreciable effect on stall speed,” whichever is more conservative. For the C-12C, zero thrust was at a higher engine setting than flight idle, which made flight idle the more conservative setting. Preliminary test results from the Pirate Snail Pacer test program indicated that the C-12C was predicted to exhibit stall characteristics of a downward pitching motion, with a slight potential for the yoke reaching the full aft position when the flaps were set to 40 percent (reference 6).

The C-12 fleet was modified with the EPIC Platinum Performance Package in 2015. This modification was installed on all four C-12C aircraft operated by USAF TPS, tail numbers 73-1215, 76-0158, 76-0161 and 76-0166. These modifications altered the stall speed of the aircraft and new stall speeds were published in the T.O. 1C-12A-1 Flight Manual (reference 7).

The Defense Security Cooperation Agency (DSCA) noted small stall speed discrepancies from the published speeds on the first C-12s to be modified with the EPIC package. USAF TPS started to collect

informal data on this discrepancy as Edwards Air Force Base received their first modified aircraft in winter of 2015. On 11 July 2016, the C-12 Program Office was notified of an issue relating to significantly higher than expected stall speeds on aircraft at Edwards AFB. The stall speed observed was approximately equal to the charted takeoff rotation speed, which was well below the 10% safety margin accepted by the industry as stated in ASTM Standard F3179 (reference 5). The Program Office acknowledged an issue in the initial buffet ranges published in 1C-12A-6CF-1 (reference 8) for an 11,300 lb aircraft in the Gear and Flaps Down and Gear and Flaps Up configurations. The Program Office updated the functional check flight procedures checklist (1C-12A-6CF-1) to correct the initial buffet ranges. However, the Program Office did not address the stall speed discrepancy but authorized Edwards AFB to use the non-EPIC (T.O. 1C-12A-1) takeoff performance data to compensate conservatively for any possible stall speed discrepancies (reference 9).

On 7 September 2016, flight idle stall speeds were informally recorded on EPIC aircraft 73-1215 during a routine flight at USAF TPS. Recorded stall speeds were observed up to 8.5 knots higher than the stall speed in the flight manual. Additional stall data from similar sorties conducted from 4 to 28 August 2016 on aircraft 73-1215 indicated stall speeds up to 8.5 knots higher than the flight manual.

A representative from the EPIC certification effort indicated that the stall speeds for the EPIC modification Supplemental Type Certificate (and Flight Manual) were determined using the zero thrust approach, while stalls performed at USAF TPS were conducted using the flight idle approach, which possibly accounted for the observed difference. Flight idle power settings created negative thrust, which reduced airflow over the inboard portion of the wings and resulted in a worse stall condition at higher airspeeds than at zero thrust. TPS began investigating the difference between zero thrust and flight idle stall speeds on the C-12C with the Pirate Snail Pacer test program (reference 10). This test program was never completed, but preliminary results confirmed a difference between the two airspeeds. Since the observed flight idle stall speeds appeared consistently higher or more conservative than the stall speeds published in the flight manual, systematic rigorous testing was warranted to determine the actual flight idle stall speeds. This systemic test approach was one objective of this test program.

Determination of Position Correction Predictors

Independent of the C-12C EPIC modification stall speeds, USAF TPS had been investigating the use of a quasi-steady flight test technique to determine the SPE of an aircraft in flight. The SPE had traditionally been determined using the tower flyby, survey, or pacer methods, which each required additional calibrated assets or infrastructure that may not be available for a program. Tower flyby and pacer were also generally limited to steady-state conditions, which restricted the data collection capabilities at very slow airspeeds, such as near the stall speed of the aircraft. For this reason, tower flyby and pacer methods required extrapolation to determine SPE at stall speeds. The quasi-steady FTT, called the Jurado-McGehee Online Self Survey (JMOSS) method (reference 11) could determine SPE accurately and directly without additional assets, and at speeds down to stall.

Previous testing in the Have SPEED test program (reference 12) demonstrated the validity of the JMOSS method to cover a wide range of Mach numbers in a quasi-steady FTT consisting of a level deceleration with a minimum 360-degree constant airspeed turn. This method was able to determine the SPE by comparing the Pitot-static measured airspeed to the true airspeed calculated by the Global Positioning System (GPS) ground speed and winds aloft, which were estimated from the constant airspeed turn. The JMOSS algorithm also estimated a temperature recovery factor (K_t), making the algorithm self-contained. The SPE calculation required the assumption that the Pitot-static measured airspeed error was only due to SPE (total pressure error was negligible) and that the winds were constant throughout the

maneuver. JMOSS estimated ambient pressure using the difference between GPS airspeed and air data system indicated airspeed. It could also include ambient pressure and ambient temperature measured from a weather balloon as an optional input.

After initial validation in the Have SPEED program, the JMOSS method was used to determine the SPE for a C-130 in May 2018 (reference 13). The results close to ground level closely matched the SPE calculated by the Tower Flyby FTT, while the JMOSS tests done at altitude followed a different SPE curve. This indicated that as the relationship between Mach and angle of attack (AOA) changed due to the ratio of aircraft gross weight (W) to the altitude-based pressure (δ) ratio (W/δ), the SPE curves also changed. However, the test did not employ weather balloons to validate the SPE curves. Additionally, the weight state of the airplane was not properly recorded. In order to properly characterize these SPE relationships, the second objective for this test plan was to determine the individual contributions of Mach and AOA on SPE.

In order to determine the individual effects of Mach and AOA on SPE, large changes in W/δ were necessary. These effects were not seen in Have SPEED's testing on a T-38, but were observed in testing involving a C-130. Without access to a C-130-size aircraft or larger to create weight changes, the C-12C was used as a light cargo platform to measure the Mach and AOA effects on SPE.

TEST ITEM DESCRIPTION

The systems under test were two C-12C aircraft with the EPIC Platinum performance modifications. The two aircraft used for testing were tail numbers 76-0158 and 76-0166. Tail number 76-0158 was a Data Acquisition System (DAS) equipped aircraft instrumented with a flight test nose boom, shown in Figure 1. Tail number 76-0166 was a non-DAS aircraft, representative of a standard C-12C fleet aircraft. The EPIC modifications included a ram air recovery system (RARS), dual aft body strakes, high flotation gear doors, swept blade turbopropellers, and enhanced performance inboard leading edges. Each modification was intended to improve the aircraft performance of the C-12C.

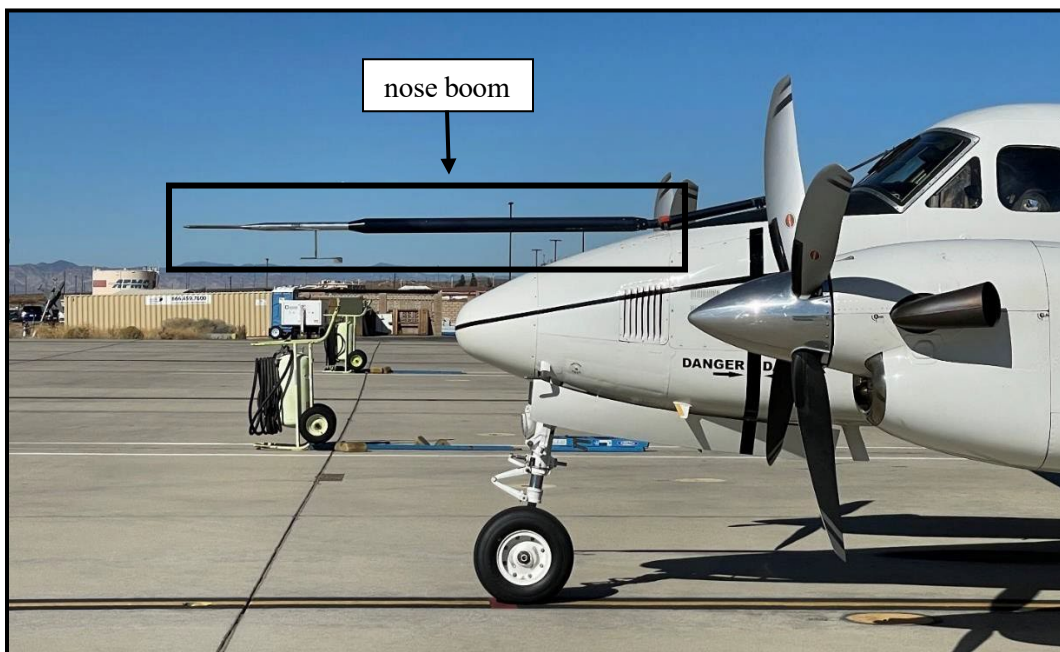


Figure 1. Flight test nose boom

The RARS, shown in Figure 2, was designed to improve climb and cruise performance and to improve engine efficiency by lowering Turbine Gas Temperature (TGT) and thus increasing available horsepower when the engines were temperature limited, but not torque limited. The RARS modification also was intended to reduce the aerodynamic penalty for deploying the ice vanes as ice vane deployment raised TGT.

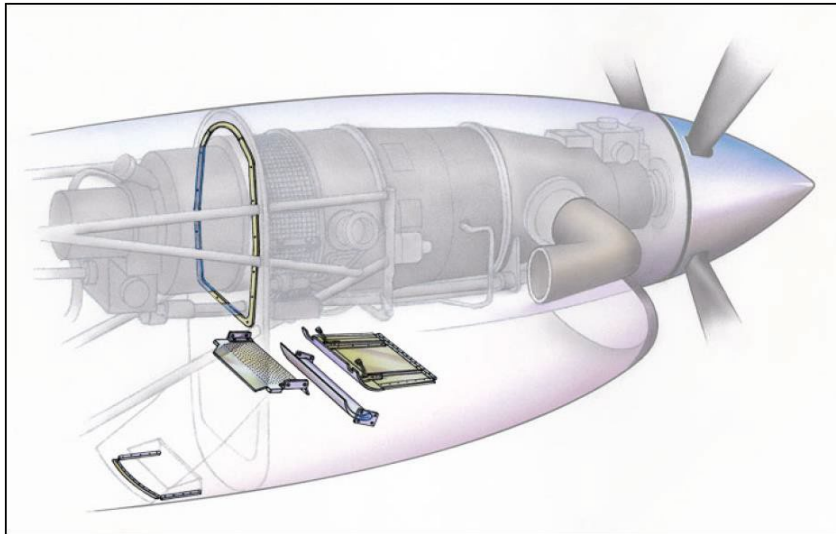


Figure 2. Ram Air Recovery System

The dual aft body strakes, as seen in Figure 3, were designed to increase climb and cruise performance, enhance handling qualities, and eliminate the yaw damper requirement above 17,000 ft.



Figure 3. Dual Aft Body Strakes

Figure 4 shows the high flotation gear doors. These gear doors were designed to minimize drag by fully enclosing the landing gear.



Figure 4. High Flotation Gear Doors

Figure 5 shows the swept-blade turbopropellers, which were designed to increase low-speed acceleration and improve takeoff and landing performance.



Figure 5. Swept Blade Turbopropellers

The inboard wing leading edge modification changed the airfoil shape, and was designed to increase cruise speeds and range. The new leading edges were also designed to reduce airflow separation inboard of the engine, intending to create a more elliptical lift distribution across the entire wing. Figure 6 shows the approximate lift profiles for the basic aircraft on the left and the EPIC modification on the right.

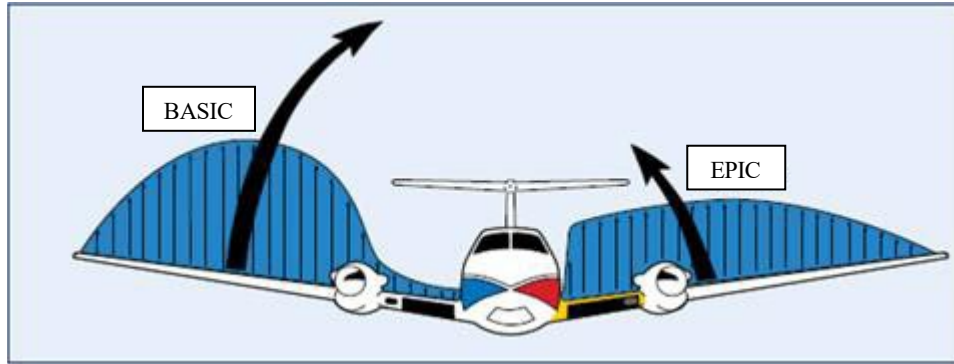


Figure 6. Inboard Wing Leading Edge Lift Distribution

According to the flight manual (reference 7), the Pitot-static system provided a source of impact air and static air for the Air Data Computers (ADC 1 and ADC 2). A Pitot probe was located on each side of the lower portion of the nose. Additionally, the DAS aircraft was equipped with a flight test nose boom, which provided yaw angle (sideslip), angle of attack, and Pitot and static pressure to the DAS. Static pressure from the boom was not considered accurate and was not used. The air data system is a dual Air Data Computer (ADC) system that senses and processes data derived from the air mass around the aircraft. The airspeed tape on the primary flight displays (PFD) indicated airspeed. Tubing connected each probe to the associated computers in the nose avionics bay. Information from the left Pitot probe was provided to ADC 1. There were four normal static ports located on the rear fuselage aft of the rear pressure bulkhead, two on each side. The four normal static ports provided two separate sources of static air, one for the pilot's system and one for the copilot's. Each of the normal static air system lines opened to the atmosphere through two static air ports, one on each side of the fuselage. The pilot's side received static information from the upper left and lower right ports and provided this information to ADC 1. The copilot's side received static information from the upper right and lower left ports and provided this information to ADC 2. There were three drain petcocks located on the right lower sidewall used for draining the static air lines. These drain valves were opened by maintenance to release any trapped moisture during routine scheduled inspections.

A GPS Aided Inertial Navigation Reference (GAINR) Lite rack was installed in the rear cargo compartment of the DAS C-12C to provide accurate time space position information (TSPI) for SPE calculations.

The aircraft was equipped with conventional dual controls for the pilot and copilot. The ailerons and elevators were operated by conventional control wheels interconnected by a T-column. The rudder pedals were interconnected by a linkage below the floor. These systems were connected to the control surfaces through closed cable-bellcrank systems. Rudder, elevator, and aileron trim were adjustable with controls mounted on the center pedestal. Position indicators for each of the trim tabs were integrated with their respective controls (reference 7). Yoke aft was considered a positive control deflection, which raised the trailing edge of the elevator. Trailing edge up was a negative surface deflection and resulted in a nose up pitching moment.

TEST OBJECTIVES

The first general test objective was to determine the stall speeds of C-12C EPIC aircraft at flight idle thrust conditions. The specific test objectives were to determine the flight idle stall speeds in cruise (Flaps Up, Gear Up), approach (Flaps 40%, Gear Down), and landing (Flaps 100%, Gear Down) configurations and to compare a sample of C-12C flight idle stall speeds between non-DAS and DAS EPIC-configured aircraft.

The second general test objective was to determine the static position error as a function of angle of attack and Mach number. The specific test objectives were to determine the statistical significance of angle of attack, Mach number, and the interaction of angle of attack and Mach number on static position error.

The general test objectives were met.

This page was intentionally left blank

TEST AND EVALUATION

Overall, the C-12C EPIC-modified aircraft flight idle stall speeds and static position error were successfully determined, resulting in defensible recommendations for flight manual updates. The wings level stall speeds of EPIC-modified C-12C aircraft were as much as seven knots higher than the stall speeds currently published in the aircraft flight manual. Stall testing in the fleet representative C-12C also revealed few statistically significant differences between the stall speeds of DAS and non-DAS aircraft, with all stall speeds higher than EPIC numbers. This meant that the flight test boom did not significantly alter the stall speed and that the collected DAS stall speeds could be considered fleet-representative. Additionally, the JMOSS method successfully determined the static position error of the C-12C and revealed the relationship of static position error to Mach and angle of attack. Although both variables exhibited a statistically significant relationship, AOA was not found to have a strong effect on the SPE variance and was not a good predictor of SPE in the C-12C. **Update C-12C flight manual stall speed figures to reflect the higher stall speeds determined during this program. (R1)¹**

A C-12C equipped with DAS, a flight test nose boom, and a GAINR Lite rack was used for the majority of the test program objectives. Stalls were accomplished at idle power with wings level in clean, flaps 40% and gear down, and flaps 100% and gear down configurations. The “Angry Silv” FTT was used to calculate SPE and analyze SPE predictors from maximum level speed to stall speed. Aircraft gross weight was between 10,550 and 12,250 pounds and aircraft center of gravity was held between 0 and 20% of the forward limit. Stall testing and “Angry Silv” maneuvers occurred at three target pressure altitudes of 8,500 ft, 14,000 ft, and 19,500 ft in order to maximize the AOA variation for the SPE modeling. Additional SPE testing included tower fly-by passes targeting 200 feet AGL at target airspeeds of 140 KIAS, 180 KIAS and 240 KIAS. Stall speeds in all three configurations were spot checked at approximately 8,500 feet pressure altitude in a non-DAS, fleet representative C-12C.

OVERALL TEST METHODS AND CONDITIONS

Ground Calibration

The test team determined the instrument corrections of the air data systems of the two test aircraft on the ground using a known, calibrated pressure source applied to the pressure ports on the outside of the aircraft. The pressure sources simulated the air pressures at the test altitudes in 10-knot increments around stall speeds. The difference between the “truth” altitude/airspeed and the indicated altitude/airspeed was recorded and used as an instrument correction. This calibration was done on both the production (ADC 1) and DAS air data systems of the DAS aircraft and the pilot side production air data system (ADC 1) for the non-DAS aircraft. The details of the ground calibration process and the resultant instrument corrections for airspeed and altitude on both aircraft are described in detail in Appendix A. The ground calibration data were not employed in the DAS aircraft speed calculations, but were used for the non-DAS aircraft.

The “Angry Silv”

The “Angry Silv” FTT combined several maneuvers in order to explore the relationship between AOA, Mach, and SPE while calculating position corrections for the flight idle stalls. While in a clean configuration, it combined a level deceleration to sweep through Mach numbers, a constant-Mach roller coaster to sweep through a variety of AOAs, a 360-degree minimum level turn to estimate winds aloft, and in most cases ended in a clean stall to determine aircraft stall speed. The level deceleration started near a

¹ Numerals following an R represent recommendation numbers.

maximum level speed of about 220 KIAS with the power at flight idle to decelerate at a constant altitude down to an initial target Mach. At this target Mach, the power was increased to hold that Mach and pressure altitude. A roller coaster was flown at the target Mach to collect AOA data from 0.5 g to 1.8 g, allowing for more AOA variation than that caused solely by weight and speed changes. Following the roller coaster, a constant altitude 360-degree minimum turn was accomplished at the target Mach to determine an average wind vector. Following the turn, the level deceleration was continued at flight idle from the target Mach down to $1.5 V_{\text{stall}}$. After reaching $1.5 V_{\text{stall}}$ and trimming to $1.5 V_{\text{stall}}$, a non-level flight-idle deceleration was continued to stall as described below. Data from the “Angry Silv” maneuvers were used to determine SPE as a function of AOA and Mach number. Figure 7 provides a visual depiction of the “Angry Silv” FTT. The test team accomplished 42 “Angry Silv” maneuvers in the DAS aircraft at the three weight bands, three altitudes, and four target Mach numbers shown in Table 1, all in clean configuration. The details of the statistical analysis done on the “Angry Silv” data to examine the SPE predictor variables are shown in Appendix C.

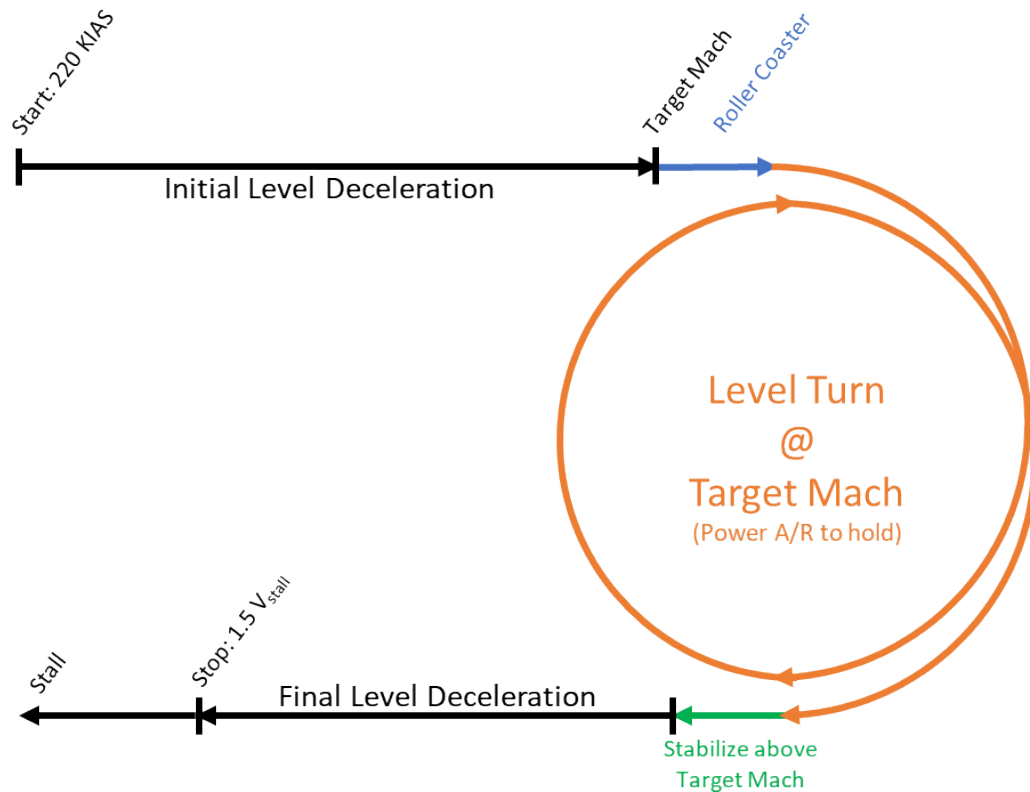


Figure 7. Graphical depiction of the “Angry Silv” FTT

Table 1. DAS Aircraft Test Condition Matrix

| Gross Weight Band (pounds) | Pressure Altitudes (feet) | Target Mach Numbers |
|----------------------------|---------------------------|---------------------|
| 10,500-11,100 | 8500 PA ± 500 ft | 0.25 |
| 11,100-11,800 | 14,000 PA ± 500 ft | 0.30 |
| 11,800-12,500 | 19,500 PA ± 500 ft | 0.35 |
| | | 0.40 |

Flight Idle Stalls

On the DAS aircraft, stall tests were conducted at flight idle power and 2000 propeller revolutions per minute (RPM) with wings level at the weights and altitudes listed in Table 1. The test team accomplished 33 clean stalls, 36 approach configuration stalls, and 34 landing configuration stalls. A clean configuration stall was completed at the end of most “Angry Silv” maneuvers described above. Independent stall test points in various configurations were also flown after the clean stall in the same airspace as the “Angry Silv” FTT. If not completed after an “Angry Silv” FTT, a minimum 360° turn was flown preceding stalls in the same airspace to facilitate SPE calculation.

In the non-DAS aircraft, stalls were performed at approximately 8,500 ft PA as listed in Appendix E, Table E1. Five stalls in clean configuration and six stalls in each of approach and landing configuration were flown. Position corrections derived from the flight manual performance appendix (reference 7) were applied to the non-DAS data to determine calibrated stall speeds. The DAS production Pitot-static system instrument-corrected flight test stall speeds were compared to the non-DAS instrument-corrected flight test stall speeds to confirm the applicability of the DAS aircraft results to a production model, per Appendix C.

The stall and stall recovery procedures followed the steps outlined in the program test plan (reference 1) and are listed in Appendix B. The stall speed was the speed at a definitive pitch break or at the minimum speed after the yoke reached the full aft position for up to two seconds without a pitch break. The aircraft center of gravity (CG) for all stalls was between 0-20 percent of the allowable CG range from the front of the aircraft. The forward CG maximized the control authority required during the stall. This increased the likelihood of a stall defined by aft yoke, which would occur at a higher speed than an aerodynamic stall, in order to collect the most conservative data. All stall data collected was a result of a definitive pitch break during these test flights, indicating that CG was not a factor.

Position Correction Calculations

To calculate calibrated airspeeds, position corrections were determined using a combination of air data methods. The details of this analysis and the air data methods briefly described below are shown in Appendix C.

Tower Flyby

The tower flyby FTT provided low altitude test data and was the traditional method to determine single-point SPEs. It was performed per the test plan by flying down the tower flyby line at approximately 200 feet AGL. Abeam the tower, data were recorded with indicated pressure altitude being the most important. At the same time, a test team member in the flyby tower recorded aircraft height and other handheld data using a theodolite. Nine tower flybys were accomplished on the DAS aircraft targeting 140, 180, and 240

knots and 200 to 250 feet AGL, at gross weights from 10,800 to 12,000 pounds. Handheld data from the tower flybys is shown in Table D5.

JMOSS Self-Contained Algorithm

The JMOSS algorithm used data from the “Angry Silv” maneuvers to determine SPE and the airspeed position corrections at stall in a self-contained mode. It also estimated the temperature recovery factor K_t using total temperature measurements from the aircraft and atmospheric temperature models. JMOSS can accept weather balloon-measured temperature to calculate K_t , but this was less accurate than the self-contained output when compared to the tower flyby data. Self-contained JMOSS was the primary source of SPE for this project. A depiction of the inputs and outputs required by the JMOSS algorithm is shown in Figure C1.

Survey Method

The survey method was applied to data from the tower flyby and “Angry Silv” FTTs as a check of the SPE calculation, using the weather balloon data as a known atmospheric pressure measurement and the static pressure recorded by the DAS. The SPE was calculated directly from these two measurements.

DETERMINATION OF C-12C FLIGHT IDLE STALL SPEEDS

The first general test objective was to determine the stall speeds of C-12C EPIC aircraft at flight idle thrust conditions.

Determine Stall Speeds

The specific test objective was to determine the flight idle stall speeds in cruise (Flaps Up, Gear Up), approach (Flaps 40%, Gear Down), and landing (Flaps 100%, Gear Down) configurations.

Test Results

In flight, the test conductor marked the DAS file at the first indication of stall. During data analysis, the load factor and airspeed were plotted for 1 second before and after this event marker. The data point immediately prior to the g-break was used for the following analysis. These data were shown Tables D1-D3 in Appendix D, with one line for each of the 103 DAS aircraft stalls. Calibrated stall speeds were determined by correcting instrument-corrected stall airspeeds for static position error (SPE) using the SPE generated by the JMOSS self-contained algorithm on the flight test data. All stalls were flown with wings level, and stall speeds for bank angles other than zero were extrapolated. The details of the data analysis are shown in Appendix C.

Indicated stall speeds at gross weights from 10,500 pounds to 12,000 pounds were collected in each configuration. The total and static pressures, instrument-corrected DAS airspeed, instrument-corrected ADC 1 airspeed, and calibrated airspeed for each cruise-configured stall are listed in Appendix D, Table D1. The data for approach-configured stalls are listed in Appendix D, Table D2, and the data for landing-configured stalls are listed in Appendix D, Table D3. The DAS and production (ADC 1) instrument-corrected airspeed (V_{ic}) were determined by the following equation:

$$V_{ic} = \sqrt{\left(\frac{1}{\rho_{SL}} \right) 7P_{SL} \left(\left(\frac{P_t - P_s}{P_{SL}} + 1 \right)^{\frac{2}{7}} - 1 \right)}$$

Where:

- $P_{SL} = 2116.2 \text{ lb/ft}^2$ is the atmospheric pressure at sea level
- P_s is the static pressure measured by the production system
- P_t is the total pressure measured by the production system or boom
- $\rho_{SL} = 0.0023769 \text{ slugs/ft}^3$ is the standard sea level density

The total boom pressure and production static pressure were used to determine the DAS V_{ic} . The production total and static pressures were used to determine the production (ADC 1) V_{ic} . The calibrated airspeed (V_c) was determined for each stall using the equation:

$$V_c = V_{ic} + \Delta V_{pc}$$

Where V_{ic} is the DAS instrument-corrected stall airspeed computed previously, and ΔV_{pc} is the velocity position correction derived from the JMOSS algorithm. The calibrated airspeeds (V_c) were calculated using these methods for each stall. Since the f-factor, used to convert equivalent to calibrated airspeeds, is approximately 1 across the C-12 operating envelope, $V_c = V_e$ (where V_e is the equivalent airspeed). The calibrated stall airspeeds above can be considered equivalent airspeeds.

This relationship allows the lift coefficient, $C_{L_{max}}$ to be determined for each stall by the following equation.

$$C_{L_{max}} = \frac{nW}{\frac{1}{2} \rho V_t^2 S} = \frac{nW}{\frac{1}{2} \rho_{SL} V_{e_{stall}}^2 S}$$

Where:

- n is the load factor
- W is the aircraft weight
- S is the planform area of the aircraft, 303 ft^2 per the flight manual (reference 7)

The load factor, n , was found from the bank angle, ϕ , assuming that the aircraft is flying level.

$$n = \frac{1}{\cos \phi}$$

The $C_{L_{max}}$ was calculated for each stall. All stalls were characterized by a g-break, therefore the $C_{L_{max}}$ for each configuration of stall was averaged to determine a $C_{L_{max}}$. All of the clean stall $C_{L_{max}}$ values were averaged to determine a single, clean configuration value. This was also done to determine an approach configuration $C_{L_{max}}$ value and a landing configuration $C_{L_{max}}$ value. Table 2 shows the $C_{L_{max}}$ values for each configuration.

Table 2. Average $C_{L_{max}}$ for Each Aircraft Configuration

| | Clean Configuration (Flaps 0%, Gear – Up) | Approach Configuration (Flaps 40%, Gear – Down) | Landing Configuration (Flaps 100%, Gear – Down) |
|---|--|--|--|
| Average Maximum Lift Coefficient, $C_{L_{max}}$ | 1.31 | 1.65 | 2.10 |

These three $C_{L_{max}}$ values were used to determine stall speeds ($V_{c_{stall}}$) at the weights and bank angles required for Figures 6-1 and 6-2 in the flight manual by using the following equation:

$$V_{c_{stall}} = \sqrt{\frac{nW}{2 \rho_{SL} C_{L_{max}} S}}$$

Since the flight manual must match C-12 indicated airspeeds, production total pressure and static pressure at stall were taken to compute $V_{ic_{stall}}$ using the formula in Appendix C. $V_{ic_{stall}}$ was plotted against $V_{c_{stall}}$ for each configuration in figures D1, D2, and D3 of Appendix D. A simple linear regression fit was used to model the relationship between these two speeds, with one model fit for each aircraft configuration as shown in each of the figures in Appendix D. The production-representative instrument-corrected stall speeds were then determined using the linear regression model between $V_{ic_{stall}}$ and $V_{c_{stall}}$.

Based on the flight test stall values and the JMOSS position corrections, an updated table for Figure 6-1 in the C-12C flight manual was generated. Figure 8 shows the current table from the 1C-12A-1 Change 4, 15 July 2020. The proposed updated table based on flight test data is shown in Figure 9.

TAKEOFF/CRUISE

POWER: IDLE
 FLAPS: UP LANDING
 GEAR: UP OR DOWN

| GROSS WEIGHT | STALL SPEEDS – KNOTS IAS ANGLE OF BANK | | | | |
|--------------|---|-----|-----|-----|-----|
| | 0° | 15° | 30° | 45° | 60° |
| 10,500 | 81 | 83 | 87 | 97 | 113 |
| 11,000 | 84 | 86 | 90 | 100 | 119 |
| 11,500 | 86 | 88 | 92 | 102 | 121 |
| 12,000 | 89 | 91 | 96 | 106 | 125 |
| 12,500 | 91 | 93 | 98 | 108 | 127 |

APPROACH

POWER: IDLE
 FLAPS: APPROACH LANDING
 GEAR: DOWN

| GROSS WEIGHT | STALL SPEEDS – KNOTS IAS ANGLE OF BANK | | | | |
|--------------|---|-----|-----|-----|-----|
| | 0° | 15° | 30° | 45° | 60° |
| 10,500 | 72 | 74 | 77 | 85 | 101 |
| 11,000 | 74 | 76 | 80 | 88 | 104 |
| 11,500 | 76 | 78 | 82 | 90 | 106 |
| 12,000 | 78 | 80 | 84 | 94 | 110 |
| 12,500 | 81 | 83 | 87 | 97 | 113 |

LANDING

POWER: IDLE
 FLAPS: FULL DOWN
 LANDING GEAR: DOWN

| GROSS WEIGHT | STALL SPEEDS – KNOTS IAS ANGLE OF BANK | | | | |
|--------------|---|-----|-----|-----|-----|
| | 0° | 15° | 30° | 45° | 60° |
| 10,500 | 65 | 66 | 70 | 77 | 92 |
| 11,000 | 67 | 68 | 72 | 79 | 94 |
| 11,500 | 68 | 69 | 74 | 81 | 97 |
| 12,000 | 70 | 71 | 75 | 83 | 99 |
| 12,500 | 71 | 73 | 76 | 84 | 100 |

Figure 8. 1C-12A-1 Figure 6-1

TAKEOFF / CRUISE

POWER: IDLE
 FLAPS: UP LANDING
 GEAR: UP OR DOWN

| GROSS WEIGHT | STALL SPEEDS – KNOTS IAS ANGLE OF BANK | | | | |
|--------------|---|-----|-----|-----|-----|
| | 0° | 15° | 30° | 45° | 60° |
| 10,500 | 92 | 94 | 99 | 110 | 131 |
| 11,000 | 94 | 96 | 101 | 112 | 133 |
| 11,500 | 95 | 97 | 102 | 113 | 135 |
| 12,000 | 97 | 98 | 104 | 115 | 137 |
| 12,500 | 98 | 100 | 106 | 117 | 139 |

APPROACH

POWER: IDLE
 FLAPS: APPROACH LANDING
 GEAR: DOWN

| GROSS WEIGHT | STALL SPEEDS – KNOTS IAS ANGLE OF BANK | | | | |
|--------------|---|-----|-----|-----|-----|
| | 0° | 15° | 30° | 45° | 60° |
| 10,500 | 81 | 82 | 87 | 96 | 114 |
| 11,000 | 82 | 83 | 88 | 98 | 116 |
| 11,500 | 83 | 85 | 89 | 99 | 118 |
| 12,000 | 85 | 86 | 91 | 101 | 120 |
| 12,500 | 86 | 87 | 92 | 102 | 121 |

LANDING

POWER: IDLE
 FLAPS: FULL DOWN
 GEAR: DOWN

| GROSS WEIGHT | STALL SPEEDS – KNOTS IAS ANGLE OF BANK | | | | |
|--------------|---|-----|-----|-----|-----|
| | 0° | 15° | 30° | 45° | 60° |
| 10,500 | 71 | 72 | 76 | 84 | 100 |
| 11,000 | 72 | 73 | 77 | 85 | 101 |
| 11,500 | 73 | 74 | 78 | 86 | 103 |
| 12,000 | 73 | 75 | 79 | 87 | 104 |
| 12,500 | 74 | 75 | 80 | 88 | 105 |

Figure 9. Proposed Figure 6-1 Update

As expected based off of the previously noted stall discrepancies, the instrument-corrected airspeeds at stall were higher than the values published in the flight manual. A proposed updated graph for Figure 6-2 in the C-12C flight manual was also generated. The current graph from the 1C-12A-1 Change 3, 31 July 2017 is shown in Figure 10 below, with the proposed update in Figure 11. An expanded version of Figure 11 is shown in Appendix D.

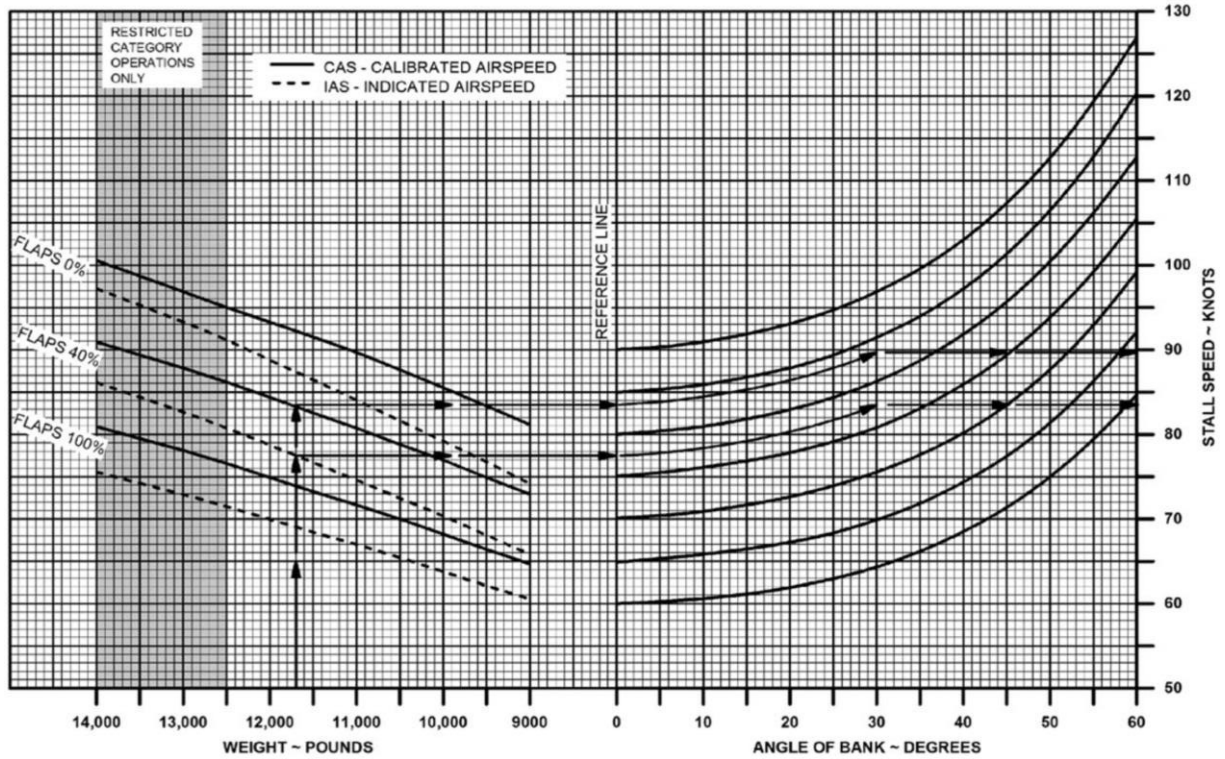


Figure 10. 1C-12A-1 Figure 6-2

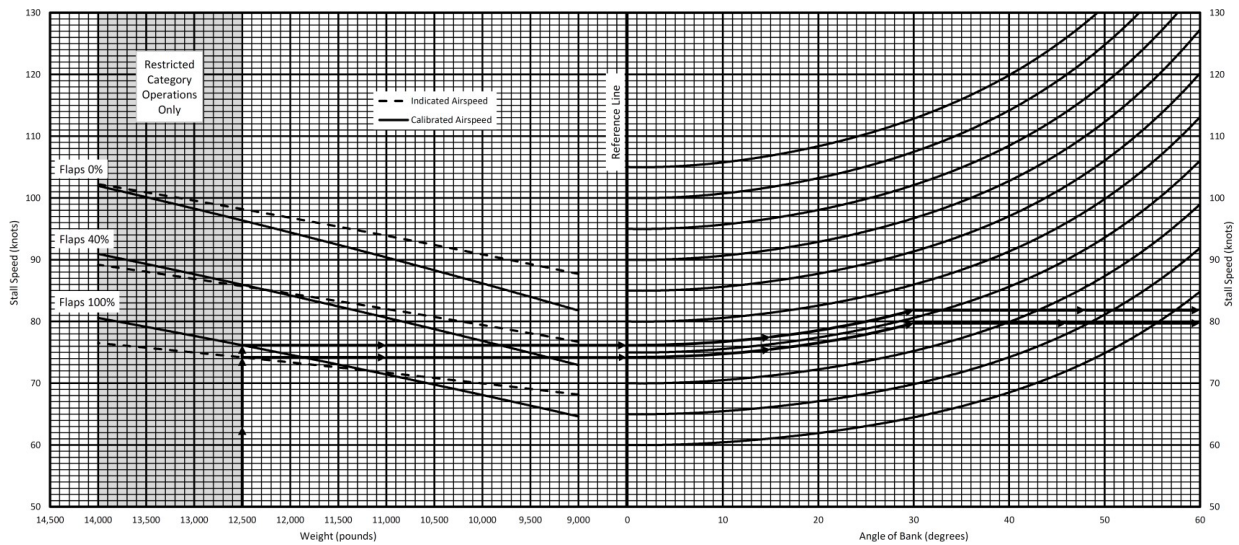


Figure 11. Proposed Figure 6-2 Update

As shown above, the stall speeds determined during this program were found to be significantly higher than the published figures in the current C-12C flight manual. Consequently, the flight manual should be updated to ensure safety of flight. **Update C-12C flight manual stall speed figures to reflect the higher stall speeds determined during this program. (R1)** Additionally, these stall speeds may impact other performance measures such as rotation speed, takeoff safety speed, or approach speed. Per ASTM F3179 (reference 5), the current FAA standard regarding performance speeds, rotation speed shall not be less than $1.1 V_{stall}$. The flight manual (reference 7) gave a rotation speed of 94 KIAS for all non-restricted weight

flaps up takeoffs, which was less than $1.1 V_{\text{stall}}$. Based on the recommended stall speed updates, flaps up rotation speeds should increase from 94 KIAS to a range from 98 KIAS to 108 KIAS based on takeoff weight. **Recommend the SPO investigate the implications of increased flight idle stall speeds on TOLD calculations. (R2)**

Compare Stall Speeds

The specific test objective was to compare a sample of C-12C flight idle stall speeds between non-DAS and DAS EPIC-configured aircraft.

Test Results

The instrument-corrected airspeeds from the production system of the DAS aircraft, calculated above, were compared to the instrument-corrected airspeeds of the non-DAS aircraft. On the non-DAS aircraft, instrument corrected airspeeds were determined by recording the indicated airspeed (V_i) from ADC 1 and applying the instrument correction (ΔV_{ic}) found in Table A5 to determine the instrument-corrected airspeed (V_{ic}) using the following equation.

$$V_{ic} = V_i + \Delta V_{ic}$$

This was performed for each of the indicated airspeeds collected for a total of 17 stalls in the non-DAS aircraft. Stalls were performed between 8,000 and 9,000 feet PA and 10,850 and 11,800 pounds gross weight. Table D4 lists the specific conditions, as well as the indicated and instrument-corrected airspeeds for each stall.

Figure 12 shows the DAS stall speeds, the ADC stall speeds from the DAS aircraft, the ADC stall speeds from the non-DAS aircraft, and the stall speeds from the flight manual for an EPIC-modified aircraft, with instrument-corrected indicated speeds in the top row of plots and calibrated speeds in the bottom row. The instrument-corrected stall speeds derived from the production ADC appear similar between the DAS and non-DAS aircraft with the exception of the approach configuration, where the non-DAS stall speeds are slightly slower. However, all stall speeds were higher than the EPIC stall speeds. As the DAS system stall speeds differed by approximately three knots, the ADC stall speeds were judged to be more representative of the fleet. With the exception of the approach configuration, calibrated stall speeds were almost identical between the two aircraft. This indicated that the stall data were likely fleet representative.

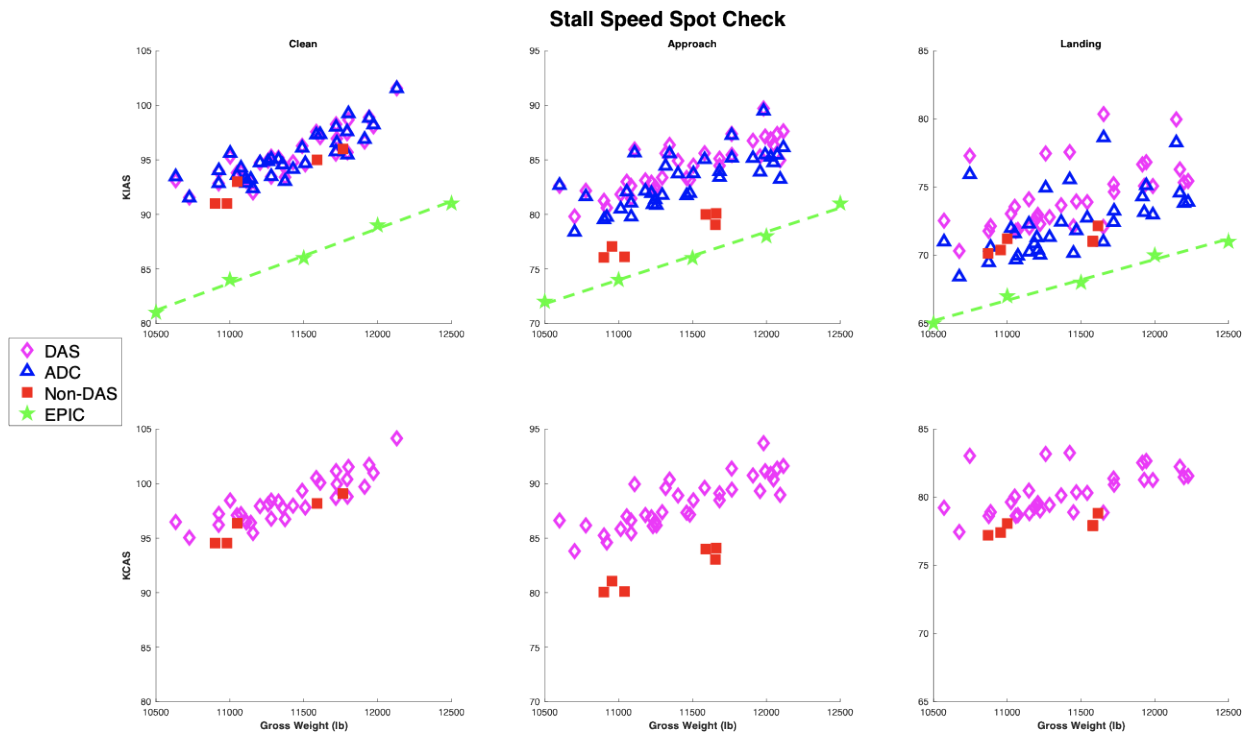


Figure 12. Instrument-Corrected Production, Instrument-Corrected DAS, Calibrated, and Flight Manual Stall Speeds for DAS and Non-DAS Aircraft

Additionally, normally distributed statistical hypothesis tests were performed to confirm that the observed instrument-corrected stall speeds samples from the non-DAS aircraft were not statistically different from those observed in the ADC dataset from the DAS aircraft. The clean and landing configurations showed no statistically significant difference in the means of stall speeds of DAS and non-DAS aircraft, as shown in Figure 13. The approach-configured stall speeds had four of the six stall speeds within the 95% confidence interval. This indicates that at the 95% confidence level, the non-DAS aircraft stall speeds matched the DAS stall speeds, validating the assumption that the DAS system and the flight test nose boom did not significantly alter the stall speeds, and more importantly, that the collected DAS stall speeds can be considered fleet-representative.

DAS vs. Non-DAS Stall Comparison

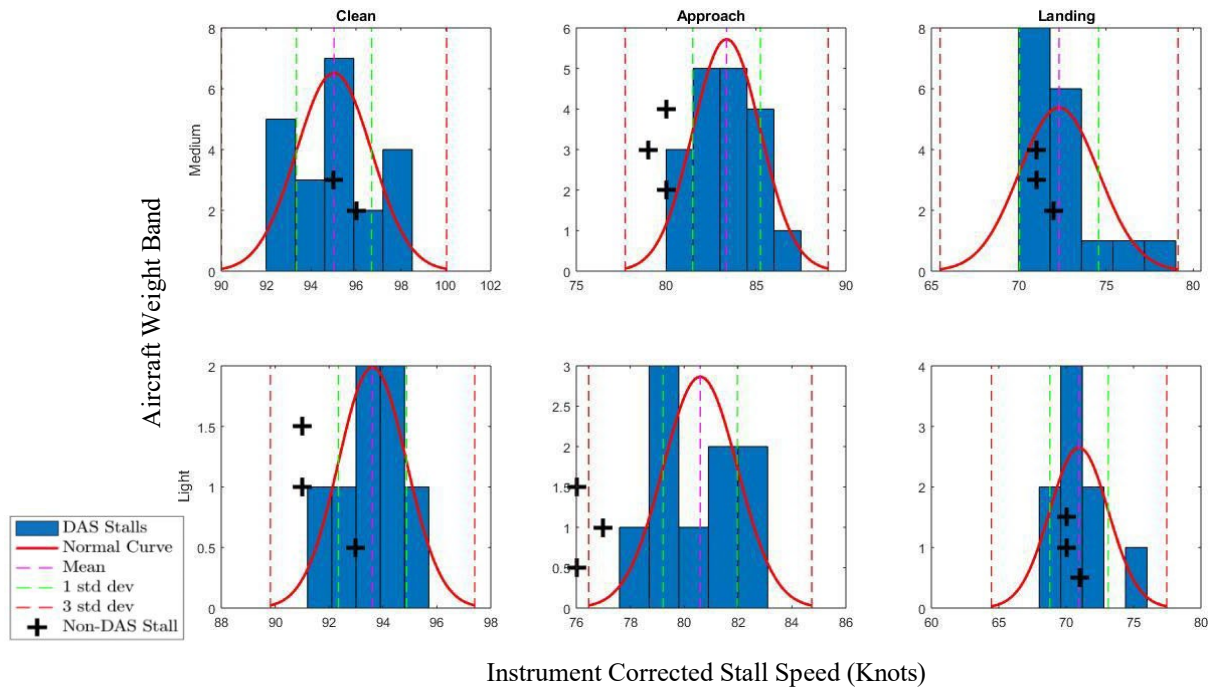


Figure 13. Hypothesis Testing the Non-DAS Data.

DETERMINATION OF SPE AS A FUNCTION OF AOA AND MACH

The second general test objective was to determine the static position error as a function of angle of attack and Mach number.

AOA, Mach, and Interaction Significance

The specific test objectives were to determine the statistical significance of angle of attack, Mach number, and the interaction of angle of attack and Mach number on static position error.

Test Results

In initial modeling of all factors and interactions, the p -values of angle of attack (α), Mach, and α *Mach were determined to be $p < 0.001$. This indicated a statistically significant relationship; there is a near zero probability that the observed AOAs, Mach numbers, and SPEs happened simultaneously by random chance. To further assess the effect on SPE, the decision was made to assess the model by measuring how much model variance was explained by each parameter. The team explored the main effects of combinations of the variables iteratively and reported an analysis of covariance (ANCOVA) as well as a generalized linear model (GLM). Table 3 shows the initial GLM.

Table 3. Initial GLM of $\Delta P_p/P_s$ by AOA, Mach

| Generalized Linear Model Coefficients of $\Delta P_p/P_s$ by Alpha, Mach | | | | | | | |
|--|---------|---------|-----------|----------|----------|----------|----------------|
| Covariate | β | p-value | Std Error | t | CI Lower | CI Upper | Part. η^2 |
| Intercept | -0.016 | <0.001 | 0.000 | -108.285 | -0.016 | -0.015 | 0.033 |
| Mach | 0.102 | <0.001 | 0.001 | 95.832 | 0.100 | 0.104 | 0.026 |
| α | 0.006 | <0.001 | 0.000 | 43.916 | 0.006 | 0.007 | 0.006 |
| $Mach^2$ | -0.207 | <0.001 | 0.002 | -99.458 | -0.211 | -0.203 | 0.028 |
| α^2 | 4.691 | <0.001 | 0.080 | 58.510 | 4.534 | 4.848 | 0.010 |

Type III sum of squares (SS) were used to adjust for all effects, meaning that each variable was assessed as if it were the last after accounting for the effects of the other variables. Overall model effectiveness was measured using the coefficient of determination (r^2). Parameter effect was measured using partial Eta-Squared (η^2), the ratio of variance explained in the dependent variable by a given predictor. In the initial GLM, AOA only had a partial η^2 of 0.006, indicating that as a standalone variable, it did not account for any significant amount of model variance. Consequently, the standalone variable of AOA was omitted from the final GLM shown in Table 4. Intercepts were also omitted from this final model, assuming that at zero Mach number and angle of attack, SPE would also be zero.

Table 4. Final GLM of $\Delta P_p/P_s$ by AOA, Mach

| Generalized Linear Model Coefficients of $\Delta P_p/P_s$ by Alpha, Mach | | | | | | | |
|--|---------|---------|-----------|----------|----------|----------|----------------|
| Covariate | β | p-value | Std Error | t | CI Lower | CI Upper | Part. η^2 |
| Mach | -0.006 | <0.001 | 1.02E-05 | -613.956 | -0.006 | -0.006 | 0.632 |
| $\alpha * Mach$ | 0.049 | <0.001 | 0.000 | 166.992 | 0.049 | 0.05 | 0.113 |
| α^2 (sign retained) | -0.044 | <0.001 | 0.000 | -105.494 | -0.044 | -0.043 | 0.048 |

Table 4 also shows the significance, effect, and variance data of the variables and their interactions on the GLM. The relationship between SPE and Mach was the strongest; the Mach parameter was predicted to explain 63% of the model variance with a partial η^2 of 0.632. The relationships of SPE to interactions of Mach and AOA were observed in $\alpha * Mach$ and α^2 (sign retained). “Sign retained” meant the original sign of the variable is kept in the expression after applying operators. The variable $\alpha * Mach$ accounted for 11% of model variance (partial $\eta^2 = 0.113$). The variable α^2 also had a significance of $p < 0.001$, but only covered 5% of the model variance (partial $\eta^2 = 0.048$). All interactions of angle of attack and Mach were statistically significant factors of SPE, but further parameters neither exhibited strong partial η^2 nor increased the coefficient of determination (r^2) described in the ANCOVA analysis in Table 5. They were therefore omitted from the model.

Table 5. ANCOVA of $\Delta P_p/P_s$ by Alpha, Mach

| Analysis of Covariance (ANCOVA) of $\Delta P_p/P_s$ by Alpha, Mach | | | | |
|--|------------------------|--------------------|--------------|-------------|
| Source of Variance | Adjusted SS (Type III) | Degrees of Freedom | Mean Square | F |
| Model | 0.775 | 3 | 0.258 | 132368.656* |
| Mach | 0.736 | 1 | 0.736 | 376942.067* |
| $\alpha \cdot Mach$ | 0.054 | 1 | 0.054 | 27886.282* |
| α^2 (sign retained) | 0.022 | 1 | 0.022 | 11128.931* |
| Error | 0.428 | 219270 | 1.95E-06 | |
| $r^2 = 0.644$ | | | * $p < 0.05$ | |

For a model with the three variables shown above and 219,270 error degrees of freedom as calculated by the number of discrete DAS/TSPI data points less the number of variables, the F-statistic was 132368.66. The F-statistic could be thought of as an inverse p-value, where a large value implies that the model mean was representative of the data set. The large F statistics seen showed that the SPE within the model also had a very low probability of occurring by chance, and that the p-value of the GLM of SPE was also significant to a $p < 0.001$ level. Additionally, the r^2 of 0.644 indicated a correlation of variables accounting for 64% of model variance. However, this was insufficient to predict SPE from only Mach and AOA in all flight environments, implying that other variables must also have been contributors. Further details of the GLM analysis are provided in Appendix C.

Overall, the test team assessed that Mach was a good predictor of SPE but that AOA alone did not add any fidelity to the model. JMOSS provided an efficient and self-contained platform for this analysis.

Additional Findings

The customer was interested in the difference of performance between the raw data of the self-contained JMOSS mode and the JMOSS mode that incorporates weather balloon temperatures. Additionally, tower flyby SPE was computed using the GLM and traditional tower flyby methods, and the survey method SPE was computed using traditional survey methods. These methods are all described in Appendix C. The mean square error (MSE) of SPE, as defined in Appendix C was used to compare the self-contained JMOSS (with derived temperature recovery factor), the JMOSS with balloon temperatures, and survey data to show the differences of accuracy. Table 6 shows the results of the comparison. The variable $\mu\Delta\Delta V_{pc}$ was the mean difference in ΔV_{pc} computed from the static position error root MSE. As expected, JMOSS SPE using balloon temperature was closer to the survey SPE that relied entirely upon balloon data than self-contained JMOSS.

The mean difference of the tower flyby to the model predicted values appeared to be as an anomaly, leading the test team to conduct further investigation into the cause. The barometer used to measure pressure altitude in the flyby tower was determined to be incorrectly calibrated. Spot checks conducted by the test team showed discrepancies of 50 feet, and the team technical expert cited discrepancies of up to 66 feet (reference 14). In all cases the tower flyby barometer read altitudes higher than the actual pressure altitude. To explore the effects of this error on the tower flyby data, the test team reanalyzed the tower flyby using heights 66 feet lower than what were collected during the tower flybys to include mean differences in ΔV_{pc} for TFB (corrected).

Table 6. MSE Across SPE Collection Types & ΔV_{pc} Error

| Mean Square Error Across SPE Collection Types | | | | |
|--|---------------------------------|--------------------------|-------------|-------------------------|
| Variable | Self-Contained JMOSS vs. Survey | Balloon JMOSS vs. Survey | GLM vs. TFB | GLM vs. TFB (corrected) |
| $\frac{\Delta P_p}{P_s}$ MSE | 2.486E-06 | 1.536E-06 | 1.455E-05 | 3.059E-06 |
| $\mu\Delta\Delta V_{pc}$ (at TFB conditions) | 2.35 kts | 1.38 kts | 5.65 kts | 2.61 kts |

Figure 14 clearly shows that this data correction brought the tower flyby data within the prediction intervals of the GLM, and that it matched with the plurality of JMOSS collected SPEs. The Digital Data Appendix contains a 3D version of this figure.

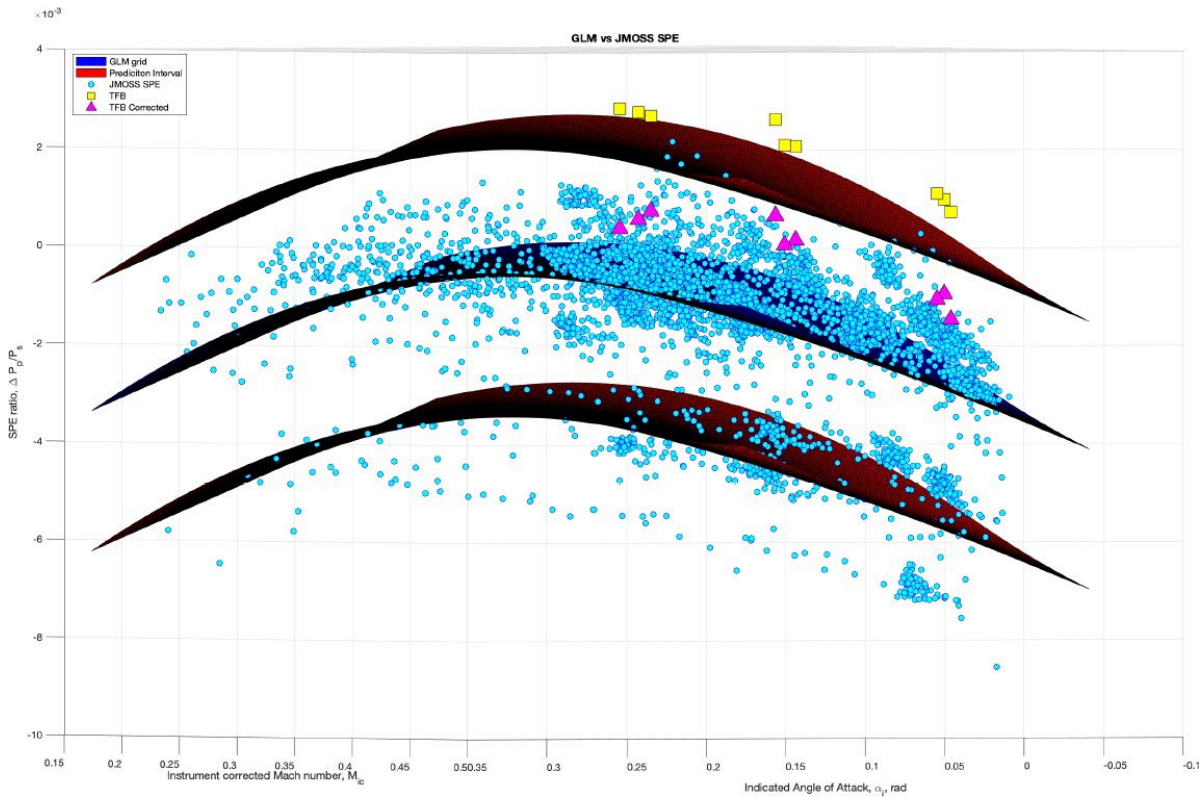


Figure 14. GLM Prediction Intervals and TFB Corrections

The test team conducted a preliminary investigation into other variables as predictors, using altitude, weight, torque, and exhaust gauge temperature, as standalone indicators, and observed $r^2 = 0.75$ with some immature modeling of additional effects. This indicated to the test team that further research into SPE modeling could explain more of the variance in SPE values observed.

TEST RESULTS SUMMARY

The Have EPIC DISCO test results showed that the wings level stall speeds of EPIC-modified C-12C aircraft were as much as seven knots higher than the stall speeds currently published in the aircraft flight manual. Stall testing in the fleet representative C-12C also revealed few statistically significant differences between the stall speeds of DAS and non-DAS aircraft, with all stall speeds higher than EPIC numbers. This means that the flight test boom did not significantly alter the stall speed and that the collected DAS stall speeds can be considered fleet-representative. Additionally, the Jurado-McGehee Online Self Survey method successfully determined the static position error of the C-12C and revealed the relationship of static position error to Mach and angle of attack. Although both variables exhibited a statistically significant relationship, AOA was not found to have a strong effect on the SPE variance and was not a good predictor of SPE in the C-12C. The test team recommends that the stall speeds in the C-12C flight manual should be updated to reflect the higher stall speeds discovered during this test program.

REFERENCES

1. *Position Corrections and Stall Characteristics of EPIC Modified C-12C*, USAFTPS-TP-20A-03, August 2020.
2. *Flying Qualities for Piloted Aircraft*, MIL-STD-1797B.
3. ASTM Compliance Standard F3180/F3180M, *Standard Specification for Low-Speed Flight Characteristics of Aircraft*, 1 June 2018.
4. Advisory Circular: Flight Test Guide for Certification of Part 23 Airplanes, AC 23-8C, U.S. Department of Transportation, Federal Aviation Administration, 16 November 2011.
5. ASTM Compliance Standard F3179/F3179M, *Standard Specification for Performance of Aircraft*, 1 May 2018.
6. Preliminary Test Results, PIRATE SNAIL PACER Test Program, emailed by Mr. Karl Major, 4 August 2020.
7. *Flight Manual USAF Series Aircraft C-12C/C-12D*, T.O. 1C-12A-1 Change 4, 15 July 2020.
8. *Flight Manual USAF Series Aircraft C-12C/C-12D*, T.O. 1C-12A-6CF-1, 31 May 2017.
9. MEMORANDUM FOR Edwards AFB C-12 Operators, 412 OG/CC, June 2017.
10. PIRATE SNAIL PACER Test Package, 201700300, March 2017.
11. Jurado, J. & McGehee, C. (2018). Complete Online Algorithm for Air Data System Calibration. *Journal of Aircraft*. 56. 1-12. 10.2514/1.C034964.
12. HAVE SPEED Test Report, USAF TPS-TIM-17A-02, December 2017.
13. Jurado, J. Air Data Academics, USAF TPS, presented to TMP group 31 May 2020.
14. See a copy of the email in the Digital Data Appendix sent from Mr. Chuck Webb, Technical Expert, to Lt Col Silv Jurado, TPS Education Director, 1 Dec 2020, concerning the calibration of the TPS tower flyby altimeter.
15. *Modification Flight Manual C-12C 76-0158*, Change 1, 1 October 2014.
16. R.E. Erb. *Pitot-statics and the Standard Atmosphere*, 4th Edition, USAF TPS, July 2020.

This page was intentionally left blank.

APPENDIX A – ADC GROUND CALIBRATION

DAS CONFIGURED GROUND CALIBRATION

Ground calibration took place on 1 September 2020 and consisted of connecting the Druck™ Air Data Test System (ADTS) 405 (Figure A1) to Air Data Computer (ADC) 1 (Figure A2) and the Data Acquisition System (DAS). The DAS was connected directly to the ADC 2 static port, but has its own total pressure port. The altimeter was set to 29.92 in. Hg. Various pressures were dialed into the Druck™ ADTS 405 to simulate changes to airspeed and altitude for the ADC. The resulting values displayed by the ADC were recorded by hand to determine the instrument corrected altitude and airspeed. The instrument corrections were calculated by subtracting the indicated airspeed and altitude from the truth airspeed and altitude. These values were recorded at the simulated altitude and airspeed conditions in Tables A1-A4. The DAS altitude was reported in inches of mercury and were converted to pressure altitudes using:

$$H_c = \frac{1 - \delta^{5.2559}}{6.87559 * 10^{-6}}$$

Where:

H_c is the pressure altitude

δ is the pressure ratio of Pressure / Pressure Sea Level



Figure A1. Druck™ ADTS 405



Figure A2. Druck™ ADTS 405 Connected to ADC 1

Table A1. ADC 1 Airspeed Instrument Corrections

| Altitude (ft) | Airspeed (knots) | | | | | | | | | | | | |
|---------------|------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 140 | 160 | 180 | 200 | 220 | 240 |
| 2500 | -3.5 | -3 | -2.5 | -2 | -2 | -1.5 | -1 | -1 | -1.5 | -1.5 | -0.5 | -0.5 | -0.5 |
| 7500 | -5 | -4 | -3.5 | -3 | -3 | -2 | -2 | -2 | -2 | -2 | -1 | -1 | -1 |
| 8000 | -5 | -4.5 | -4 | -3.5 | -3 | -2 | -2 | -2 | -2 | -2 | -1 | -0.5 | -1 |
| 8500 | -5 | -4.5 | -4 | -3.5 | -3 | -2 | -2 | -2 | -2 | -2 | -1 | -1 | -1 |
| 9000 | -5 | -4.5 | -4 | -3.5 | -3 | -2 | -2 | -2 | -2 | -2 | -1 | -1 | -1 |
| 9500 | -5 | -5 | -4 | -4 | -3 | -2.5 | -2 | -2 | -2 | -2 | -1 | -1 | -1 |
| 13000 | -6 | -5.5 | -5 | -4 | -3 | -3 | -2.5 | -2.5 | -2.5 | -2 | -1.5 | -1 | -1 |
| 13500 | -6 | -5 | -5 | -4 | -3.5 | -3 | -2.5 | -2.5 | -2.5 | -2 | -1.5 | -1 | -1 |
| 14000 | -6 | -5.5 | -5 | -4.5 | -4 | -3 | -2.5 | -2.5 | -2.5 | -2 | -1.5 | -1 | -1 |
| 14500 | -6.5 | -6 | -5 | -4.5 | -4 | -3 | -2.5 | -3 | -3 | -2.5 | -1.5 | -1 | -1 |
| 15000 | -6.5 | -6 | -5 | -4.5 | -4 | -3 | -2.5 | -2.5 | -3 | -2.5 | -1.5 | -1 | -1 |
| 18500 | -7.5 | -6.5 | -6 | -5 | -4 | -3.5 | -3 | -3 | -3 | -2.5 | -1.5 | -1.5 | -1.5 |
| 19000 | -7 | -6 | -5.5 | -5 | -4 | -3.5 | -3 | -3 | -3 | -3 | -2 | -1.5 | -1.5 |
| 19500 | -7 | -6 | -6 | -5 | -4.5 | -3.5 | -3 | -3 | -3 | -3 | -2 | -1.5 | -1.5 |
| 20000 | -7 | -6 | -6 | -5 | -4.5 | -3.5 | -3 | -3 | -3 | -3 | -2 | -1.5 | -1.5 |
| 20500 | -7 | -6 | -6 | -5 | -4.5 | -3.5 | -3 | -3 | -3 | -3 | -2 | -1.5 | -1.5 |

Table A2. ADC 1 Altitude Instrument Corrections

| Altitude (ft) | Airspeed (knots) | | | | | | | | | | | | |
|---------------|------------------|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 140 | 160 | 180 | 200 | 220 | 240 |
| 2500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 8000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 8500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 9500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 13000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 |
| 13500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 |
| 14000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 |
| 14500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 |
| 15000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 30 |
| 18500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 40 |
| 19000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 40 |
| 19500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 30 | 50 |
| 20000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 30 | 50 |
| 20500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 30 | 50 |

It is unknown why altitude corrections changed at high speeds on the DAS aircraft, but these values were not used.

Table A3. DAS Airspeed Instrument Corrections

| Altitude (ft) | Airspeed (knots) | | | | | | | | | | | | |
|---------------|------------------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 140 | 160 | 180 | 200 | 220 | 240 |
| 2500 | -1 | -1 | -0.5 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7500 | -1 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8000 | -1 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8500 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9000 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9500 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13000 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13500 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14000 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14500 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15000 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18500 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19000 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19500 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20000 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20500 | -0.5 | -0.5 | -0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table A4. DAS Altitude Instrument Correction

| Altitude (ft) | ΔH_{ic} (ft) |
|---------------|----------------------|
| 2500 | -4 |
| 7500 | -3 |
| 8000 | -5 |
| 8500 | -3 |
| 9000 | 3 |
| 9500 | 2 |
| 13000 | -1 |
| 13500 | -1 |
| 14000 | 5 |
| 14500 | 3 |
| 15000 | 7 |
| 18500 | 7 |
| 19000 | 8 |
| 19500 | 0 |
| 20000 | 1 |
| 20500 | 11 |

Tables A1-A4 were not used in the calculation of instrument-corrected stall speed, as these speeds were directly derived from pressure values. However, this information is presented here for completeness.

NON-DAS CONFIGURED GROUND CALIBRATION

Ground calibration took place on 24 September 2020 and was the same setup and procedure as during the DAS configured ground calibration. Ground calibration took 20 minutes. The instrument corrections were recorded at the simulated altitude and airspeed conditions in Tables A5-A6. Ground calibration requirements were reduced for altitudes between 8,000 – 9,000 ft. pressure altitude because stalls were only accomplished between those altitudes in the non-DAS configured aircraft.

Table A5. Non-DAS ADC 1 Airspeed Instrument Correction

| Altitude (ft) | Airspeed (knots) | | | | | |
|------------------|------------------|-----|-----|----|-----|-----|
| | 60 | 70 | 80 | 90 | 100 | 110 |
| 8000 | 0 | 0 | 0.5 | 0 | 0 | 0.5 |
| 8500 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| 9000 | 0 | 0.5 | 0 | 0 | 0 | 0.5 |

Table A6. Non-DAS ADC 1 Altitude Instrument Correction

| Altitude (ft) | ΔH_{ic} (ft) |
|------------------|-------------------------|
| 8000 | -20 |
| 8500 | -20 |
| 9000 | -20 |

This page was intentionally left blank.

APPENDIX B – DETAILED TEST ITEM DESCRIPTION

The C-12C was a twin engine power turbine aircraft operating between 1600 to 2000 RPM. It was primarily used to transport people or cargo. Figure B1 shows the size and dimensions of the aircraft. The information below could be found in the flight manual (reference 7) and modified flight manual (reference 15).

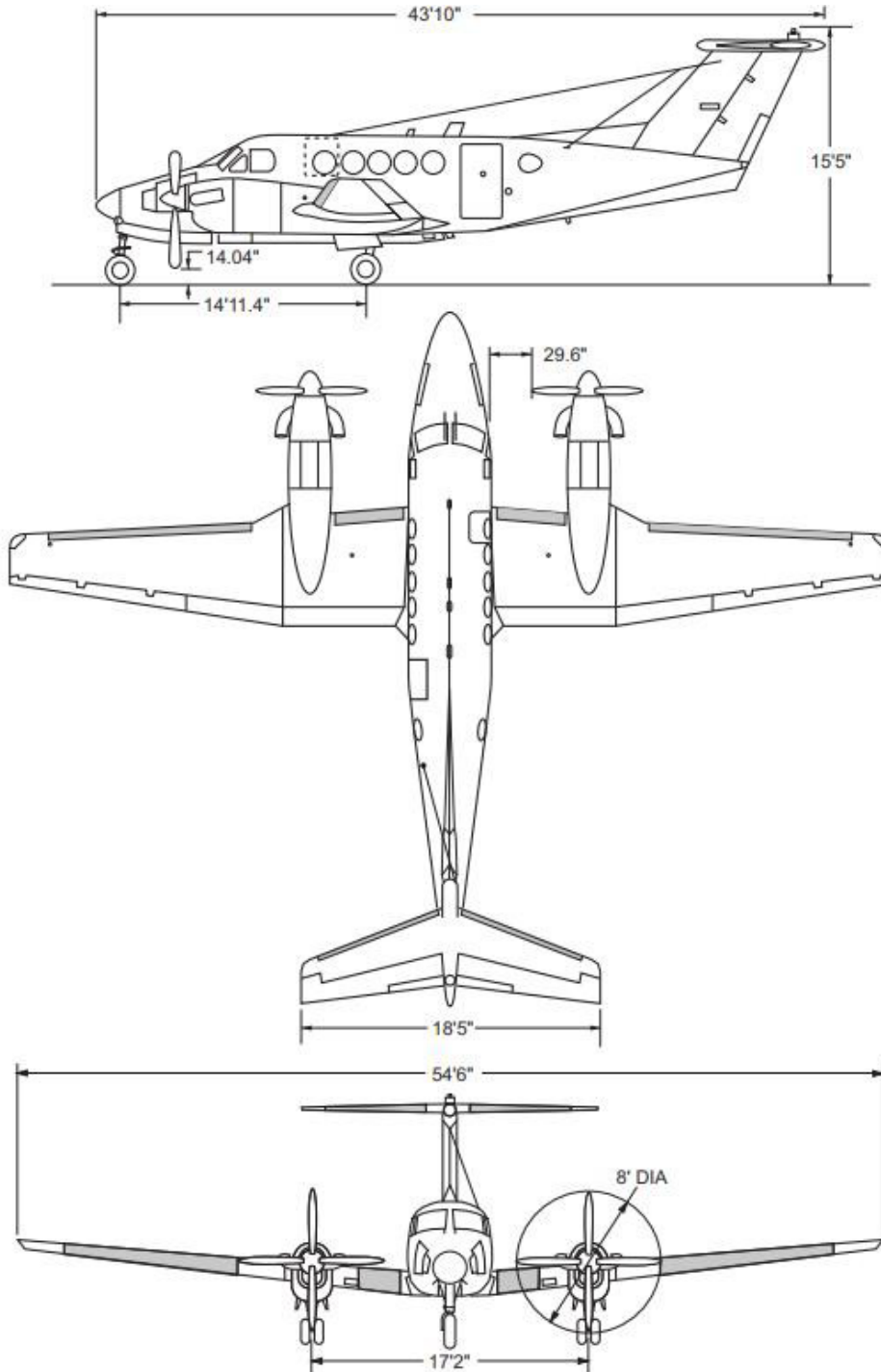


Figure B1. C-12C Three view drawing

PROPELLERS

The C-12C used two Hartzell four-bladed swept blade turbofan propellers. The propellers were manufactured with aluminum hubs and blades mounted to the output shaft of the reduction gearbox and were full-feathering, constant speed, counter weighted, reversing, variable pitch, and were controlled by engine oil through a primary governor.

PRODUCTION PITOT STATIC SYSTEM

The Pitot and static system provided a source of impact air and static air for the Air Data Computers (ADC1 and ADC2). A Pitot mast was located on each side of the lower portion of the nose. Tubing from each mast extended into the nose avionics bay to the associated computers. Information from the left Pitot mast was provided to ADC1 as well as the ESIS and similar information from the right Pitot mast was provided to ADC2 and the Flight Data Recorder (FDR). There were four normal static system ports with two each located on the left and right side of the rear fuselage aft of the rear pressure bulkhead. The four normal static ports provided two separate sources of static air; one for the pilot's system and one for the copilot's. Each of the normal static air system lines opened to the atmosphere through two static air ports; one on each side of the fuselage. The pilot's side received static information from the upper left and lower right ports and provided this information to ADC1, the ESIS, and the Autopilot Computer. The copilot's side received static information from the upper right and lower left ports and provided this information to ADC2, the FDR, and the Autopilot Computer. These ports were not heated. There were three drain petcocks located on the right lower sidewall used for draining the static air lines. These drain valves were opened by maintenance to release any trapped moisture during a routine scheduled inspection.

STALL WARNING SYSTEM

The stall warning system consisted of a transducer, a lift computer, a warning horn, and a test switch. Angle of attack was sensed by aerodynamic pressure on the lift transducer vane located on the left wing leading edge. When a stall was imminent, the output of the transducer sent a signal to the stall warning computer which in turn activated the stall warning horn and sent a digital discreet signal to the autopilot to disconnect. The system had preflight test capability through the use of a switch placarded STALL WARN TEST - OFF - LANDING GEAR WARN TEST on the right subpanel. Holding this switch in the STALL WARN TEST position actuated the warning horn by moving the transducer vane. The lift transducer was equipped with anti-icing capability on both the mounting plate and the vane.

PRIMARY FLIGHT DISPLAY

The Primary Flight Display (PFD), Figure B2, displayed pitch, roll, heading, airspeed, airspeed targets, vertical speed, altitude, altitude pre-select target, vertical speed, radio altitude, decision altitude/radio altitude minimums, flight guidance steering commands, flight guidance modes, auto-pilot/yaw damper modes, lateral/vertical deviation steering cues and warning/caution annunciators.



Figure B2. PFD

DATA ACQUISITION SYSTEM

The DAS consisted of the Instrumentation Master Power System, the DAS rack (Figure B3), Attitude Heading and Reference System (AHRS) tray, Flight Test Engineer (FTE) console with keyboard and mouse, special instrumentation sensors, C-Band Telemetry Transmitter, taps into several production Electronic Flight Instrument System (EFIS) ARINC-429 avionics busses, flight test nose boom and a C-Band beacon transponder. Data recording was performed by a Teletronics Technology Corporation (TTC) solid state recorder (SSR) onto a removable flash drive.



Figure B3. DAS Rack

STALL AND RECOVERY PROCEDURES

The stall procedures used during this test were as follows:

- 1) Verify altimeter set to 29.92 in. Hg.
- 2) Trim aircraft at 1.5 times the predicted stall speed for a clean stall, or 1.3 times the predicted stall speed for a configured stall at the specified test configuration.
- 3) Set engine power to flight idle.
- 4) Slow the aircraft to approximately 10 kts above stall speed.
- 5) Pitch airplane to decelerate at a rate less than 1 knot per second.
- 6) Maintain wings level, zero yaw rate.
- 7) Record indicated airspeed at key events such as stall warning, buffet, pitch down, yoke reaches full aft stop, minimum full aft stop speed, speed two seconds after full aft stop, etc.
- 8) Recover aircraft from stall at first indication of stall: uncontrolled downward pitch or yoke reaches aft stop for 2 seconds. Additionally, recover if bank angle exceeds 15 degrees or a significant yaw rate develops.

For intentional stalls above 5000' AGL, the aircrew followed the modified stall recovery procedure below:

- 1) Attitude – Pitch nose down to reduce the angle of attack below stall value
- 2) Wings – Level
- 3) Sideslip – Center ball
- 4) Power – As required
- 5) Attitude – Return to horizon
- 6) Gear – Up (when rate of descent breaks)
- 7) Airspeed – Return to trim speed
- 8) Flaps – Up

APPENDIX C – DATA ANALYSIS

DATA REQUIREMENTS

Table C1 describes the data that were collected for each FTT.

Table C1. Data Collected.

| Name | Platform | Source | Units | FTTs |
|---|--------------|--------------------|--------|--------------------|
| Instrument Correction | DAS C-12 | Handheld Data | feet | Ground Calibration |
| Instrument Correction | Non-DAS C-12 | Handheld Data | feet | Ground Calibration |
| Indicated Airspeed | DAS C-12 | Handheld Data, DAS | knots | Stall Tower Flyby |
| Indicated Altitude | DAS C-12 | Handheld Data, DAS | feet | Stall Tower Flyby |
| Aircraft Total Weight | DAS C-12 | Handheld Data, DAS | pounds | Stall Angry Silv |
| Fuel Weight | DAS C-12 | Handheld Data, DAS | pounds | Stall Angry Silv |
| Indicated Airspeed | Non-DAS C-12 | Handheld Data | knots | Stall |
| Indicated Altitude | Non-DAS C-12 | Handheld Data | feet | Stall |
| Aircraft Total Weight | Non-DAS C-12 | Handheld Data | pounds | Stall |
| Fuel Weight | Non-DAS C-12 | Handheld Data | pounds | Stall |
| Indicated-Corrected Static Pressure (P_s) | DAS C-12 | DAS | | Stall Angry Silv |
| Indicated-Corrected Total Pressure (P_T) | DAS C-12 | DAS | | Stall Angry Silv |
| Total Air Temperature | DAS C-12 | DAS | | Stall |
| Radar Altimeter Reading | DAS C-12 | DAS | | Stall |
| Engine Torque | DAS C-12 | DAS | | Stall |
| Indicated Angle of Attack (α_i) | DAS C-12 | DAS | | Stall Angry Silv |
| Propeller RPM | DAS C-12 | DAS | | Stall |
| Mach Number | DAS C-12 | DAS | | Stall |
| Elevator Position | DAS C-12 | DAS | | Stall |
| Yoke Position | DAS C-12 | DAS | | Stall |
| Normal Load Factor | DAS C-12 | DAS | | Stall |
| GPS Time | DAS C-12 | GAINR Lite | | Stall |
| Geometric Altitude (h_g) | DAS C-12 | GAINR Lite | | Stall Angry Silv |
| Vertical Velocity Down (v_D) | DAS C-12 | GAINR Lite | | Stall Angry Silv |
| Roll Angle (Φ) | DAS C-12 | DAS | | Angry Silv |
| Pitch Angle (Θ) | DAS C-12 | DAS | | Angry Silv |

| Name | Platform | Source | Units | FTTs |
|---|----------|-----------------|-------|---------------------------|
| Yaw Angle (Ψ) | DAS C-12 | DAS | | Angry Silv |
| North Velocity (v_N) | DAS C-12 | GAINR Lite | | Angry Silv |
| East Velocity (v_E) | DAS C-12 | GAINR Lite | | Angry Silv |
| Indicated Angle of Sideslip (β_i) | DAS C-12 | DAS | | Angry Silv |
| Instrument Corrected Temperature (T_{ic}) | DAS C-12 | DAS | | Angry Silv Tower Flyby |
| Ambient Pressure | N/A | Weather Balloon | | Angry Silv |
| Ambient Temperature | N/A | Weather Balloon | | Angry Silv |
| Time | DAS C-12 | Handheld Data | | Tower Flyby |
| Theodolite Measurement | Tower | Handheld Data | | Tower Flyby |
| Theodolite Pressure Altitude | Tower | Handheld Data | | Tower Flyby |
| Theodolite Ambient Temperature | Tower | Handheld Data | | Tower Flyby |
| Time | Tower | Handheld Data | | Tower Flyby |

AIRSPPEED DATA ANALYSIS

Instrument-Corrected Airspeed at Stall

The test team calibrated the air data system on the ground prior to the start of testing using a TTU-205 calibrated pressure source attached to the total and static pressure ports. The TTU-205 simulated the total and static pressure at a variety of altitudes and airspeeds. A Druck™ Precision Pressure Monitor (PPM) was connected in series between the TTU-205 and the aircraft ports and provide a truth source of the altitude and airspeed. The difference between the truth source's altitude/airspeed and the indicated altitude/airspeed was recorded by hand and used as an instrument correction (ΔV_{ic}). This, combined with the indicated airspeed (V_i) read from the aircraft in flight, was used to determine the instrument-corrected airspeed on the non-DAS aircraft.

$$V_{ic} = V_i + \Delta V_{ic}$$

The DAS aircraft recorded the production total and static pressure, as well as the boom total pressure. Boom static pressure was unreliable and therefore not used. The DAS and production (ADC 1) instrument-corrected airspeed (V_{ic}) were determined by the following equation:

$$V_{ic} = \sqrt{\left(\frac{1}{\rho_{SL}} \right) 7P_{SL} \left(\left(\frac{P_t - P_s}{P_{SL}} + 1 \right)^{\frac{2}{7}} - 1 \right)}$$

Where:

$P_{SL} = 2116.2 \text{ lb/ft}^2$ is the atmospheric pressure at sea level
 P_s is the static pressure measured by the production system
 P_t is the total pressure measured by the production system or boom
 $\rho_{SL} = 0.0023769 \text{ slugs/ft}^3$ is the standard sea level density

The total boom pressure and production static pressure were used to determine the DAS V_{ic} . The production total and static pressures were used to determine the production (ADC 1) V_{ic} .

Calibrated Airspeed at Stall

The airspeed position error, ΔV_{pc} , was computed using the JMOSS algorithm applied to the stall data. This algorithm is provided in the digital appendix (Appendix G). The calibrated airspeed V_c can be obtained from the instrument-corrected airspeed and the position error by using the following equation:

$$V_c = V_{ic} + \Delta V_{pc}$$

The DAS instrument-corrected airspeed and JMOSS ΔV_{pc} were used to generate a calibrated stall speed for each stall maneuver.

The production system ΔV_{pc} was determined by subtracting the production system V_{ic} from the calculated V_c .

Generate Stall Speed Table

In order to generate flight manual Figures 6-1 and 6-2, the equivalent airspeed V_e was also required. The f-factor, used to convert calibrated to equivalent airspeeds, was approximately 1 across the C-12 operating envelope; therefore, $V_c = V_e$.

The true airspeed (V_t) is related to the equivalent airspeed (V_e) by the following equation:

$$V_e = V_t \sqrt{\frac{\rho}{\rho_{SL}}}$$

This relationship allows the lift coefficient at stall, $C_{L_{max}}$ to be determined by the following equation.

$$C_{L_{max}} = \frac{nW}{\frac{1}{2} \rho V_t^2 S} = \frac{nW}{\frac{1}{2} \rho_{SL} V_{e_{stall}}^2 S}$$

Where:

n is the load factor
 W is the aircraft weight
 S is the planform area of the aircraft, 303 ft² per the flight manual (reference 7)

The load factor, n , was found from the bank angle, ϕ , assuming that the aircraft is flying level.

$$n = \frac{1}{\cos \phi}$$

The $C_{L_{max}}$ was calculated for each stall. All stalls were characterized by a g-break, therefore the $C_{L_{max}}$ for each configuration of stall was averaged to determine a $C_{L_{max}}$. All of the clean stall $C_{L_{max}}$ values were averaged to determine a single, clean configuration value. This was also done to determine an approach configuration $C_{L_{max}}$ value and a landing configuration $C_{L_{max}}$ value.

These three $C_{L_{max}}$ values were used to determine stall speeds ($V_{c_{stall}}$) at the weights and bank angles required for Figures 6-1 and 6-2 in the flight manual by using the following model:

$$V_{c_{stall}} = \sqrt{\frac{nW}{2 \rho_{SL} C_{L_{max}} S}}$$

Since the flight manual must match production representative airspeeds, the production system position error correction ΔV_{pc} , calculated in the section above was used. An equation to estimate ΔV_{pc} as a function of weight was calculated for each aircraft configuration. The ΔV_{pc} is plotted against aircraft gross weight for each configuration figures D1, D2, and D3 in Appendix D. The equation to calculate ΔV_{pc} is on each figure. These equations were applied to the calibrated airspeeds found above to determine the production-representative instrument-corrected stall airspeeds.

These methods are in line with *Pitot-Statics and the Standard Atmosphere* (reference 16).

Difference Between DAS and Non-DAS Indicated Airspeed at Stall

Indicated Airspeed (V_i) and indicated altitude (H_i) were read from the non-DAS aircraft's ADC 1. An instrument correction (ΔV_{ic} , ΔH_{ic}) was determined during ground testing. These two parameters were used to determine the instrument-corrected airspeed and altitude for the non-DAS aircraft.

$$V_{ic} = V_i + \Delta V_{ic}$$

$$H_{ic} = H_i + \Delta H_{ic}$$

The DAS aircraft production system instrument-corrected airspeeds were computed to compare production systems between the two aircraft using the following equation:

$$V_{ic} = \sqrt{\left(\frac{1}{\rho_{SL}} \right) 7P_{SL} \left(\left(\frac{P_t - P_s}{P_{SL}} + 1 \right)^{\frac{2}{7}} - 1 \right)}$$

Where:

P_{SL} = 2116.2 lb/ft² is the atmospheric pressure at sea level

P_s is the static pressure measured by the production system

P_t is the total pressure measured by the production system

ρ_{SL} = 0.0023769 slugs/ft³ is the standard sea level density

Non-DAS stall speeds were spot checked against the data set of stall speeds assuming normal distribution of DAS stall speeds. Frequencies of DAS stall speeds were plotted with a normal curve superimposed, and individual non-DAS stall events were scatter-plotted.

STATIC POSITION ERROR DETERMINATION

The static position error was determined using a customer-provided script available in the Digital Data Appendix, which used data from the Tower Flyby, “Angry Silv” maneuver, and weather balloon to determine SPE using the Tower Flyby, Survey, and JMOSS algorithms. This Appendix discusses methods of determining SPE.

Tower Flyby

Tower Flyby FTT

The tower flyby FTT provided low altitude test data at subsonic airspeeds. The aircraft flew down the tower flyby line at approximately 200 feet AGL, maintaining level flight and constant velocity. Abeam the tower, the aircrew recorded indicated altitude, indicated velocity, vertical velocity, fuel, and time. At the same time, a test team member in the flyby tower recorded geometric aircraft height using a theodolite, as well as the ambient pressure and ambient temperature in the tower. By comparing pressure altitude in the aircraft to pressure altitude calculated using geometric aircraft height from the tower, the test team determined a pressure error coefficient.

Tower Flyby Data Analysis

The tower flyby data reduction was performed by comparing the altitude readings of the test aircraft to the aircraft’s altitude as read from a theodolite using the similar triangles method.

$$\Delta H = \textit{Theodolite Measurement} * 31.4$$

This change in geometric altitude was used to solve for the altitude correction ΔH_c .

$$\Delta H_c = \Delta H \frac{T_{std}}{T_{test}}$$

T_{test} was the ambient temperature measured in the fly-by tower and T_{std} was the standard day temperature at the pressure altitude measured in the tower. The truth pressure altitude of the aircraft can be calculated.

$$H_c = H_{c_{tower}} + \Delta H_c$$

The instrument corrected airspeed and altitude of the aircraft were calculated by adding instrument corrections to the indicated values from the aircraft. Using these instrument corrected values, the test team solved for ΔH_{pc} (position corrected altitude) for a given instrument airspeed.

$$\Delta H_{pc} = H_c - H_{ic}$$

Finally, the test team solved for the position error ΔP_p from the static and ambient pressure.

$$P_s = P_{SL}(1 - 6.87559 * 10^{-6}H_{ic})^{5.2559}$$

$$P_a = P_{SL}(1 - 6.87559 * 10^{-6}H_c)^{5.2559}$$

$$\Delta P_p = P_s - P_a$$

And the static position error was found using $\Delta P_p/P_s$.

Survey Method

Survey Method FTT

In this technique, a weather balloon capable of measuring ambient temperature, pressure altitude, and ambient pressure was launched into the local air mass. The balloon measurements of ambient pressure were then directly used to compute SPE. The survey method assumes constant atmospheric properties between the balloon and the area where the experimental aircraft collects its data. This assumption also limits the test window because the truth data needed for calibration is only available and/or valid for a limited time and geographic location.

Survey Method Data Analysis

The instrument corrected altitude H_{ic} was used to determine to static pressure P_s using the following equation.

$$P_s = P_{SL}(1 - 6.87559 * 10^{-6}H_{ic})^{5.2559}$$

The geometric altitude h of the aircraft was determined via TSPI vertical position information. The weather balloon(s) data were used to determine the ambient pressure P_a at that same geometric altitude.

This allowed the test team to derive directly the static position error, comparing the ambient pressure (balloon information) with the static pressure measured by the aircraft.

$$\Delta P_p = P_s - P_a$$

From there, the static position error ratio $\Delta P_p/P_s$ was calculated directly.

JMOSS Method

JMOSS was based on a statistical analysis of continuous flight data, with a model of the unknown SPE created based on classical curve fitting techniques. It was successfully demonstrated on a T-38 in the Have SPEED program (reference 12), and the test team used the version given in the Digital Data Appendix (Appendix G) to determine the SPE on the C-12. As flight data were analyzed, a model of the unknowns (static position error being the unknown of interest) was created based on classical curve fittings. As the model was built, a statistical analysis of the relevancy of each possible curve fitting was executed, keeping the best fit as a local solution.

Figure C1 depicts a flow chart of the process associated with the JMOSS statistical method and data reduction technique. For each set of test data, a set of inputs (shown on the far left of the figure) were taken from the test aircraft. GPS data was collected from the GAINR Lite TSPI system and air data system (ADS) and inertial measurements (IMU) were collected from aircraft via the DAS.

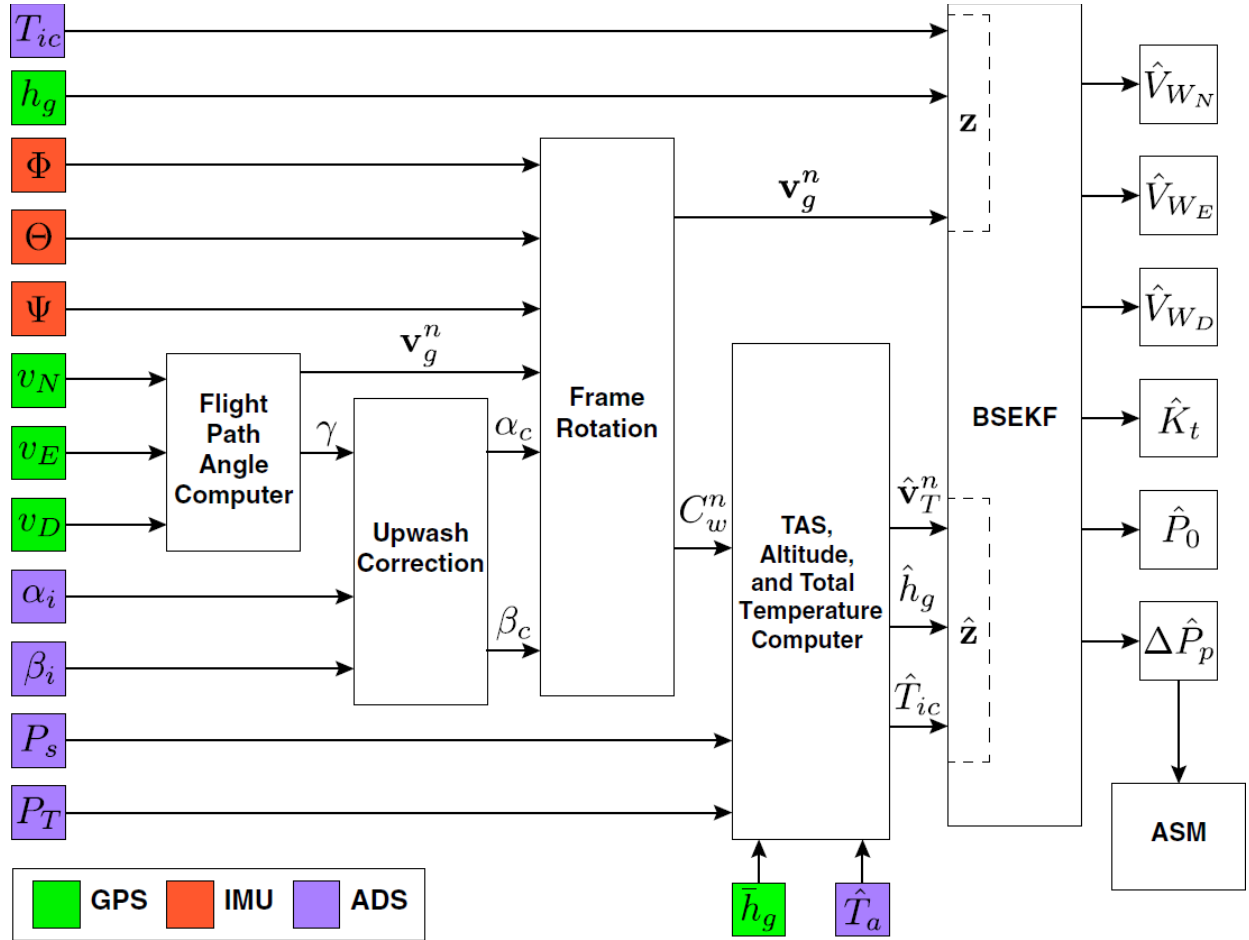


Figure C1. Flow Chart Depicting the JMOSS Data Reduction Algorithm

JMOSS first ran a Backwards-Smoothing Extended Kalman Filter (BSEKF) on the continuous data, represented by the 12 parameters on the left side of Figure C1. It produced continuous estimates of six variables of interest on the right of Figure C1. The BSEKF produces estimates of the North wind component (\hat{V}_{W_N}), East wind component (\hat{V}_{W_E}), downward wind component (\hat{V}_{W_D}), SPE ($\Delta \hat{P}_p$), temperature correction factor (\hat{K}_t), and a pressure bias (\hat{P}_0) for each time step of the input data. The SPE was the parameter of interest for this program and was used to generate a GLM using methods described in the next section.

STATISTICAL ANALYSIS

The customer employed the JMOSS algorithm in data analysis to generate SPE. The JMOSS data was processed using SPSS Statistics to construct the model of SPE by Mach number and angle of attack as follows:

$$SPE = \beta_0 + \beta_1 * Mach + \beta_2 * AoA + \beta_3 * Mach^2 + \beta_4 * AoA^2 + \beta_5 * Mach * AoA;$$

This returned a table of estimated coefficients. The function also returned standard error, t-statistics, and p-values for each coefficient, as well as degrees of freedom, dispersion and F-statistic with p-value for the model. Statistical significance was measured by the reported p-values: lower p-values translating to higher confidence. Effect sizes were assessed using the coefficient of determination ($r^2 = 1 - \frac{SS_{residual}}{SS_{total}}$)

for the full model, and partial Eta-squared (Partial $\eta^2 = \frac{SS_{effect}}{SS_{effect}+SS_{error}}$) for coefficients. Partial η^2 can also be described as the ratio of variance explained in the dependent variable by a predictor. For the initial model, the test team observed a low $r^2 = 0.124$ with partial Eta-square as low as $\eta^2 = 0.007$. The decision was made to explore the main effects of combinations of the variables in different combinations iteratively, to increase the power of the coefficient of determination, and report an analysis of covariance (ANCOVA) as well as the generalized linear model (GLM). Type III sum of squares were used to adjusted for all effects. Consequently, the standalone variable of AOA was omitted from the reported GLM. Ultimately, the model was specified as:

$$SPE = \beta_1 * Mach + \beta_2 * Mach * AoA; + \beta_3 * AoA^2$$

Results of evaluation of the assumptions of normality of sampling distributions, linearity, homogeneity of variance, homogeneity of regression, and reliability of covariates were satisfactory. A sample size of N=226,405 DAS datapoints from “Angry Silv” maneuvers was used, with 3.2% excluded. Each of the included covariates exhibited statistically significant main effects, in all iterations of the model. The final model was judged to be strongest due to the $r^2 = 0.644$. The strength of the relationship between SPE and Mach number was particularly strong at $\eta^2 = 0.632$. The other effects were much weaker. The full SPSS analysis of covariates and residuals is included in the digital appendix.

Mean squared error was reported for the comparisons JMOSS, balloons, and tower flyby SPE reporting methods. MSE is computed as follows:

$$MSE = \frac{1}{n} \sum_{i=1}^n (Y_i - \hat{Y}_i)^2$$

APPENDIX D – SUPPLEMENTAL DATA

Tables D1, D2, and D3 present the stall data for all stalls performed in the clean, powered-approach, and landing configurations, respectively, in the DAS aircraft. Figures D1, D2, and D3 plotted the production ΔV_{pc} against aircraft gross weight for each configuration. The equation to calculate ΔV_{pc} is on each figure. Table D4 shows the stall data for the Non-DAS aircraft. Figure D4 shows an enlarged version of the recommended flight manual stall update chart. The details on how these data were calculated was described in Appendix C.

Table D1. Cruise Configuration Stall Data

| Pressure Altitude (ft) | Aircraft Gross Weight (pounds) | Angle of Bank (degs) | Static Pressure, P_s (psi) | Total Boom Pressure, P_t (psi) | Total Production Pressure, P_t (psi) | DAS Instrument Corrected Airspeed, V_{ic} (knots) | JMOSS DAS Position Correction, ΔV_{pc} (knots) | Calibrated Airspeed, V_c (knots) | Lift Coefficient, C_{Lmax} (no units) | Production Instrument Corrected Airspeed, V_{ic} (knots) | Production Position Correction, ΔV_{pc} (knots) |
|------------------------|--------------------------------|----------------------|------------------------------|----------------------------------|--|---|--|------------------------------------|---|--|---|
| 8684 | 10633 | 1.1 | 10.63 | 10.84 | 10.84 | 93.13 | -4.07 | 89.06 | 1.31 | 93.46 | -4.40 |
| 8759 | 10726 | -2.8 | 10.61 | 10.80 | 10.80 | 91.55 | -0.95 | 90.60 | 1.28 | 91.52 | -0.91 |
| 8488 | 10924 | -3.9 | 10.71 | 10.92 | 10.92 | 92.84 | -1.43 | 91.41 | 1.28 | 92.84 | -1.43 |
| 19655 | 10925 | -7.0 | 6.85 | 7.06 | 7.06 | 93.94 | -4.41 | 89.54 | 1.34 | 94.02 | -4.48 |
| 8843 | 11002 | 0.7 | 10.56 | 10.78 | 10.78 | 95.30 | -4.90 | 90.40 | 1.31 | 95.61 | -5.21 |
| 19635 | 11048 | 14.6 | 6.87 | 7.07 | 7.07 | 93.81 | -4.01 | 89.81 | 1.38 | 93.58 | -3.77 |
| 8629 | 11075 | 9.8 | 10.66 | 10.87 | 10.87 | 93.92 | -2.92 | 91.00 | 1.32 | 94.26 | -3.26 |
| 8594 | 11107 | -7.8 | 10.67 | 10.88 | 10.88 | 93.22 | -0.54 | 92.67 | 1.27 | 93.28 | -0.61 |
| 19401 | 11112 | 0.3 | 6.93 | 7.14 | 7.14 | 93.08 | 0.23 | 93.31 | 1.24 | 92.86 | 0.45 |
| 13724 | 11142 | 7.7 | 8.73 | 8.94 | 8.94 | 93.05 | -3.23 | 89.82 | 1.36 | 93.23 | -3.40 |
| 19664 | 11157 | 9.1 | 6.85 | 7.05 | 7.05 | 92.02 | -5.07 | 86.95 | 1.46 | 92.37 | -5.41 |
| 8660 | 11204 | 1.0 | 10.64 | 10.86 | 10.86 | 94.73 | -3.09 | 91.64 | 1.30 | 94.74 | -3.11 |
| 19613 | 11259 | -0.2 | 6.87 | 7.08 | 7.08 | 94.92 | -1.21 | 93.70 | 1.25 | 94.85 | -1.15 |
| 8634 | 11280 | -6.9 | 10.66 | 10.87 | 10.87 | 93.46 | -2.15 | 91.31 | 1.33 | 93.48 | -2.17 |
| 19594 | 11280 | -3.8 | 6.87 | 7.09 | 7.08 | 95.29 | -4.79 | 90.49 | 1.35 | 95.08 | -4.59 |
| 13831 | 11329 | 6.1 | 8.70 | 8.91 | 8.91 | 95.19 | -2.93 | 92.26 | 1.30 | 95.04 | -2.78 |
| 13735 | 11356 | 2.7 | 8.73 | 8.94 | 8.94 | 94.58 | -2.87 | 91.71 | 1.32 | 94.55 | -2.84 |
| 8548 | 11373 | -4.0 | 10.69 | 10.90 | 10.90 | 93.41 | -1.70 | 91.71 | 1.32 | 93.03 | -1.32 |
| 19520 | 11427 | 4.6 | 6.89 | 7.10 | 7.10 | 94.78 | -3.33 | 91.45 | 1.34 | 94.14 | -2.69 |
| 19514 | 11489 | -8.1 | 6.89 | 7.11 | 7.11 | 96.28 | -4.21 | 92.06 | 1.33 | 96.09 | -4.03 |
| 8376 | 11510 | -5.6 | 10.76 | 10.97 | 10.97 | 94.59 | -0.11 | 94.48 | 1.26 | 94.67 | -0.18 |
| 13964 | 11585 | 0.1 | 8.65 | 8.87 | 8.87 | 97.57 | -3.72 | 93.84 | 1.28 | 97.30 | -3.46 |
| 19452 | 11611 | 4.9 | 6.91 | 7.13 | 7.13 | 97.09 | -3.67 | 93.42 | 1.30 | 97.33 | -3.91 |
| 8562 | 11717 | -8.0 | 10.69 | 10.90 | 10.91 | 95.57 | -0.90 | 94.67 | 1.29 | 95.75 | -1.08 |
| 13933 | 11719 | -9.3 | 8.66 | 8.88 | 8.88 | 98.26 | -2.89 | 95.37 | 1.27 | 98.01 | -2.64 |
| 8370 | 11724 | 8.5 | 10.77 | 10.99 | 10.99 | 96.95 | -2.66 | 94.29 | 1.30 | 96.57 | -2.28 |
| 19550 | 11793 | 7.6 | 6.88 | 7.11 | 7.11 | 97.44 | -3.21 | 94.23 | 1.31 | 97.59 | -3.36 |
| 13994 | 11796 | 10.0 | 8.64 | 8.86 | 8.86 | 95.69 | -5.66 | 90.03 | 1.44 | 95.46 | -5.43 |
| 8531 | 11803 | 12.8 | 10.69 | 10.93 | 10.93 | 98.68 | -2.86 | 95.82 | 1.28 | 99.24 | -3.42 |
| 8384 | 11912 | 3.9 | 10.76 | 10.98 | 10.98 | 96.68 | -2.35 | 94.34 | 1.31 | 96.89 | -2.55 |
| 8304 | 11943 | -5.0 | 10.79 | 11.02 | 11.02 | 98.89 | -2.97 | 95.92 | 1.27 | 98.82 | -2.90 |
| 8465 | 11972 | -3.7 | 10.73 | 10.96 | 10.96 | 98.07 | -1.84 | 96.23 | 1.26 | 98.22 | -1.99 |
| 19630 | 12012 | 0.9 | 6.86 | 7.09 | 3.48 | 98.57 | -6.93 | 91.63 | 1.39 | 98.21 | -6.58 |
| 13923 | 12065 | -4.2 | 8.67 | 8.89 | 4.37 | 96.57 | -2.48 | 94.09 | 1.33 | 96.47 | -2.38 |
| 8263 | 12129 | -0.6 | 10.81 | 11.06 | 11.06 | 101.56 | -2.68 | 98.89 | 1.21 | 101.54 | -2.66 |
| 8684 | 10633 | 1.1 | 10.63 | 10.84 | 10.84 | 93.13 | -4.07 | 89.06 | 1.31 | 93.46 | -4.40 |

Table D2. Powered Approach Configuration Stall Data

| Pressure Altitude (ft) | Aircraft Gross Weight (pounds) | Angle of Bank (degs) | Static Pressure, P_s (psi) | Total Boom Pressure, P_t (psi) | Total Production Pressure, P_t (psi) | DAS Instrument Corrected Airspeed, V_{ic} (knots) | JMOSS DAS Position Correction, ΔV_{pc} (knots) | Calibrated Airspeed, V_c (knots) | Lift Coefficient, C_{Lmax} (no units) | Production Instrument Corrected Airspeed, V_{ic} (knots) | Production Position Correction, ΔV_{pc} (knots) |
|------------------------|--------------------------------|----------------------|------------------------------|----------------------------------|--|---|--|------------------------------------|---|--|---|
| 8354 | 10600 | 1.3 | 10.78 | 10.94 | 10.94 | 82.62 | -2.79 | 79.83 | 1.62 | 82.67 | -2.84 |
| 8867 | 10702 | -0.9 | 10.56 | 10.72 | 10.71 | 79.81 | -0.48 | 79.34 | 1.66 | 78.38 | 0.96 |
| 13988 | 10778 | -5.0 | 8.64 | 8.80 | 8.80 | 82.17 | -1.20 | 80.97 | 1.61 | 81.64 | -0.67 |
| 8673 | 10901 | -0.4 | 10.64 | 10.80 | 10.79 | 81.25 | 0.00 | 81.25 | 1.61 | 79.53 | 1.73 |
| 13908 | 10920 | -1.0 | 8.67 | 8.82 | 8.82 | 80.60 | -0.14 | 80.46 | 1.64 | 79.75 | 0.71 |
| 19420 | 11014 | 1.0 | 6.93 | 7.08 | 7.08 | 81.84 | -2.14 | 79.70 | 1.69 | 80.50 | -0.80 |
| 14179 | 11055 | -3.2 | 8.58 | 8.74 | 8.74 | 83.00 | -1.09 | 81.90 | 1.61 | 82.07 | -0.16 |
| 19232 | 11084 | -0.1 | 6.98 | 7.14 | 7.13 | 82.62 | 0.94 | 83.56 | 1.55 | 81.05 | 2.51 |
| 8541 | 11085 | 0.0 | 10.70 | 10.85 | 10.85 | 81.46 | 1.46 | 82.92 | 1.57 | 79.78 | 3.14 |
| 13782 | 11108 | -5.8 | 8.71 | 8.88 | 8.88 | 85.95 | -4.01 | 81.93 | 1.62 | 85.65 | -3.71 |
| 8417 | 11181 | -5.7 | 10.75 | 10.91 | 10.91 | 83.12 | -1.26 | 81.86 | 1.63 | 82.14 | -0.28 |
| 13498 | 11222 | -0.5 | 8.81 | 8.98 | 8.97 | 82.91 | -1.93 | 80.97 | 1.67 | 81.93 | -0.95 |
| 19319 | 11232 | -0.4 | 6.95 | 7.11 | 7.11 | 82.11 | -0.44 | 81.66 | 1.64 | 80.91 | 0.75 |
| 19849 | 11248 | -2.3 | 6.80 | 6.96 | 6.96 | 82.51 | -3.89 | 78.62 | 1.78 | 81.36 | -2.74 |
| 8535 | 11256 | -1.0 | 10.70 | 10.86 | 10.85 | 82.17 | -1.80 | 80.37 | 1.70 | 80.84 | -0.47 |
| 13676 | 11295 | -1.4 | 8.75 | 8.91 | 8.91 | 83.38 | -1.98 | 81.40 | 1.66 | 81.76 | -0.36 |
| 14006 | 11318 | -3.1 | 8.63 | 8.81 | 8.80 | 85.60 | -2.97 | 82.63 | 1.62 | 84.43 | -1.80 |
| 8251 | 11345 | -3.8 | 10.81 | 10.99 | 10.98 | 86.37 | -3.84 | 82.53 | 1.63 | 85.57 | -3.04 |
| 19421 | 11402 | -3.0 | 6.92 | 7.09 | 7.08 | 84.91 | -2.03 | 82.88 | 1.62 | 83.73 | -0.85 |
| 19430 | 11460 | 0.3 | 6.92 | 7.09 | 7.08 | 83.34 | -3.00 | 80.34 | 1.73 | 81.73 | -1.38 |
| 8467 | 11482 | 1.8 | 10.73 | 10.89 | 10.88 | 83.16 | 0.58 | 83.74 | 1.60 | 81.94 | 1.79 |
| 14164 | 11506 | -3.9 | 8.59 | 8.76 | 8.76 | 84.47 | -1.84 | 82.63 | 1.65 | 83.74 | -1.11 |
| 19232 | 11582 | -2.1 | 6.98 | 7.15 | 7.15 | 85.61 | -3.26 | 82.35 | 1.67 | 85.04 | -2.69 |
| 8438 | 11683 | -7.6 | 10.74 | 10.91 | 10.90 | 84.47 | -1.78 | 82.69 | 1.68 | 83.94 | -1.25 |
| 8801 | 11683 | 1.2 | 10.59 | 10.76 | 10.75 | 85.11 | -0.01 | 85.10 | 1.57 | 83.41 | 1.69 |
| 19334 | 11765 | 0.3 | 6.95 | 7.13 | 7.13 | 87.38 | -3.81 | 83.56 | 1.64 | 87.25 | -3.68 |
| 13670 | 11766 | -4.5 | 8.75 | 8.93 | 8.93 | 85.45 | -6.04 | 79.42 | 1.82 | 85.17 | -5.76 |
| 19748 | 11909 | -1.1 | 6.83 | 7.00 | 7.00 | 86.75 | -2.89 | 83.85 | 1.65 | 85.15 | -1.30 |
| 13497 | 11957 | 0.6 | 8.81 | 8.98 | 8.98 | 85.32 | -5.26 | 80.06 | 1.82 | 83.89 | -3.83 |
| 19186 | 11981 | 0.4 | 7.00 | 7.19 | 7.18 | 89.71 | -5.97 | 83.74 | 1.67 | 89.48 | -5.74 |
| 19656 | 11992 | -2.2 | 6.85 | 7.03 | 7.03 | 87.14 | -2.98 | 84.16 | 1.65 | 85.47 | -1.30 |
| 13713 | 12029 | -1.6 | 8.74 | 8.91 | 8.91 | 86.89 | -2.12 | 84.77 | 1.63 | 85.25 | -0.47 |
| 8885 | 12048 | -0.9 | 10.56 | 10.73 | 10.73 | 86.39 | -0.85 | 85.54 | 1.61 | 84.75 | 0.80 |
| 8601 | 12073 | 0.5 | 10.67 | 10.85 | 10.84 | 87.37 | -1.81 | 85.56 | 1.61 | 85.44 | 0.12 |
| 8867 | 12093 | -0.7 | 10.57 | 10.74 | 10.73 | 84.97 | -0.53 | 84.44 | 1.65 | 83.23 | 1.20 |
| 8475 | 12115 | -1.6 | 10.72 | 10.90 | 10.90 | 87.62 | -1.95 | 85.66 | 1.61 | 86.13 | -0.47 |

Table D3. Landing Configuration Stall Data

| Pressure Altitude (ft) | Aircraft Gross Weight (pounds) | Angle of Bank (degs) | Static Pressure, P_s (psi) | Total Boom Pressure, P_t (psi) | Total Production Pressure, P_t (psi) | DAS Instrument Corrected Airspeed, V_{ic} (knots) | JMOSS DAS Position Correction, ΔV_{pc} (knots) | Calibrated Airspeed, V_c (knots) | Lift Coefficient, C_{Lmax} (no units) | Production Instrument Corrected Airspeed, V_{ic} (knots) | Production Position Correction, ΔV_{pc} (knots) |
|------------------------|--------------------------------|----------------------|------------------------------|----------------------------------|--|---|--|------------------------------------|---|--|---|
| 8812 | 10572 | 1.6 | 10.58 | 10.71 | 10.70 | 72.54 | -2.99 | 69.54 | 2.13 | 70.99 | -1.45 |
| 8674 | 10675 | 1.8 | 10.64 | 10.76 | 10.75 | 70.32 | 0.31 | 70.63 | 2.09 | 68.42 | 2.21 |
| 13983 | 10746 | 2.4 | 8.63 | 8.77 | 8.76 | 77.30 | -4.05 | 73.25 | 1.95 | 75.93 | -2.68 |
| 8797 | 10875 | 1.2 | 10.59 | 10.71 | 10.70 | 71.78 | 2.37 | 74.15 | 1.93 | 69.47 | 4.68 |
| 13974 | 10887 | 6.1 | 8.65 | 8.77 | 8.76 | 72.14 | 0.00 | 72.13 | 2.05 | 70.60 | 1.54 |
| 13797 | 11026 | 4.4 | 8.71 | 8.83 | 8.83 | 73.05 | -1.02 | 72.03 | 2.08 | 71.98 | 0.05 |
| 8747 | 11058 | 0.7 | 10.61 | 10.73 | 10.73 | 71.79 | 4.41 | 76.20 | 1.86 | 69.67 | 6.54 |
| 14016 | 11072 | 2.6 | 8.63 | 8.75 | 8.75 | 71.86 | -0.89 | 70.98 | 2.14 | 69.95 | 1.03 |
| 13765 | 11147 | 1.0 | 8.72 | 8.85 | 8.84 | 74.11 | -1.54 | 72.57 | 2.06 | 72.30 | 0.27 |
| 8360 | 11150 | 6.4 | 10.77 | 10.90 | 10.89 | 72.04 | 0.51 | 72.55 | 2.08 | 70.24 | 2.30 |
| 13683 | 11184 | 6.0 | 8.75 | 8.87 | 8.87 | 72.57 | -1.39 | 71.17 | 2.16 | 70.85 | 0.33 |
| 19134 | 11200 | 4.2 | 7.01 | 7.13 | 7.13 | 72.74 | 1.22 | 73.96 | 2.00 | 71.30 | 2.66 |
| 8241 | 11223 | 0.6 | 10.82 | 10.94 | 10.93 | 72.30 | 0.27 | 72.57 | 2.08 | 70.02 | 2.54 |
| 13773 | 11260 | 7.6 | 8.71 | 8.85 | 8.84 | 77.47 | -4.68 | 72.80 | 2.09 | 74.94 | -2.15 |
| 13748 | 11287 | 1.2 | 8.72 | 8.85 | 8.84 | 72.80 | -2.00 | 70.80 | 2.20 | 71.32 | -0.52 |
| 19199 | 11365 | 3.2 | 6.99 | 7.12 | 7.11 | 73.67 | 0.85 | 74.53 | 2.00 | 72.44 | 2.09 |
| 14315 | 11468 | 2.1 | 8.53 | 8.66 | 8.65 | 73.95 | -0.97 | 72.98 | 2.10 | 71.81 | 1.17 |
| 19305 | 11542 | 4.6 | 6.96 | 7.09 | 7.08 | 73.90 | -0.39 | 73.51 | 2.09 | 72.74 | 0.77 |
| 8412 | 11652 | 6.6 | 10.75 | 10.87 | 10.87 | 72.09 | 1.00 | 73.09 | 2.14 | 70.98 | 2.11 |
| 8471 | 11653 | 6.4 | 10.70 | 10.86 | 10.85 | 80.36 | -5.16 | 75.20 | 2.02 | 78.63 | -3.42 |
| 13700 | 11721 | 1.2 | 8.74 | 8.87 | 8.86 | 75.22 | -5.38 | 69.84 | 2.34 | 72.42 | -2.59 |
| 19281 | 11724 | 2.1 | 6.96 | 7.10 | 7.09 | 74.65 | -0.90 | 73.75 | 2.10 | 73.25 | 0.50 |
| 13904 | 11916 | 1.3 | 8.67 | 8.81 | 8.80 | 76.67 | -6.09 | 70.57 | 2.33 | 74.30 | -3.73 |
| 19301 | 11928 | 1.8 | 6.96 | 7.09 | 7.08 | 75.09 | -2.16 | 72.94 | 2.19 | 73.15 | -0.22 |
| 19624 | 11942 | 7.4 | 6.86 | 7.00 | 7.00 | 76.83 | -4.36 | 72.47 | 2.24 | 75.12 | -2.65 |
| 13952 | 11987 | 0.2 | 8.65 | 8.79 | 8.78 | 75.08 | -1.94 | 73.14 | 2.18 | 72.97 | 0.18 |
| 8574 | 12170 | 0.1 | 10.68 | 10.82 | 10.81 | 76.30 | -0.89 | 75.41 | 2.09 | 74.58 | 0.82 |
| 8214 | 12226 | 12.2 | 10.83 | 10.96 | 10.96 | 75.45 | -1.13 | 74.32 | 2.21 | 73.90 | 0.42 |
| 8812 | 10572 | 1.6 | 10.58 | 10.71 | 10.70 | 72.54 | -2.99 | 69.54 | 2.13 | 70.99 | -1.45 |
| 8674 | 10675 | 1.8 | 10.64 | 10.76 | 10.75 | 70.32 | 0.31 | 70.63 | 2.09 | 68.42 | 2.21 |
| 13983 | 10746 | 2.4 | 8.63 | 8.77 | 8.76 | 77.30 | -4.05 | 73.25 | 1.95 | 75.93 | -2.68 |

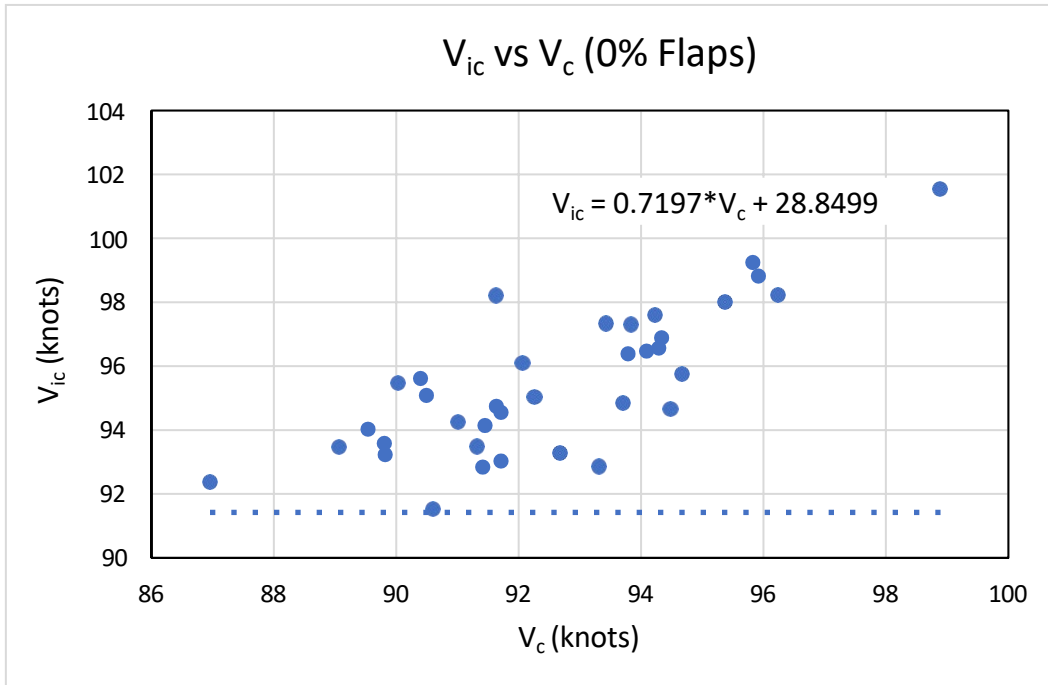


Figure D1. Production System Position Error Correction, Clean Configuration

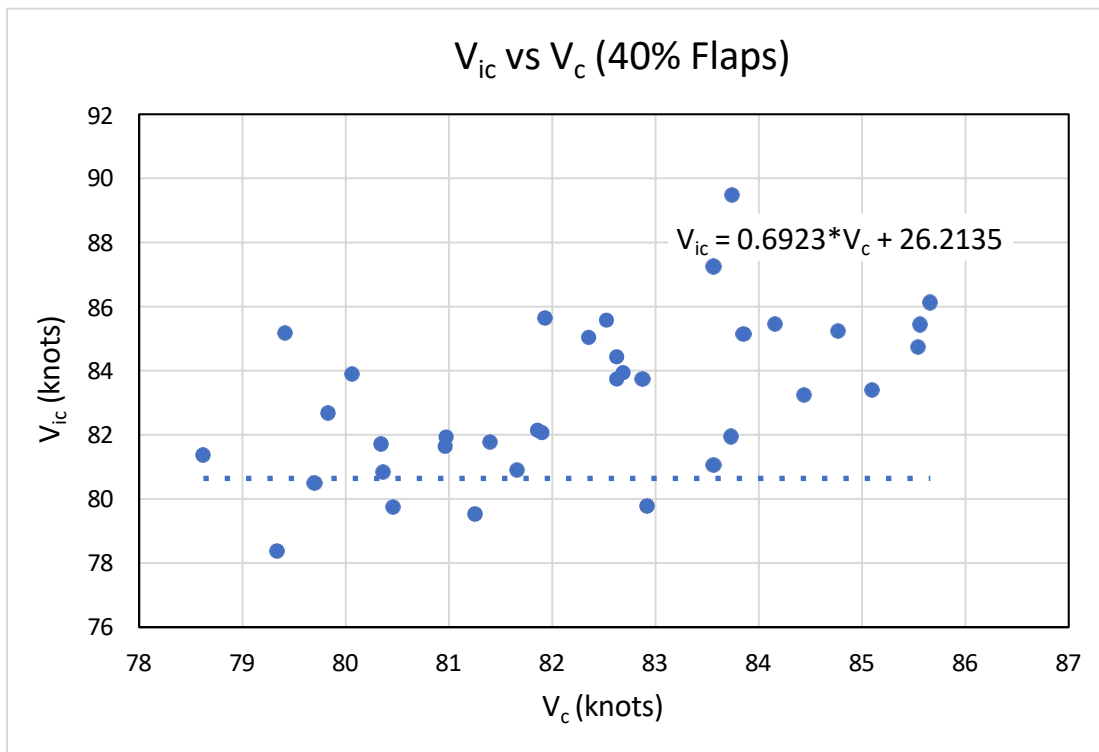


Figure D2. Production System Position Error Correction, Approach Configuration

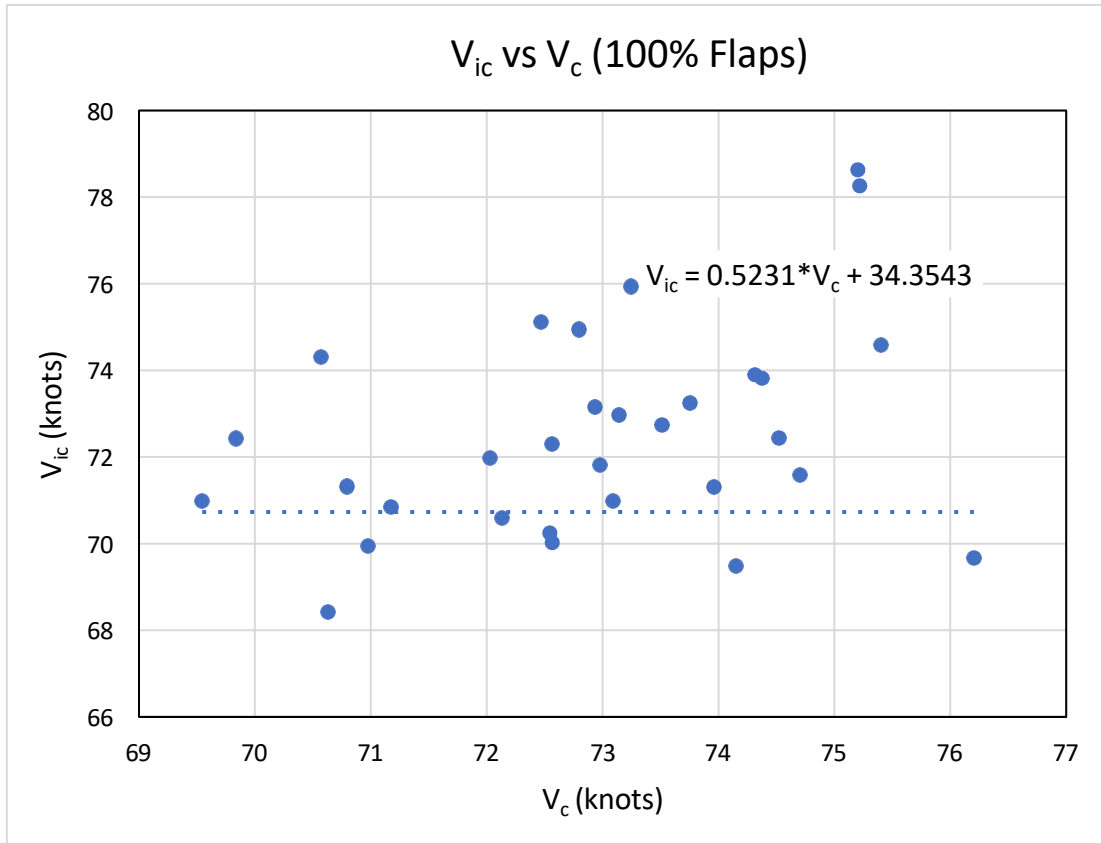


Figure D3. Production System Position Error Correction, Landing Configuration

Table D4. Non-DAS Stall Data

| Configuration | Pressure Altitude (ft) | Aircraft Gross Weight (pounds) | Indicated Airspeed, V_i (knots) | Instrument Correction, ΔV_{ic} (knots) | Instrument Corrected Airspeed, V_{ic} (knots) |
|---------------|------------------------|--------------------------------|-----------------------------------|--|---|
| Clean | 8520 | 10900 | 91 | 0.0 | 91.0 |
| | 8910 | 10980 | 91 | 0.0 | 91.0 |
| | 8700 | 11050 | 93 | 0.0 | 93.0 |
| | 8680 | 11590 | 95 | 0.0 | 95.0 |
| | 8590 | 11765 | 96 | 0.0 | 96.0 |
| Approach | 8640 | 10900 | 76 | 0.1 | 76.1 |
| | 8700 | 10955 | 77 | 0.1 | 77.1 |
| | 8770 | 11040 | 76 | 0.1 | 76.1 |
| | 8710 | 11590 | 80 | 0.0 | 80.0 |
| | 9000 | 11655 | 79 | 0.1 | 79.1 |
| | 8410 | 11660 | 80 | 0.1 | 80.1 |
| Landing | 8640 | 10870 | 70 | 0.1 | 70.1 |
| | 8890 | 10955 | 70 | 0.4 | 70.4 |
| | 8740 | 11000 | 71 | 0.2 | 71.2 |
| | 8560 | 11580 | 71 | 0.1 | 71.1 |
| | 8480 | 11580 | 71 | 0.0 | 71.0 |
| | 8700 | 11615 | 72 | 0.2 | 72.2 |

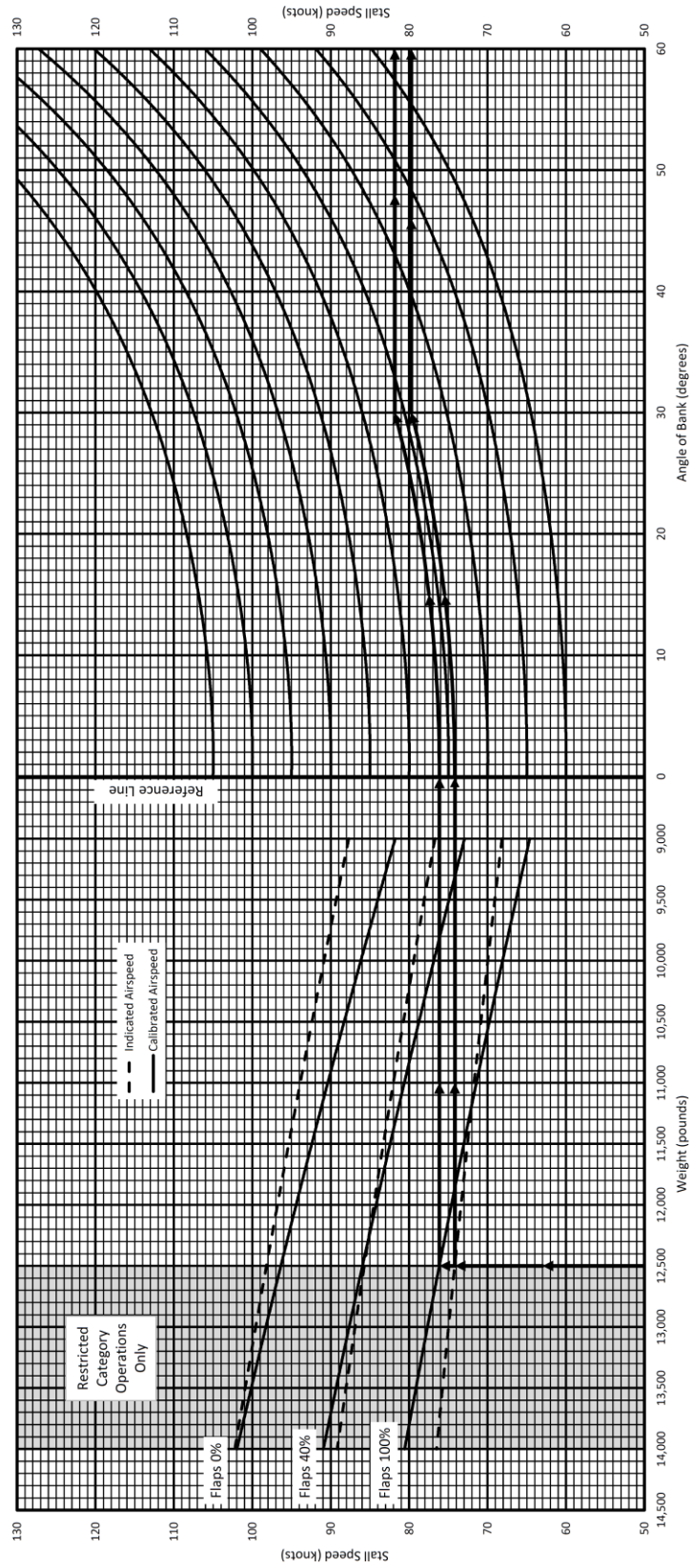


Figure D4. Proposed Flight Manual Stall Chart Update

Table D5. Tower Flyby Handheld Data

| Indicated Airspeed, V_i (knots) | Indicated Altitude, H_i (feet) | Aircraft Indicated Temperature (°C) | Grid Reading | Tower Pressure Altitude, H_c (feet) | Tower Ambient Temperature (°C) | Fuel Weight (pounds) | Aircraft Gross Weight (pounds) |
|---|--|--|-----------------|--|---|----------------------------|-----------------------------------|
| 183 | 2460 | 23 | 7.5 | 2318 | 31.1 | 2700 | 12000 |
| 239 | 2480 | 23 | 6.75 | 2317 | 30.7 | 2700 | 12000 |
| 147 | 2440 | 24 | 6.75 | 2323 | 33.3 | 2500 | 12000 |
| 180 | 2270 | 15 | 5 | 2179 | 11.8 | 2200 | 11600 |
| 232 | 2340 | 21 | 6.3 | 2180 | 12.2 | 2125 | 11525 |
| 140 | 2260 | 21 | 5 | 2178 | 12.4 | 2100 | 11500 |
| 181 | 2300 | 16 | 6.25 | 2174 | 14.8 | 1525 | 10925 |
| 238 | 2320 | 17 | 5.5 | 2174 | 15.5 | 1500 | 10900 |
| 140 | 2290 | 16 | 6.3 | 2174 | 16 | 1400 | 10800 |

This page was intentionally left blank.

APPENDIX E – TEST CONDITION MATRIX

Table E1. Non-DAS Aircraft Test Condition Matrix

| Test Maneuver | Configuration | Altitude Data Band (feet) | Airspeed (KIAS) | Weight Band | Flown | Comments | |
|---------------|---------------|---------------------------|---------------------|---------------|-------|------------------------------|----------------------------------|
| Stall | Clean | 8,000 – 9,000 PA | 1.5 Vstall - Vstall | 10,500-11,100 | 3 | Flaps Up, Gear Up, CG: 0-20% | |
| | | | | 11,100-11,800 | 2 | | |
| | Approach | | 1.3 Vstall - Vstall | 10,500-11,100 | 3 | | Flaps 40%, Gear Down, CG: 0-20% |
| | | | | 11,100-11,800 | 3 | | |
| | Landing | | | 10,500-11,100 | 3 | | Flaps 100%, Gear Down, CG: 0-20% |
| | | | | 11,100-11,800 | 3 | | |

Table E2. DAS Aircraft Test Condition Matrix

| Test Maneuver | Configuration | Altitude Data Band (feet) | Airspeed (KIAS) | Weight Band | Roller Coaster / Turn Mach | Flown |
|--|---------------|---------------------------|--------------------------|---------------|----------------------------|-------|
| Stall | Clean | 8,000 – 20,000 PA | 1.5 Vstall - Vstall | 10,500-11,100 | N/A | 13 |
| | | | | 11,100-11,800 | | 14 |
| | | | | 11,800-12,500 | | 10 |
| | Approach | | 1.3 Vstall - Vstall | 10,500-11,100 | | 10 |
| | | | | 11,100-11,800 | | 12 |
| | | | | 11,800-12,500 | | 10 |
| | Landing | | | 10,500-11,100 | | 10 |
| | | | | 11,100-11,800 | | 12 |
| | | | | 11,800-12,500 | | 10 |
| Tower Flyby | Clean | 200-250 AGL | 140 | 10,500-11,100 | N/A | 1 |
| | | | | 11,100-11,800 | | 1 |
| | | | | 11,800-12,500 | | 1 |
| | | | 180 | 10,500-11,100 | | 1 |
| | | | | 11,100-11,800 | | 1 |
| | | | | 11,800-12,500 | | 1 |
| | | | 240 (or Vh) | 10,500-11,100 | | 1 |
| | | | | 11,100-11,800 | | 1 |
| | | | | 11,800-12,500 | | 1 |
| The "Angry Silly" - Level Deceleration - Constant Mach Roller Coaster - Constant Mach Turn - Continuing Level Deceleration | Clean | 8500 PA ± 500 | 220 (or Vh) - 1.5 Vstall | 10,500-11,100 | 0.25M | 1 |
| | | | | 11,100-11,800 | | 2 |
| | | | | 11,800-12,500 | | 1 |
| | | | | 10,500-11,100 | 0.30M | 1 |
| | | | | 11,100-11,800 | | 2 |
| | | | | 11,800-12,500 | | 1 |
| | | | | 10,500-11,100 | 0.35M | 1 |
| | | | | 11,100-11,800 | | 2 |
| | | | | 11,800-12,500 | | 1 |
| | | 10,500-11,100 | | 0.40M | 1 | |
| | | 11,100-11,800 | | | 1 | |
| | | 11,800-12,500 | | | 1 | |
| | | 10,500-11,100 | | 0.25M | 1 | |
| | | 11,100-11,800 | | | 1 | |
| | | 11,800-12,500 | | | 1 | |
| | | 10,500-11,100 | | 0.30M | 1 | |
| | | 11,100-11,800 | | | 2 | |
| | | 11,800-12,500 | | | 1 | |
| | | 10,500-11,100 | | 0.35M | 1 | |
| | | 11,100-11,800 | | | 1 | |
| | | 11,800-12,500 | | | 1 | |
| | | 10,500-11,100 | | 0.40M | 1 | |
| | | 11,100-11,800 | | | 1 | |
| | | 11,800-12,500 | | | 1 | |
| | | 10,500-11,100 | | 0.25M | 1 | |
| | | 11,100-11,800 | | | 1 | |
| | | 11,800-12,500 | | | 1 | |
| 10,500-11,100 | 0.30M | 1 | | | | |
| 11,100-11,800 | | 1 | | | | |
| 11,800-12,500 | | 1 | | | | |
| 10,500-11,100 | 0.35M | 1 | | | | |
| 11,100-11,800 | | 2 | | | | |
| 11,800-12,500 | | 1 | | | | |
| 10,500-11,100 | 0.40M | 1 | | | | |
| 11,100-11,800 | | 2 | | | | |
| 11,800-12,500 | | 1 | | | | |

APPENDIX F – LESSONS LEARNED

The following are lessons learned during the execution of Have EPIC DISCO:

- When additional assets are being used to collect data during a test flight and the test aircraft is delayed or canceled, it is important to call and let them know of the delays or cancellations as soon as possible to prevent unnecessary resource expenditures. Weather balloons were used to collect atmospheric data, but there were a few times that they weren't called until after the balloons were already launched or filled, making it too late to cancel launching the balloons.
- The ability to communicate as a team is key, which means that more than one person needs to have the contact information for all players involved in a test. If one person has the contact information for the weather balloons and they are unaware that the balloons need to be delayed, then the balloons will end up getting launched prematurely.
- It is just as important to have the aircraft in the right configuration and weight as it is for the test team to know what FTTs and test points they are attempting. Because the weight of the aircraft was part of the test plan, it was important to let the maintenance personnel know how much fuel to load into the aircraft prior to the next event. The best time for the test team to let them know how much fuel to put into the aircraft was when they returned from a sortie. However, follow up was required, especially for a non-standard fuel load. Additionally, it is important to specify tolerances on the fuel load given, especially when the weight or CG is near a limit.
- Flexibility was a useful tool that can only be available if proper planning has taken place. The test team was ready to change to different test conditions when turbulence, weather, airspace, etc. were uncooperative because they knew what data were still required. The ability to change the test points once airborne allowed the team to get all the desired test points from the test plan. If the team wasn't familiar with the data requirements, they would not have been able to collect all the data.
- Updating the test matrix at the end of each sortie allowed for efficient planning for follow on sorties. Knowing that the test matrix was correct at the beginning of each briefing prevented the team from wasting time trying to figure out if a test point had been completed or not, and helped the team know what the options were going to be if there were issues during the flight.
- The test plan had test points that were only attainable for a limited portion each flight. If you are able to identify these test points, you should try to get them early in the schedule. This allows multiple attempts to collect the data if you find out in post flight analysis that the planned data point was not obtained. This happened a few times as hand-held weight estimates were corrected with DAS fuel flow data. If you wait until the end of the fly window to try and get some of the more difficult points, you may be forced to choose which data points you will omit.
- It's better to ask for extra flight hours and not need them than to need them and not have them. In the second half of the TMP window, additional flight hours were needed due to early RTBs for maintenance issues. By recognizing the problem early, additional hours were approved.
- Ask questions early. A couple of flights were shortened so that corrective maintenance could be performed on the aircraft after an issue was observed airborne. After the third occurrence, it was determined that it would be ok to continue with the flight and that there was no need to RTB early because of it. By not asking the questions sooner, the number of sorties was increased unnecessarily. Receiving this guidance when the issue first appeared would have increased test efficiency.
- Seek out ways to reduce the cost of your test project by "piggy backing" off of other missions. One member of the test team was able to complete the crew-solo training requirements while

flying as a chase aircraft for a different test. This reduced spending for training, potentially allowing more flight hours.

- Equipment calibration is extremely important. The TPS tower flyby altimeter was found to have not been calibrated during an unknown amount of time prior to the test, and ended up introducing errors into the data. Do not trust that equipment is accurate enough for real world test without calibrating it yourself or confirming calibration methods.

APPENDIX G – DIGITAL DATA

Digital data for this project is organized as follows.

1. Raw Sortie Data

Flights 1-13

- Balloon Data Folder (when applicable)
- TSPI Data Folder (when applicable)
- Quick-Look Report (Date – Aircrew Names TMP – quicklook.doc)
- DAS Data (Flight X DAS Data.xlsx)
- Filled-In Test Cards (Flight X Test Cards.pdf)

Ground Cal

- DAS Tail 158 Handheld Ground Cal (DAS Tail 158 Cal.pdf)
- Non-DAS Tail 166 Handheld Ground Cal (NonDAS Tail 166 Cal.xlsx)

Non Das Flight

- Quick-Look Report
- NonDAS Test Cards

2. Raw MATLAB Imports

Imported DAS Data, TSPI Data, Balloon Data concatenated into one matrix (FlightX_Date.mat)

3. JMOSS Self Contained Data

DAS data run through JMOSS without balloon inputs (FlightX_Date_Kt_JMOSS.mat)

4. JMOSS Balloon Temp Data

DAS data run through JMOSS using balloon temp (FlightX_Date_JMOSS.mat)

5. MATLAB Code

JMOSS Code (JMOSSV6.m)

6. Miscellaneous

- 1 Final Epic Disco GLM.pdf
- 2 Initial Epic Disco GLM.pdf
- Figure 14 in 3D (3 GLM Prediction Intervals and TFB Corrections.fig)
- 4 C-12 DAS Decoder (C12_DAS_Decoder.xlsx)
- Tower Fly By Data (5 TFB_Data.mat)
- 6 TPS Tower Flyby Altimeter Calibration Email.pdf

This page was intentionally left blank.

APPENDIX H – ABBREVIATIONS, ACRONYMS, AND SYMBOLS

| <u>Abbreviation</u> | <u>Definition</u> | <u>Units</u> |
|---------------------|--|-------------------|
| ADC | air data computer | --- |
| ADS | air data system | --- |
| ADTS | air data test system | --- |
| AFB | Air Force Base | --- |
| AFBI | Air Force Base Instruction | --- |
| AFTC | Air Force Test Center | --- |
| AGL | above ground level | --- |
| ANCOVA | analysis of covariance | --- |
| AOA | angle of attack | degrees |
| a_{SL} | speed of sound at sea level | knots |
| ASTM | American Society for Testing and Materials | --- |
| BSEKF | Backwards-Smoothing Extended Kalman Filter | --- |
| CAS | calibrated air speed | knots |
| CI | confidence interval | --- |
| CG | center of gravity | % MAC |
| C_L | lift coefficient | --- |
| C_{Lmax} | maximum lift coefficient | --- |
| DISCO | Determine Stall Characteristics Online | --- |
| DAS | data acquisition system | --- |
| DSCA | Defense Security Cooperation Agency | --- |
| EPIC | Enhanced Performance Increased Capability | --- |
| F | F-test statistic | --- |
| FAA | Federal Aviation Administration | --- |
| FDR | Flight Data Recorder | --- |
| ft | feet | feet |
| FTT | Flight Test Techniques | --- |
| g | acceleration of gravity | ft/s ² |
| GAINR | GPS Aided Inertial Navigation Reference | --- |
| GLM | generalized linear model | --- |
| GPS | global positioning system | --- |
| H_c | truth pressure altitude | feet |

| | | |
|----------------|--|--------|
| $H_{c,tower}$ | truth pressure altitude of flyby tower | feet |
| h_g | geometric altitude | feet |
| H_i | indicated pressure altitude | feet |
| H_{ic} | instrument corrected indicated pressure altitude | feet |
| IAS | indicated airspeed | knots |
| IMU | inertial measurements unit | --- |
| in. Hg | inches mercury | inches |
| JMOSS | Jurado-McGehee Online Self Survey | --- |
| JON | job order number | --- |
| K_t | Temperature Correction Factor | --- |
| $\hat{\kappa}$ | JMOSS estimated temperature correction factor | --- |
| KCAS | Knots Calibrated Air Speed | --- |
| KIAS | Knots Indicated Air Speed | --- |
| KS | Kolmogorov-Smirnov | --- |
| kts | knots | knots |
| lb | pound | pounds |
| M | mach | --- |
| MATLAB | matrix laboratory | --- |
| MSE | mean square error | --- |
| MSL | mean sea level | --- |
| N | sample size | each |
| n | load factor | --- |
| N/A | not applicable | --- |
| p-value | probability value | --- |
| \hat{p} | JMOSS estimated pressure bias | --- |
| P_a | ambient pressure | psi |
| P_s | static pressure | psi |
| P_{SL} | sea level static pressure | psi |
| P_t | total pressure | psi |
| PA | pressure altitude | --- |
| PFD | Primary Flight Display | --- |
| PPM | precision pressure monitor | --- |
| p | p-value | % |
| q_c | differential pressure | psi |

| | | |
|-----------------|--|-----------------|
| q_{cic} | instrument-corrected differential pressure | psi |
| r^2 | coefficient of determination | % |
| RARS | ram air recovery system | --- |
| RPM | revolutions per minute | --- |
| RTB | return to base | --- |
| S | wing planform area | ft ² |
| SPE | static position error | --- |
| SPEED | static position error enhanced determination | --- |
| SPO | system program office | --- |
| SPSS | Statistical Product and Service Solutions | --- |
| SS | Sum of Squares | --- |
| t | Student's t | --- |
| T_{ic} | instrument corrected temperature | °C |
| T_{std} | standard day ambient temperature | °C |
| T_{test} | test day ambient temperature | °C |
| TFB | tower flyby | each |
| TGT | turbine gas temperature | °C |
| TIM | technical information manual | --- |
| T.O. | technical order | --- |
| TOLD | Takeoff and Landing Data | --- |
| TMP | Test management project | |
| TP | test plan | --- |
| TPS | Test Pilot School | --- |
| TSPI | time space position information | --- |
| TW | Test Wing | --- |
| USAF | United States Air Force | --- |
| USN | United States Navy | --- |
| \hat{V}_{W_D} | JMOSS estimate of Down wind component | ft/s |
| \hat{V}_{W_E} | JMOSS estimate of East wind component | ft/s |
| \hat{V}_{W_N} | JMOSS estimate of North wind component | ft/s |
| V_c | calibrated airspeed | knots |
| V_D | GPS down velocity | ft/s |
| V_e | equivalent airspeed | knots |
| V_{estall} | equivalent stall airspeed | knots |

| | | |
|--------------------------|---|-----------------------|
| V_E | GPS East velocity | ft/s |
| V_e | equivalent airspeed | knots |
| V_h | maximum level airspeed | knots |
| V_i | indicated airspeed | knots |
| V_{ic} | instrument corrected indicated airspeed | knots |
| V_N | GPS North velocity | ft/s |
| V_{stall} | stall speed | knots |
| V_t | true airspeed | knots |
| W | aircraft gross weight | pounds |
| W/δ | Weight to pressure ratio | --- |
| WSO | Weapons System Operator | --- |
| Y_i | Sample run | --- |
| \hat{Y} | Test sample run | --- |
| α | angle of attack | degrees |
| α_i | indicated angle of attack | degrees |
| β_i | indicated angle of sideslip | degrees |
| β | estimated model coefficients | --- |
| δ | pressure ratio | --- |
| ΔH | change in geometric altitude | feet |
| ΔH_c | change in pressure altitude | feet |
| ΔH_{ic} | altitude instrument error correction | feet |
| ΔH_{pc} | altitude position error correction | feet |
| ΔP_p | static position error | psi |
| $\Delta \hat{P}_p$ | JMOSS static position error estimate | psi |
| $\Delta P_p/P_s$ | static position error ratio | --- |
| ΔV_{ic} | airspeed instrument error correction | knots |
| ΔV_{pc} | airspeed position correction | knots |
| η^2 | Eta-squared | % |
| γ | ratio of specific heats | --- |
| γ | flight path angle | degrees |
| $\mu\Delta\Delta V_{pc}$ | mean difference of airspeed position correction | knots |
| Φ | roll/bank angle | degrees |
| Ψ | yaw angle | degrees |
| ρ | density | slugs/ft ³ |

ρ_{SL}

sea level standard density

slugs/ft³

θ

pitch angle

degrees

This page was intentionally left blank.

APPENDIX I – DISTRIBUTION LIST

| <u>Onsite</u> | <u>Number of Copies</u> | | |
|---|-------------------------|----------------|--------------|
| | <u>E-mail</u> | <u>Digital</u> | <u>Paper</u> |
| 419 FLTS Attn: Capt John Stevenson 118 E Jones Rd Edwards AFB CA 93524 Email: john.stevenson.10@us.af.mil | 1 | 0 | 0 |
| Edwards AFB Technical Research Library Attn: Darrell Shiplett 307 E Popson Ave Edwards AFB CA 93524 | 0 | 0 | 2 |
| AFTC/HO Attn: AF Test Center/HO Mailbox 305 E Popson Ave Edwards AFB CA 93524 | 1 | 0 | 0 |
| AFTC/CA Attn: Eileen Bjorkman/Executive Director 1 S Rosamond Blvd Edwards AFB CA 93524 Email: eileen.bjorkman.1@us.af.mil | 1 | 0 | 0 |
| USAF TPS Attn: Dave Vanhoy 220 Wolfe Ave Edwards AFB CA 93524 | 1 | 0 | 0 |
| USAF TPS Attn: Karl Major 220 Wolfe Ave Edwards AFB CA 93524 | 1 | 1 | 0 |
| USAF TPS Attn: LtCol Juan Jurado 220 Wolfe Ave Edwards AFB CA 93524 | 1 | 1 | 0 |

Offsite

Defense Technical Information Center
Submit per DTIC procedures
Attn: DTIC-O
8725 John J. Kingman Rd, Ste 0944
Ft Belvoir VA 22060
[Email: aq@dtic.mil](mailto:aq@dtic.mil)

| | | | |
|-------|----------|----------|----------|
| | 1 | 0 | 0 |
| Total | <u>7</u> | <u>2</u> | <u>2</u> |