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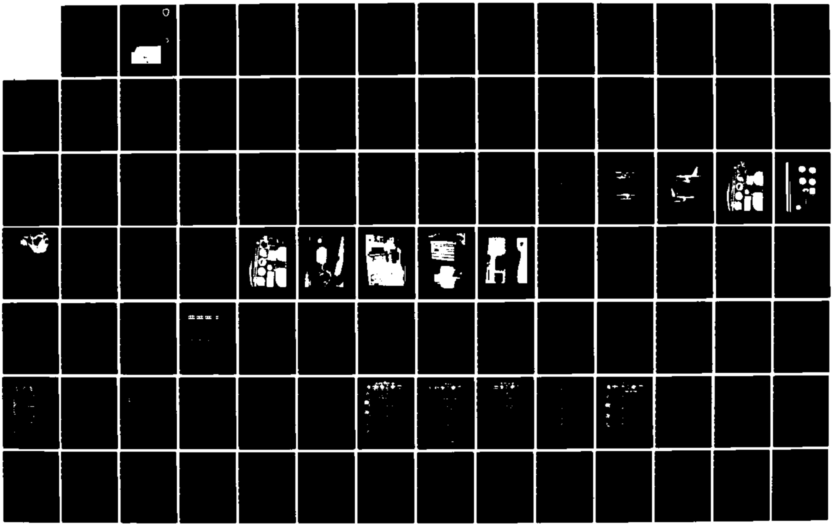

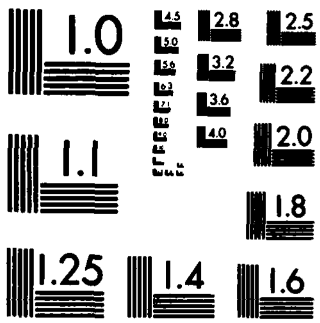

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USAAEFA

USAAEFA PROJECT NO. 84-04

PRELIMINARY AIRWORTHINESS EVALUATION OF THE RUTAN AIRCRAFT FACTORY (RAF), INC. LONG - EZ AIRPLANE WITH EXTERNAL SIGHT

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MAY 1984

FINAL REPORT

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED.

UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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Preliminary Airworthiness Evaluation
LONG-EZ Airplane with an External Sensor
Combat Surveillance Airborne Test Bed Configuration
Assess Performance and Handling Qualities

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The US Army Aviation Engineering Flight Activity conducted a Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory, Inc. designed LONG-EZ airplane with an external sensor (Combat Surveillance Airborne Test Bed (CSATB) configuration), from 12 March through 10 April 1984 at Edwards Air Force Base, California. During the test program 13 flights were conducted for a total of 15.3 hours, of which 11.6 were productive. The objectives of the evaluation were to assess the performance and handling qualities of the LONG-EZ so that

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) the US Army Aviation Systems Command could issue an airworthiness release to allow the 9th Infantry Division to conduct a mission evaluation of the CSATB configured aircraft. All tests were performed at an average gross weight of 1335 pounds and nominal mission longitudinal center of gravity (cg). Test results were compared with basic data obtained during previous testing and evaluated against military specification MIL-F-8785C. The performance was degraded considerably by the installation of the external sensor with handling qualities at the mid cg essentially identical to those obtained near the aft cg limit, FS 104.0, for the basic aircraft. The performance capabilities and handling qualities, however, are adequate for for the CSATB evaluation including night operations. There were no new deficiencies and one additional shortcoming identified during this evaluation. A previously reported shortcoming of limited directional control has been eliminated by the increase in rudder area in the CSATB configured LONG-EZ aircraft.

DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

REPLY TO
ATTENTION OF

DRSAV-ED

SUBJECT: Directorate for Engineering Position of the Final Report of USAAEFA Project No. 84-04, Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc., LONG-EZ Airplane with External Sight

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The report documents the flight test results of the Rutan Aircraft Factory (RAF) LONG-EZ aircraft with a mockup installation of an external FLIR sensor. This was the third evaluation in a series of three which were conducted by the US Army Aviation Engineering Flight Activity (USAAEFA). The two previous evaluations were conducted in the clean configurations (no FLIR sensor) under USAAEFA Projects 82-18, "Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc., LONG-EZ Airplane" and 83-18, "Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory, Inc., LONG-EZ Airplane (S/N 1241)". Based on the results of the two evaluations, the 9th Infantry Division (9th ID) was issued Airworthiness Releases for the conduct of special mission concept evaluations. As a result of the recent evaluation by the USAAEFA, the 9th ID was issued an Airworthiness Release for the LONG-EZ Airplane with a FLIR sensor for continued special mission concepts evaluations.

2. The Directorate for Engineering agrees with the subject report Conclusions and Recommendation and the following additional comments are provided. Comments are directed to the report paragraphs as indicated.

a. Paragraph 46. The potential for loss of directional control due to a single point brake failure during takeoff/landing and ground handling was identified as a deficiency in the two previous evaluations. The LONG-EZ is currently being used only for conceptual evaluations under an Airworthiness Release and there is no intent to release the airplane operationally at this time. Consequently, continued operations under the Airworthiness Release is acceptable. However, if the LONG-EZ is to be type classified or used operationally, then correction of this deficiency is mandatory.

b. Paragraph 47. The objectionable internal light reflections of the landing light on the canopy has a direct impact on the pilot performance and could distract his attention during critical takeoff/landing maneuvers. Consequently, it is considered a shortcoming that must be corrected prior to type classification or operational use. It appears this type of problem can be easily corrected.

SUBJECT: Directorate for Engineering Position of the Final Report of USAAEFA Project No. 84-04, Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc., LONG-EZ Airplane with External Sight

c. Paragraph 48. While the LONG-EZ airplane met all the requirements of MIL-F-8785C, except for the unaccelerated stall warning characteristics, there is no requirement for such compliance. This characteristic remains a shortcoming which is not considered essential to correct by aerodynamic correction of installation of a stall warning system because of the docile stall characteristics.

3. The results of the USAAEFA flight evaluation, contractor flight testing and evaluation of contractor analyses and reports of the LONG-EZ airplane with the FLIR sensor by the Directorate of Engineering provide the basis for issuance of the Airworthiness Release to the 9th ID for continued conceptual testing. When operated within the restrictions and limitations of the Airworthiness Release, the LONG-EZ airplane can be safely flown for the 9th ID evaluations.

RONALD E. GORMONT
Acting Director of Engineering

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INTRODUCTION

BACKGROUND

1. The LONG-EZ is a small, lightweight airplane designed by the Rutan Aircraft Factory (RAF), Inc. The airplane is a home-built, experimental class aircraft certified under Federal Air Regulation Part 21 (ref 1, app A) of the Federal Aviation Administration. It is intended to be built according to the LONG-EZ manufacturing manual by private construction with materials and prefabricated parts obtained from commercial sources. The Army's interest in the aircraft is exploratory for missions as yet not defined. Two airplanes were assembled by the 9th Infantry Division (9th ID) at Fort Lewis, Washington, and evaluated in a clean configuration during US Army Aviation Engineering Flight Activity (USAAEFA) Projects No. 82-18 and 83-18 (refs 2 and 3, app A). The California Institute of Technology, Jet Propulsion Laboratory (JPL) was under government contract to modify LONG-EZ aircraft, US Army Serial Number (S/N) 1241 to the Combat Surveillance Airborne Test Bed (CSATB) configuration in support of 9th ID evaluations. The structural modification was performed by RAF under JPL contract and included the installation of a forward looking infrared (FLIR) sensor. Additional modifications requested by the 9th ID included the addition of a landing light, modification of the instrument panel and an increase in rudder area. USAAEFA was tasked by the US Army Aviation Systems Command (AVSCOM) (ref 4, app A) to conduct a Preliminary Airworthiness Evaluation (PAE) on the performance and handling qualities of the CSATB configuration LONG-EZ aircraft, S/N 1241.

TEST OBJECTIVES

2. The objectives of the evaluation were to obtain quantitative and qualitative flight test data on performance and flying qualities necessary for AVSCOM to prepare an airworthiness release to allow the 9th ID to conduct mission evaluations of the CSATB configured LONG-EZ aircraft.

DESCRIPTION

3. The test vehicle designed by RAF and constructed by the 9th ID according to the LONG-EZ manufacturing plans is a two place, tandem seat, home-built, experimental class aircraft. Unique features include composite construction, a nose mounted canard for pitch control, and a mid-mounted, high aspect ratio, swept wing featuring an Eppler airfoil and tip mounted winglets. The airplane also features tricycle landing gear (with a retractable nose wheel) and a landing airbrake (belly mounted "speed brake").

Propulsion is provided by a rear mounted, four cylinder, Lycoming O-235-L2C reciprocating engine and a fixed pitch wooden propeller. Modifications to the basic configuration include a belly mounted FLIR sensor, increase in rudder surface area, and relocated and enlarged engine ram air inlets. A mock-up external FLIR sensor identical in weight and size was used for this test. Other changes include a landing light, additional avionics, and rearranged cockpit instruments. Further description of the aircraft is presented in appendix B and a more detailed description of the LONG-EZ is contained in the owner's manual (ref 5, app A).

TEST SCOPE

4. A limited performance and handling qualities evaluation of the CSATB configured LONG-EZ was conducted at Edwards Air Force Base, California (2302 foot field elevation). The evaluation was conducted from 12 March through 10 April 1984. During the test program 13 flights were conducted for a total of 15.3 hours, of which 11.6 were productive. Test results were compared with baseline data obtained during previous testing (refs 2 and 3, app A). A qualitative evaluation was also conducted to determine aircraft suitability for night flight. Flight restrictions and operating limitations contained in the airworthiness release issued by AVSCOM (ref 6, app A) were observed during the evaluation. The airplane configurations are presented in table 1 with the test conditions shown in tables 2 and 3.

TEST METHODOLOGY

5. Established flight test techniques and data reduction procedures were used during this test program (refs 7 and 8, app A). The test methods are described briefly in the Results and Discussion section of this report. Flight test data were automatically recorded on ground based magnetic tape via telemetry. A list of the test instrumentation is contained in appendix C. Test techniques (other than the standard techniques described in appropriate references), weight and balance, and data reduction techniques are contained in appendix D. A Handling Qualities Rating Scale (HQRS) (fig. 1, app D) was used to augment pilot comments relative to the aircraft handling qualities. Deficiencies and shortcomings are in accordance with the definitions presented in appendix D.

Table 1. Airplane Configurations[1]

Configuration	Nose Gear Position	Power Setting
Takeoff (TO)	down	TO[2]
Climb (CL)	up	MCP[2]
Cruise (CR)	up	PLF[3]
Power Approach (PA)	up	PNA[4]
Landing (L)	down	IDLE
Glide (G)	up	IDLE

NOTES:

[1]Landing airbrake retracted in all configurations

[2]Takeoff and maximum continuous power: maximum brake horsepower (BHP) available, (rated at 118 BHP at 2800 engine RPM, sea level standard day, full rich mixture), or full throttle.

[3]Power for level flight: BHP required to maintain level flight, peak exhaust gas temperature (EGT) mixture.

[4]Power for normal approach: BHP required to maintain 3-degree glide angle.

Table 2. Test Conditions

Test	Average Gross Weight[1] (lb)	Conditions			
		Average Longitudinal CG Location[2] (in.)	Density Altitude (ft)	Trim Calibrated Airspeed (KCAS)	Configuration
Airspeed Calibration	1330	100.2	4000-5640	81 - 150	TO, CL, CR, PA, L
Takeoff Performance	1340	100.9	2700	54 - 71	TO
Level Flight Performance	1325	100.8	7175-12,112	64 - 78	G,L
Landing Performance	1340	100.9	2700	59 - 77	L
Stall Characteristics	1330	100.2	7135-8120	63 - 80	TO, CL, CR PA, L
Control Positions in Trimmed Forward Flight	1330	100.6	4000-5640	81 - 150	CL, CR, PA
Static Longitudinal Stability	1335	100.1	4600-7300	95, 97, 105	CL, CR, L
Static Lateral-Directional Stability	1330	100.8	4690-7200	94, 96, 103, 116	CL, CR, L
Manuevering Stability	1330	100.2	5800-8000	92 - 140	CR
Dynamic Stability	1335	100.8	4000-7480	95 - 122	CR
Roll Control Effectiveness	1335	100.2	7200-7500	100	CR
Vibration Characteristics	1330	100.2	4000-5640	81 - 150	TO, CL, CR, PA, L
Night Evaluation	1345	100.9	2700-5100	0 - 150	TO, CL, CR PA, L

NOTES:

[1]Normal maximum gross weight: 1325 lb. Alternate maximum gross weight: 1425 lb (takeoff only).
[2]Center of gravity (cg) range: FS 97 to 104

RESULTS AND DISCUSSION

GENERAL

6. Performance and handling qualities of the CSATB configured LONG-EZ aircraft were evaluated under the conditions and configurations listed in tables 1 and 2. All tests were performed at an average gross weight of 1335 pounds and nominal mission longitudinal center of gravity (cg), fuselage station (FS) 101.0 (mid). The FLIR sensor was ballasted to the representative system weight and moments of inertia. Test results were compared with baseline data (refs 2 and 3, app A) obtained during previous testing and evaluated against military specification MIL-F-8785C (ref 9, app A). The performance was degraded considerably by the installation of the FLIR sensor with handling qualities at the mid cg essentially identical to the those obtained near the aft cg limit, FS 104.0, for the basic aircraft. The performance capabilities and handling qualities, however, are adequate for the CSATB evaluation including night operations. There were no new deficiencies and one additional shortcoming identified during this evaluation. A previously reported shortcoming of limited directional control has been eliminated by the increase in rudder area in the CSATB configured LONG-EZ aircraft. The previously reported deficiency of loss of directional control due to single point brake failure during takeoff/landing and ground handling, although improved by the increase in rudder area, remains a deficiency.

PERFORMANCE

General

7. The performance capabilities of the CSATB configured LONG-EZ airplane were evaluated to provide data for comparison with and as a supplement to baseline data obtained during previous testing (refs 2 and 3, app A). All tests were conducted at an average gross weight of 1335 pounds and at the nominal mission cg, FS 101.0 (mid). Test conditions are outlined in table 2 and data analysis techniques are contained in appendix D. The performance was degraded considerably by the installation of the FLIR sensor.

Takeoff Performance

8. Takeoff tests were performed at the conditions listed in table 2. Takeoffs were conducted from a level dry concrete runway by aligning the aircraft on centerline of the runway with the nose wheel straight. Full power was applied prior to releasing the brakes. The initial rotation speed and liftoff airspeeds were

determined by maintaining full aft longitudinal control until nose wheel liftoff and then adjusting longitudinal control to maintain the canard upper surface level on the horizon (approximately 12 degrees of pitch) until takeoff was achieved. On subsequent takeoffs, rotation speed was then incrementally increased to the point where rotation to a 12 degree pitch attitude resulted in a simultaneous takeoff. Predetermined climb airspeeds were maintained until 100 feet above the ground and then adjusted to a normal cruise climb airspeed of 90 knots indicated airspeed (KIAS). Ground roll and simulated obstacle clearance distances were determined by use of runway ground observers and a visual theodolite. The best takeoff performance was obtained using a rotation speed of 65 KIAS, liftoff at 63 KIAS, and climb at 65 KIAS at the maximum gross weight (1325 lb). At this condition the minimum ground roll was approximately 2100 feet. This was approximately 75 percent longer ground roll than takeoff performance data presented in the operator's manual (ref 5, app A) or obtained during previous testing (refs 2 and 3, app A) for the baseline aircraft. Qualitative estimate of the minimum incremental distance required to attain a 50 foot obstacle clearance height after liftoff while climbing at 65 KIAS is 800 feet at a maximum gross weight of 1325 lb.

9. Analysis of data obtained during the takeoff roll showed a simultaneous decrease in indicated airspeed (typically 3 to 6 knots) and pressure altitude (typically 50 feet) with aft stick application which would indicate a static port position error change. The apparent static port position error change coincident with rotation, which resulted in an abrupt decrease in indicated airspeed, had no measurable effect on the takeoff performance. The following note should be incorporated in the operator's manual.

NOTE

> An abrupt decrease in both indicated airspeed (typically 3 to 6 knots) and pressure altitude (approximately 30 feet) will occur coincident with rotation due to an apparent static port position error change.

Level Flight Performance

10. The zero thrust glide test method was used to determine the drag difference between the CSATB configured LONG-EZ aircraft and the basic aircraft (ref 2, app A). The test aircraft was stabilized and trimmed (ball centered) at incremental airspeeds from 59 knots calibrated airspeed (KCAS) to 106 KCAS in a descent

in both the glide and landing configuration with the engine and propeller stopped through a target pressure altitude band of 10,000 to 6,000 feet. Comparative results are presented in figure 1, appendix E. Modification of the basic airframe to the CSATB configuration (with the FLIR sensor installed) resulted in an equivalent flat plate area (F_e) increase of 2.09 square feet in the cruise configuration and 0.76 square feet for the landing configuration.

11. The level flight performance capabilities of the CSATB configured LONG-EZ aircraft were determined by computing power required as a function of airspeed. Thrust horsepower (THP) was calculated from the glide drag polar (fig. 1, app E). A comparison of the level flight performance capabilities between the CSATB configured LONG-EZ and the baseline aircraft for a nominal mission gross weight (1300 lb) at standard day, sea level conditions is presented in figure A. Comparatively, at 80 THP, the level flight airspeed of the CSATB configured LONG-EZ aircraft was approximately 117 knots true airspeed (KTAS) versus 145 KTAS for the basic aircraft in the cruise configuration. With the FLIR sensor installed on the CSATB configured LONG-EZ aircraft, the F_e increase of 2.09 square feet (cruise configuration) reduces considerably the level flight speed capability of the aircraft by approximately 30 KTAS.

Stall Performance

12. Stall performance was evaluated at the conditions and aircraft configurations listed in table 2. The aircraft was trimmed at 1.2 stall airspeed. Airspeed was then decreased at approximately 1 knot per second until achieving a stall. Typical time histories of the stall characteristics are presented in figures 2 through 9, appendix E. Table 3 shows stall airspeeds for the various aircraft configurations and loadings. The stall airspeeds for the CSATB configured aircraft were essentially unchanged from the basic aircraft.

Landing Performance

13. Landing performance evaluations were conducted concurrently with the takeoff performance tests listed in table 2. Landing approaches were made at a constant airspeed from 75 to 60 KTAS in five knot increments with power required to maintain a final descent path of approximately 3 degrees to a predetermined touchdown point. After touchdown on the main wheels, the nose wheel was lowered to the ground immediately with maximum braking applied to smoothly and rapidly stop the aircraft in a straight line. The best landing performance at the maximum gross weight

FIGURE A
LEVEL FLIGHT PERFORMANCE COMPARISON
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT = 1300 POUNDS
PRESSURE ALTITUDE = SEA LEVEL
AMBIENT TEMPERATURE = 15.0 DEG C

NOTES: 1. CLEAN AIRCRAFT DATA OBTAINED FROM USAAEFA PROJECT NO. 82-18, "PRELIMINARY AIRWORTHINESS EVALUATION OF THE RUTAN AIRCRAFT FACTORY (RAF), INC, LONG-EZ AIRPLANE", DATED JUNE 1983, FINAL REPORT.
2. FLIR CONFIGURED AIRCRAFT DATA OBTAINED FROM FIG. 1, APP. E.

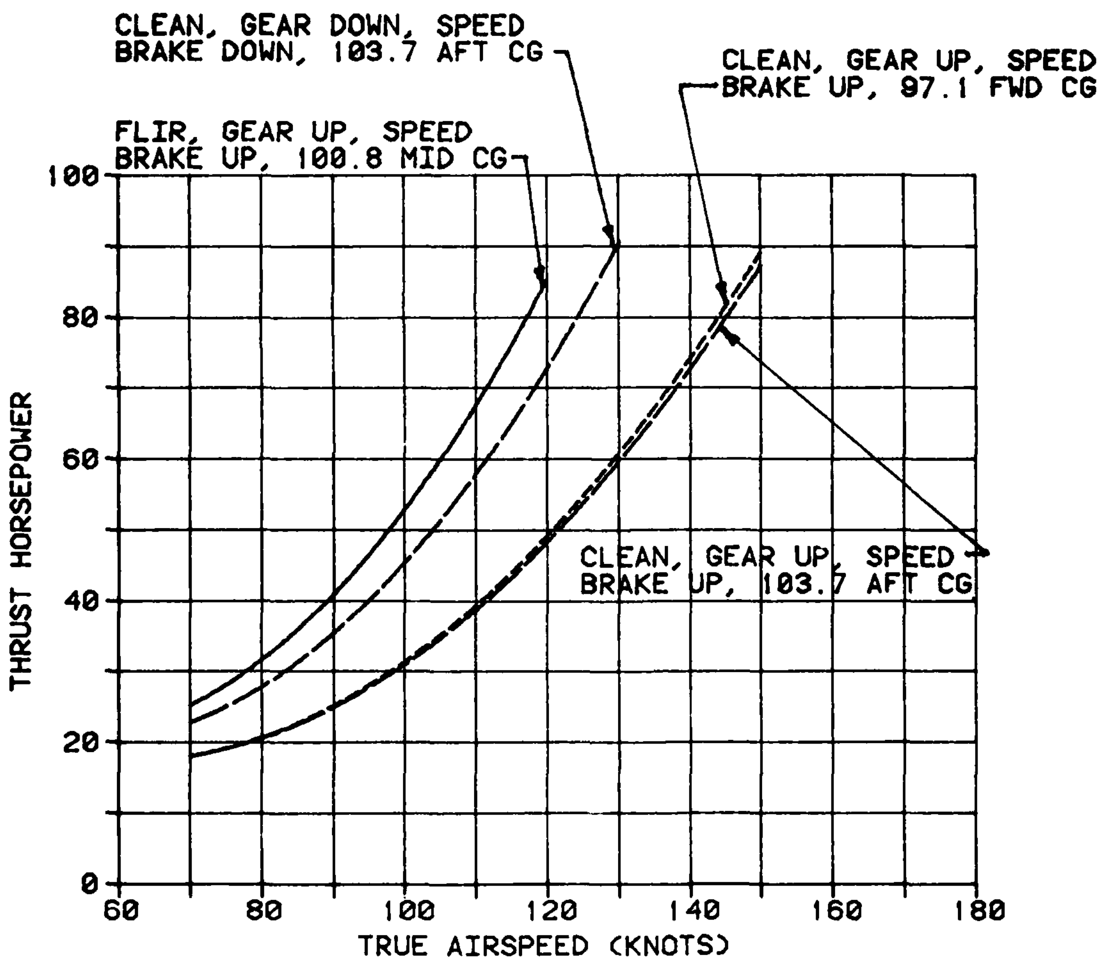


Table 3. Stall Performance

Configuration	Gross Weight (lb)	Center of Gravity (FS)	Density Altitude (ft)	Outside Air Temperature (°C)	Bank Angle (deg)	Indicated Stall Airspeed (kts)
Takeoff	1320	100.1	8200	-2.0	0	51
Climb	1320	100.1	7920	-1.0	0	52
Cruise	1320	100.1	7820	-0.5	0	52
Glide	1330	100.1	7820	-0.5	0	51
Landing	1320	100.1	7740	-1.0	0	52
Cruise	1320	100.1	7500	-0.5	51L	63
Landing	1320	100.1	7300	0.0	45L	60

of 1325 lb was obtained during approaches made at 70 KIAS with a touchdown airspeed of 61 KIAS. At this condition the ground roll distances ranged from 805 to 910 feet. The landing performance capabilities of the CSATB configured LONG-EZ compared favorably with previously obtained results for the basic aircraft.

HANDLING QUALITIES

General

14. A limited handling qualities and pilot workload evaluation of the CSATB configured LONG-EZ was conducted to determine stability and control characteristics at the test conditions listed in table 2. Emphasis was placed on operation at the maximum mission gross weight of 1325 pounds and nominal mission cg, FS 101.0 (mid). All coordinated flight maneuvers were flown in trimmed (ball-centered) flight. Where applicable, the test results were compared with basic data obtained during previous testing (refs 2 and 3, app A). Handling qualities at the mid cg were essentially identical to those obtained near the aft cg limit, FS 104.0, for the basic aircraft, and therefore, the aft cg should be limited to FS 101.5 for the CSATB configured aircraft. The roll oscillations in light to moderate turbulence were not noticeably different with the FLIR sensor installed than previously reported with extension of the landing gear and speed brake (ref 2, app A). A previously reported shortcoming of limited directional control has been eliminated by the increase in rudder area in the CSATB configured LONG-EZ aircraft. The previously reported deficiency of loss of directional control due to single point brake failure during takeoff/landing and ground handling although improved by the increase in rudder area remains a deficiency.

Control Positions in Trimmed Forward Flight

15. Control positions in forward flight were evaluated from 76 to 148 KCAS in conjunction with the airspeed calibration test at the conditions shown in table 2. The variation of control positions and pitch attitude with airspeed is shown in figures 10 and 11, appendix E, and are essentially unchanged to those obtained near the aft cg limit for the basic aircraft. The longitudinal control position variation with airspeed in level flight was conventional, in that increasing forward stick position was required with increasing airspeed. The lateral and directional control positions did not change with airspeed. Pitch attitude varied from 11 degrees nose up at 81 KCAS in the climb configuration to 10.5 degrees nose down at 149 KCAS in the cruise configuration during diving flight. Control margins at all airspeeds

exceeded 35 percent. These characteristics decreased pilot workload to accurately attain a desired airspeed within 3 knots (HQRS 3). The control positions in trimmed forward flight are satisfactory.

Trimmability

16. The capability to trim the aircraft to a given airspeed and zero control force was evaluated concurrently with other testing. The trim system of the CSATB configured LONG-EZ was identical to the basic aircraft. A detailed description of the trim system is presented in USAAEFA Project No. 82-18, (ref 2, app A).

17. The inadequate longitudinal trimmability and the inaccessibility of the lateral trim system are previously reported shortcomings that remain uncorrected.

18. Directional trim characteristics were satisfactory throughout the flight envelope although there was no cockpit-adjustable rudder trim. Due to the lateral-directional stability characteristics (paras 21, 28 and 29), ball-centered flight was readily maintained in any configuration or condition tested with very light rudder pedal forces.

Static Longitudinal Stability

19. The static longitudinal stability characteristics of the LONG-EZ airplane were evaluated at the conditions shown in table 2. The aircraft was trimmed in level flight at the desired trim airspeed, then stabilized in 5 KIAS increments up to 20 KIAS faster or slower than the trim airspeed while maintaining constant throttle and trim settings. Longitudinal control positions were measured and control forces qualitatively evaluated with the test results presented in figures 12 through 14, appendix E.

20. The apparent stick-free static longitudinal stability, as indicated by the variation of control force with airspeed about trim, was weakly positive for all configurations tested. The control forces about the trim airspeed were relatively light (1 to 2 lb to vary airspeed ±5 KIAS), but were not objectionable.

21. The stick-fixed static longitudinal stability, as indicated by the variation of longitudinal control position with airspeed, was weakly positive and in climb and landing configurations essentially identical. The weak stick-fixed stability was not objectionable due to positive stick-free stability. The static longitudinal stability characteristics met the requirements of

MIL-F-8785C. The static longitudinal stability of the CSATB configured LONG-EZ is satisfactory.

Static Lateral-Directional Stability

22. Static lateral-directional stability tests were performed at the conditions listed in table 2. The tests were conducted by trimming the aircraft (ball-centered), and then stabilizing in sideslips with zero turn rate at constant airspeed and engine speed (RPM). Test data are presented in figures 15 through 18, appendix E, and are essentially identical to data obtained near the aft cg limit for the basic aircraft. The sideslip indicator was a canopy-mounted yaw string. Apparent dihedral (variation of lateral control position with sideslip) and apparent directional stability (variation of directional control position with sideslip) were both positive. Directional stability was very strong as indicated by a rapid return to coordinated trim flight when the aircraft was released from sideslip. Pedal and lateral control forces were light, but provided adequate cues to out-of-trim conditions. There was no control force lightening observed. Sideforce cues (variation of bank angle with sideslip) provided an additional indication of out-of-trim conditions. The maximum sideslip angles in the landing configuration were 14 degreees left and 15 degrees right with full pedal displacement. This indicates a significant increase in the crosswind landing capabilities over the basic aircraft to a maximum crosswind landing component limitation of 25 knots from the previous limit of 15 knots. The yaw and roll control power in the power approach and landing configurations met the requirement of MIL-F-8785C. As a result, the previously reported shortcoming of limited directional control has been eliminated with the increase in rudder area.

Maneuvering Stability

23. Maneuvering stability characteristics were evaluated at the conditions presented in table 2. The variation of longitudinal control position and control force with normal acceleration was determined by trimming the aircraft in coordinated (ball-centered) level flight at 96 and 136 KCAS, and then stabilizing at incremental bank angles in steady turns, both left and right. Airspeed and power were held constant and the aircraft was allowed to descend during the maneuver. Data were obtained at each stabilized bank angle. Symmetrical pull-up and pushover maneuvers were conducted at a trim airspeed of 104 KCAS. Maneuvering stability data are presented in figures 19 and 20, appendix E, and are essentially identical to data obtained near the aft cg limit for the basic aircraft.

24. Maneuvering stability, as indicated by the variation of longitudinal control position (apparent stick-fixed stability) and control force (apparent stick-free stability) with normal acceleration, was positive (increased aft longitudinal control position and force with increased load factor) and essentially linear for all conditions tested. The longitudinal control position gradient varied from approximately 0.3 inches per g at 96 KCAS to 0.2 inches per g at 136 KCAS. Qualitatively, the longitudinal control force gradient was 5 to 7 pounds per g for all airspeeds tested. During maneuvering, normal accelerations to 3.5 g were easy to accomplish by banking the aircraft rapidly and applying a moderate amount (1/2 inch) of aft longitudinal stick. The stick-fixed and stick-free maneuvering stability is satisfactory.

25. The previously identified decrease in engine power during low g maneuvers is an uncorrected shortcoming that restricts maneuvering versatility. Additionally, on two occasions decreases in power were observed while maneuvering at 3.4 g at 104 KCAS. Release of aft stick resulted in immediate return to normal engine operation.

Dynamic Longitudinal Stability

26. The dynamic longitudinal stability characteristics were evaluated at the conditions shown in table 2. The long-term (phugoid) response characteristics were evaluated by varying the airspeed 10 and 20 KIAS above and below the trim airspeed, followed by returning the longitudinal control to the trim position (stick-fixed) or releasing the control and allowing it to seek the trim position (stick-free). Short-term dynamic characteristics, simulating gust response, were evaluated by introducing longitudinal control pulses (1 in. from trim for a duration of 0.5 sec). Representative times histories are presented in figures 21 and 22, appendix E. Test results are summarized in table 4.

27. The long-term (phugoid) response of the LONG-EZ was oscillatory, moderately damped, and not easily excited in the cruise configuration at 116 KIAS. The period was approximately 40 seconds. From trim, the phugoid caused airspeed variations of less than 3 knots, but did not degrade aircraft control. The long-term dynamic characteristics of the LONG-EZ met the requirements of MIL-F-8785C and are satisfactory.

28. Longitudinal short-term characteristics were essentially deadbeat for all test conditions, including flight in light and moderate turbulence. The short-term characteristics met the

Table 4. Dynamic Longitudinal Characteristics

Dynamic[1] Characteristics	Trim Indicated Airspeed (kt)	Period (sec)	Natural Frequency (rad/sec)	Undamped Natural Frequency (rad/sec)	Damping Ratio
Long-term	103	40	0.1686	0.1571	0.3630
Short-term	103	1.4	4.860	4.488	0.3837

NOTES:

[1]Propeller speed: 2525 RPM, Gross weight: 1330 lb, CG: FS 101.1 (mid), cruise configuration.

requirements of MIL-F-8785C. For the conditions investigated, the short-term longitudinal dynamic characteristics are satisfactory.

Dynamic Lateral-Directional Stability

Dutch Roll Characteristics:

29. The dynamic lateral-directional stability characteristics (lateral-directional damping and dutch roll characteristics) were evaluated at the conditions shown in table 2. These tests were conducted by exciting the aircraft from a coordinated level flight trim condition with either aileron pulses or doublets, rudder doublets, or release from sideslips. Time histories of representative dynamic lateral-directional responses are presented in figures 23 through 26, appendix E. The lateral-directional oscillations were heavily damped and not easily excited. The dutch roll period was approximately three seconds with a damping ratio of approximately 0.7 and roll-to-yaw ratios of approximately 1:1.5. In light to moderate turbulence without pilot inputs the dutch roll tended to damp out in two or three cycles. The dutch roll characteristics of the CSATB configured LONG-EZ are satisfactory.

Spiral Stability:

30. The spiral stability characteristics of the LONG-EZ aircraft were evaluated at the conditions shown in table 2. These tests were conducted by establishing 10 and 20 degree bank angles (both left and right) from trim conditions, using aileron or rudder only, and then after stabilizing at the prescribed bank angle, the control was slowly returned to trim. Spiral stability, as indicated by change in bank angle with elapsed time was convergent (approximately 3 to 4 seconds time to half amplitude) for both left and right turns. Any small disturbance of the lateral or directional control system or gust would result in a tendency for the aircraft to return to trim without pilot compensation. The spiral stability of the CSATB configured LONG-EZ is satisfactory.

Gust Response:

31. Roll oscillations in light to moderate turbulence (fig. 27, app E) with the FLIR sensor installed were similar to those previously reported with extension of the landing air brake. The pilot workload in turbulence required to maintain runway alignment and glide path control is essentially unchanged and remains

objectionable during the landing task. The roll oscillations in light to moderate turbulence remains a shortcoming.

Roll Control Effectiveness

32. Roll control effectiveness was evaluated at the conditions shown in table 2. These tests were initiated from trimmed unaccelerated flight conditions by applying 1/4 to full-lateral control inputs (in 0.2 sec) in approximately 1/4-inch increments without changing longitudinal or directional pedal control position. Representative time histories of airplane response with 1 inch and full deflection lateral control inputs are presented in figures 28 through 31, appendix E, and summarized for all deflections in table 5. Time required to roll 60 degrees left and right for full control deflections was 1.5 sec and 2.3 sec, respectively. Roll rates to the right appeared to be more heavily damped than to the left achieving much lower steady state roll rates. Although noticeable during the evaluation, the difference in roll rates was not objectionable while maneuvering in flight. A higher roll rate was perceived initially with the steady state rate being reached in approximately 1 second. Control forces were qualitatively determined to be light (less than 5 lb maximum) and proportional to control displacement. Roll-to-pitch and roll-to-yaw cross coupling was not noticeable and there were no adverse handling qualities. There was, however, a perceptable, but not objectionable, adverse yaw associated with the lateral control inputs. The roll control effectiveness met the Class I, Category B (light-reconnaissance airplane) requirements of MIL-F-8785C. The roll performance characteristics of the LONG-EZ are satisfactory.

Takeoff and Landing Characteristics

General:

33. Takeoff and landing characteristics were evaluated in conjunction with takeoff and landing performance testing (paras 8 and 15, respectively) and qualitatively during all other testing. A representative time history of each task is presented in figures 32 and 33, appendix E.

Takeoff:

34. During the initial portion of the takeoff roll (below 30 KIAS) in calm to variable light wind conditions (less than 7 knots) continuous to intermittent braking was required to maintain runway heading (HORS 4). With gusty crosswind conditions (up to 45 degress off the nose) at 10 to 25 knots further intermittent

Table 5. Roll Control Effectiveness[1]

Control Deflection (in.)	Roll Mode Time Constant (T_R-sec)	Steady State Roll Rate (deg/sec)
Left		
0.4	.13	10
0.6	.13	17
1.2	.13	20
1.8	.12	35
Right		
0.9	.10	17
1.3	.10	20
1.8	.09	22

NOTE:

[1]Trim airspeed 100 KCAS

braking was necessary up to 50 KIAS to maintain heading (HQRS 5). The minimum rotation airspeed was 56 KIAS with minimum liftoff airspeed at 65 KIAS. Control power was not available to affect an earlier rotation or liftoff at the conditions tested. Pitch attitudes were approximately 12 degrees during takeoff and were not uncomfortable to the pilot. Climbout airspeeds were easy to maintain except during gusty conditions where large uncommanded changes in roll and pitch were experienced (HQRS 6) (para 32).

Landing:

35. Landing approaches under calm to gusty crosswind conditions (10-20 knots) were accomplished at a constant airspeed with power at idle except for occasional small power applications to adjust the touchdown point. Approaches made at 75 KIAS resulted in excessive float prior to touchdown (several hundred feet). Approaches made at 70 KIAS were accompanied by very little float and the glide path to touchdown could be adequately controlled with power (HQRS 3). Approaches performed at 65 KIAS required continuous power modulation to maintain glide path control (HQRS 5) with approximately 2-3 degree higher pitch attitudes than experienced during approaches at 70 KIAS. These higher pitch attitudes further degraded the forward field-of-view by obscuring the intended touchdown point. During gusty conditions the roll oscillatons (para 32) significantly increased pilot workload necessary to maintain wings level flight during the approach (HQRS 5). Sufficient control power and authority was available during all conditions tested to affect a smooth touchdown while maintaining runway heading. Directional control requirements during the landing roll were similar to those required for takeoff below 50 KIAS. Under turbulent crosswind conditions with wind gusts to 22 knots, however, the directional control limits were reached several times during the landing flare in order to maintain runway heading (HQRS 6).

36. Based upon the demonstrated takeoff and landing characteristics and increase in sideslip capability (para 21) the maximum recommended takeoff and landing crosswind component limitation should be changed from 15 to 20 knots (ref 5, app A) for the CSATB configured LONG-EZ aircraft. A previously reported deficiency (ref 2, app A) pertaining to the loss of directional control due to single point brake failure during takeoff/landing and ground handling remains uncorrected, although improved.

Stall Characteristics

37. Stall characteristics were evaluated in conjunction with stall performance testing (para 12). During unaccelerated stalls control forces were light during the approach to the stall with very little lateral or directional control required to keep the aircraft straight and level. There was essentially no stall warning. The canard stall was defined by a docile pitch break, or pitch oscillation, at full aft longitudinal control. Deep stall reactions were characterized by a gentle nose drop, and the aircraft entered a mild longitudinal oscillation with about a 10 second period and airspeed variations of 6 to 8 KIAS. The test aircraft exhibited a slight (2-3 degree) increase in pitch break over the clean configuration tested in USAAEFA Projects No. 82-18 and 83-18 (refs 2 and 3, app. A). With the longitudinal control full aft there was no tendency for the aircraft to depart controlled flight. There were almost no lateral or directional control input requirements to maintain a desired flight path. Recovery was accomplished by release of aft longitudinal control pressure and addition of power (except for climb configuration). The aircraft immediately returned to level flight. The mild stall characteristics, ease of recovery, and mild post-stall reactions give the pilot increased confidence in his ability to operate the aircraft in the low airspeed regime. The 1g stall characteristics of the CSATB configured LONG-EZ aircraft are satisfactory. The CSATB configured LONG-EZ stall characteristics failed to meet the requirements of paragraph 3.4.2.1.1 of MIL-F-8785C, in that there was no easily perceptible warning of approaching stall. The absence of the stall warning remains a shortcoming.

38. Accelerated stalls were conducted using constant bank angle turns and applying aft longitudinal control to establish a 2 knots per second deceleration until stall occurred. There was no stall warning. The approach to stalls and post-stall reactions were mild and required almost no lateral or directional inputs to maintain roll attitude. Longitudinal control forces were considerably higher than the 1g stalls. The longitudinal control had to be pulled against the aft stop to effect a stall. The pitch break was mild and the post-stall reactions were similar to the 1g stall characteristics. The mild stall characteristics and good aircraft controllability during the stall increases the pilot's confidence to maneuver. The accelerated stall characteristics failed to meet the requirements of paragraph 3.4.2.1.1 of MIL-F-8785C, in that there was no warning of approaching a stall. The accelerated stall characteristics of the CSATB configured LONG-EZ are satisfactory.

VIBRATION CHARACTERISTICS

39. The forward flight vibration characteristics of the LONG-EZ with the FLIR sensor installed were qualitatively evaluated throughout the test program and quantitatively evaluated at the conditions listed in table 2. Three axis vibration data intended to supplement the data obtained during the initial PAE (ref 2, app A) were measured at the upper, aft, center section of the FLIR flange mount (photo 5, app C) and are presented in figures 34 through 42, appendix E. Quantitatively, vibration analysis of the FLIR mount data indicates five distinctive aircraft responses; a wing torsional resonant excitation of 15 hertz (HZ), an assymetric winglet resonant excitation of 22.9 HZ, and the first, second, and fourth harmonic of the propeller speed. These vibrations were greatest in the 95 to 105 KCAS range at propeller speeds greater than 2400 RPM. At the 4 per revolution harmonic the vibratory accelerations were between 0.6 and 0.9 g in all axes. At the same conditions, a 2/rev vibratory acceleration in the FLIR vertical axis was measured in excess of 0.8g. Qualitatively, the objectionable engine/propeller vibration characteristics experienced between 90 to 100 KCAS at power required for level flight or greater (engine RPM 1900-2800) are essentially unchanged. As previously reported, the engine/propeller vibration characteristic between 90 to 100 KCAS at power required for level flight or greater remains a shortcoming.

NIGHT EVALUATION

40. A qualitative night evaluation was conducted to determine the suitability of the cockpit lighting, instrument displays, and landing light during night operations. Night visibility and internal and external light reflectivity characteristics on the canopy were evaluated on the ground by covering the canopy to simulate "black night" conditions and during actual night flight over both sparsely lighted and mid to high density lighted (city and airport) areas between 500 to 3000 feet above the ground. Takeoff, approach and landing tasks were performed to a fully lighted US Air Force standard Level 1 (minimum), Level 3 (medium) and Level 5 (maximum) runway environment, with and without use of the landing light. Adequate cockpit and instrument lighting was attainable through use of the instrument panel lights rheostat control and integral lighting features of primary flight instruments and avionics equipment with no apparent degradation in the night field-of-view. Additionally, piloting tasks such as reading of kneeboard data or map navigation was easily accomplished through use of the instrument panel lights set to approximately 70 percent of maximum intensity without objectionable internal

light reflections on the canopy. Objectionable internal light reflections on the canopy (approximately 10 percent of the center forward field-of-view) occurred whenever the landing light was illuminated. To minimize this effect the pilot positioned his left leg over the landing light control lever panel to partially shield the landing light glare. Use of the landing light was essential to prevent high round-out (approximately 10 to 15 ft above the ground) during the landing flare for all levels of runway lighting tested. The objectionable internal light reflections of the landing light on the canopy is a shortcoming.

ELECTRO-MAGNETIC COMPATABILITY

41. Qualitative evaluation of installed electrical and avionics equipment electro-magnetic compatibility was conducted throughout the test program. During the ground night cockpit lighting evaluation, it was observed that the King Instruments, Inc., KLS-55A compass system, precessed at a constant rate when the instrument light rheostat was adjusted to greater than 50 percent intensity even through the circuit breaker controlling the compass system was deactivated. When power was applied to the compass system the precession ceased once the system was aligned with the heading flux valve. Subsequent variation of the instrument light rheostat had no apparent effect on the compass system and was not objectionable to the pilot. As previously reported, the false increase in propeller speed indications caused by the very high frequency transmitter remains a shortcoming.

MISCELLANEOUS

Weight and Balance Determination

42. Prior to flight testing, a weight and balance determination was conducted on the aircraft in the instrumented configuration, both with and without crew. A post-evaluation weighing was conducted to verify gross weight and cg location after test instrumentation was removed. The aircraft basic weight and cg were 995 lb at FS 110.58 uninstrumented, and 1093.2 lb at FS 109.1 instrumented.

Pitot-Static System Calibration

43. The pitot-static position error of the standard ship's system was determined at conditions presented in table 2 using the calibrated pace method. The test results are presented in figure 43, appendix E. The maximum position error was +6 knots

at 80 KIAS and gradually decreased to a 1 knot error within the airspeed range of 120 to 150 KIAS. The position error characteristics of the ship's airspeed system are unchanged by the FLIR installation.

Engine Cooling Characteristics

44. Engine cooling characteristics were evaluated throughout the tests and at the conditions listed in table 2 during maximum continuous power climbs from 86 to 106 KCAS. During the tests the outside air temperature varied from 22 to 78 degrees fahrenheit. Cylinder head temperatures were consistent with previously reported data and within recommended operating limits. The number four cylinder continues to indicate the highest temperature.

CONCLUSIONS

GENERAL

45. The following conclusions were reached upon the completion of the PAE evaluation of the CSATB configured LONG-EZ aircraft.

a. The performance capabilities and handling qualities are adequate for the CSATB evaluation including night operations (para 6).

b. Modification of the basic airframe to the CSATB configuration (with the FLIR sensor installed) resulted in an equivalent flat plate area (F_e) increase of 2.09 square feet in the cruise configuration and 0.76 square feet for the landing configuration (para 10).

c. Handling qualities at the mid cg were essentially identical to those obtained near the aft cg limit, FS 104.0, for the basic aircraft, and therefore, the aft cg should be limited to FS 101.5 for the CSATB configured aircraft (para 14).

d. There were no new deficiencies and one additional shortcoming identified during this evaluation (para 6).

e. One previously reported shortcoming of limited directional control has been eliminated (para 22).

DEFICIENCY

46. The following deficiency was identified during the initial PAE evaluation of the LONG-EZ aircraft and has not been corrected: The loss of directional control due to single point brake failure during takeoff/landing and ground handling (para 36).

SHORTCOMINGS

47. The following new shortcoming was identified: The objectionable internal light reflections of the landing light on the canopy (para 40).

SPECIFICATION COMPLIANCE

48. The LONG-EZ aircraft met all the requirements of the specification, MIL-F-8785C against which it was tested except for paragraph 3.4.2.1.1 in that there was no easily perceptible warning of approaching stall (para 37 and 38).

RECOMMENDATIONS

49. The uncorrected deficiency identified during this evaluation should be corrected as a matter of highest priority if development continues (para 6).

50. The shortcoming should be corrected prior to production (para 6).

51. Incorporate the following NOTE from para 9 of this report in the operator's manual:

NOTE

> An abrupt decrease in both indicated airspeed (typically 3 to 6 knots) and pressure altitude (approximately 50 feet) will occur coincident with rotation due to an apparent static port position error change.

APPENDIX A. REFERENCES

1. Federal Air Regulation, Federal Aviation Administration, FAR Part 21, *Certification Procedures for Products and Parts,* 1 January 1981.

2. Final Report, USAAEFA Project No. 82-18, *Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc. LONG-EZ Airplane,* June 1983.

3. Letter Report, USAAEFA No. 83-18, Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory Inc. LONG-EZ Airplane (S/N 1241), 15 December 1983.

4. Letter, AVSCOM, DRSAV-E, 9 March 1984, subject: Test Request No. 84-04, Preliminary Airworthiness Evaluation of Rutan Aircraft Factory, Inc. LONG-EZ with External Sight.

5. Owner's Manual, *Rutan Aircraft Factory, Inc, LONG-EZ Aircraft,* Second edition, October 1981,

6. Letter, AVSCOM, DRSAV-E, 14 March 1984, with revision 1, 23 March 1984, subject: Airworthiness Release for Rutan Aircraft Factory (RAF), Inc. LONG-EZ Aircraft S/N 1241.

7. Flight Test Manual, Naval Air Test Center, FTM No. 104, *Fixed Wing Performance,* July 1977.

8. Flight Test Manual, Naval Air Test Center, FTM No. 103, *Fixed Wing Stability and Control,* 1 January 1975, revised 1 August 1972.

9. Military Specification, MIL-F-8785C, *Flying Qualities of Piloted Airplanes,* 5 November 1980.

10. Federal Air Regulation, Federal Aviation Administration, FAR Part 91, *General Operating and Flight Rules,* 1 January 1981.

11. Sighard, F. Hoerner, *Fluid Dynamic Drag,* 1965

APPENDIX B. DESCRIPTION

GENERAL

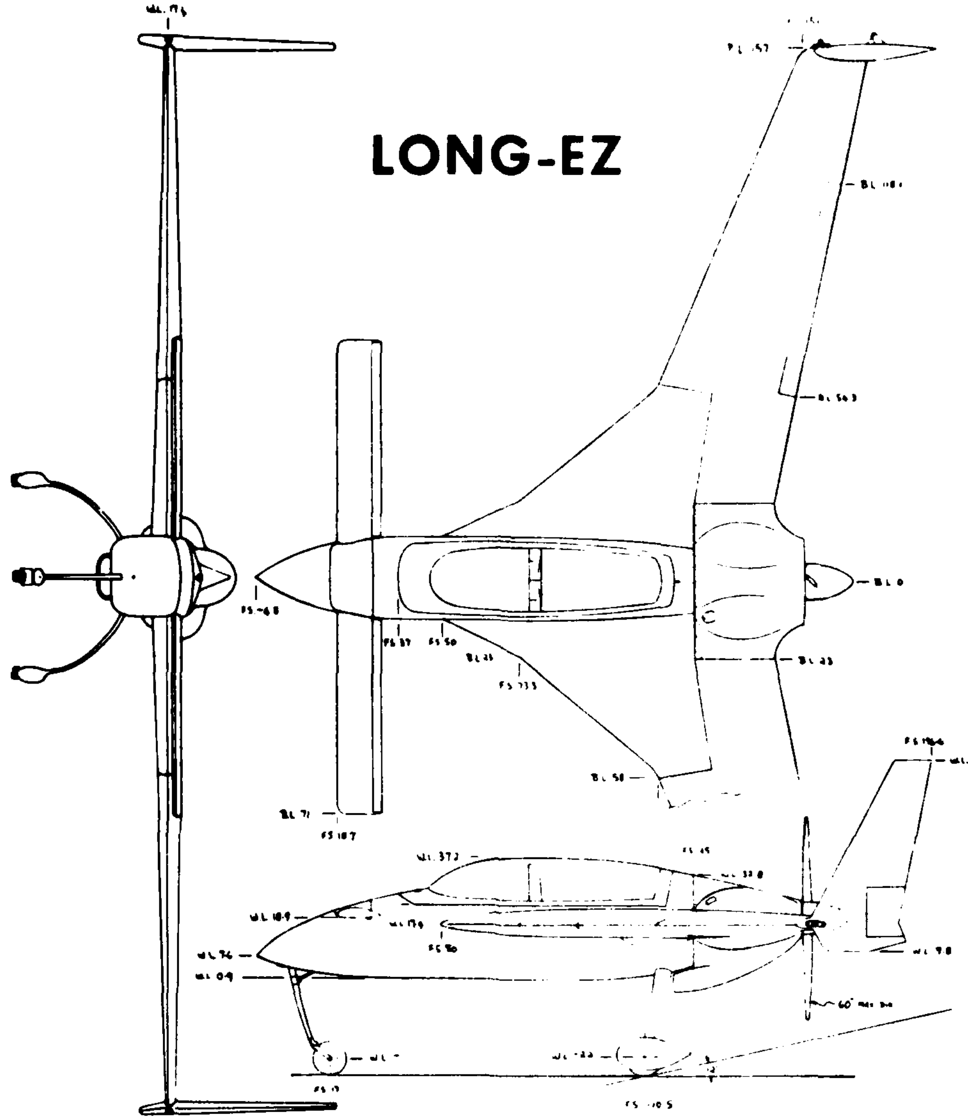
1. The LONG-EZ airplane is a small, lightweight, home-built experimental class aircraft designed by Rutan Aircraft Factory (RAF), Inc. and privately constructed according to the LONG-EZ manufacturing plans. It is certified under FAR Part 21 (ref 1, app A) and operated in accordance with the provisions of FAR Part 91.42 (ref 10, app A). A complete description of the unmodified aircraft is contained in the owner's manual (ref 5, app A) and a three-view drawing of the aircraft with dimensions and general data is presented in figure 1.

COMBAT SURVEILLANCE AIRBORNE TEST BED (CSATB)

2. The basic LONG-EZ airplane has been modified to the CSATB configuration by the addition of a mission equipment package consisting of an external, belly mounted, forward looking infrared (FLIR) sensor, a loran receiver, a King KLS-55A compass system, and an encoding altimeter. A schematic drawing of the mission configured aircraft is presented in figure 2. Photos 1 through 4 show the test CSATB configured aircraft. The loran receiver and the compass system indicator are mounted on the front instrument panel (photo 5). A side panel has been added to accomodate front panel instruments relocated by these two systems (photo 6). Additionally, the original rudder system (1.07 sq ft), has been replaced by larger high aspect ratio rudders (1.85 sq ft), located on the winglets at the wing tips. Because of the location of the infrared sensor (directly in front of the original engine air inlet the engine cowling was redesigned for improved cooling. Two air inlets, each 60% of the size of the original, were mounted on the side of the engine underneath the wing. A landing light has been installed to accommodate night VFR operation. It is manually deployed and mounted on the belly of the aircraft in front of the air brake. Principal dimensions and airfoil geometry of the CSATB configured LONG-EZ are identical to those of the unmodified aircraft and can be found in reference 2, appendix A.

FORWARD LOOKING INFRARED (FLIR) SYSTEM

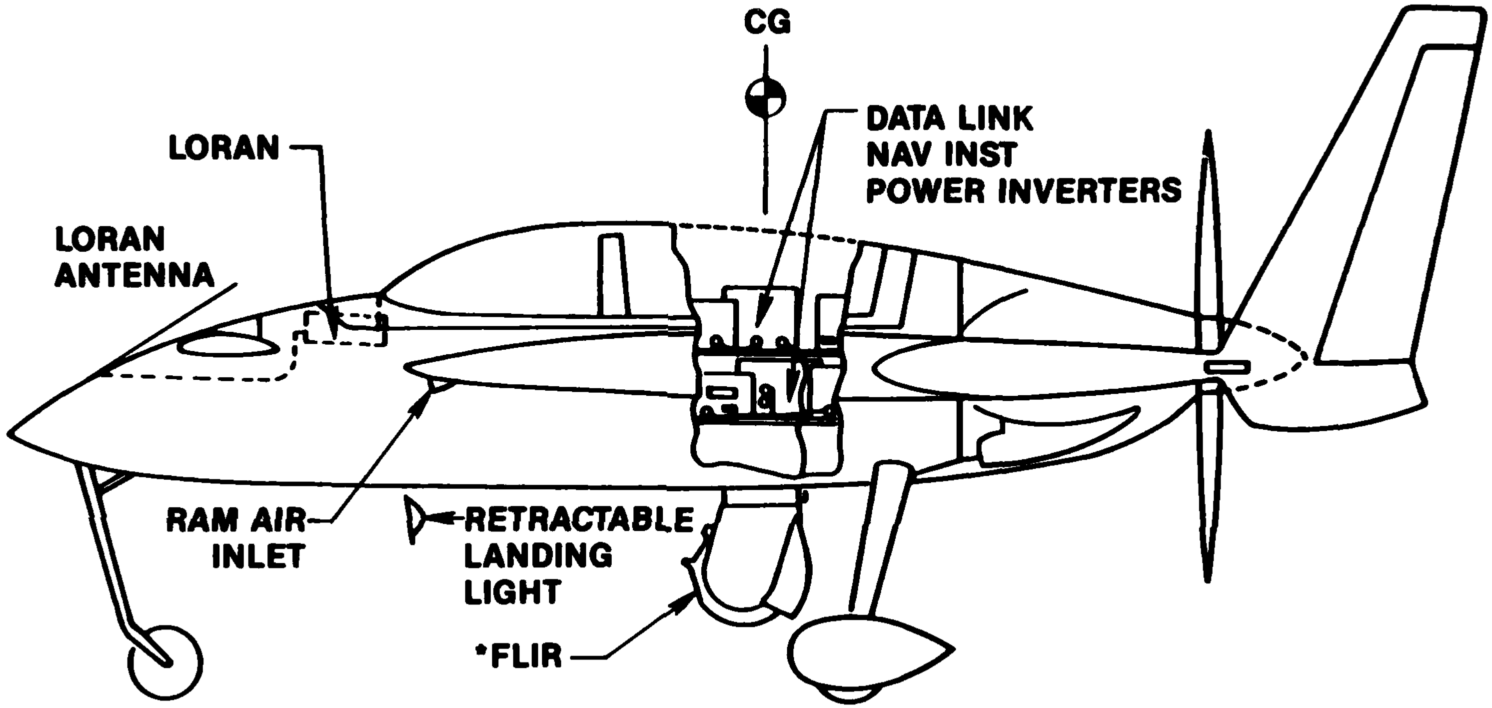
3. A series 2000 FLIR system, manufactured by FLIR Systems, Inc. of Lake Oswego, Oregon, is belly mounted at FS 100. Figure 3 depicts dimensions and weight of the external sensor component. The FLIR is supported by framing mounted in the rear cockpit seat which eliminates the rear seating capability of the CSATB configured LONG-EZ.



DIMENSIONS AND GENERAL DATA

WING SPAN	26.1 FT	ENGINE LYCOMING	0-235 L2C
WING AREA	94.8 SQ FT	RECOMMENDED FUEL	100LL OR 100/130
CABIN		MAX FUEL CAPACITY	52 GALLONS
LENGTH	100 IN	MAX GROSS WEIGHT	1325 LBS
WIDTH	23 IN		
HEIGHT	37 IN		

Figure 1. Dimensions and General Data



*POSSIBILITY OF CCD VIDEO CAMERA MOUNTED IN FLIR OR VIDEO CAMERA(S) ON INTERCHANGEABLE TWO-AXIS GIMBAL ASSEMBLY

Figure 2. Mission Configured LONG-EZ

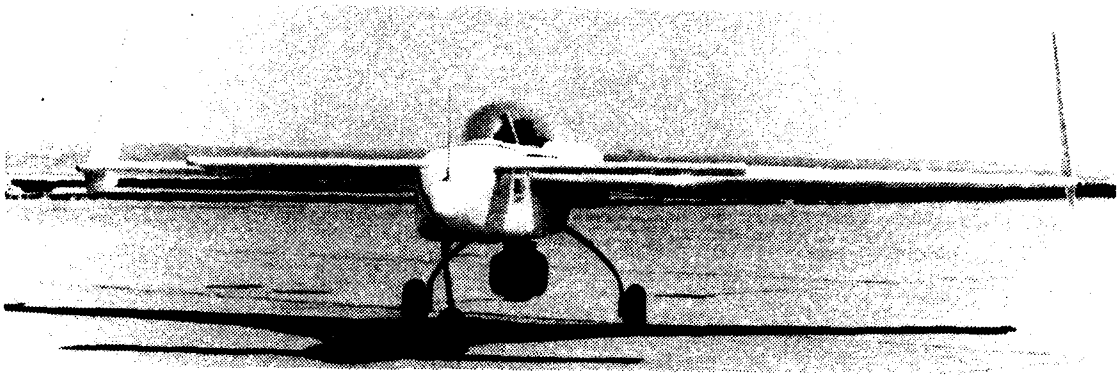


Photo 1. Left Quartering Front View

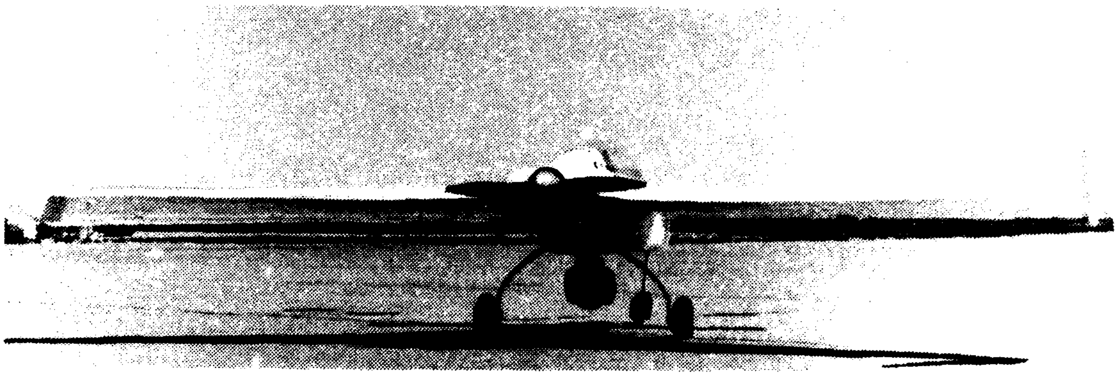


Photo 2. Right Quartering Rear View

Photo 3. Left Side View

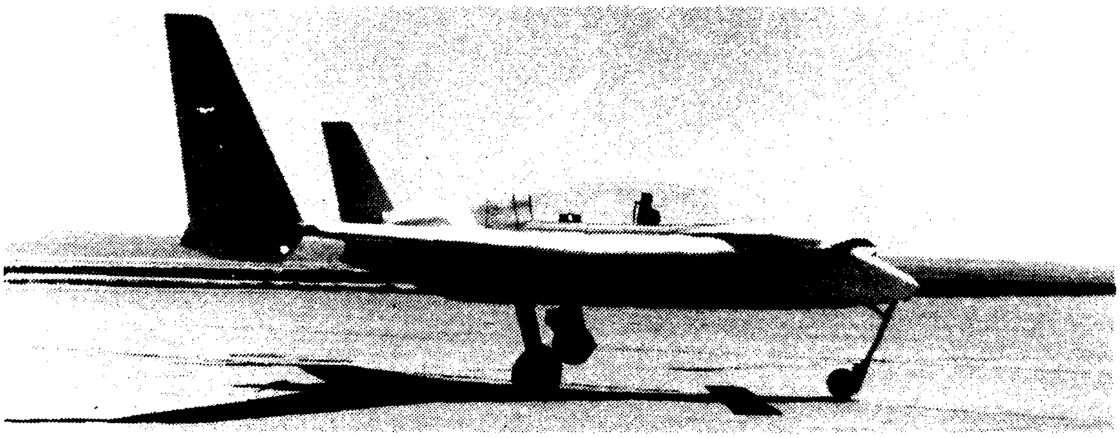


Photo 4. Right Side View

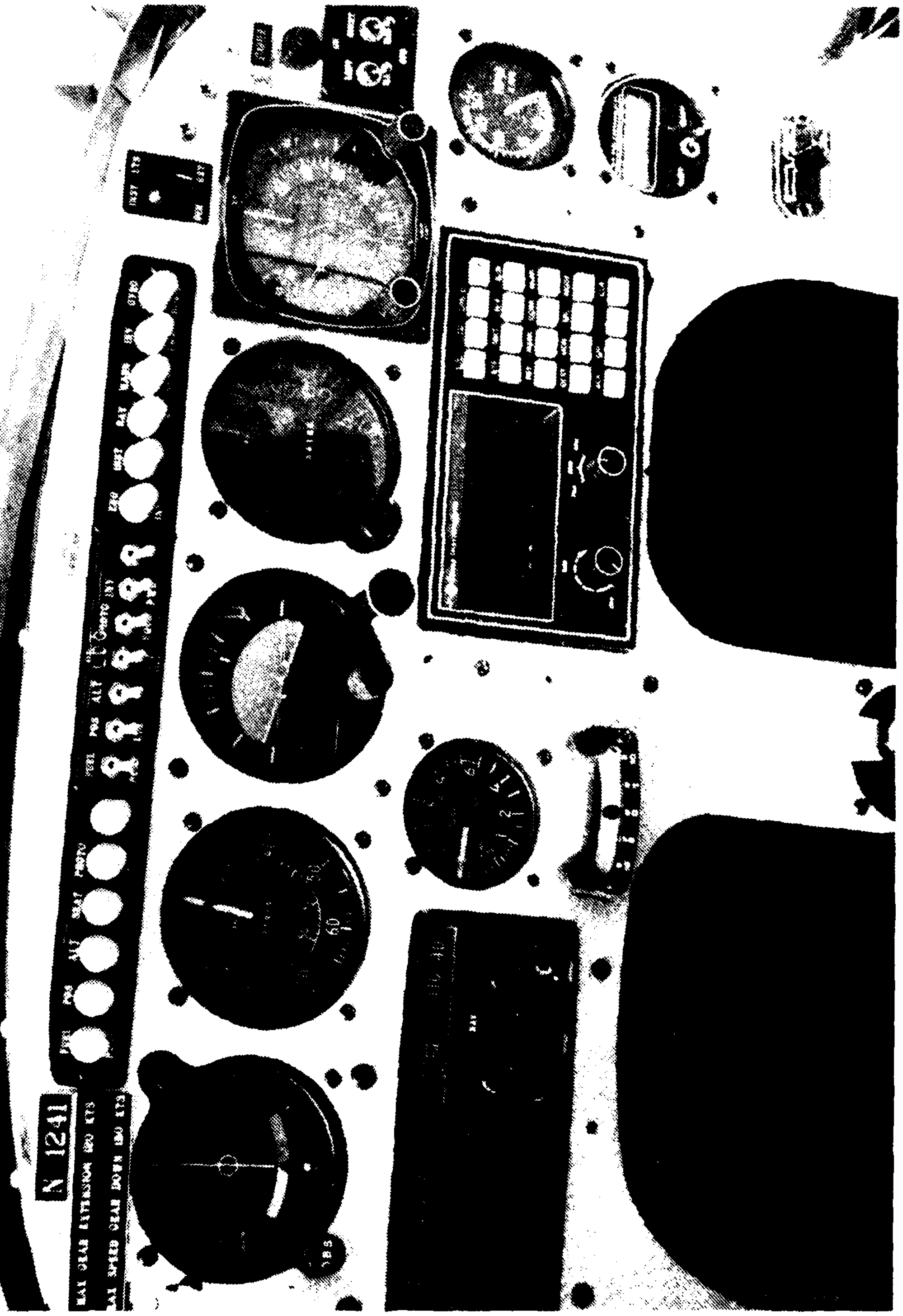


Photo 5. Front Instrument Panel

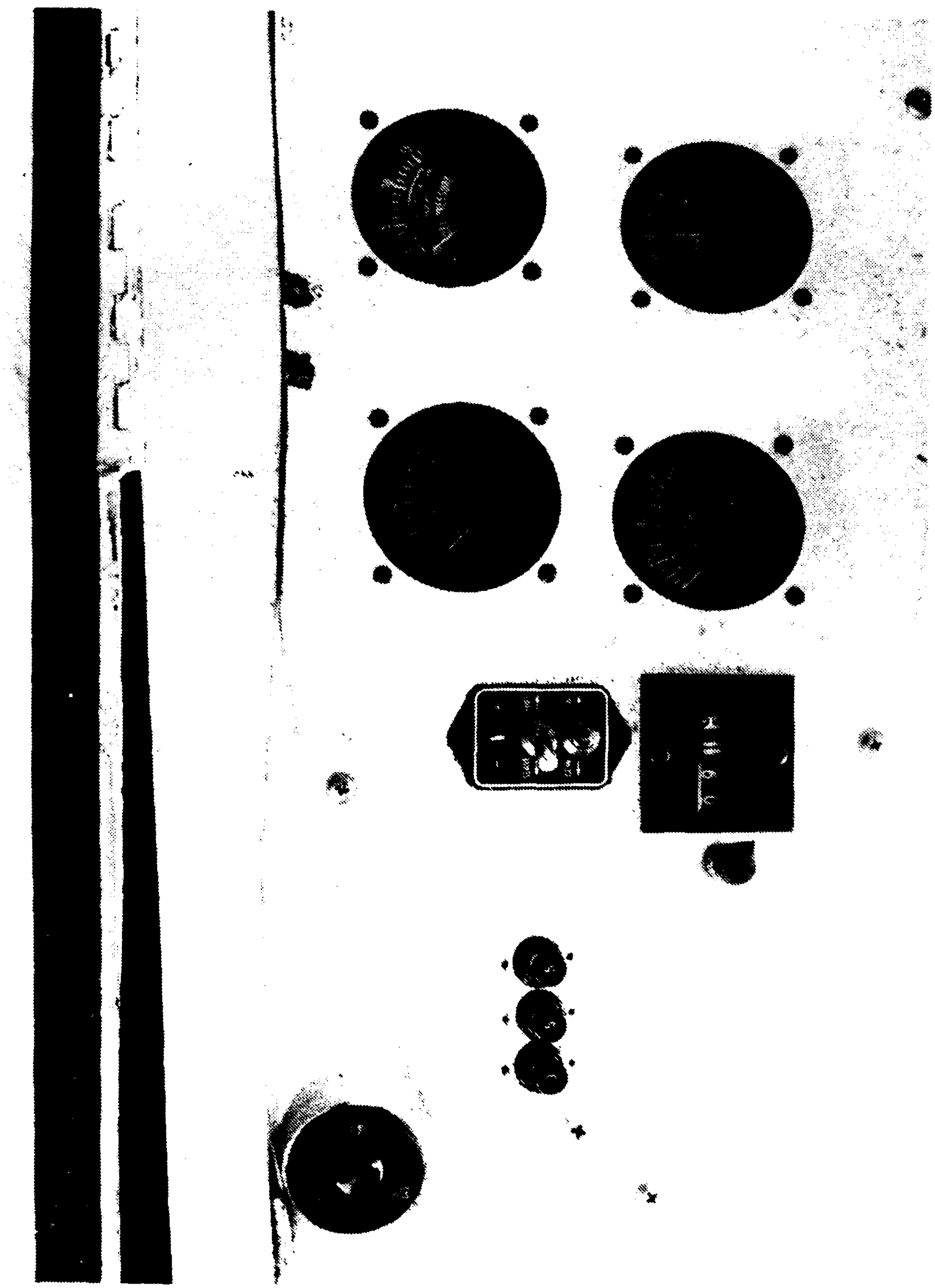


Photo 6. Right Side Instrument Panel

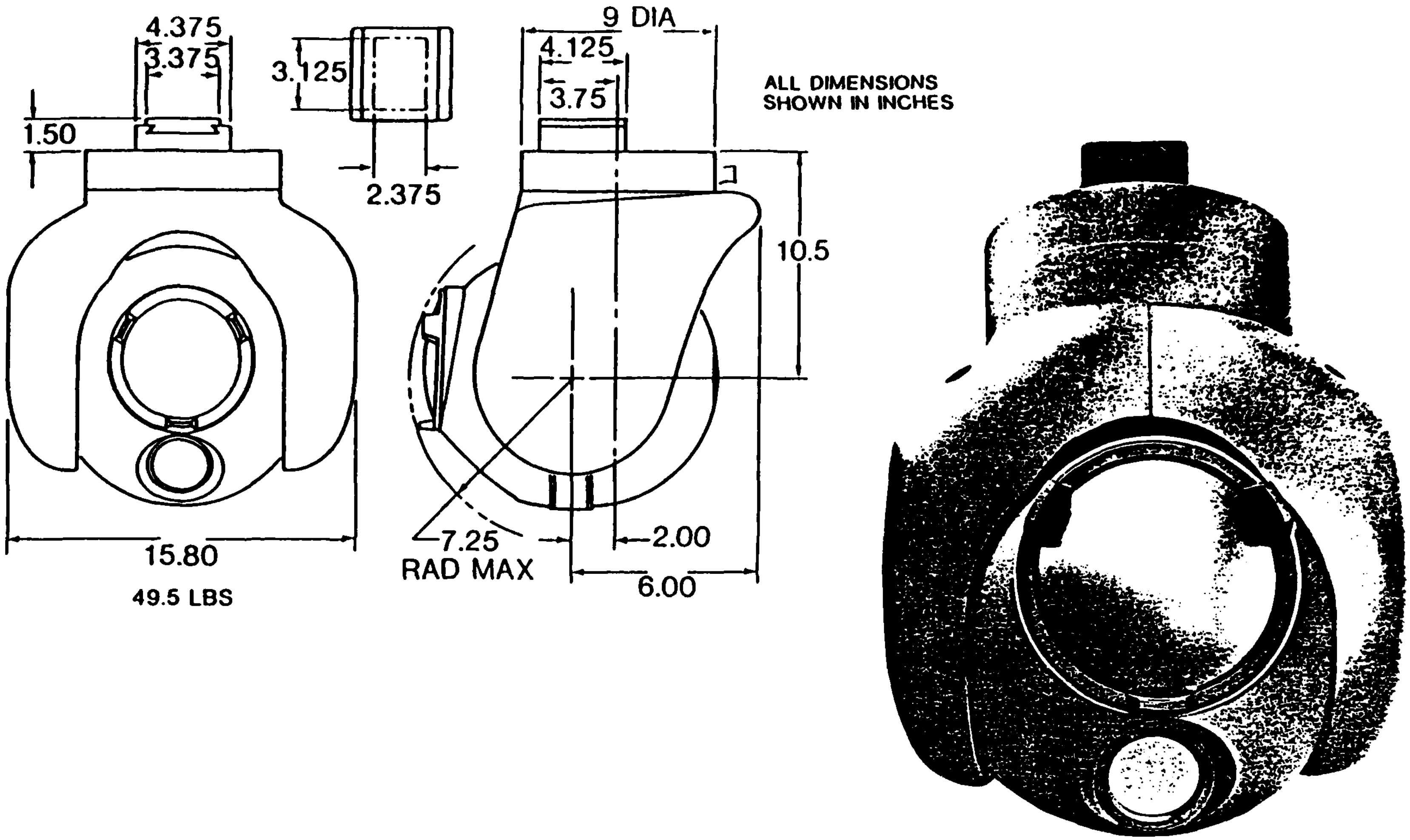


Figure 3. 2000A System Size and Weight

FLIGHT CONTROLS

4. The LONG-EZ is equipped with a reversible type mechanical flight control system actuated through the side-arm control stick (pitch and roll) and rudder pedals (yaw). Flight controls are provided only in the front cockpit of the CSATB configured LONG-EZ. The control stick normally located in the rear seat has been removed in the CSATB configured aircraft. The cockpit flight controls are identical to those described in reference 2, appendix A. Control system rigging is presented in table 3.

Table 3. Control System Rigging

Control	Average Measured	Tolerance
ELEVATOR		
<u>Left</u>		
Travel		
Trailing edge up	22.0°	20°±2° TEU
Trailing edge down	20.7°	22°± 2° TED
Free play (static)	0.04 in.	-----
<u>Right</u>		
Travel		
Trailing edge up	21.1°	20°±2°TEU
Trailing edge down	20.4°	22±2° TED
Free play (static)	0.04 in.	-----
Total longitudinal control travel	2.5 in.	
AILERONS		
<u>Left</u>		
Travel		
Trailing edge up	2.0 in.	2.1 in.±0.3in. TED
Trailing edge down	1.92 in.	2.1 in.±0.3in. TED
Free play (static)	0.1 in.	-----
<u>Right</u>		
Travel		
Trailing edge up	2.05 in.	2.1 in.±0.3in. TEU
Trailing edge down	2.1 in.	2.1 in.±0.3in. TED
Free play (static)	0.02 in. TED	
Total lateral control travel	3.7 in.	
RUDDERS		
Left deflection	5.9 in.	6 in.±0.5 in.
Total left directional control travel	1.4 in.	
Right deflection	5.75 in.	6 in.±0.5 in.
Total right directional control travel	1.17 in.	

APPENDIX C. INSTRUMENTATION

1. An airborne data telemetry system was installed and maintained by USAAEFA. The system utilized pulse code modulation (PCM) encoding and incorporated a self-contained 24 VDC power source with sufficient capacity for a minimum of one hour test duration. The data was transmitted to the Real Time Data Acquisition and Processing (RDAPS) for processing and storage.

2. Instrumentation and related special equipment installed are presented below. Photos 1 through 6 show the cockpit instrument panel, auxillary instrument panel controls, cockpit location and installation of the airborne data telemetry system, and the FLIR system vibration sensor location.

Pilot Station (Front cockpit display)

Sensitive airspeed
Sensitive normal acceleration
Calibrated altimeter
Calibrated engine speed
Cyclinder head temperatures (4)
Exhaust gas temperatures (4)

Airborne Data Telemetry System

Pilot event
Airspeed
Altitude
Pitch attitude
Roll attitude
Pitch rate
Roll rate
Yaw rate
Normal acceleration (CG)
Longitudinal control position
Lateral control position
Rudder pedal position left
Rudder pedal position right
Fuel flow
Fuel totalizer
Outside air temperature
IR sensor vertical vibration
IR sensor lateral vibration
IR sensor longitudinal vibration

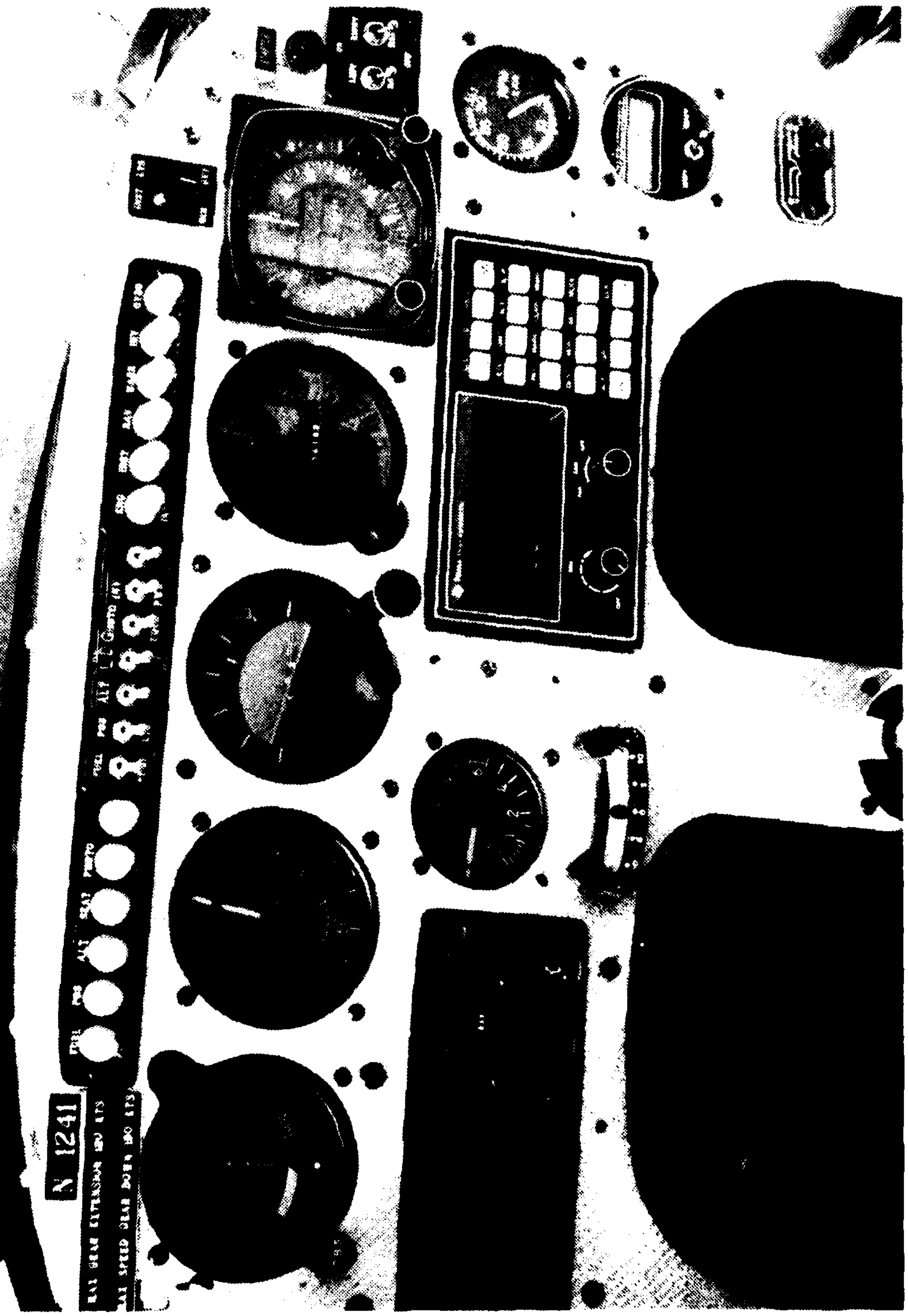


Photo 1. Cockpit Instrument Panel

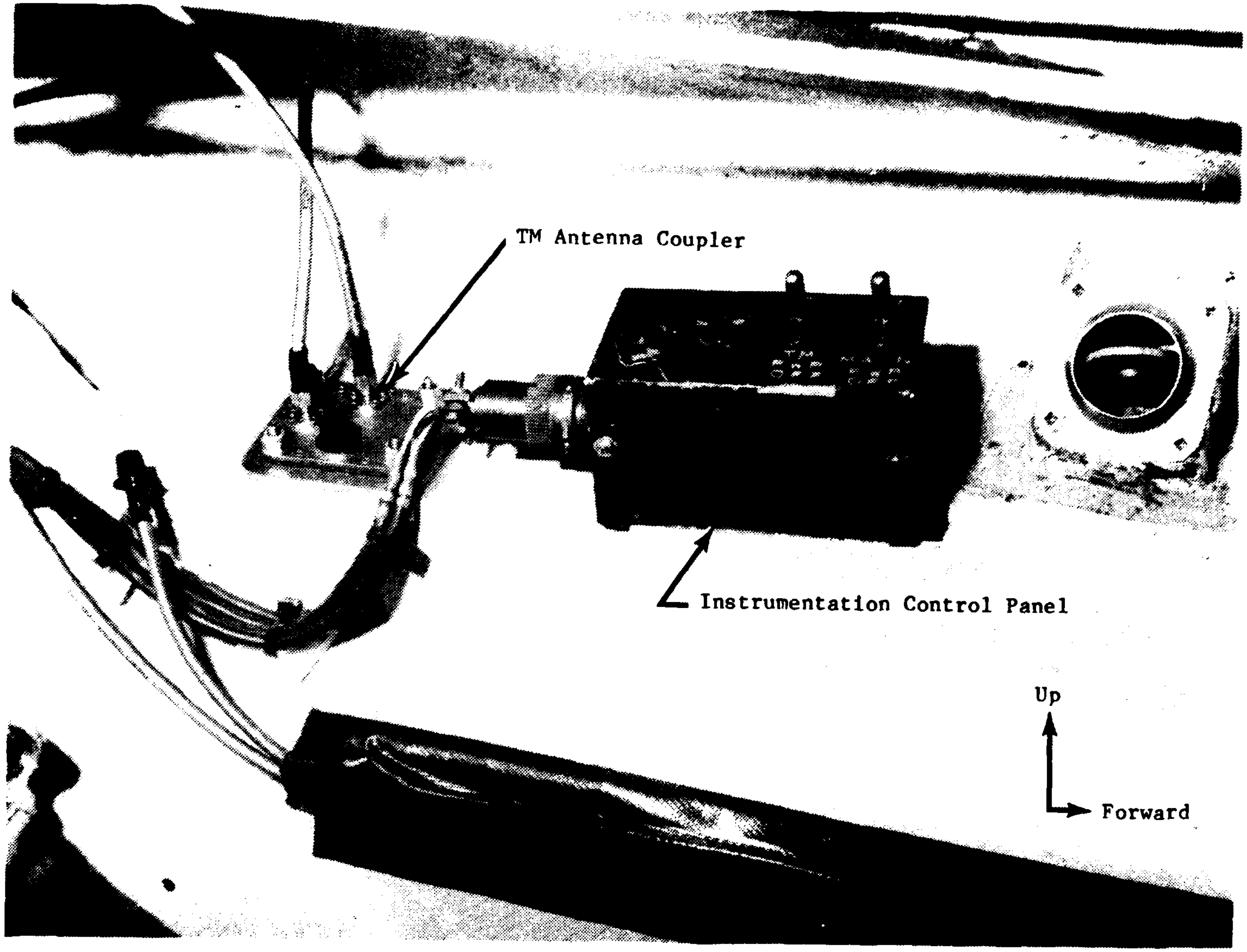


Photo 2. Auxillary Instrument Panel Controls
(Front Cockpit)

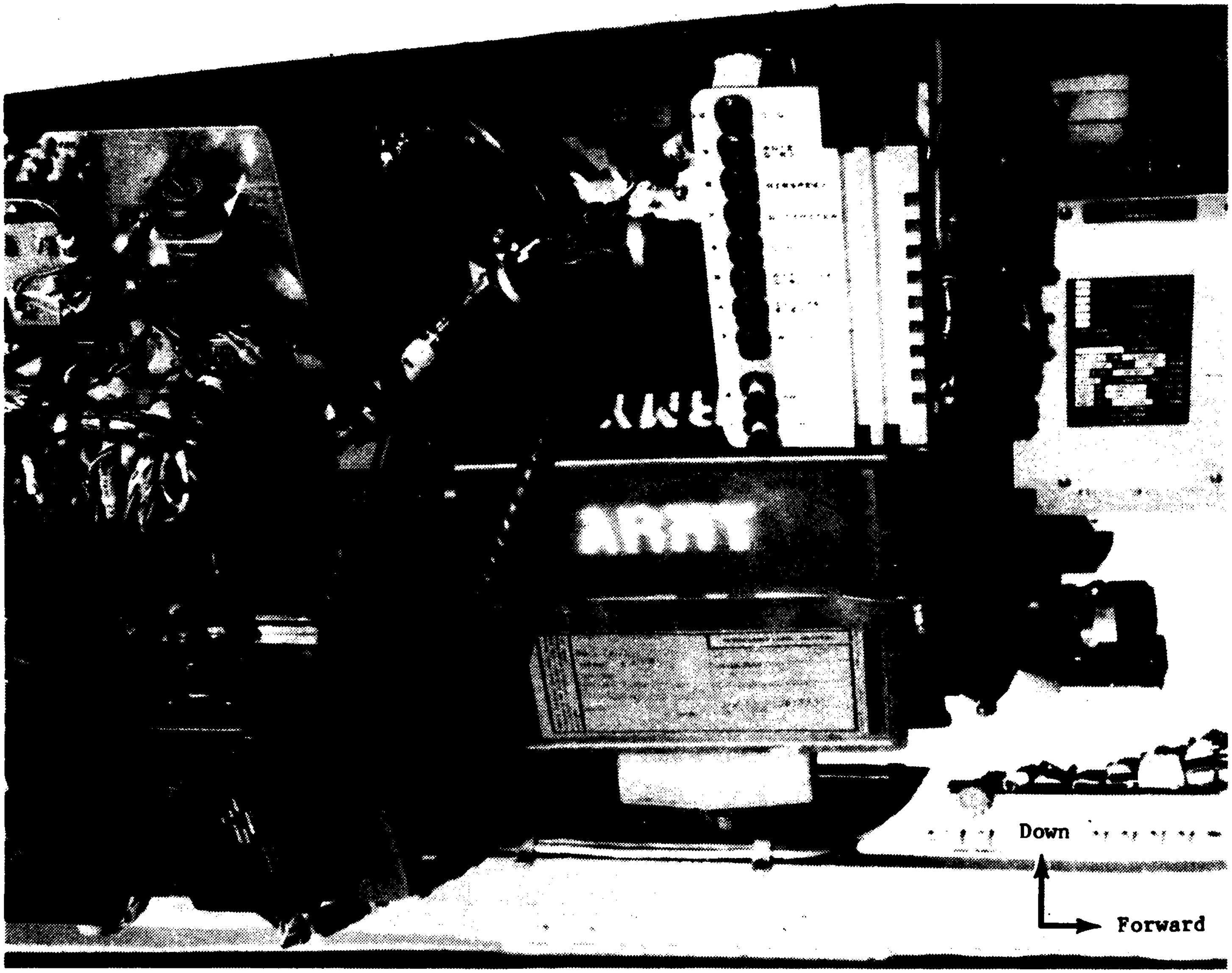


Photo 3. Instrumentation Aft Cockpit

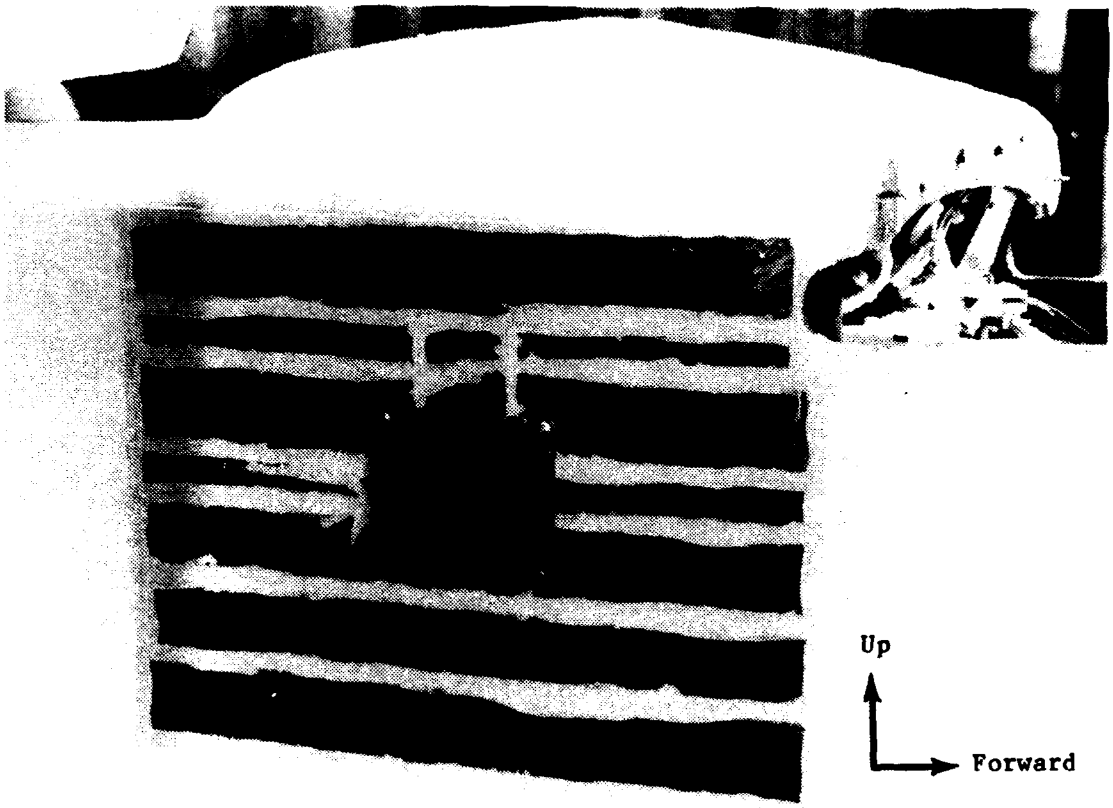


Photo 4. Right Side Telemetry Antenna

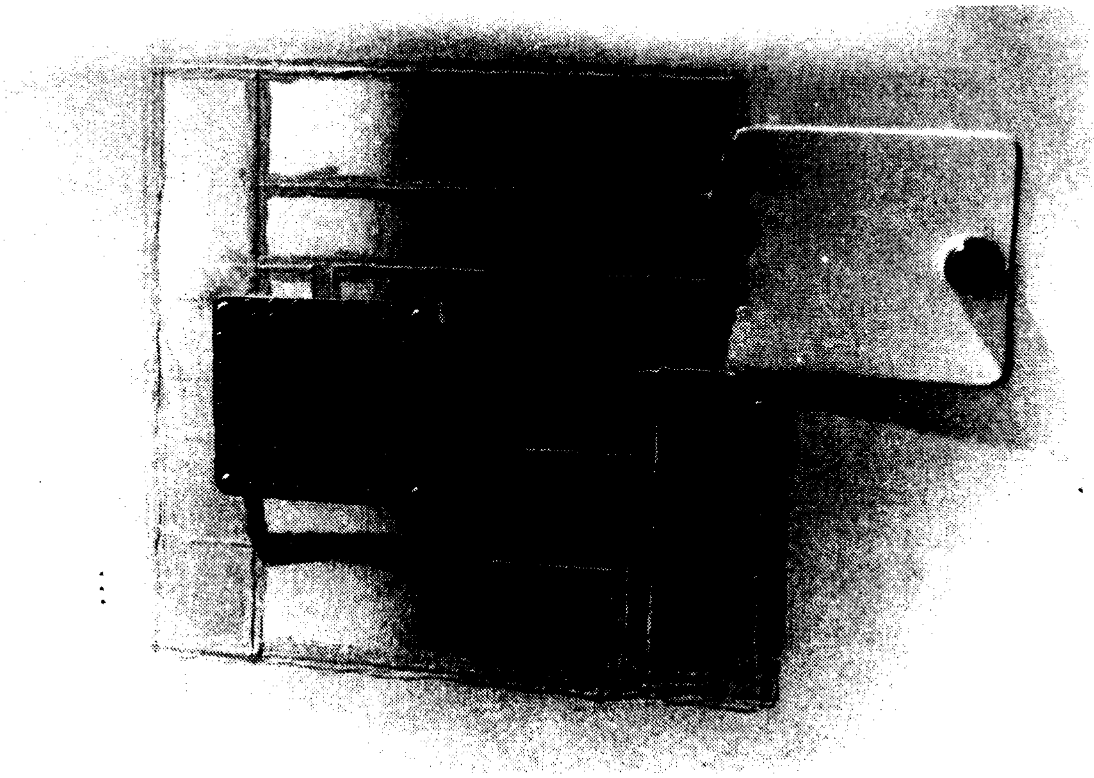


Photo 5. Left Front Fuselage - TM Antenna

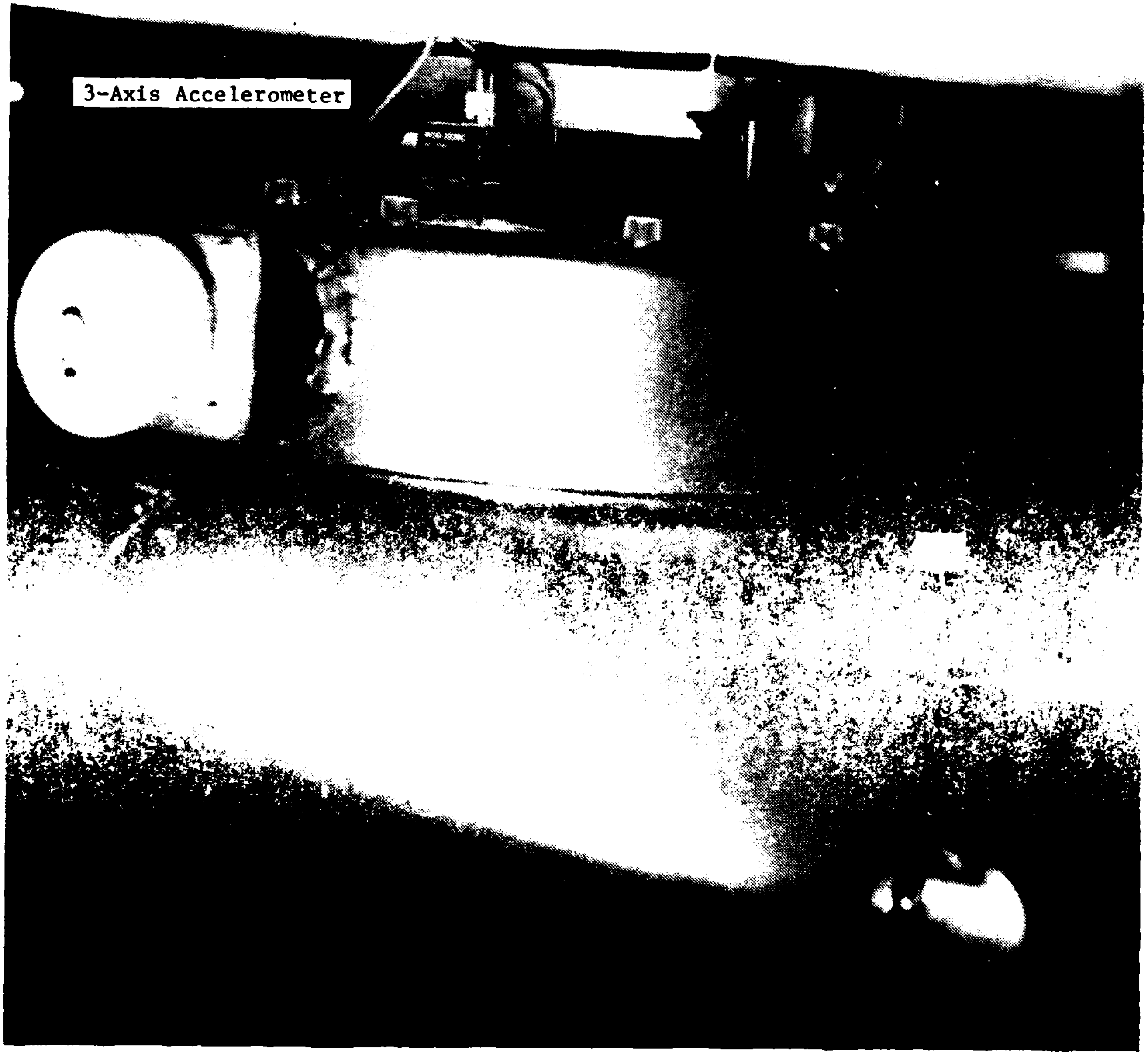


Photo 6. FLIR Flange Mount Accelerometer Location

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. This appendix contains some of the data reduction techniques and analysis methods used to evaluate the LONG-EZ aircraft. Topics discussed include glide, level flight, takeoff and landing performance, airspeed calibration, and weight and balance.

GLIDE PERFORMANCE

2. The propeller stopped glide method was used to define the drag of the LONG-EZ aircraft in the cruise and landing configurations. The method involved obtaining flight data while the aircraft was stabilized in a constant-airspeed descent with the engine shutdown and propeller stopped. Parameters measured included airspeed, pressure altitude, outside air temperature, gross weight, and elapsed time. The airspeed range from $1.1V_S$ to maximum operating airspeed with the propeller stopped was investigated through a target pressure altitude (Hp) band of 10,000 to 6,000 feet. The technique used to develop the baseline-drag equation is shown below.

$$L = W \cos \theta$$

$$D = T + W \sin \theta$$

$$DV_T = TV_t + WV_t \sin \theta$$

$$-V_T \sin \theta = \frac{dh}{dt} = \frac{TV_t - DV_t}{W}$$

Where:

L = Lift force (lb)

W = Aircraft gross weight (lb)

θ = Descent angle (deg) = $\sin^{-1} \frac{dhp/dt}{V_T}$

T = Net thrust (lb) = zero with propeller stopped.

D = Drag force (lb)

V_t = Aircraft true airspeed on flight path (ft/sec)

$$\frac{dh}{dt} = \text{Tapeline rate of descent (ft/sec)} \; \frac{dH_p}{dt} \; \frac{T_{a_t}}{T_{a_s}}$$

$$\frac{dHp}{dt} \quad \text{is measured}$$

where:

T_{a_t} = test day ambient temperature (°K)

T_{a_s} = standard day ambient temperature (°K)

Considering the drag and lift force equations and applying power-off glide conditions, the following non-dimensional relationships can be developed:

$$C_D = \frac{D}{qs}$$

$$C_D = \frac{W \sin \theta}{qs}$$

$$C_L = \frac{L}{qs}$$

$$C_L = \frac{W \cos \theta}{qs}$$

Where:

C_D = Coefficient of drag

$q = 1/2 \; \rho \; V_T^2$ (lb/ft^2) dynamic pressure

S = Total wing area (ft^2)

C_L = Coefficient of lift

ρ = Air density ($slug/ft^3$)

The drag equation (C_D) was then developed by plotting C_D versus $C_L{}^2$ and fitting a first-order equation to the test points.

$$C_D = C_{DO} + \frac{\Delta C_D}{\Delta C_L{}^2} C_L{}^2$$

Coefficient of drag of the stopped propeller was determined from methods described in Hoerner's Fluid-Dynamic Drag (ref 11, app A) and the following equation.

$$C_{D_{prop}} = 0.1 + \cos^2 R$$

Where:

$C_{D_{prop}}$ = Coefficient of drag of the propeller blade

R = blade angle at 0.7 radius

The drag of the stopped propeller is then calculated from the following equation.

$$Drag_{prop} = C_{D_{prop}} \times q \times S_{blade}$$

Where:

$Drag_{prop}$ = Drag of the stopped propeller

S_{blade} = The developed blade area which includes blockage effects of the fuselage estimated to be 0.9 ft^2 for the Ted's propeller)

TAKEOFF AND LANDING PERFORMANCE

3. Takeoff and landing performance was evaluated at a constant density altitude of 2700 feet using ground observers and a visual theodolite to quantify distance.

4. Takeoff data were corrected to standard conditions. The wind correction was the first to be applied. For winds less than 5 knots, the equation is:

$$Sg_w = Sg \left(1 + \frac{V_w}{V_{To}}\right)^{1.85}$$

Where:

Sg = Ground distance (ft)

V_w = Wind velocity (ft/sec)

V_{To} = Velocity at takeoff (ft/sec)

Sg_w = Ground distance corrected for wind (ft)

Corrections for runway slope were made with the following equation:

$$Sg_{SL} = \frac{Sg_w}{1 + \frac{2g\ Sg_w \sin\theta}{V_{TO}^2}}$$

Where:

Sg_{SL} = Ground distance corrected for slope (ft)

θ = Runway slope (positive uphill in degrees)

g = Acceleration due to gravity - 32.1741 ft/sec^2

The combined equations for thrust, weight, and densi :orrections are shown below. The subscripts, t and s, refer to test data (corrected for wind and runway slope) and standard data, respectively.

$$\frac{Sg_s}{Sg_t} = \left[\frac{\frac{W_s}{W_t}\ \frac{\sigma_t}{\sigma_s}}{\frac{2g\ Sg_t}{W_t\ V_{TO_t}^2}\left(\frac{W_t}{W_s} Fn_s - Fn_t\right) + 1} \right]$$

Where:

Subscript s refers to standard data
Subscript t refers to test data
Sg = Ground distance (ft)

w = Gross weight (lb)

σ = Air density ratio

g = Acceleration due to gravity (ft/sec^2)

V_{TO} = Velocity at takeoff (ft/sec)

F_n = Mean net thrust

5. Dynamic stability characteristics were evaluated to determine the damping ratios and damped natural frequencies. They were derived for all conditions tested by the transient peak ratio.

6. The two transient peak ratio methods used for lightly damped, moderately damped, and unstable aircraft motion are the "half-amplitude" and the "double-amplitude" methods. The range of damping ratios determined by these methods is from -0.5 to +0.5. The damped natural frequencies were obtained by direct measurement of the period of oscillation and computed by the formula:

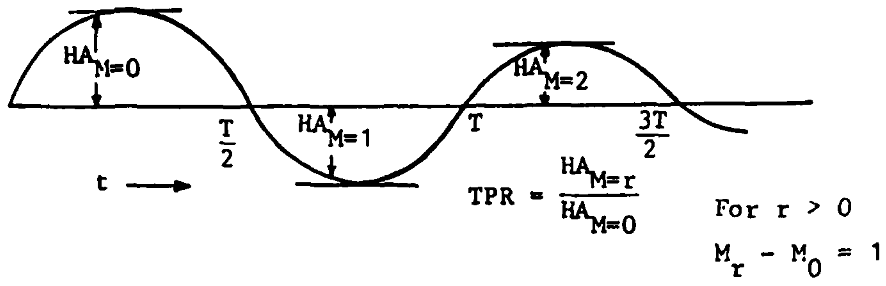
$$\omega_{damped} = \frac{1}{\tau}$$

Where:

ω_{damped} = Damped natural frequency (cycles/sec)

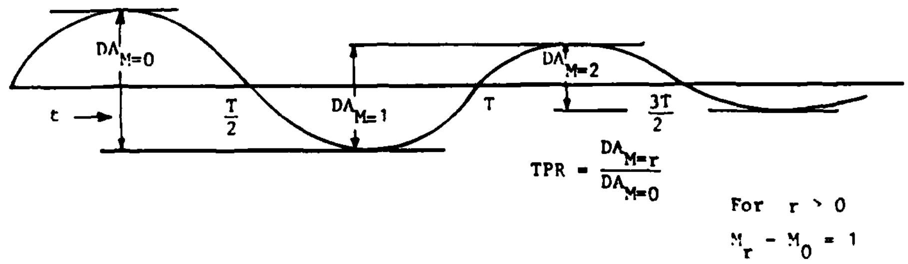
τ = The period of one oscillation from one peak to the next peak (sec)

The half-amplitude method requires that the initial steady-state value be known and that the steady state be constant. Once the steady-state value has been determined, the half-amplitudes are obtained by measuring the distance from the steady state to the maximum and minimum points of response.



Half-Amplitude Method

The double amplitude method also requires that the steady state be a constant, but if the double amplitudes are measured as shown below, the transient peak ratio can be obtained without having to establish the steady state or trim value of response.



Double-Amplitude Method

7. Roll mode time constant was determined as the time to achieve 63 percent of steady state roll rate.

AIRSPEED CALIBRATION

8. The ship's standard pitot-static system was calibrated using the pace aircraft method to determine the airspeed position error (fig. 52, app F). Calibrated airspeed (V_{cal}) was obtained by correcting indicated airspeed (V_i) for instrument error (ΔV_{ic}) and position error (ΔV_{pc}).

$$V_{cal} = V_i + \Delta V_{ic} + V_{pc} \quad (17)$$

9. Equivalent airspeed (V_e) was used to reduce the flight test data, as it is a direct measure of the free stream dynamic pressure (q).

$$V_e = V_{cal} + \Delta V_c$$

Where:

ΔV_c is the compressibility correction, $q = 0.00339 V_e^2$

10. True airspeeds (V_T) were determined from the test altitude air density ratio (σ) and equivalent airspeed, as follows:

$$V_T = \frac{V_e}{\sqrt{\sigma}}$$

<u>Weight and Balance</u>

11. Prior to the start of flight tests, the aircraft was weighed to determine weight, and longitudinal and lateral center of gravity locations. The aircraft was weighed in the following configurations:

a. Full oil, trapped fuel, no crew, and instrumentation.

b. Full oil, full fuel, no crew, and instrumentation.

c. Full oil, full fuel, crew, and instrumentation.

d. Full oil, full fuel, no instrumentation, and no crew.

<u>Rigging Check</u>

12. Mechanical rigging of engine and flight controls was checked for compliance with applicable RAF and Lycoming documents.

<u>DEFINITIONS</u>

13. Results were categorized as deficiencies or shortcomings in accordance with the following definitions.

Deficiency

14. A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if operation is continued, or indicates improper design or other cause of an item or part, which seriously impairs the equipment's operational capability. A deficiency normally disables or immobilizes the equipment; and if occurring during test phases, will serve as a bar to type classification action.

Shortcoming

15. An imperfection or malfunction occurring during the life cycle of equipment, which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the material or end product. If occurring during test phases, the shortcoming should be corrected if it can be done without unduly complicating the item or inducing another undesirable characteristic such as increase cost, weight, etc.

16. A Handling Oualities Rating Scale was used to augment pilot comments relative to handling qualities. This scale is presented in figure 1.

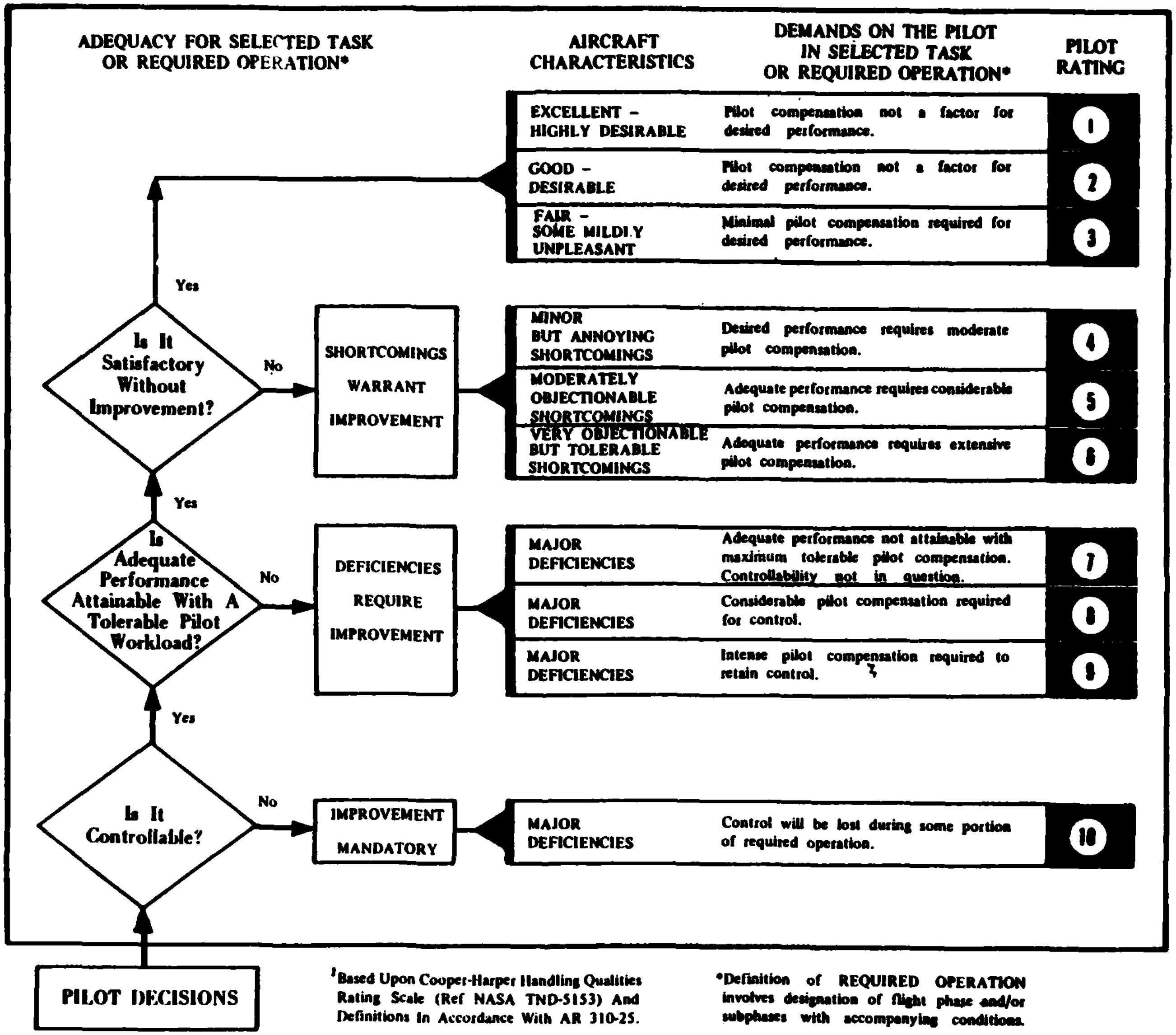


Figure 1. Handling Qualities Rating Scale

APPENDIX E. TEST DATA

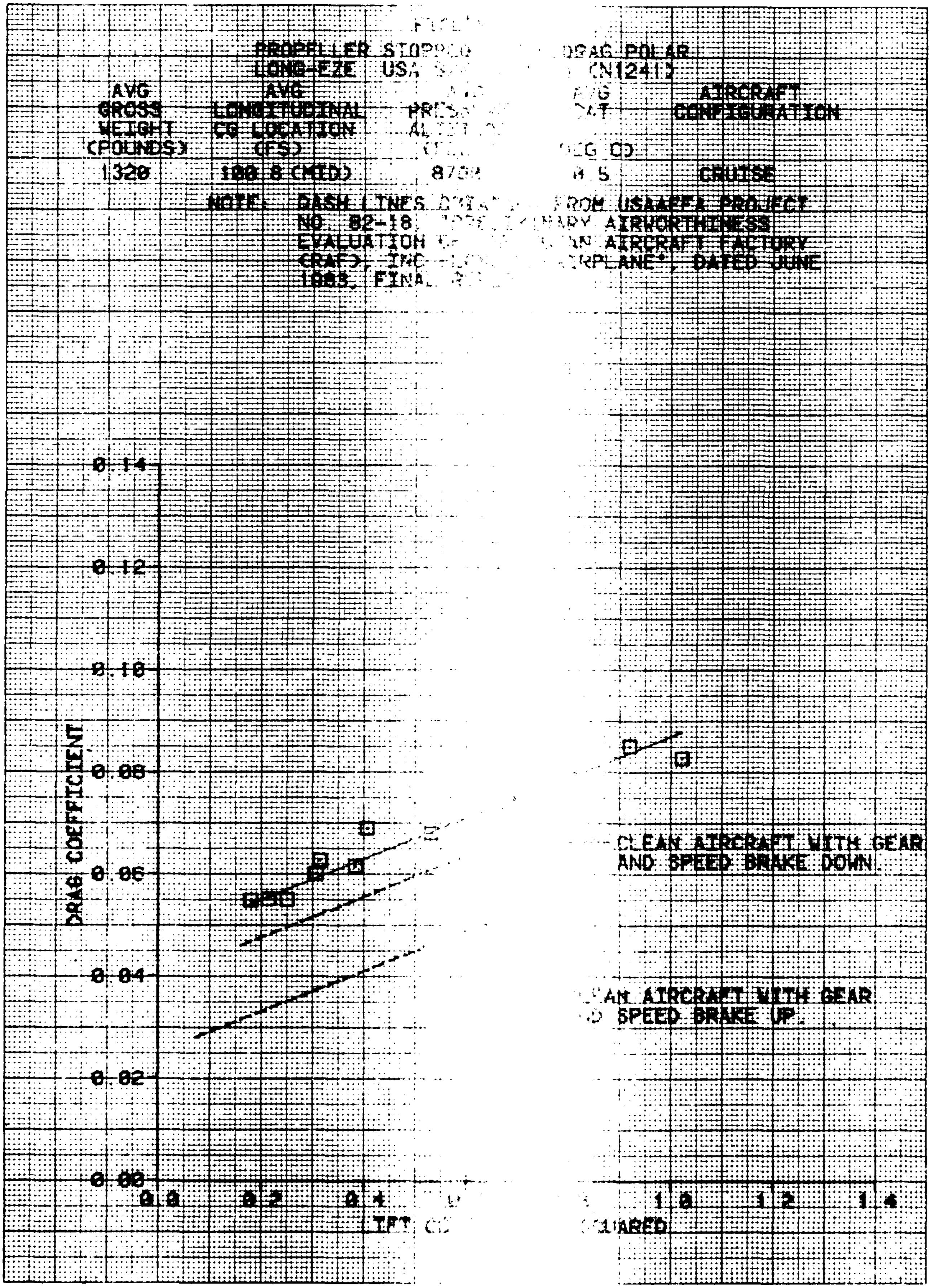

PROPELLER STOPPED
DRAG POLAR
LONG-EZE USA
(N1241)
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AIRCRAFT CONFIGURATION
1320
100.8 (MID)
CRUISE
NOTE: DASH LINES
FROM USAAEFA PROJECT
NO. 82-18,
AIRWORTHINESS
EVALUATION
AIRCRAFT FACTORY
(RAF), INC
AIRPLANE", DATED JUNE
1983, FINAL
CLEAN AIRCRAFT WITH GEAR
AND SPEED BRAKE DOWN.
AN AIRCRAFT WITH GEAR
SPEED BRAKE UP.
DRAG COEFFICIENT
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.0
0.2
0.4
1.0
1.2
1.4

FIGURE 2

STALL PERFORMANCE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	8200	-2.0	TAKEOFF

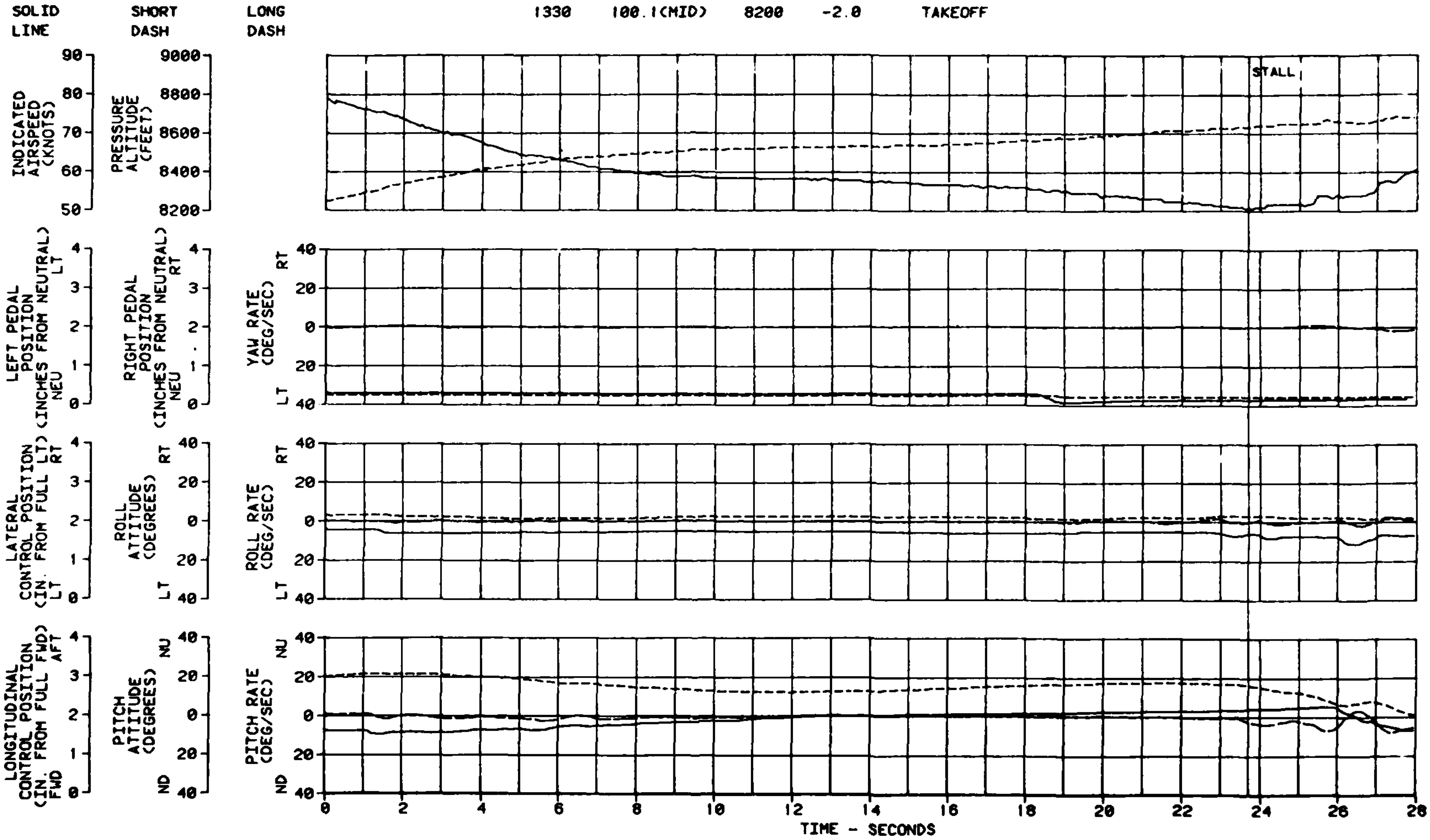


FIGURE 3
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	7920	-1.0	CLIMB

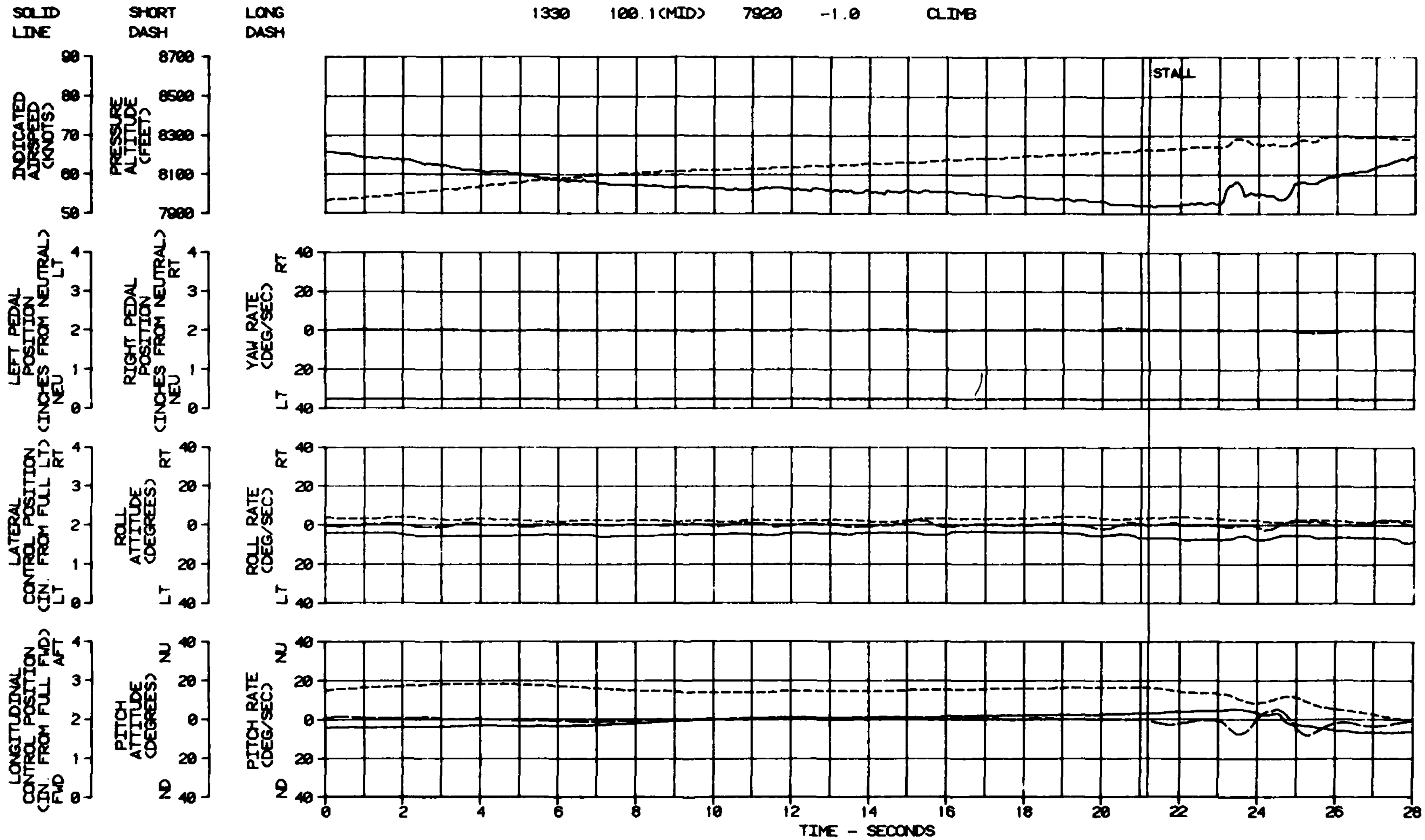


FIGURE 4

STALL PERFORMANCE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	7820	-0.5	CRUISE

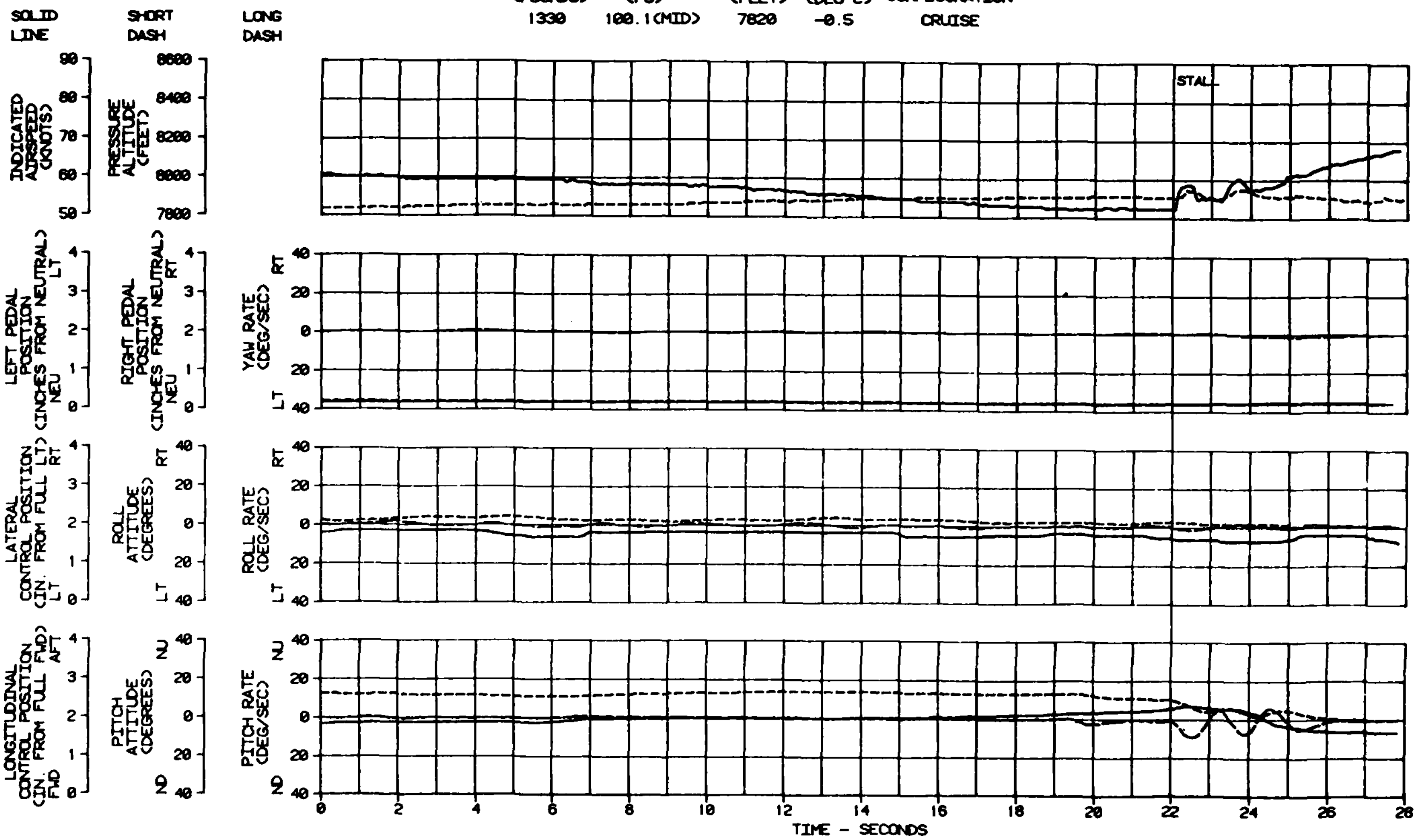


FIGURE 5
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	7380	0.5	POWER APPROACH

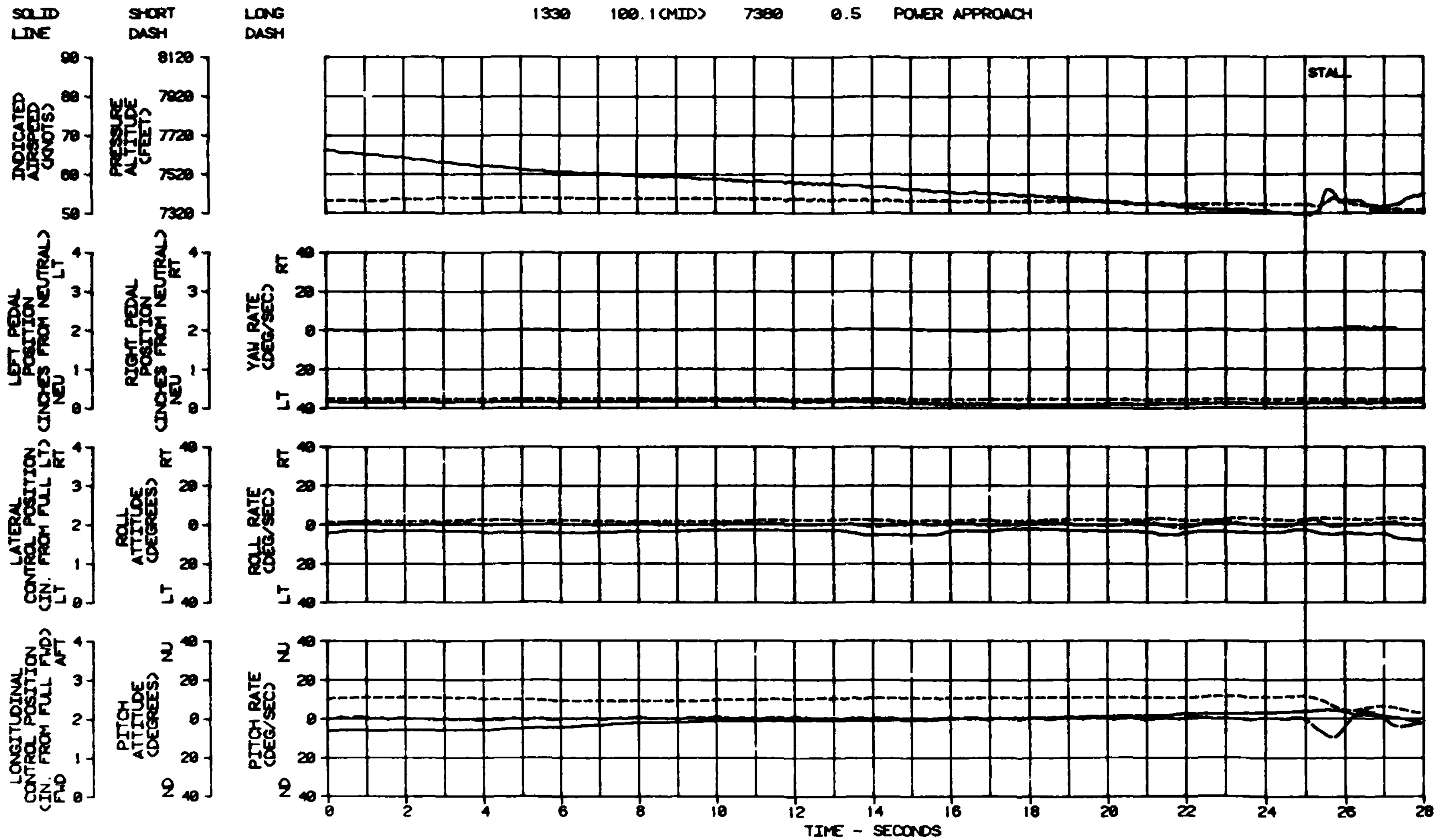


FIGURE 6

STALL PERFORMANCE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	7820	-0.5	GLIDE

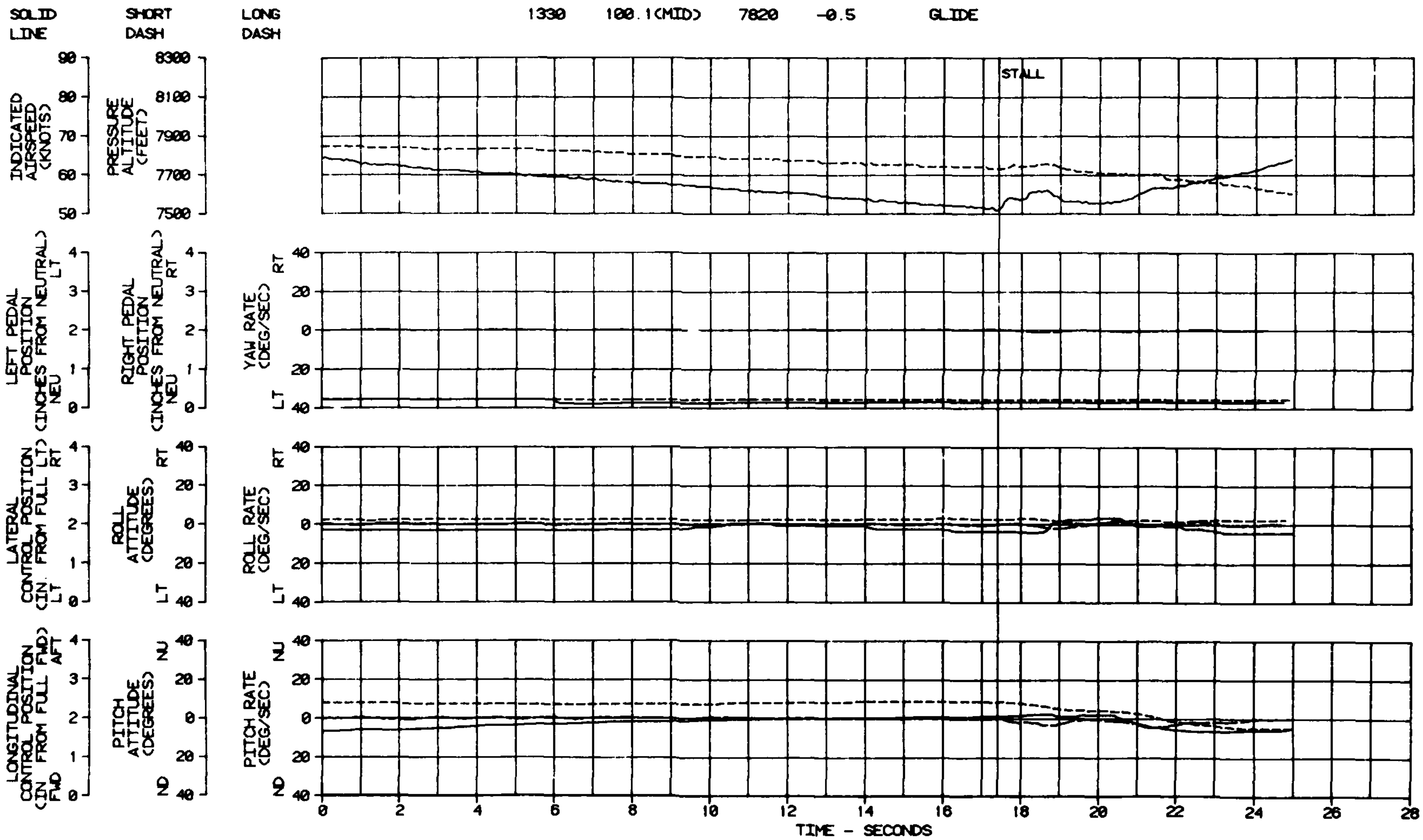


FIGURE 7
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	7740	-1.0	LANDING

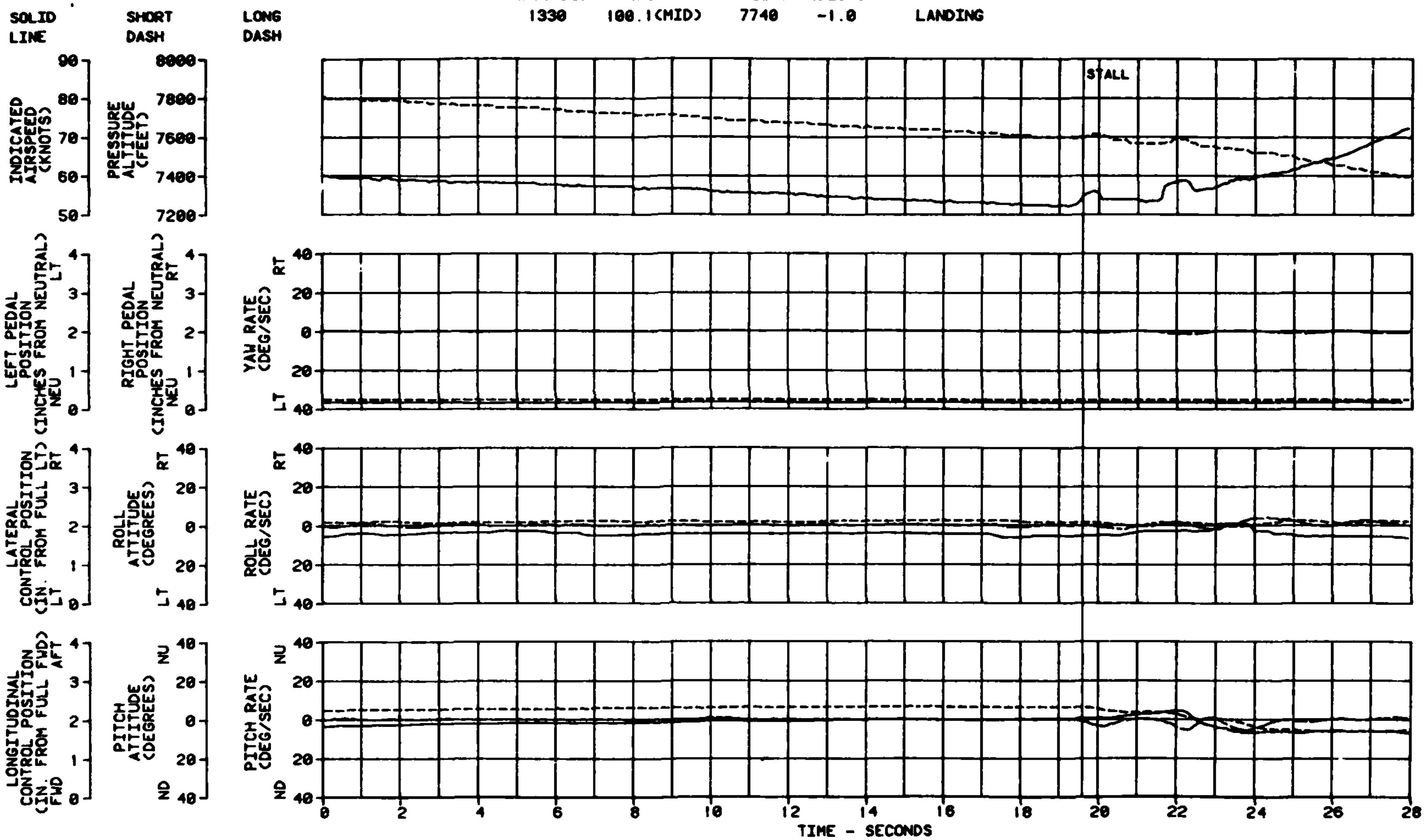


FIGURE 8

ACCELERATED STALL PERFORMANCE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	7480	-0.5	CRUISE

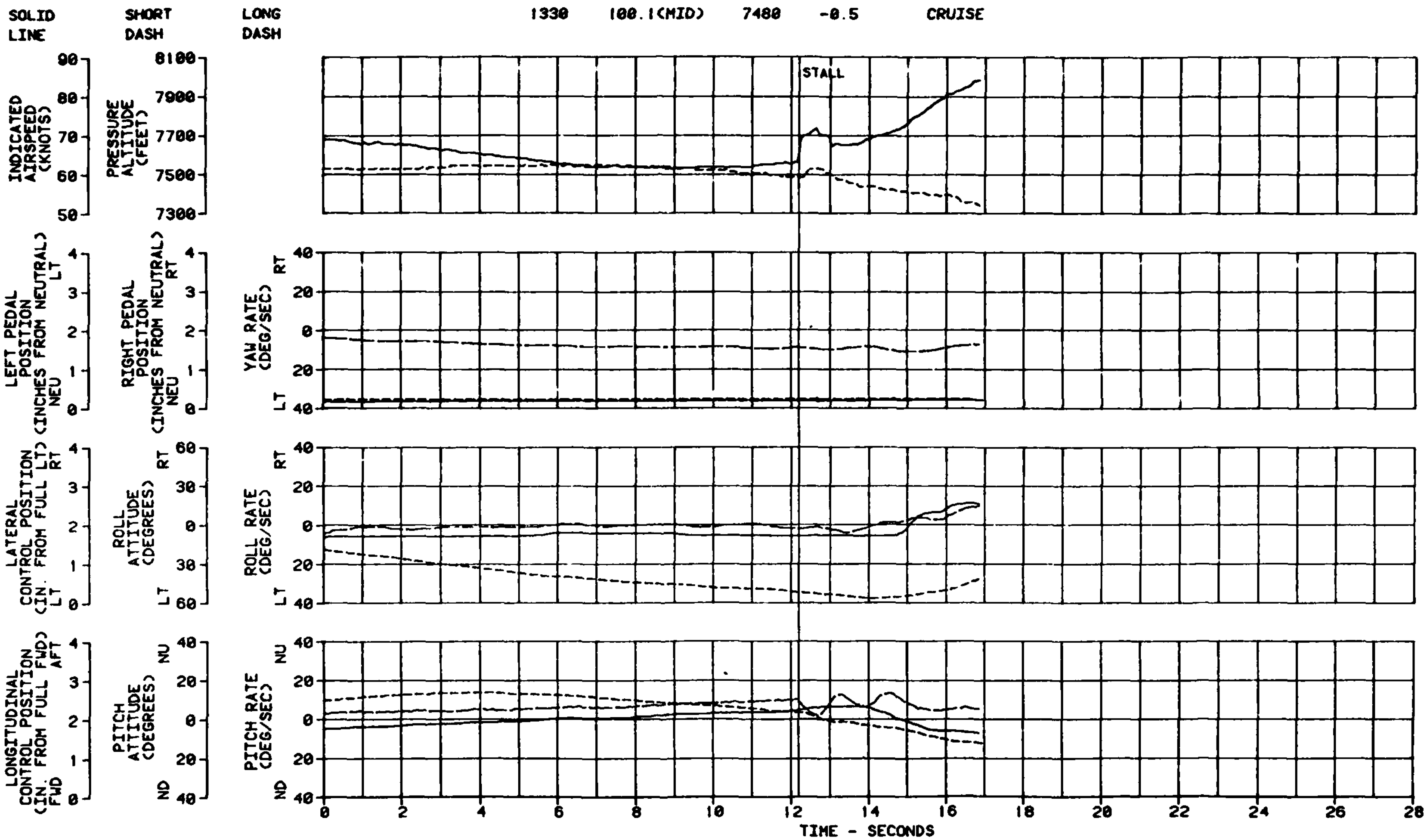
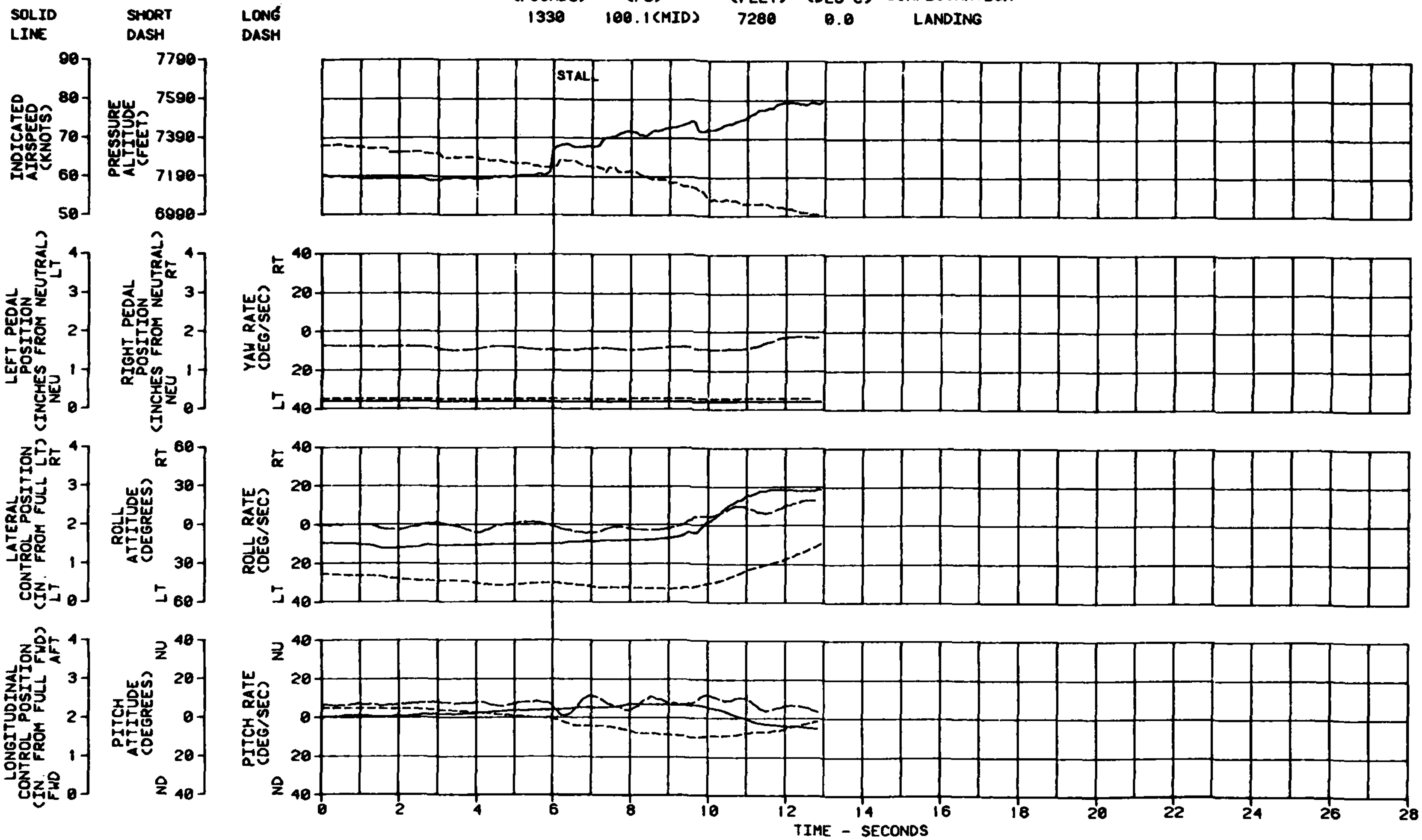


FIGURE 9

ACCELERATED STALL PERFORMANCE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	100.1(MID)	7280	0.0	LANDING



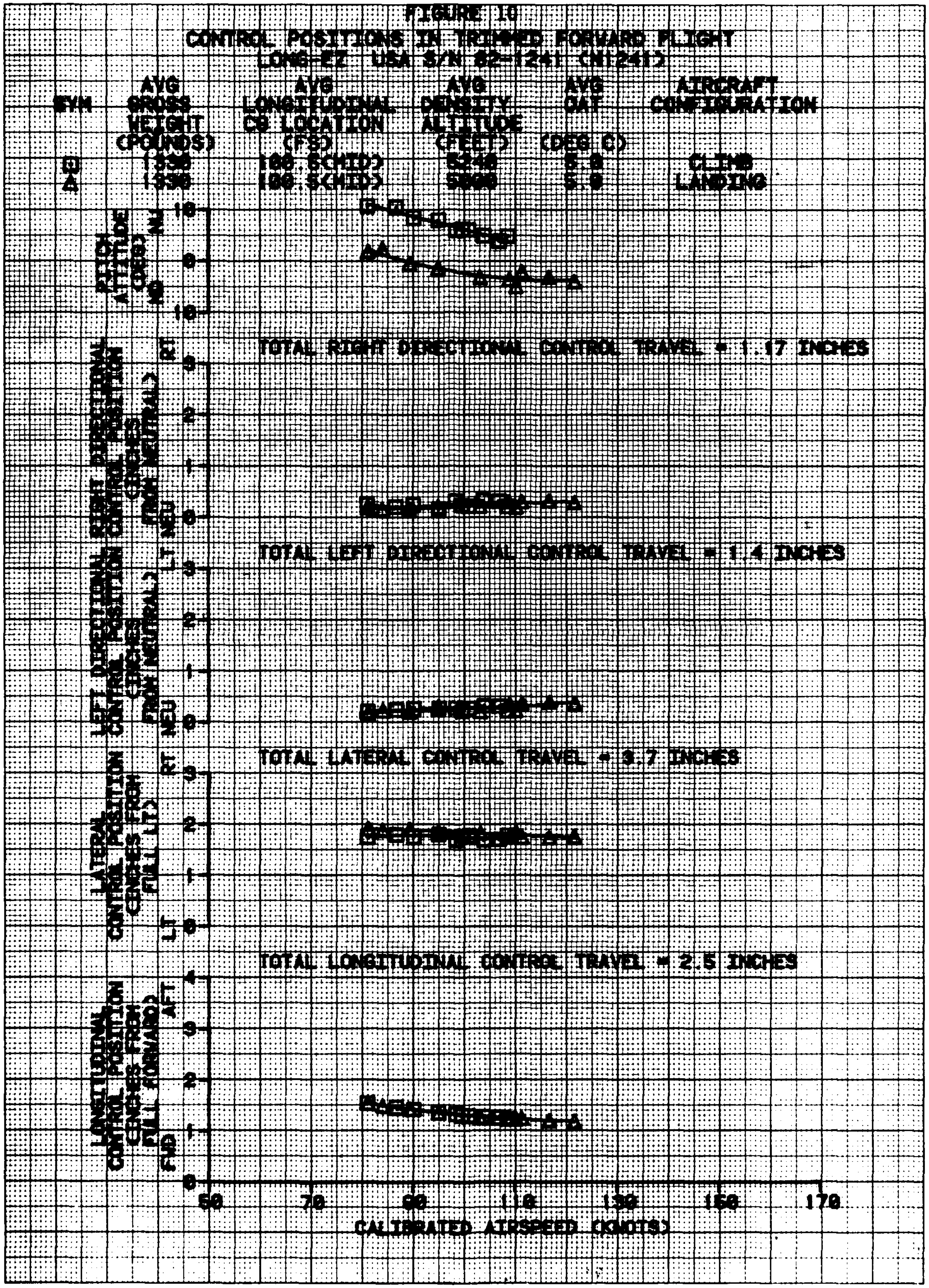


FIGURE 10
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
LONG-EZ USA S/N 82-1241 (N1241)
SYM
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
AIRCRAFT CONFIGURATION
CLIMB
LANDING
PITCH ATTITUDE (DEG)
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
TOTAL LATERAL CONTROL TRAVEL = 3.7 INCHES
LATERAL CONTROL POSITION (INCHES FROM FULL LT)
TOTAL LONGITUDINAL CONTROL TRAVEL = 2.5 INCHES
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
CALIBRATED AIRSPEED (KNOTS)

FIGURE 11
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
LONG-EZ USA S/N 82-1241 (N1241)

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
□	1325	100.6(MID)	4680	5.5	CRUISE
△	1305	101.1(MID)	4980	5.0	CRUISE(DIVE)

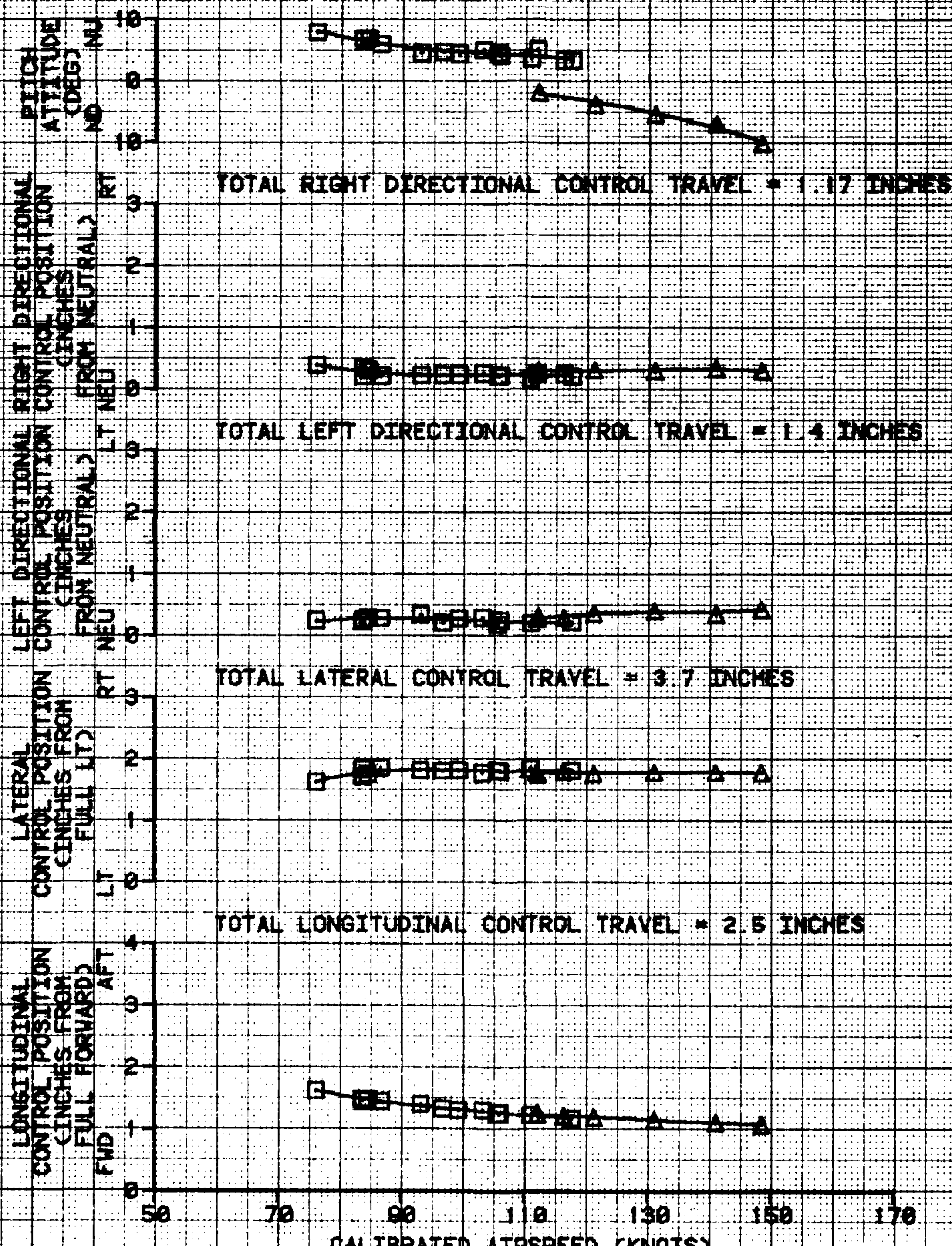
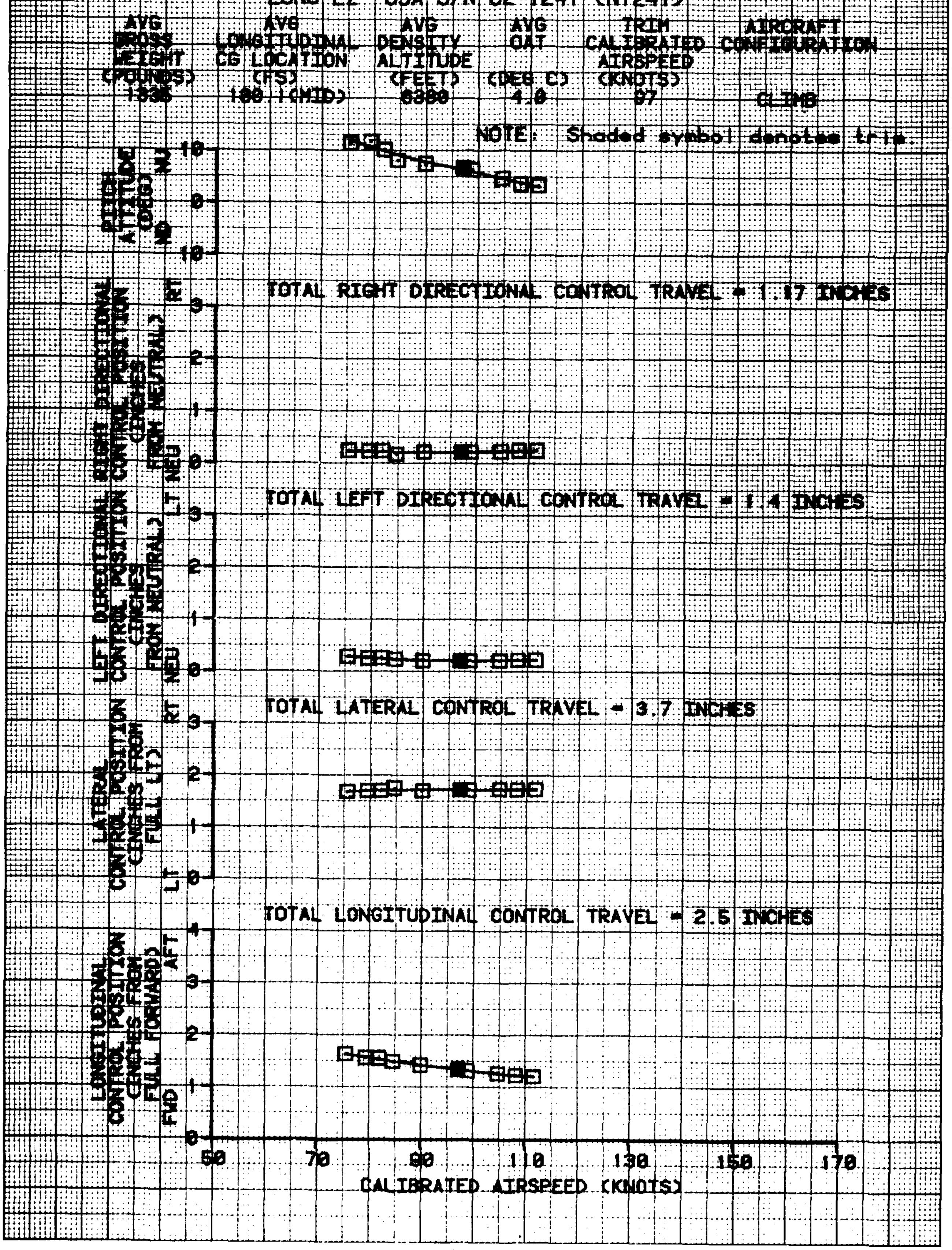


FIGURE 12
STATIC LONGITUDINAL STABILITY
LONG-EZ USA S/N 82-1241 (N1241)



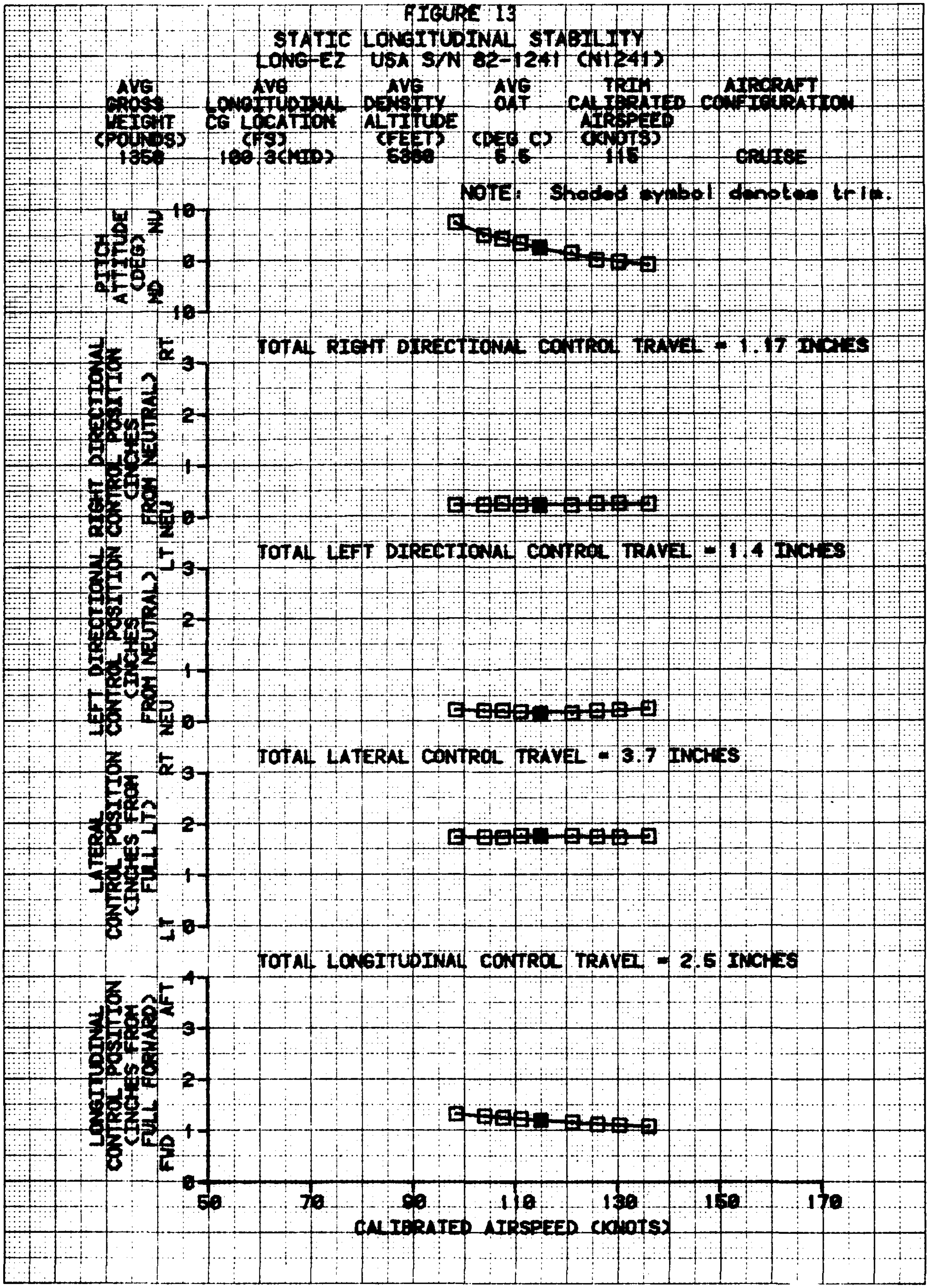
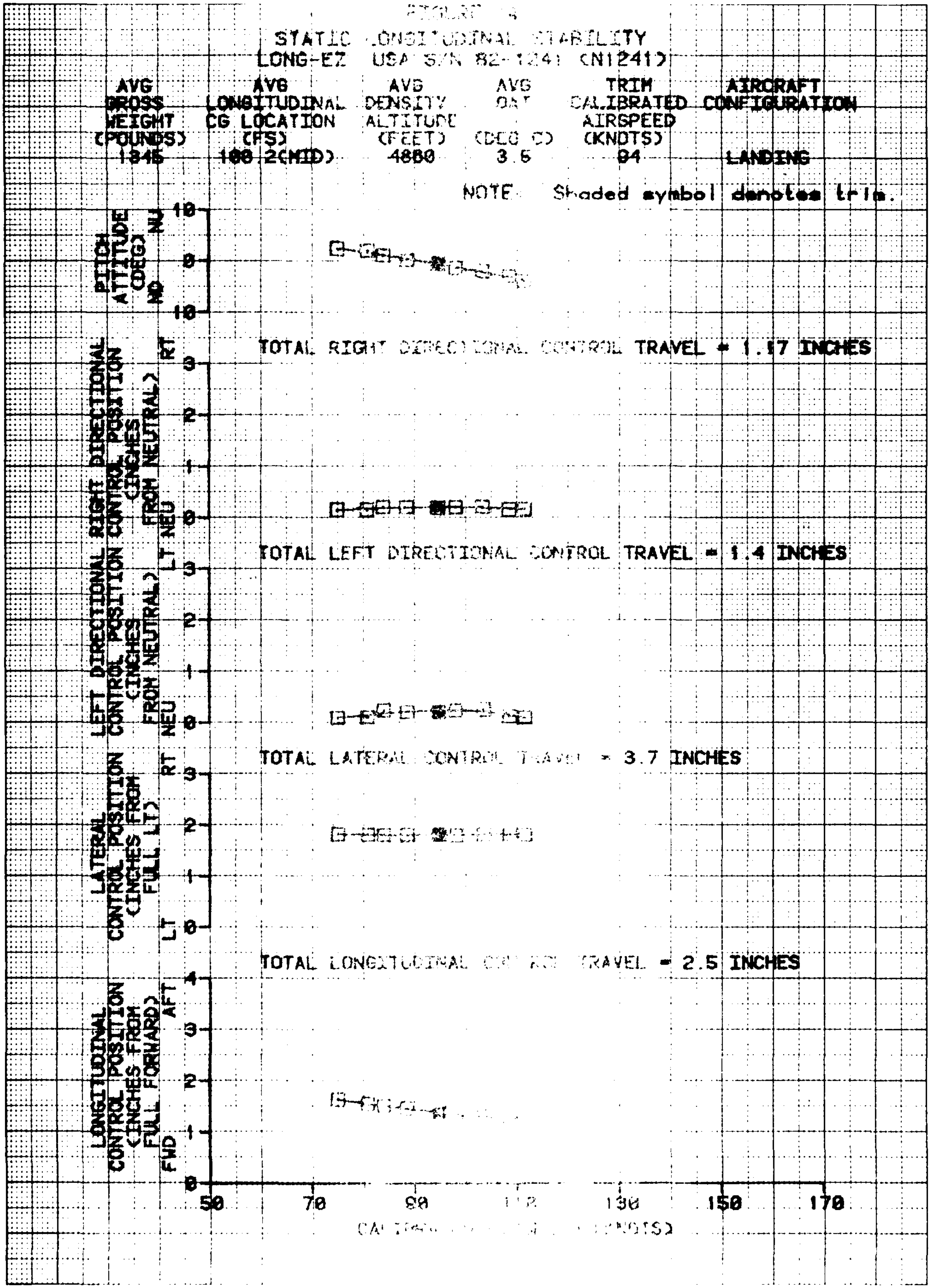


FIGURE 13
STATIC LONGITUDINAL STABILITY
LONG-EZ USA S/N 82-1241 (N1241)


STATIC LONGITUDINAL STABILITY
LONG-EZ USA S/N 82-1241 (N1241)
AVG GROSS WEIGHT (POUNDS)
1345
AVG LONGITUDINAL CG LOCATION (FS)
100.2(MID)
AVG DENSITY ALTITUDE (FEET)
4880
AVG OAT (DEG C)
3.5
TRIM CALIBRATED AIRSPEED (KNOTS)
94
AIRCRAFT CONFIGURATION
LANDING
NOTE: Shaded symbol denotes trim.
PITCH ATTITUDE (DEG)
NU
ND
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
RT
NEU
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LT
NEU
TOTAL LATERAL CONTROL TRAVEL = 3.7 INCHES
LATERAL CONTROL POSITION (INCHES FROM FULL LT)
RT
LT
TOTAL LONGITUDINAL CONTROL TRAVEL = 2.5 INCHES
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
AFT
FWD
50
70
90
110
130
150
170

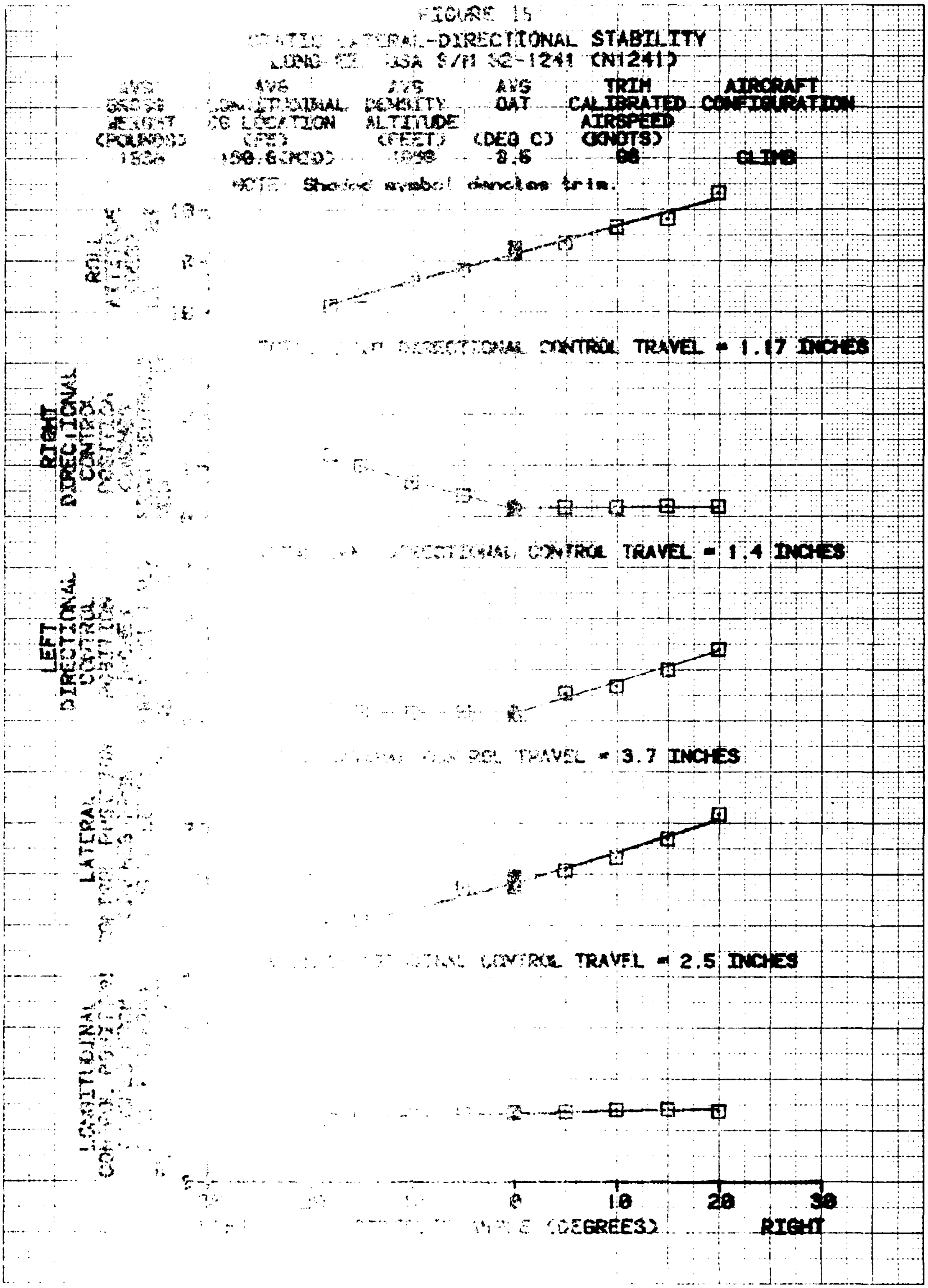
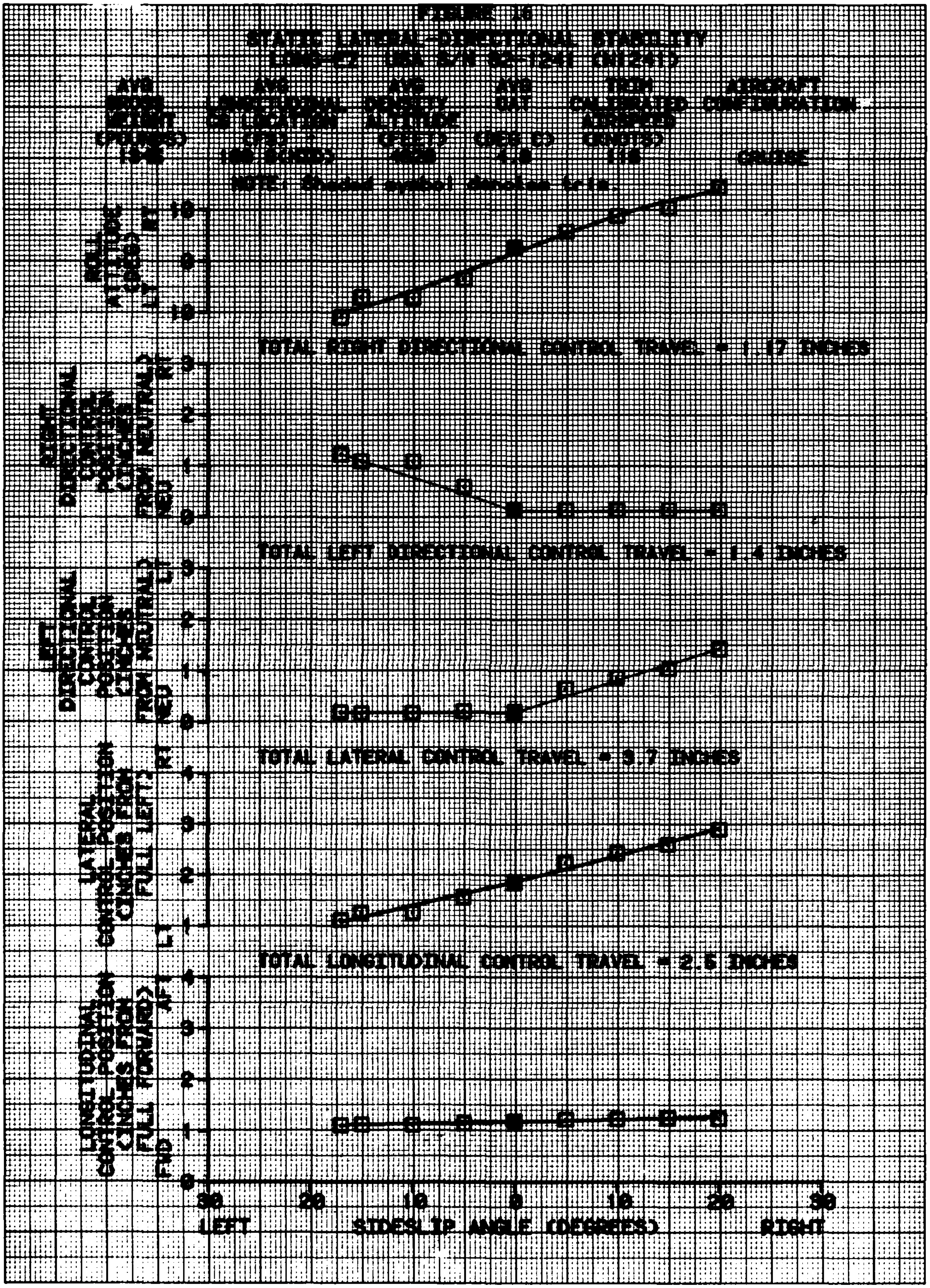


FIGURE 15
LATERAL-DIRECTIONAL STABILITY
S/N 32-1241 (N1241)
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
8.6
TRIM CALIBRATED AIRSPEED (KNOTS)
90
AIRCRAFT CONFIGURATION
CLIMB
NOTE: Shaded symbol denotes trim.
ROLL
DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES
RIGHT DIRECTIONAL CONTROL
DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES
LEFT DIRECTIONAL CONTROL
CONTROL TRAVEL = 3.7 INCHES
LATERAL
CONTROL TRAVEL = 2.5 INCHES
LONGITUDINAL
0
10
20
30
(DEGREES)
RIGHT


STATIC LATERAL-DIRECTIONAL STABILITY
LONG-EZ USA S/N 82-1241 (N1241)
AVG
AVG
AVG
AVG
TRIM
AIRCRAFT
CRUISE
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES
TOTAL LATERAL CONTROL TRAVEL = 3.7 INCHES
TOTAL LONGITUDINAL CONTROL TRAVEL = 2.5 INCHES
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
LATERAL CONTROL POSITION (INCHES FROM FULL LEFT)
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
FWD
AFT
LT
RT
NEU
30
20
10
0
10
20
30
LEFT
SIDESLIP ANGLE (DEGREES)
RIGHT

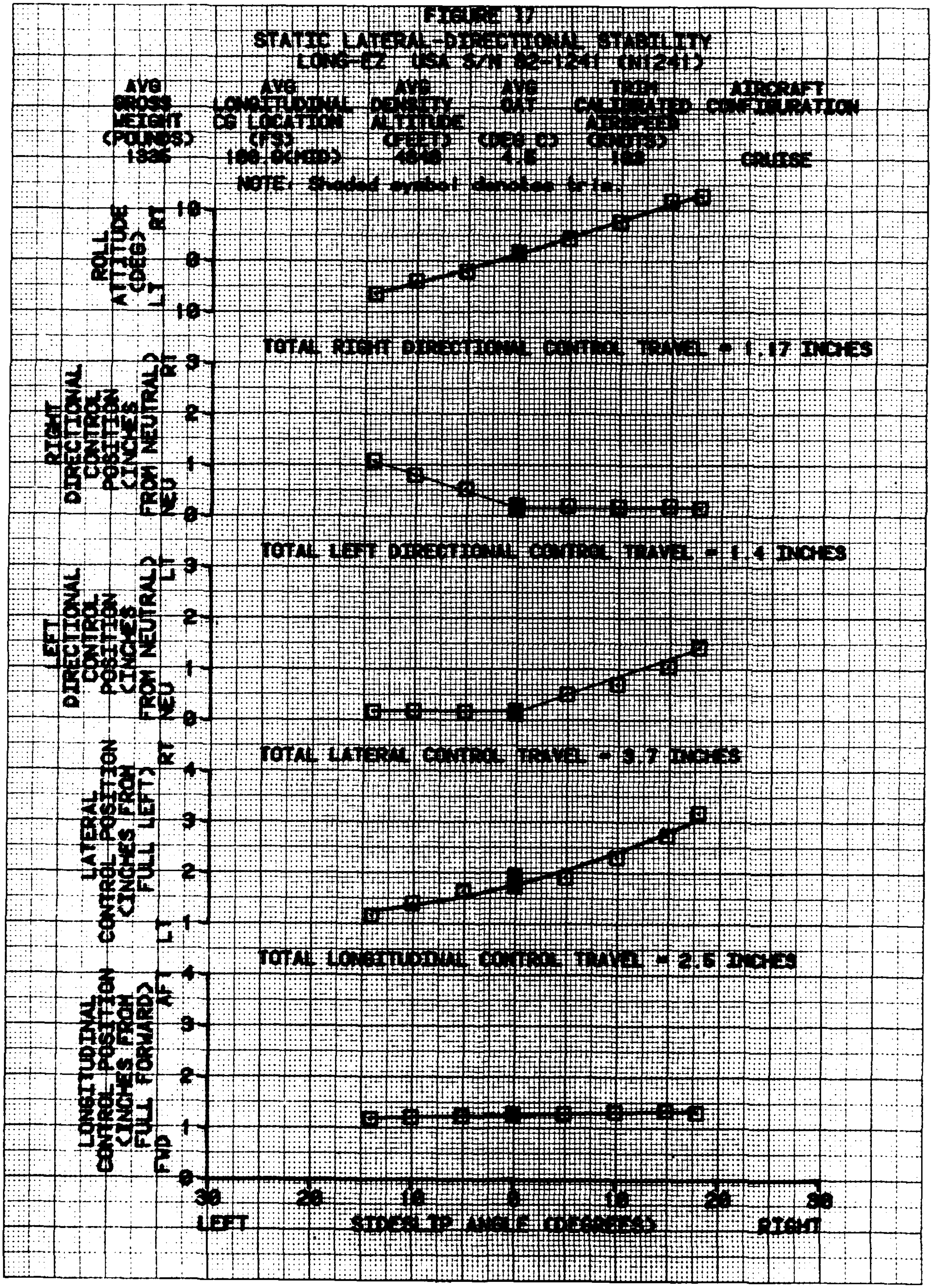


FIGURE 17
STATIC LATERAL-DIRECTIONAL STABILITY
LONG-EZ USA S/N 82-1241 (N1241)
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
TRIM CALIBRATED AIRSPEED (KNOTS)
AIRCRAFT CONFIGURATION
CRUISE
NOTE: Shaded symbol denotes trim.
ROLL ATTITUDE (DEG)
LT
RT
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
NEU
RT
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
NEU
LT
TOTAL LATERAL CONTROL TRAVEL = 3.7 INCHES
LATERAL CONTROL POSITION (INCHES FROM FULL LEFT)
LT
RT
TOTAL LONGITUDINAL CONTROL TRAVEL = 2.5 INCHES
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
FWD
AFT
30
20
10
0
10
20
30
LEFT
SIDESLIP ANGLE (DEGREES)
RIGHT

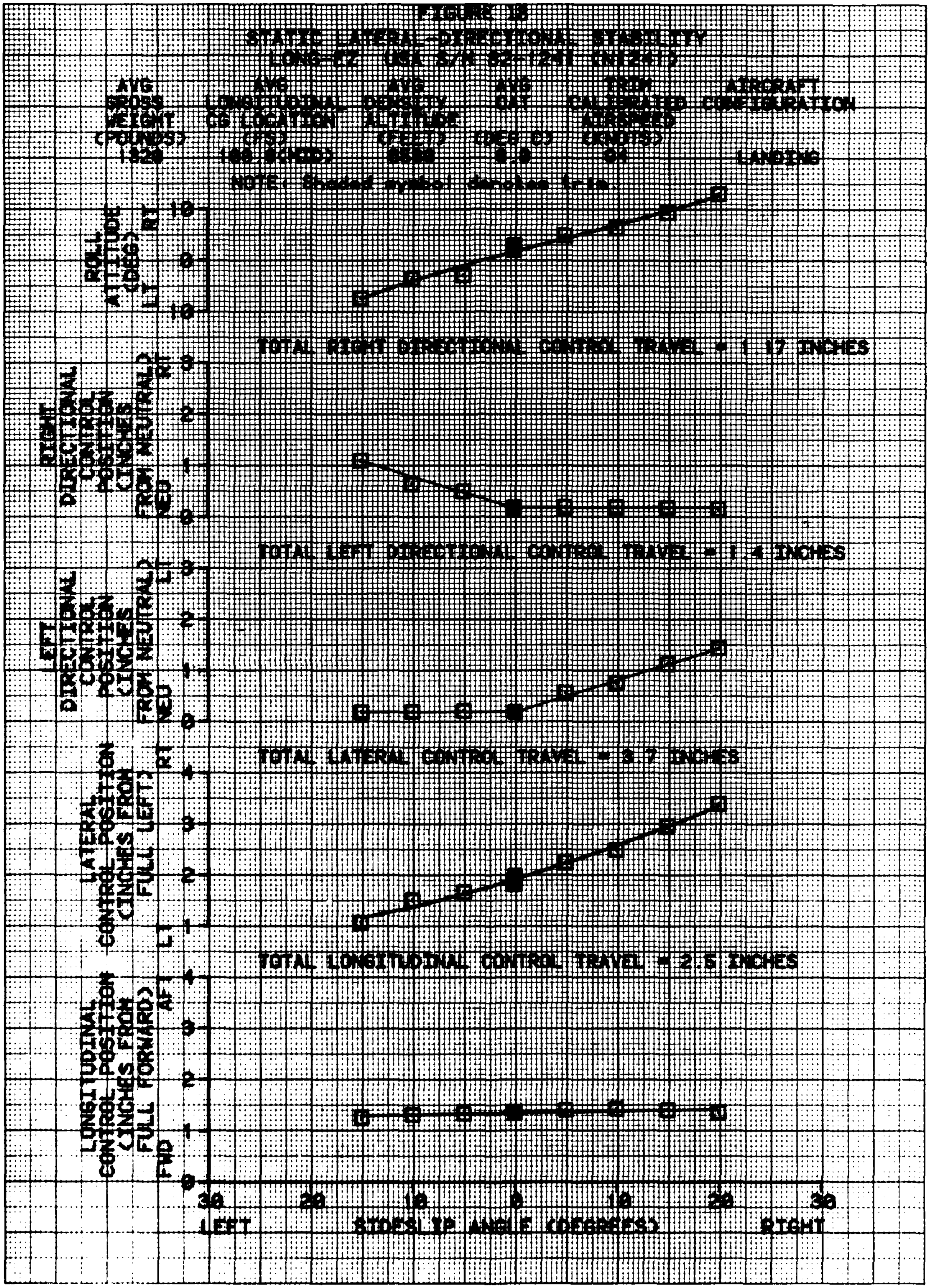
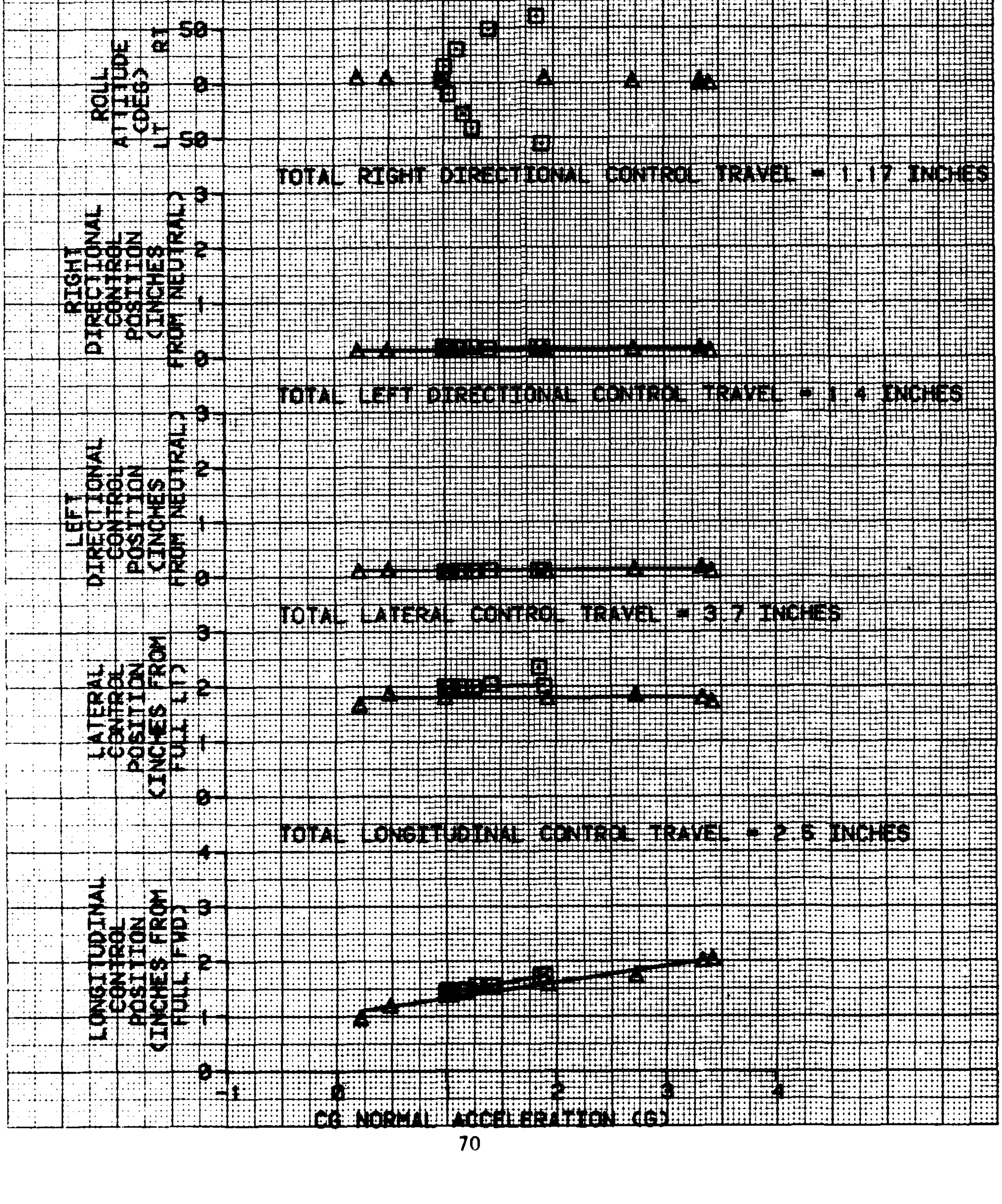

STATIC LATERAL-DIRECTIONAL STABILITY
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION
AVG DENSITY ALTITUDE (FEET)
AVG OAT
TRIM CALIBRATED AIRSPEED (KNOTS)
AIRCRAFT CONFIGURATION
LANDING
ROLL ATTITUDE (DEG)
LT
RT
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES
RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
NEU
RT
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL)
NEU
LT
TOTAL LATERAL CONTROL TRAVEL = 3.7 INCHES
LATERAL CONTROL POSITION (INCHES FROM FULL LEFT)
LT
RT
TOTAL LONGITUDINAL CONTROL TRAVEL = 2.5 INCHES
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FORWARD)
FWD
AFT
30
20
10
0
10
20
30
LEFT
SIDESLIP ANGLE (DEGREES)
RIGHT

FIGURE 19
MANEUVERING STABILITY
LONG-EZ USA S/N 82-1241 (N1241)

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	TRIM CALIBRATED AIRSPEED (KNOTS)	FLIGHT CONDITION
□	1350	100.2(MID)	7660	-0.5	96	TURNS
△	1340	100.2(MID)	7020	-1.6	104	PULLUP/PUSHOVER

NOTES: 1. CRUISE CONFIGURATION
2. SHADED SYMBOL DENOTES TRIM



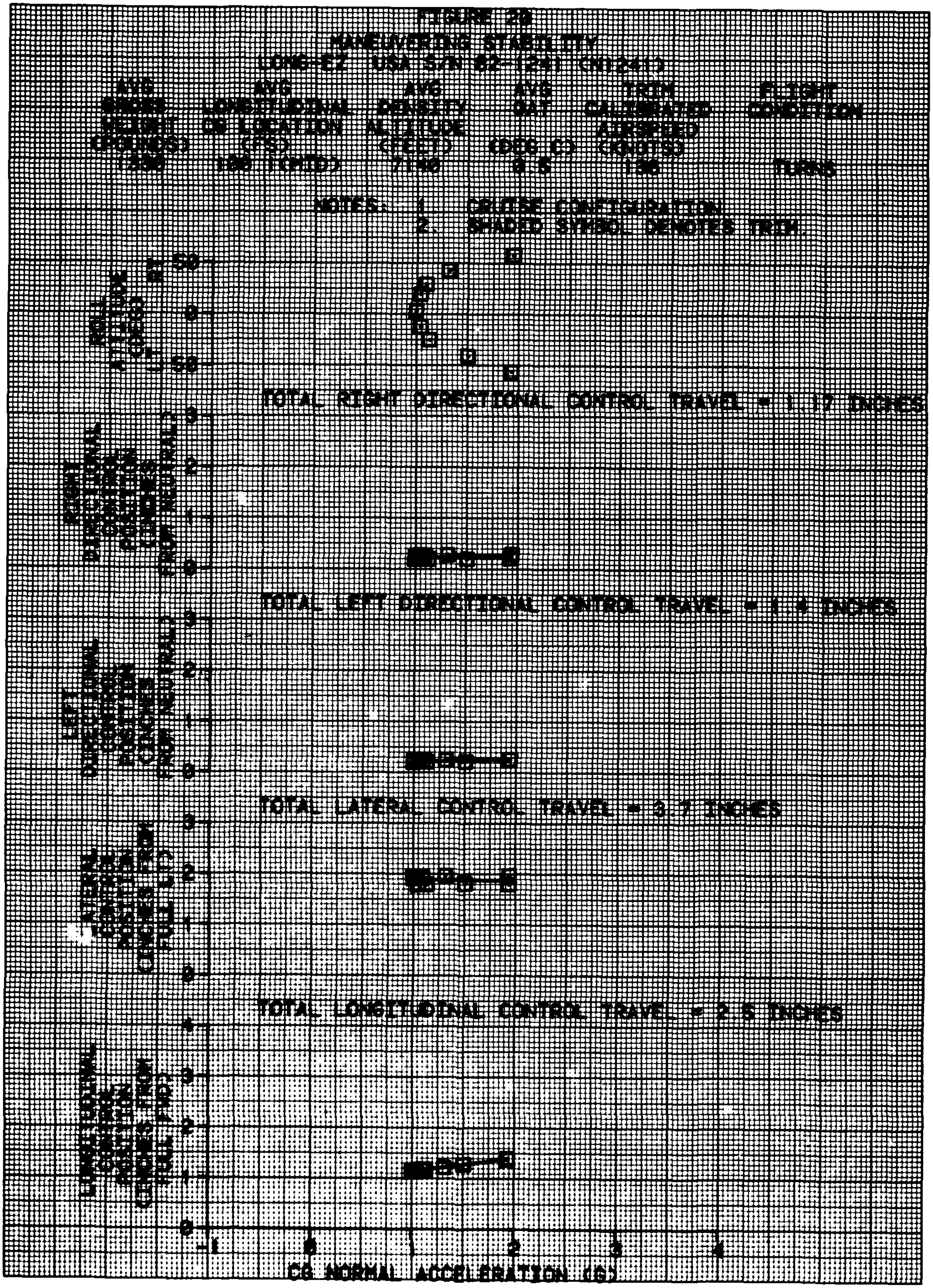

MANEUVERING STABILITY
LONG-EZ USA S/N
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
7140
AVG OAT (DEG C)
TRIM CALIBRATED AIRSPEED (KNOTS)
FLIGHT CONDITION
TURNS
NOTES: 1. CRUISE CONFIGURATION.
2. SHADED SYMBOL DENOTES TRIM.
TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES
TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES
TOTAL LATERAL CONTROL TRAVEL = 3.7 INCHES
TOTAL LONGITUDINAL CONTROL TRAVEL = 2.5 INCHES
CG NORMAL ACCELERATION (G)

FIGURE 21
PHUGOID
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	101.1(MID)	7580	-2.5	CRUISE

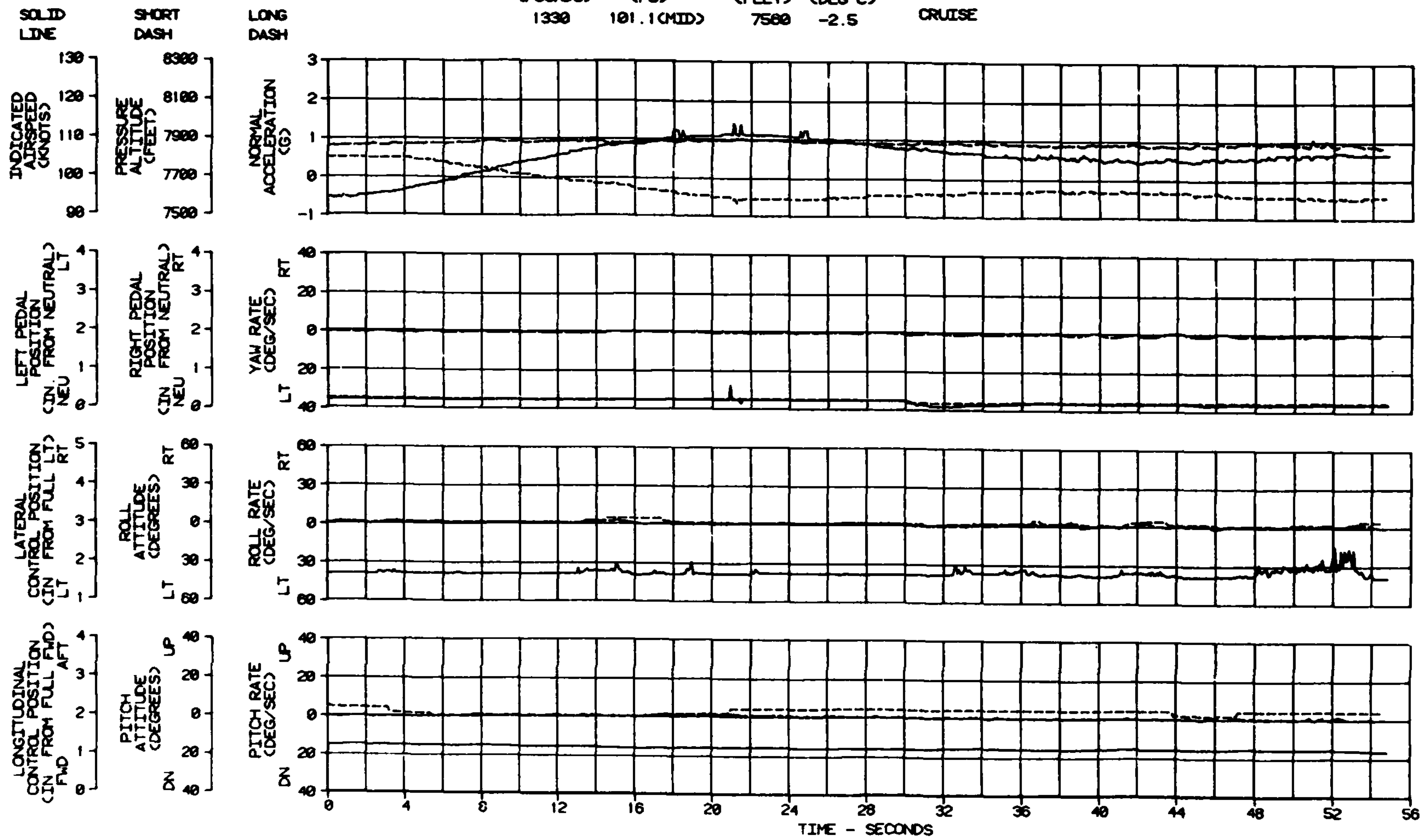


FIGURE 22
LONGITUDINAL SHORT PERIOD RESPONSE
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1320	100.8(MID)	7520	-2.5	CRUISE

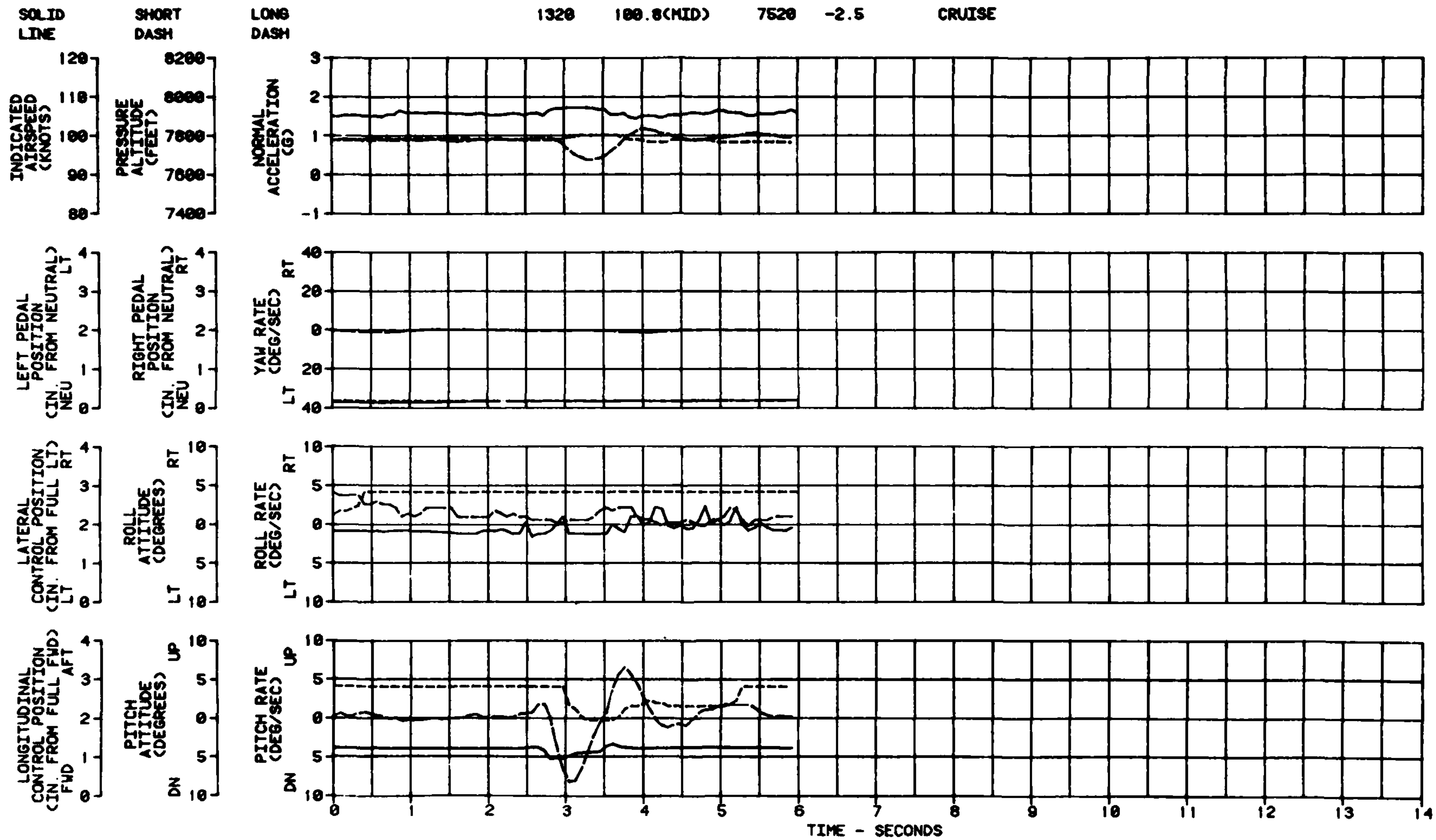


FIGURE 23

LATERAL-DIRECTIONAL RESPONSE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1330	101.1(MID)	7400	-2.5	CRUISE

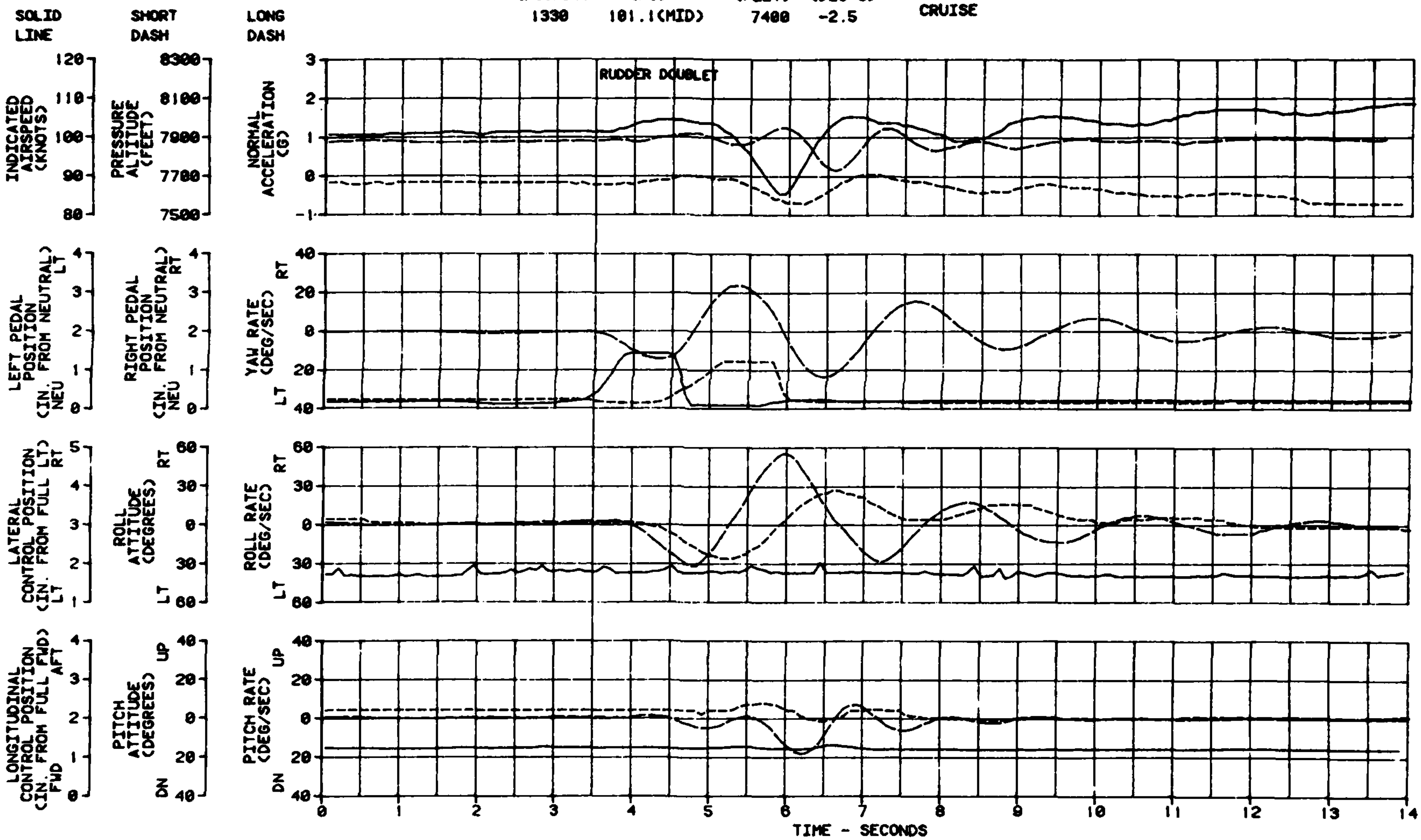


FIGURE 24
LATERAL-DIRECTIONAL RESPONSE
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION	SIDESLIP ANGLE (DEG C)
1330	100.1(MID)	4600	4.5	CLIMB	17.0

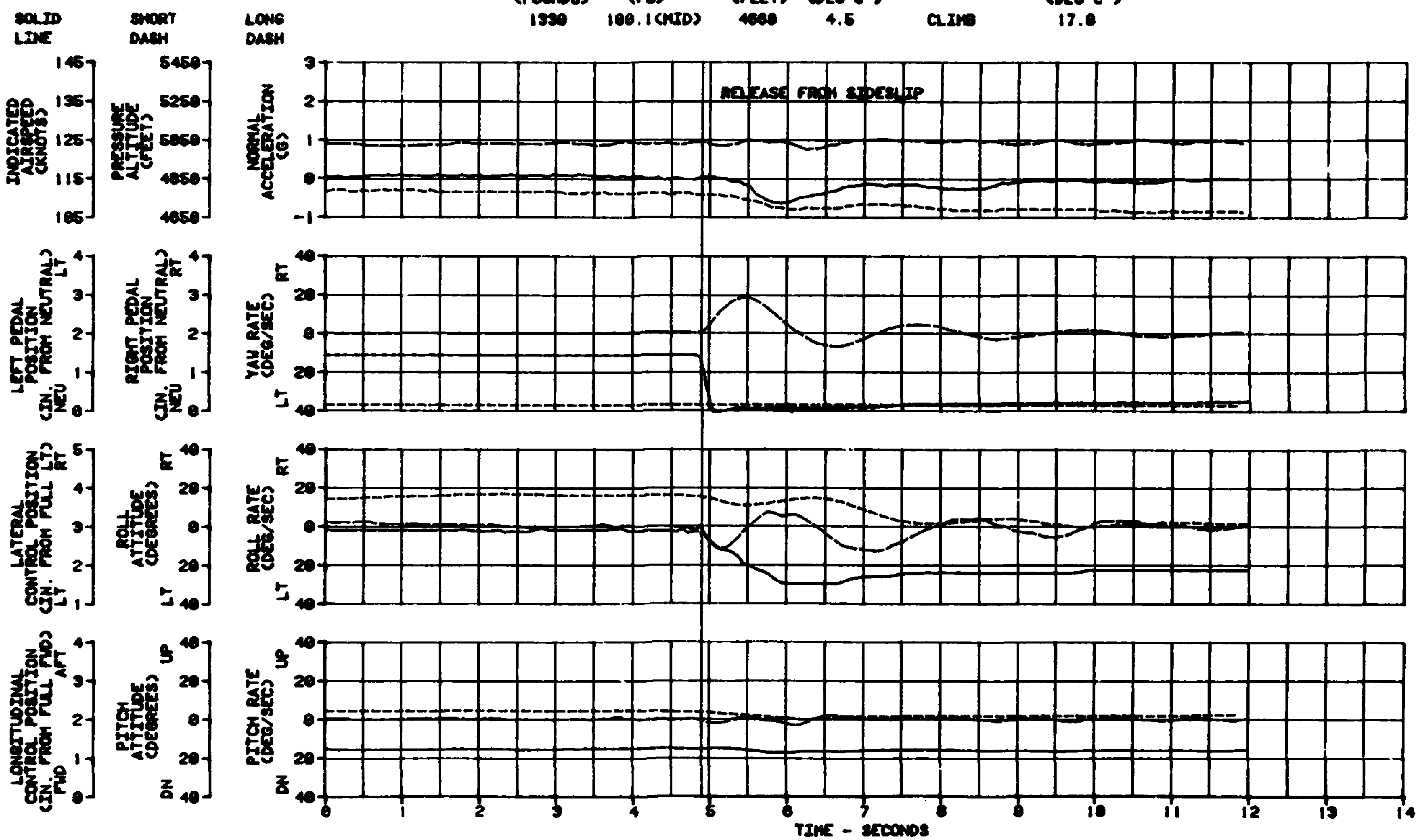


FIGURE 25

LATERAL-DIRECTIONAL RESPONSE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION	SIDESLIP ANGLE (DEG C)
1330	100.1(MID)	4500	4.5	CLIMB	10.0

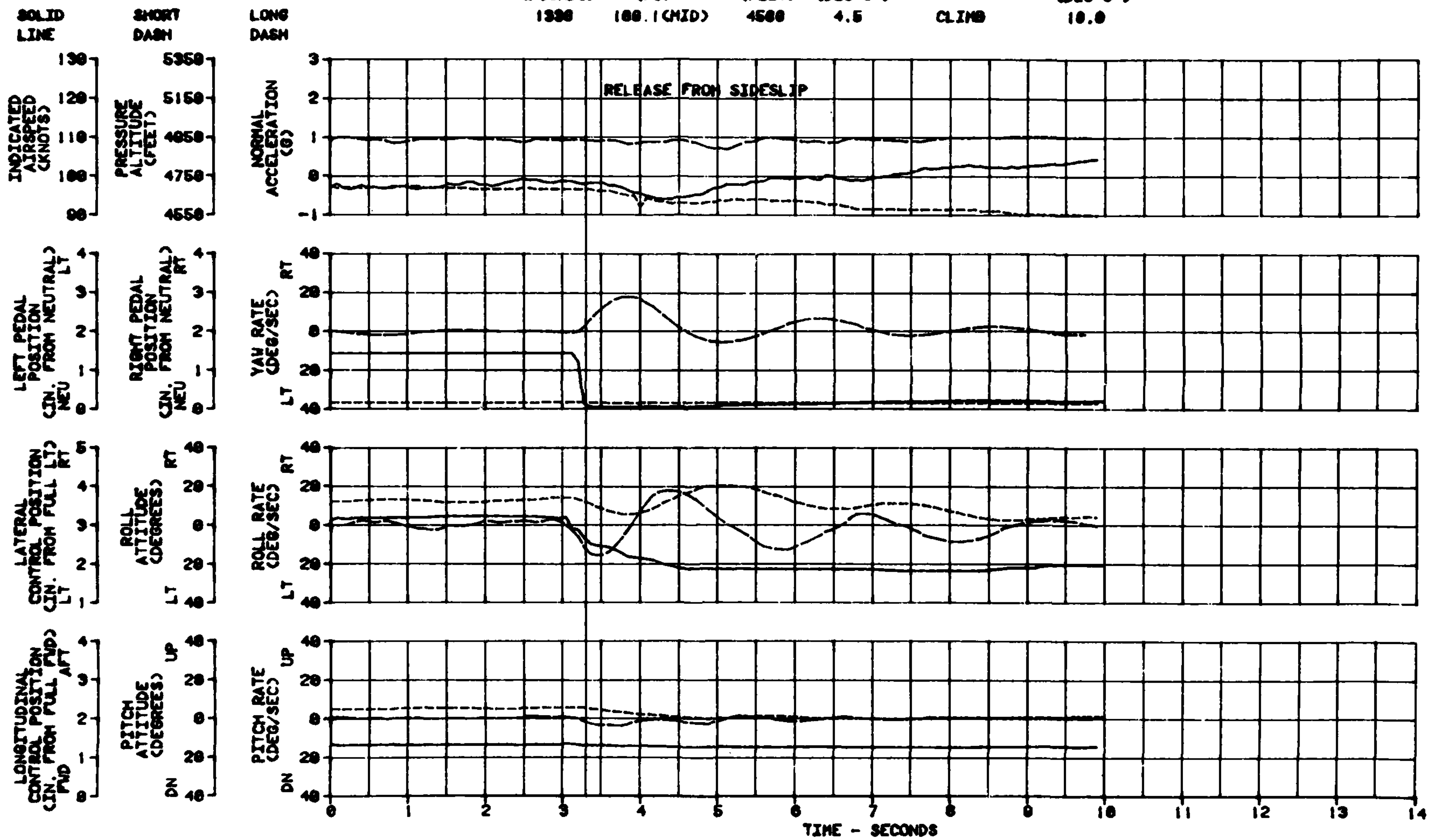


FIGURE 26

LATERAL-DIRECTIONAL RESPONSE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION	SIDESLIP ANGLE (DEG C)
1330	100.1(MID)	5000	3.5	LANDING	14.0

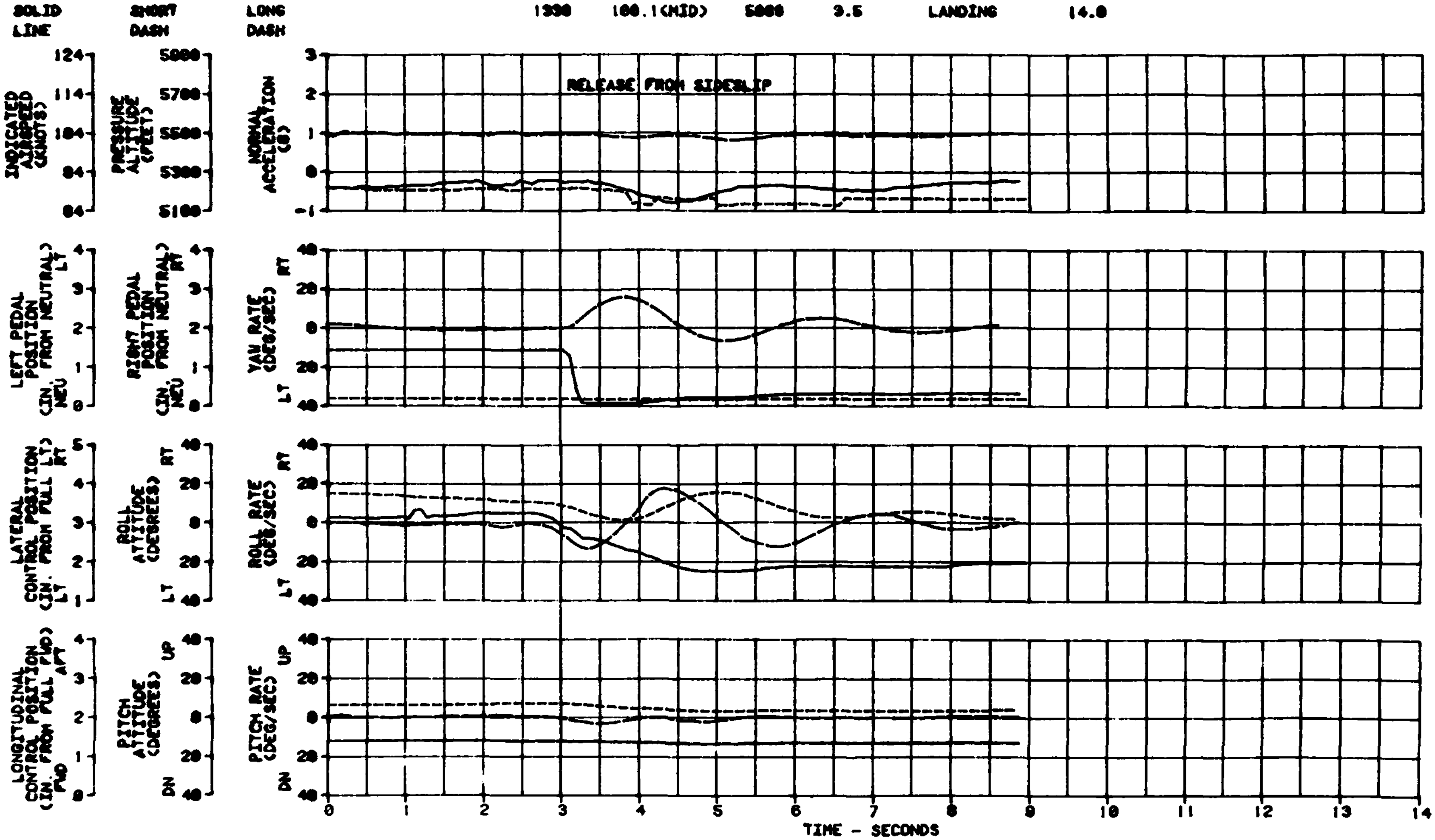


FIGURE 27

GUST RESPONSE

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	INDICATED AIRSPEED (KNOTS)	AIRCRAFT CONFIGURATION
1360	101.0(MID)	2620	12.5	80	LANDING

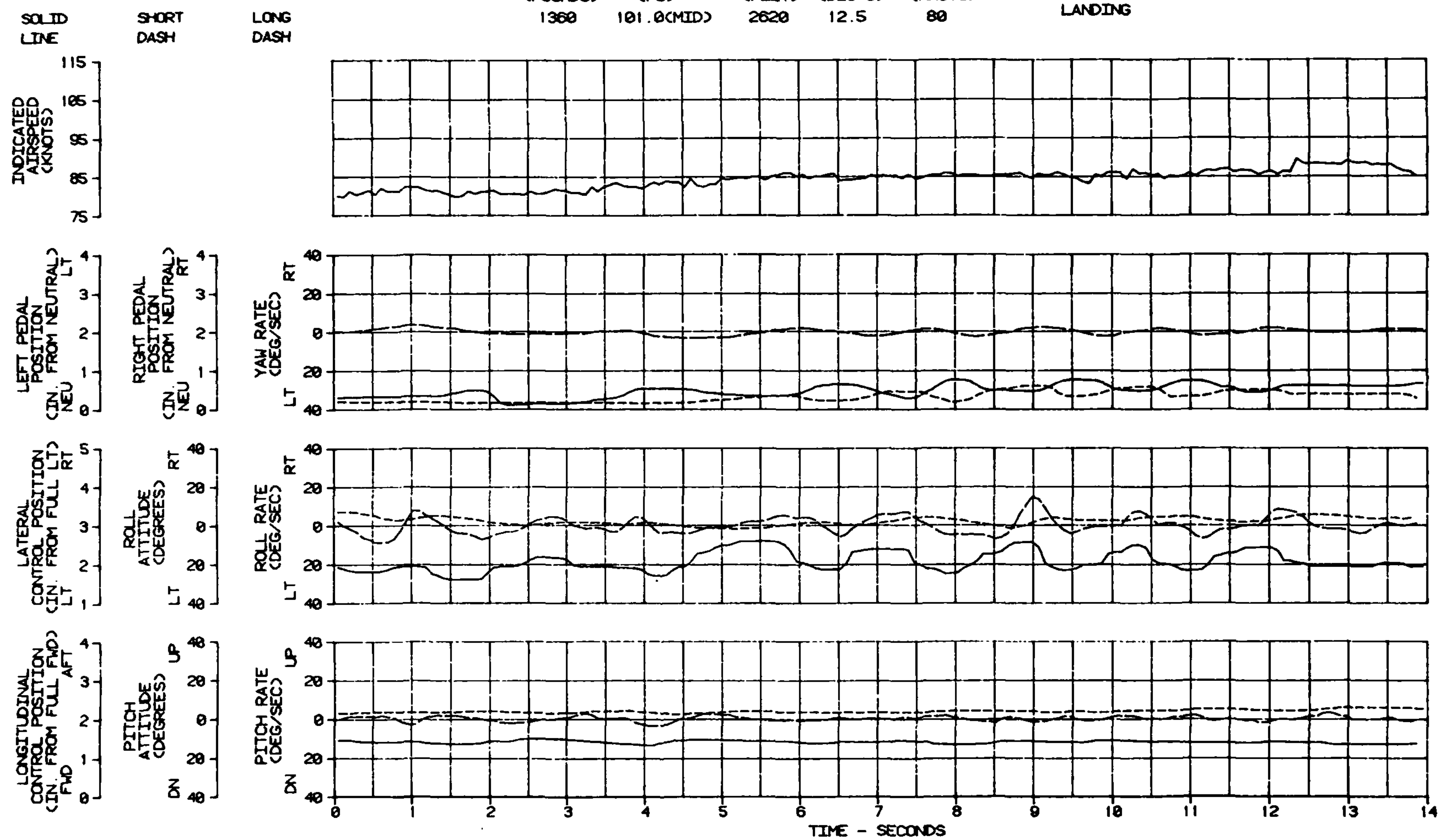


FIGURE 28

ROLL CONTROL EFFECTIVENESS

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1370	100.3(MID)	7400	-1.0	CRUISE

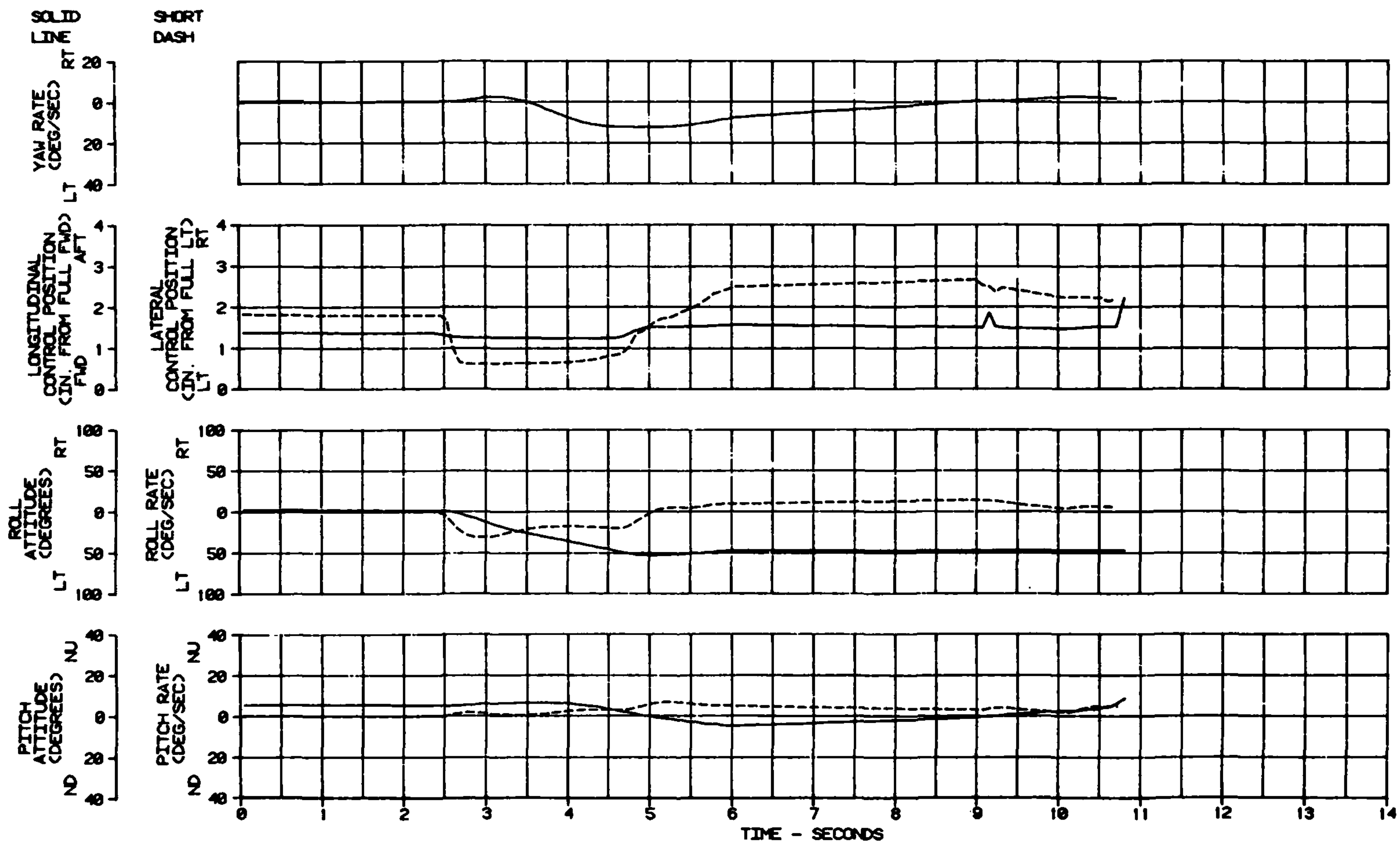


FIGURE 29

ROLL CONTROL EFFECTIVENESS

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1370	100.3(MID)	7380	-1.0	CRUISE

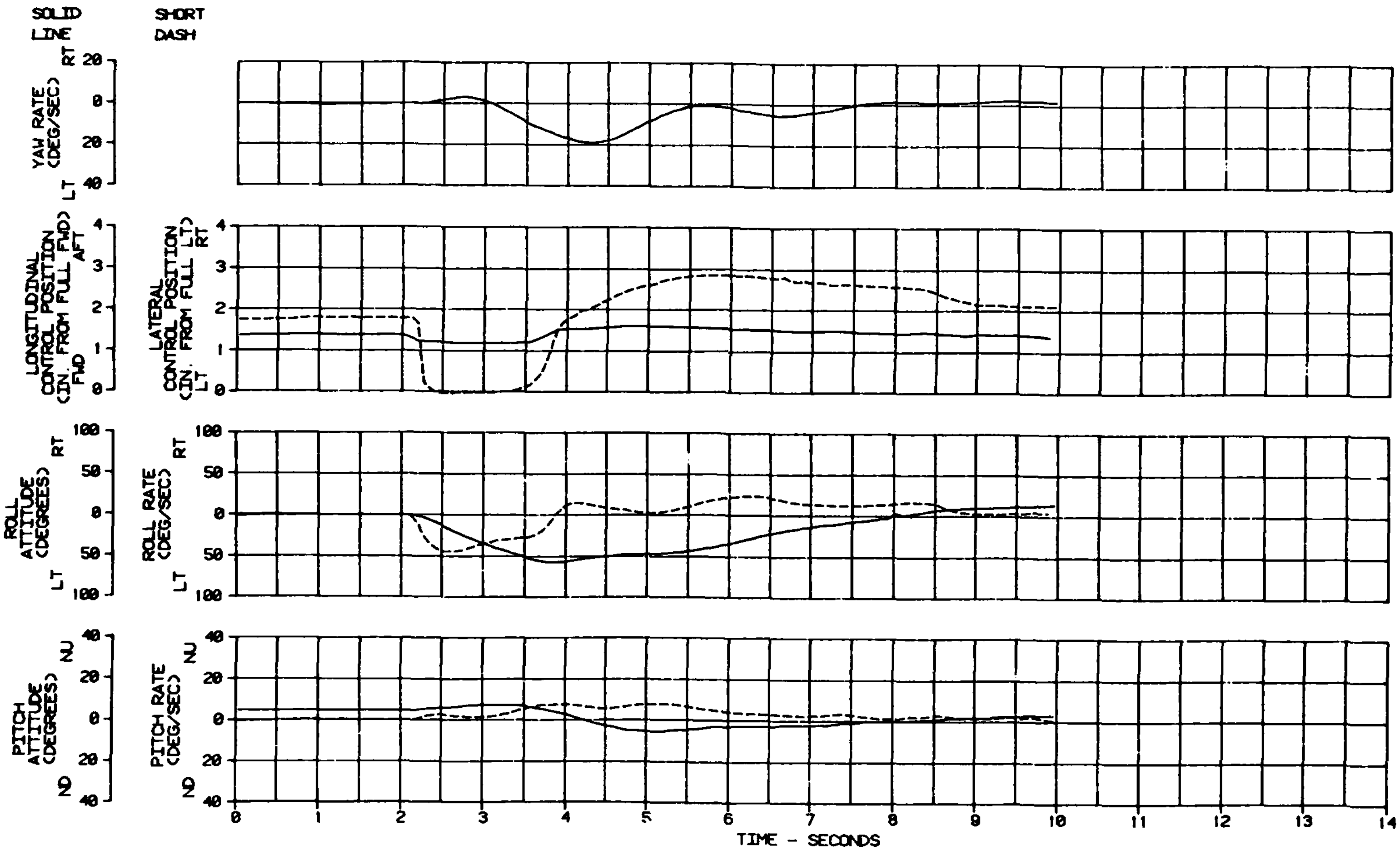


FIGURE 30
ROLL CONTROL EFFECTIVENESS
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1370	100.3(MID)	7340	-0.5	CRUISE

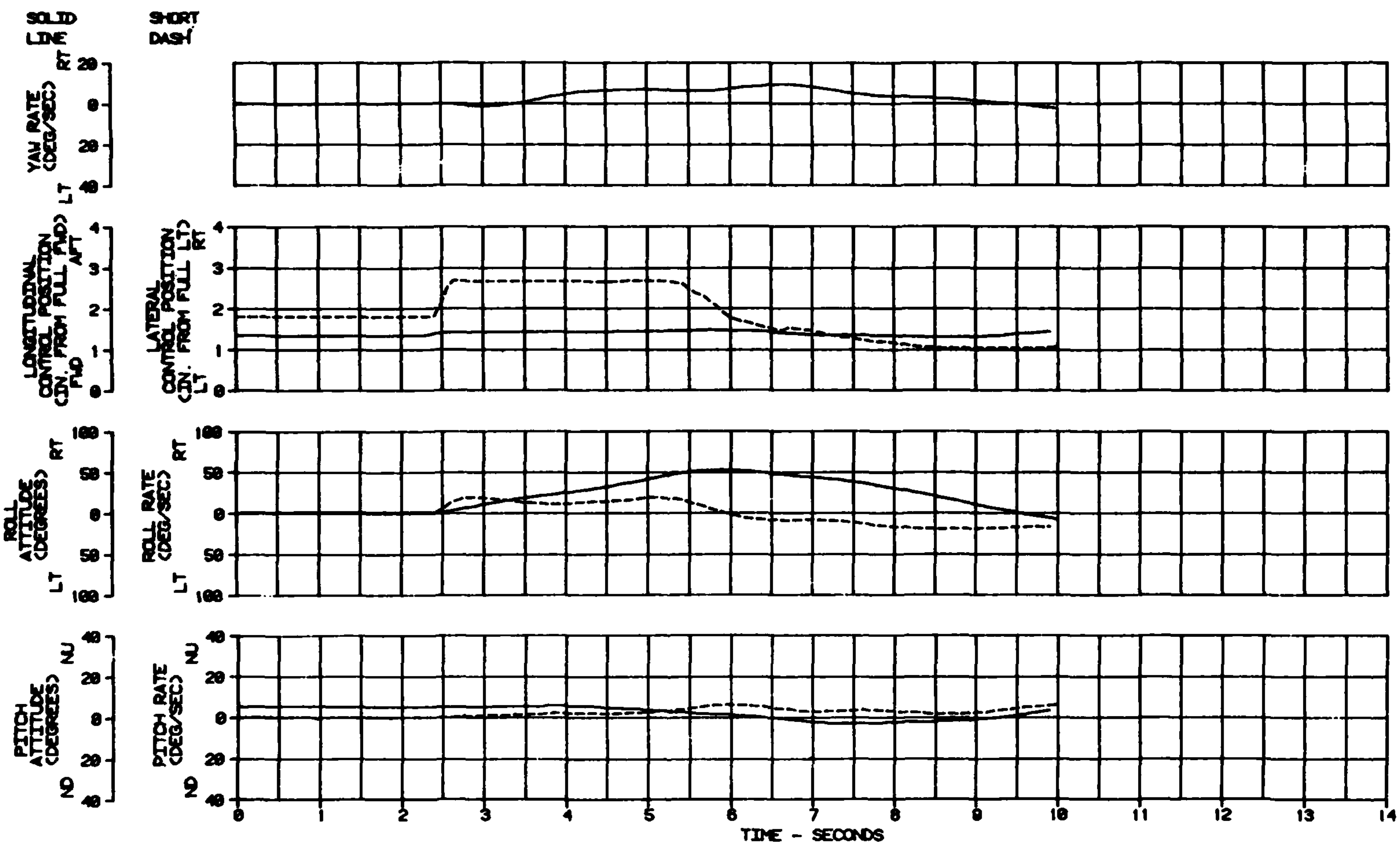


FIGURE 31

ROLL CONTROL EFFECTIVENESS

LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1370	100.3(MID)	7420	-1.0	CRUISE

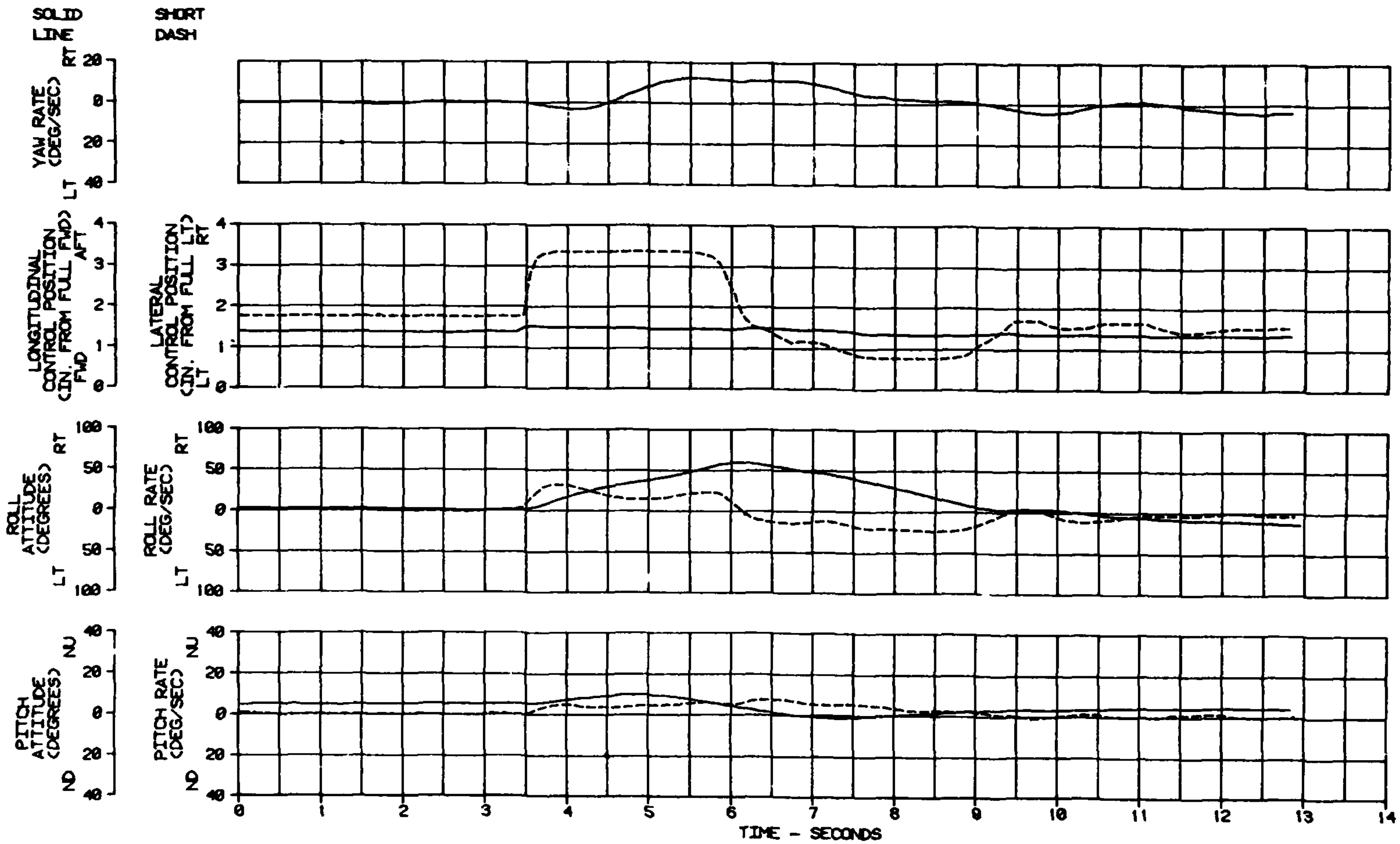


FIGURE 32
TAKEOFF PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	PRESSURE ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1335	100.9(MID)	2200	15.0	TAKEOFF

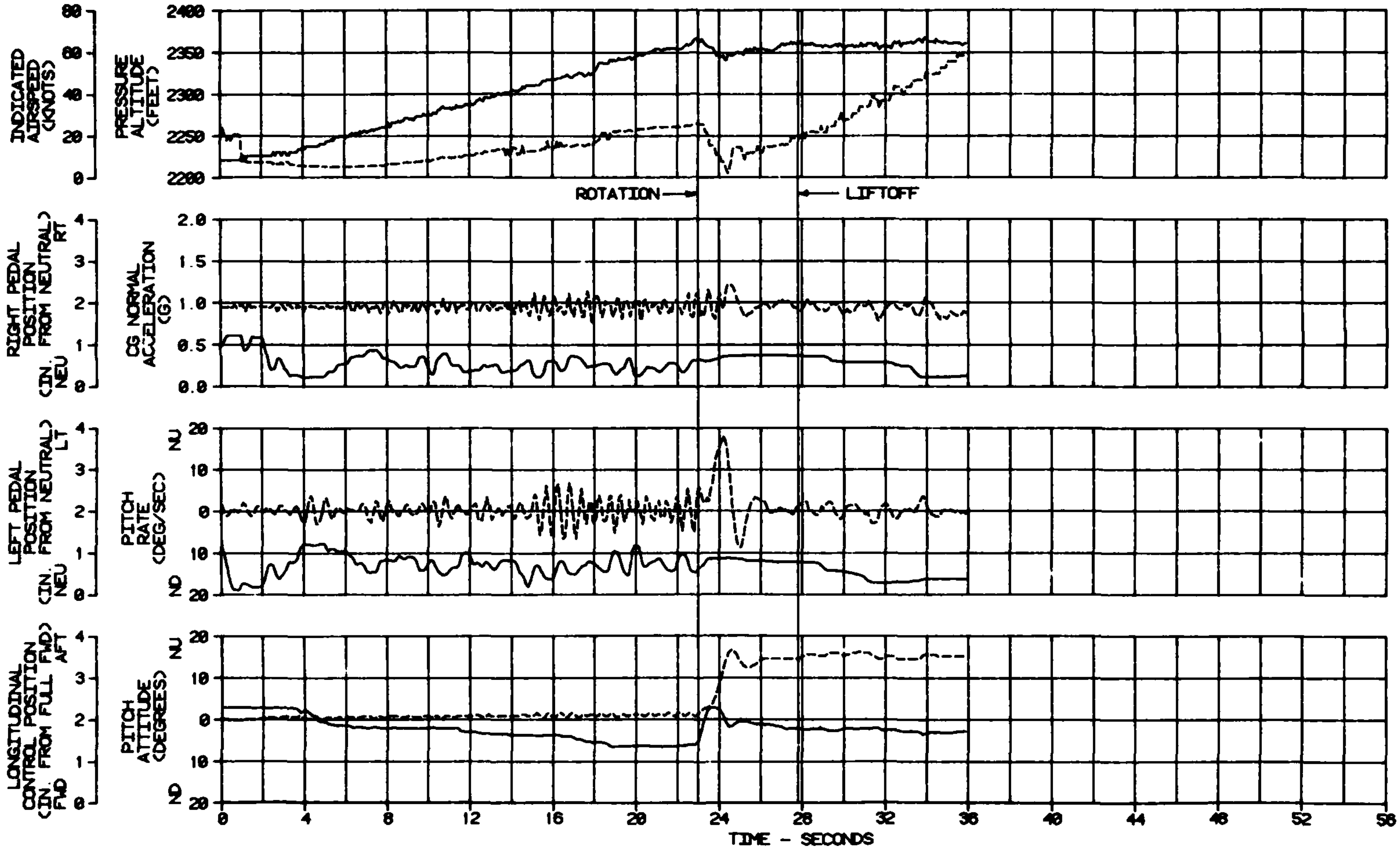


FIGURE 33
LANDING PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT (POUNDS)	LONGITUDINAL CG LOCATION (FS)	PRESSURE ALTITUDE (FEET)	OAT (DEG C)	AIRCRAFT CONFIGURATION
1345	100.9(MID)	2200	13.0	LANDING

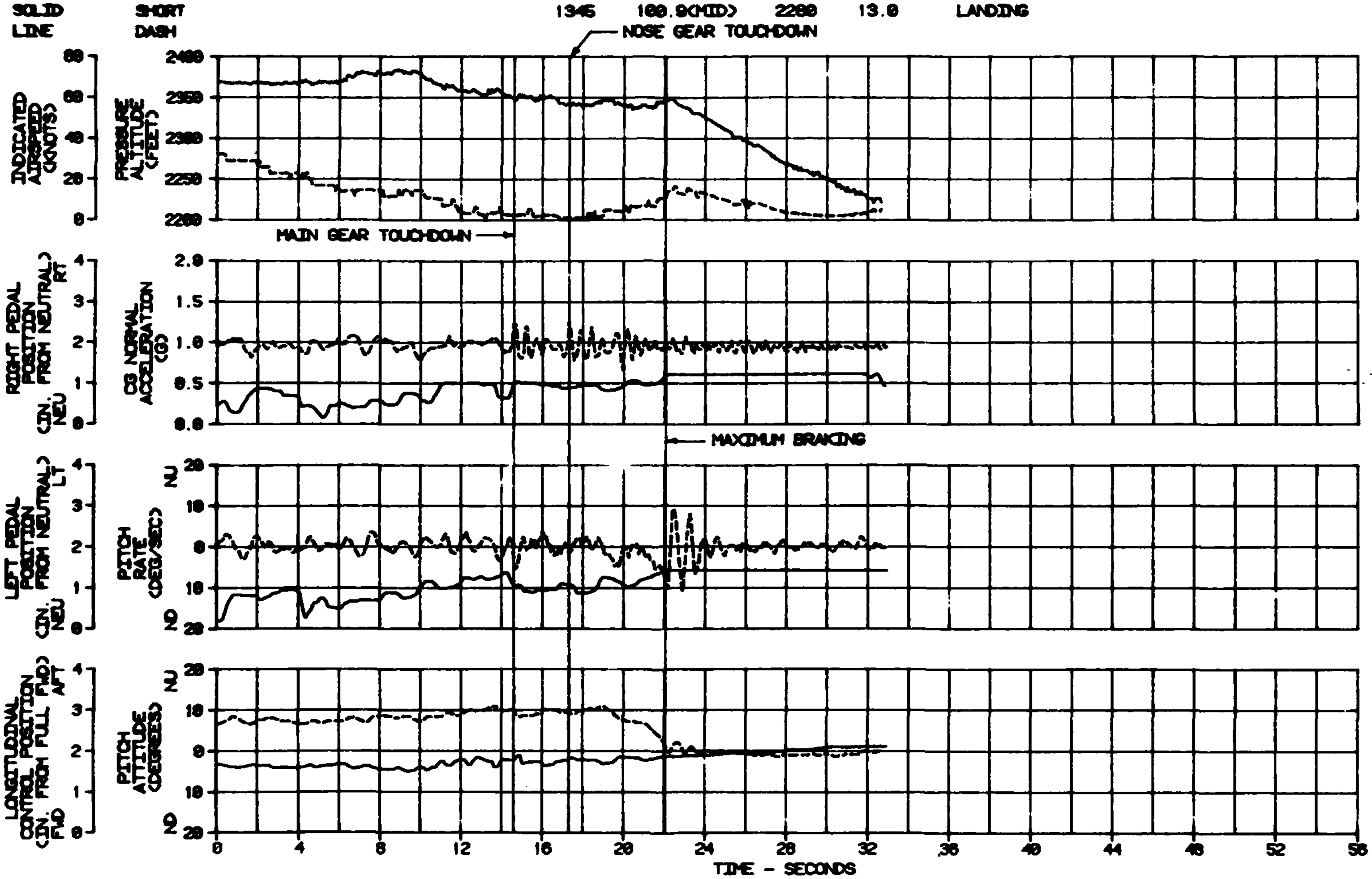
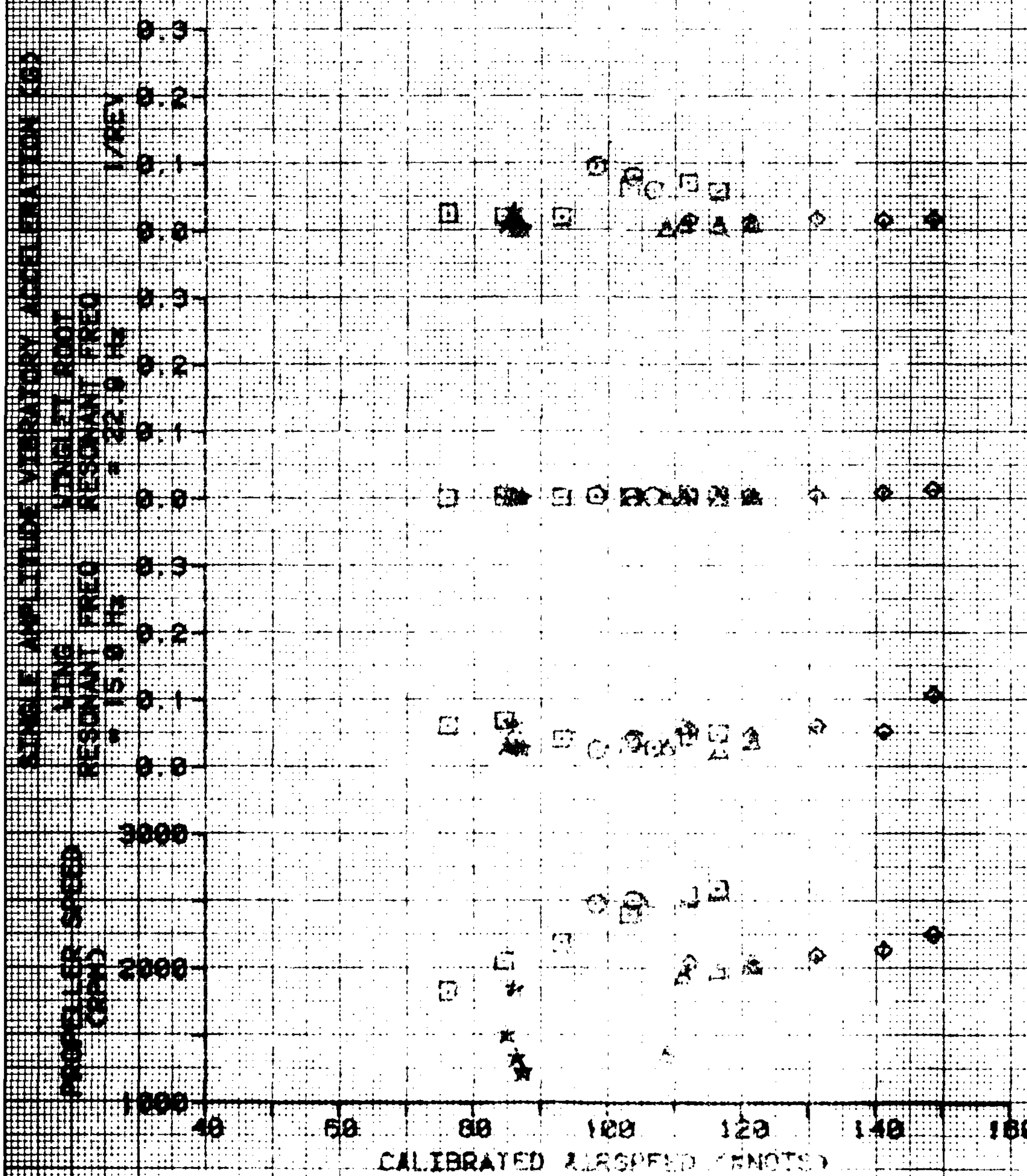


FIGURE 34
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LONGITUDINAL ACCELERATION

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
⊙	1325	101.2(MID)	5980	1.0	CLIMB
△	1315	101.1(MID)	5400	2.0	LANDING
◇	1305	101.1(MID)	4900	2.5	CRUISE(DIVE)
★	1206	101.1(MID)	4400	4.0	CRUISE(DESCENT)
⊡	1295	101.0(MID)	4700	3.5	CRUISE(LEVEL)



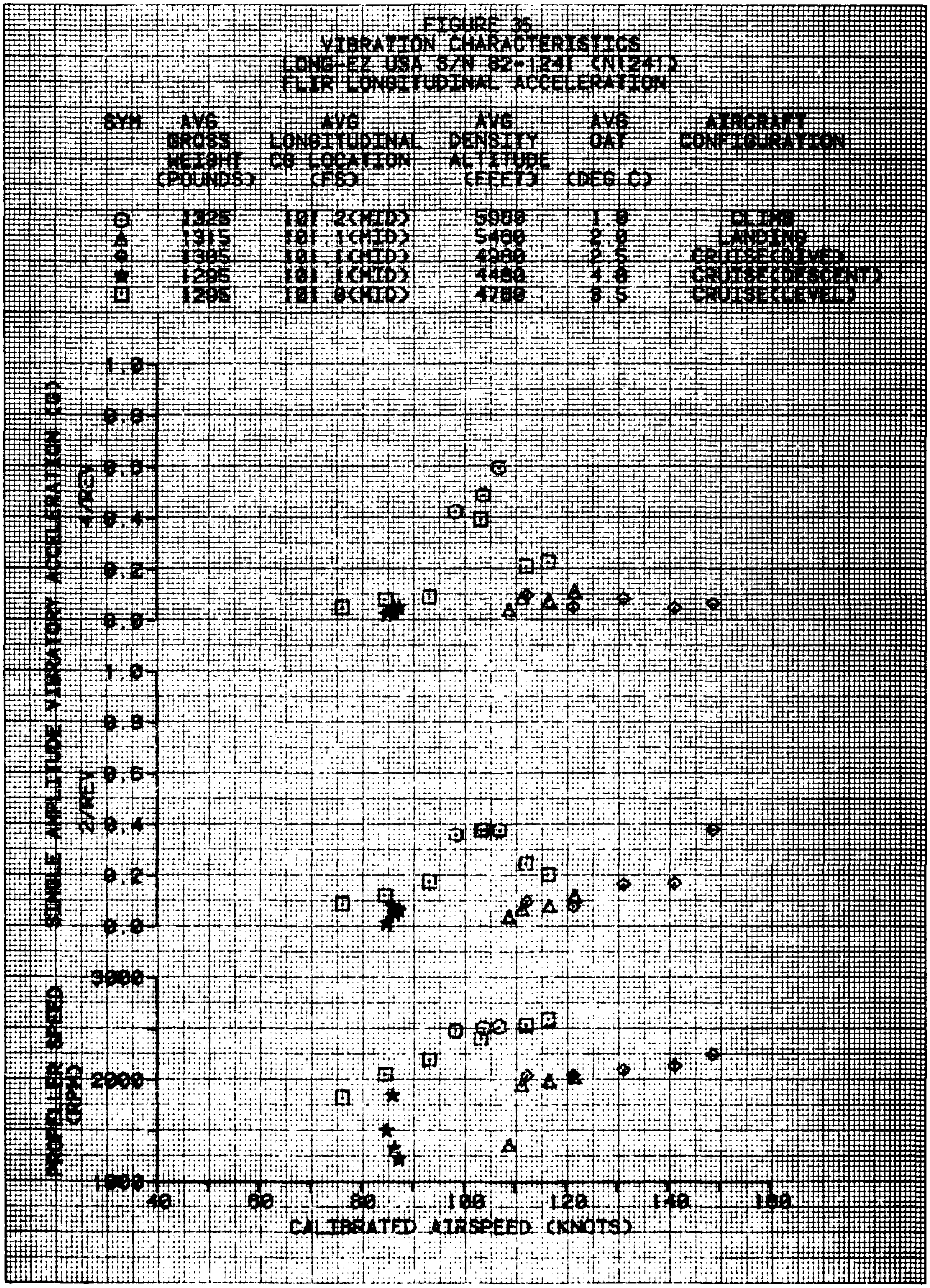


FIGURE 35
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LONGITUDINAL ACCELERATION
SYM
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
AIRCRAFT CONFIGURATION
1325 101.2(MID) 5000 1.0 CLIMB
1315 101.1(MID) 5400 2.0 LANDING
1305 101.1(MID) 4900 2.5 CRUISE(DIVE)
1295 101.1(MID) 4400 4.0 CRUISE(DESCENT)
1295 101.0(MID) 4700 5.5 CRUISE(LEVEL)
SINGLE AMPLITUDE VIBRATORY ACCELERATION (G)
1/REV
2/REV
PROPELLER SPEED (RPM)
1.0
0.8
0.6
0.4
0.2
0.0
3000
2000
1000
40
60
80
100
120
140
160
CALIBRATED AIRSPEED (KNOTS)

FIGURE 36
VIBRATION SPECTRUM
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LONGITUDINAL ACCELERATION

CALIBRATED AIRSPEED (KT)	GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	PROPELLER SPEED (RPM)	AIRCRAFT CONFIGURATION
107	1825	101.2(MID)	5640	1.0	2523	CLIMB

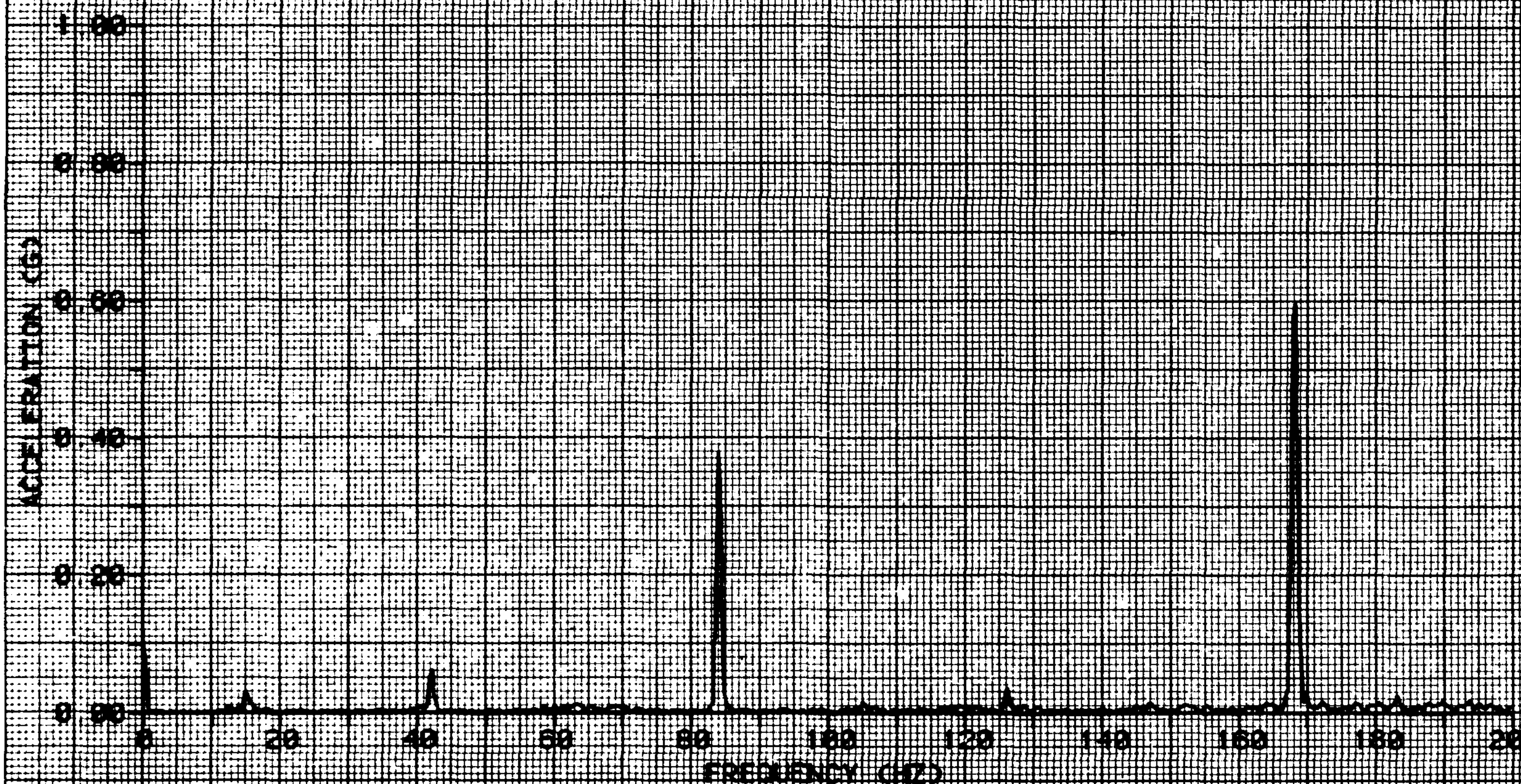
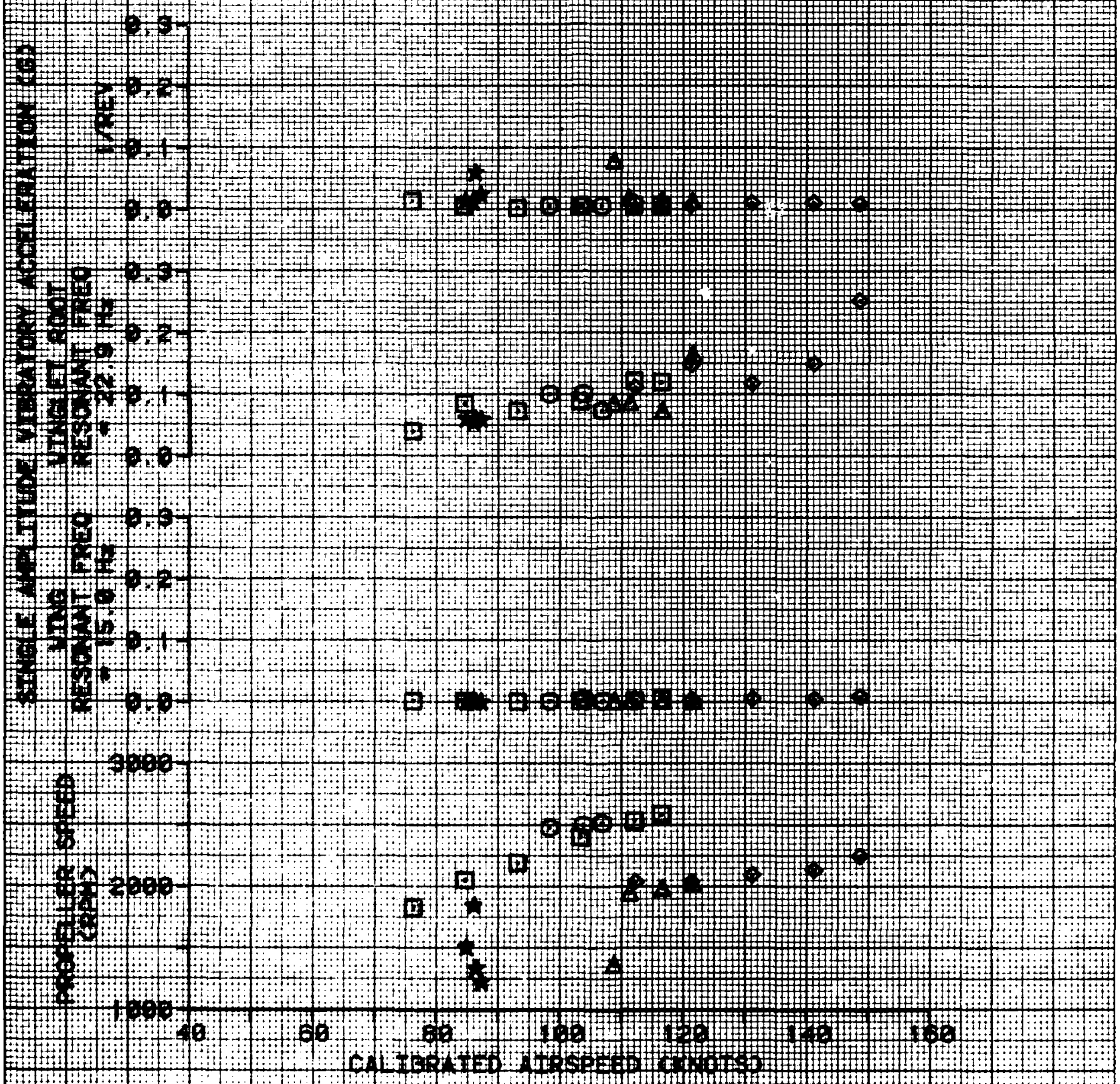


FIGURE 37
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LATERAL ACCELERATION

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
⊙	1325	101.2(MID)	5980	1.0	CLIMB
▲	1315	101.1(MID)	5460	2.0	LANDING
◈	1305	101.1(MID)	4980	2.5	CRUISE(DIVE)
★	1295	101.1(MID)	4480	4.0	CRUISE(DESCENT)
⊡	1295	101.0(MID)	4760	3.5	CRUISE(LEVEL)



AD-A145 381 PRELIMINARY AIRWORTHINESS EVALUATION OF THE RUTAN AIRCRAFT FACTORY (RAF)..(U) ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AFB CA D L UNDERWOOD ET AL. 2/2

UNCLASSIFIED MAY 84 USAAEFA-84-04 F/G 1/3 NL

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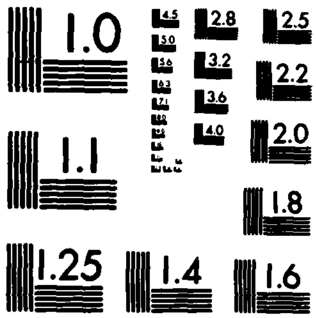


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FIGURE 38
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LATERAL ACCELERATION

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
⊙	1325	101.2(MID)	5000	1.0	CLIMB
△	1315	101.1(MID)	5400	2.0	LANDING
◇	1305	101.1(MID)	4900	2.5	CRUISE(DIVE)
★	1296	101.1(MID)	4400	4.0	CRUISE(DESCENT)
⊡	1295	101.0(MID)	4700	3.5	CRUISE(LEVEL)

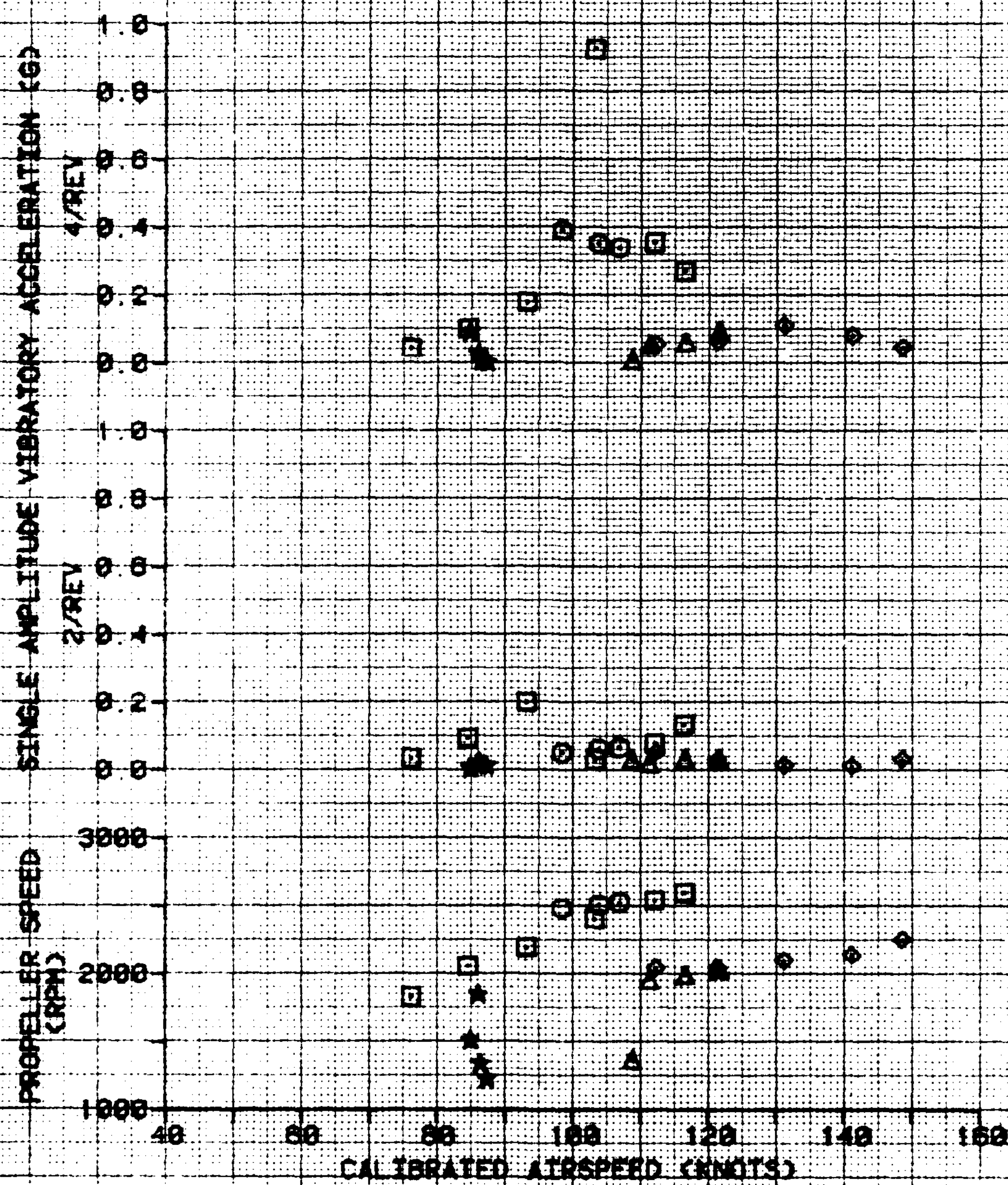


FIGURE 39
VIBRATION SPECTRUM
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LATERAL ACCELERATION

CALIBRATED AIRSPEED (KT)	GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	PROPELLER SPEED (RPM)	AIRCRAFT CONFIGURATION
100	1200	101.0(MID)	4840	3.5	2400	LEVEL

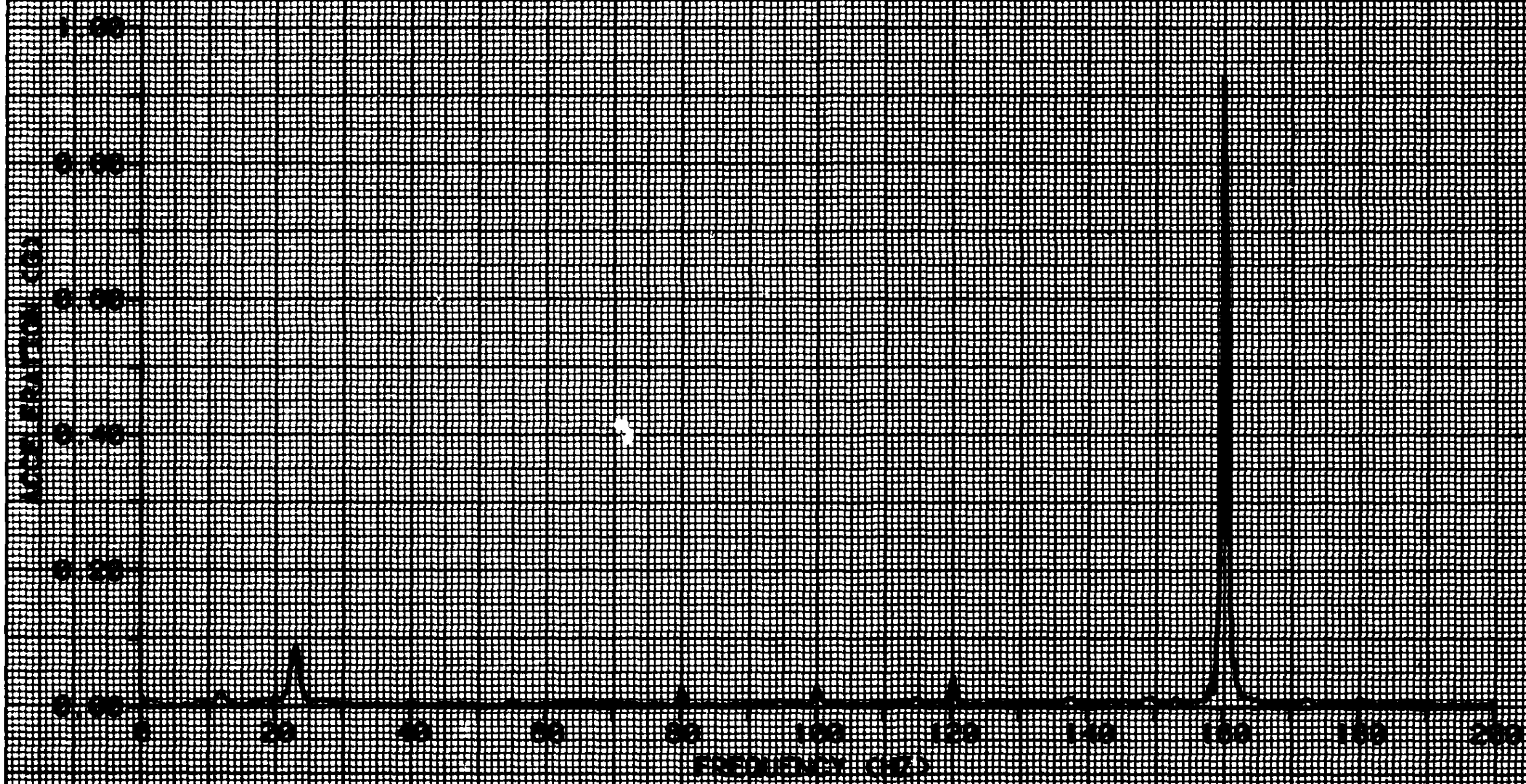
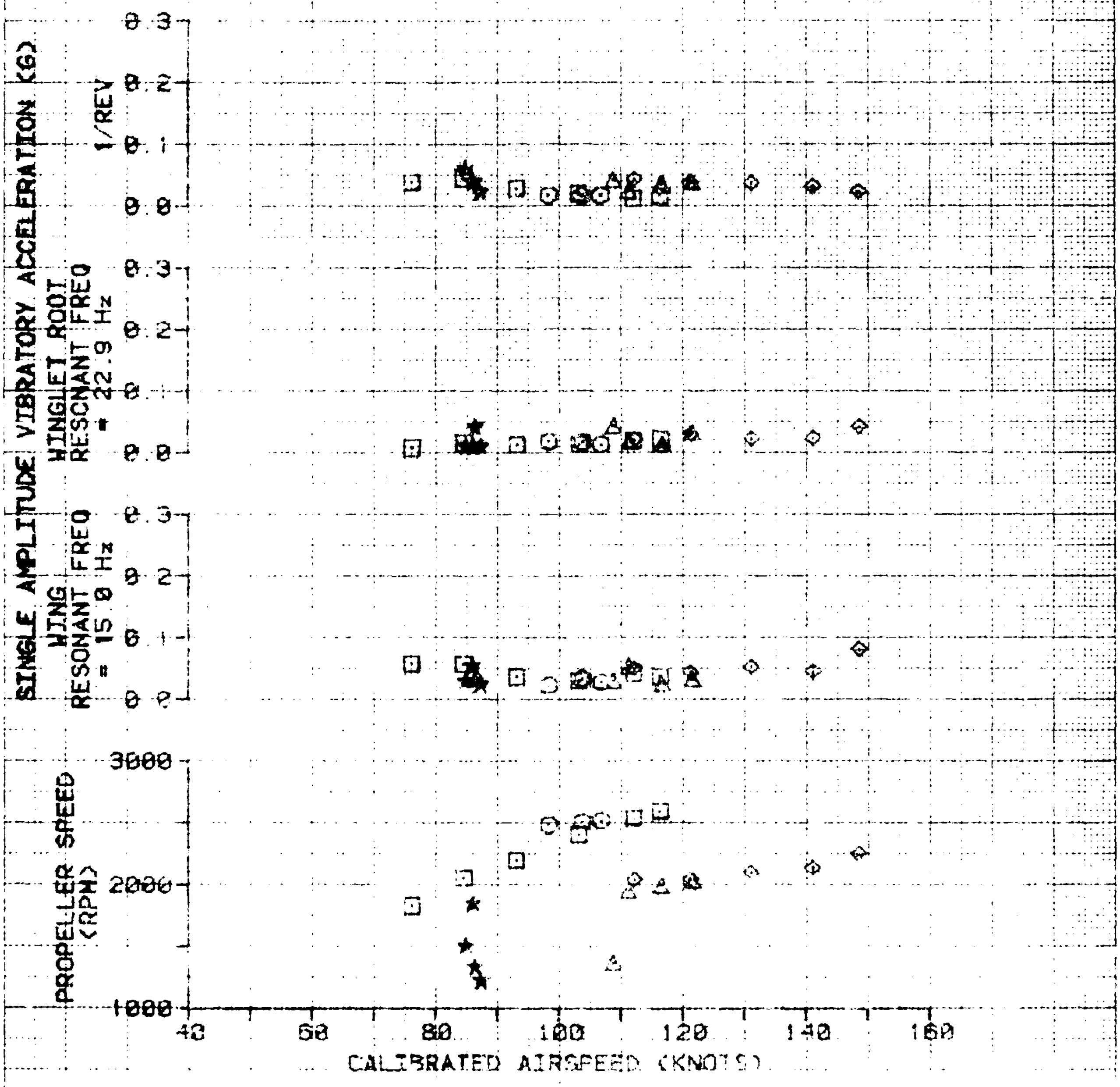


FIGURE 40
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR VERTICAL ACCELERATION

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
○	1325	101.2(MID)	5980	1.0	CLIMB
△	1315	101.1(MID)	5460	2.0	LANDING
◇	1305	101.1(MID)	4980	2.5	CRUISE(DIVE)
★	1295	101.1(MID)	4480	4.0	CRUISE(DESCENT)
□	1295	101.0(MID)	4760	3.5	CRUISE(LEVEL)



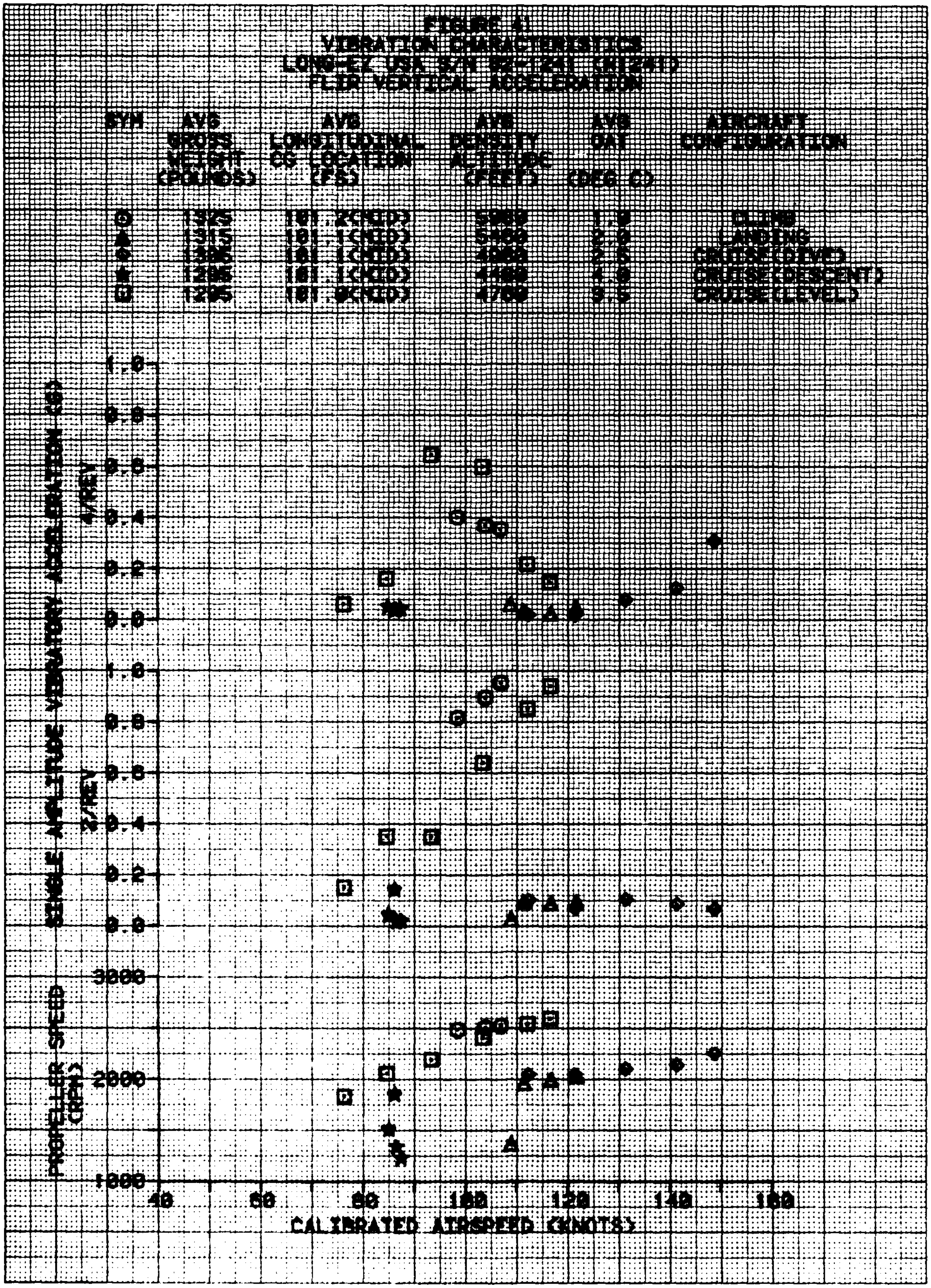


FIGURE 41
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR VERTICAL ACCELERATION
SYM
AVG GROSS WEIGHT (POUNDS)
AVG LONGITUDINAL CG LOCATION (FS)
AVG DENSITY ALTITUDE (FEET)
AVG OAT (DEG C)
AIRCRAFT CONFIGURATION
1325
1315
1305
1295
1295
CLIMB
LANDING
CRUISE(DIVE)
CRUISE(DESCENT)
CRUISE(LEVEL)
SINGLE AMPLITUDE VIBRATORY ACCELERATION (G)
4/REV
2/REV
PROPELLER SPEED (RPM)
1.0
0.8
0.6
0.4
0.2
0.0
3000
2000
1000
40
60
80
100
120
140
160
CALIBRATED AIRSPEED (KNOTS)

FIGURE 42
VIBRATION SPECTRUM
LONG-EZ USA S/N 82-1241 (N1241)
FLIR VERTICAL ACCELERATION

CALIBRATED AIRSPEED (KT)	GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	PROPELLER SPEED (RPM)	AIRCRAFT CONFIGURATION
107	1825	101.2(MID)	5640	1.0	2523	CLIMB

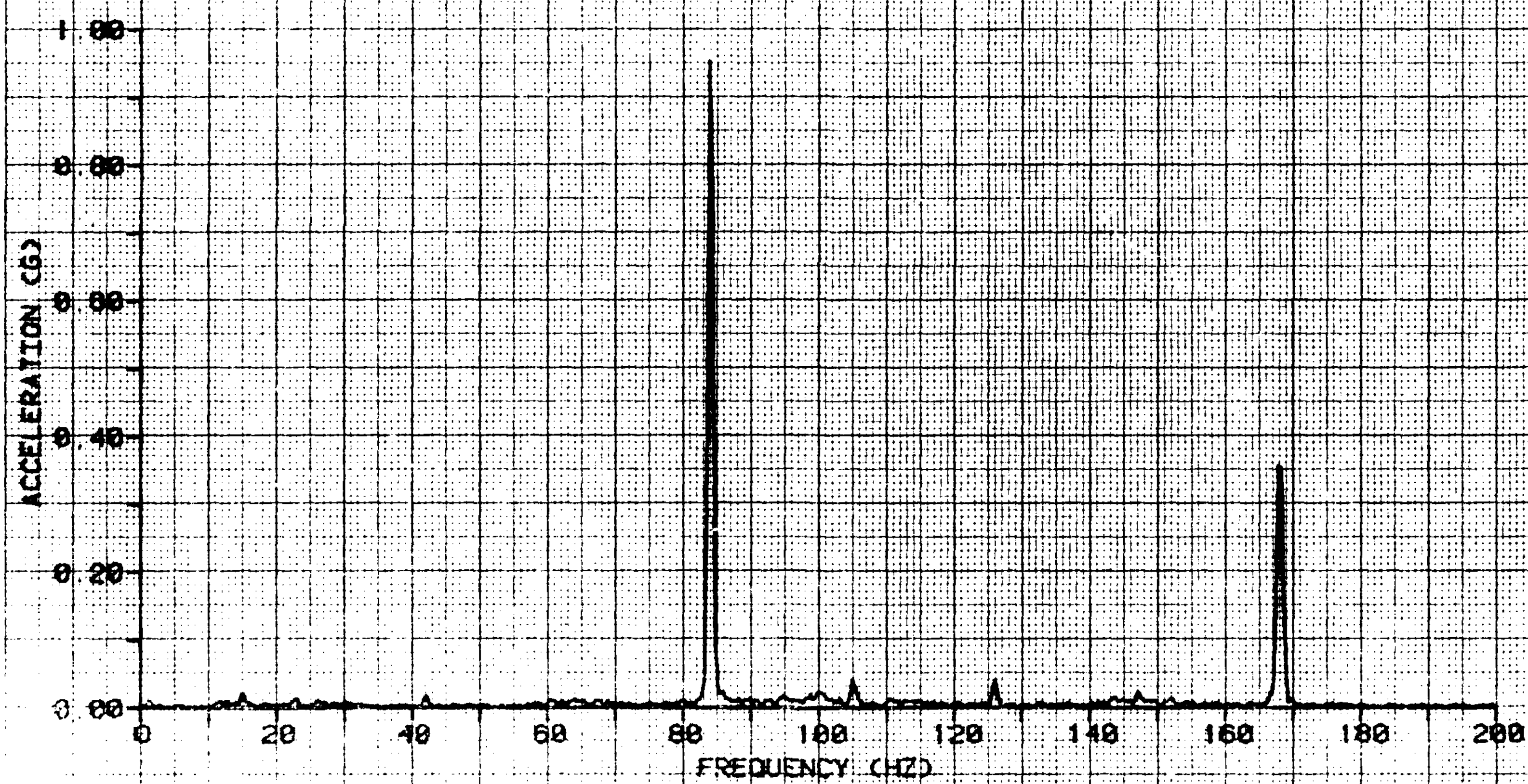


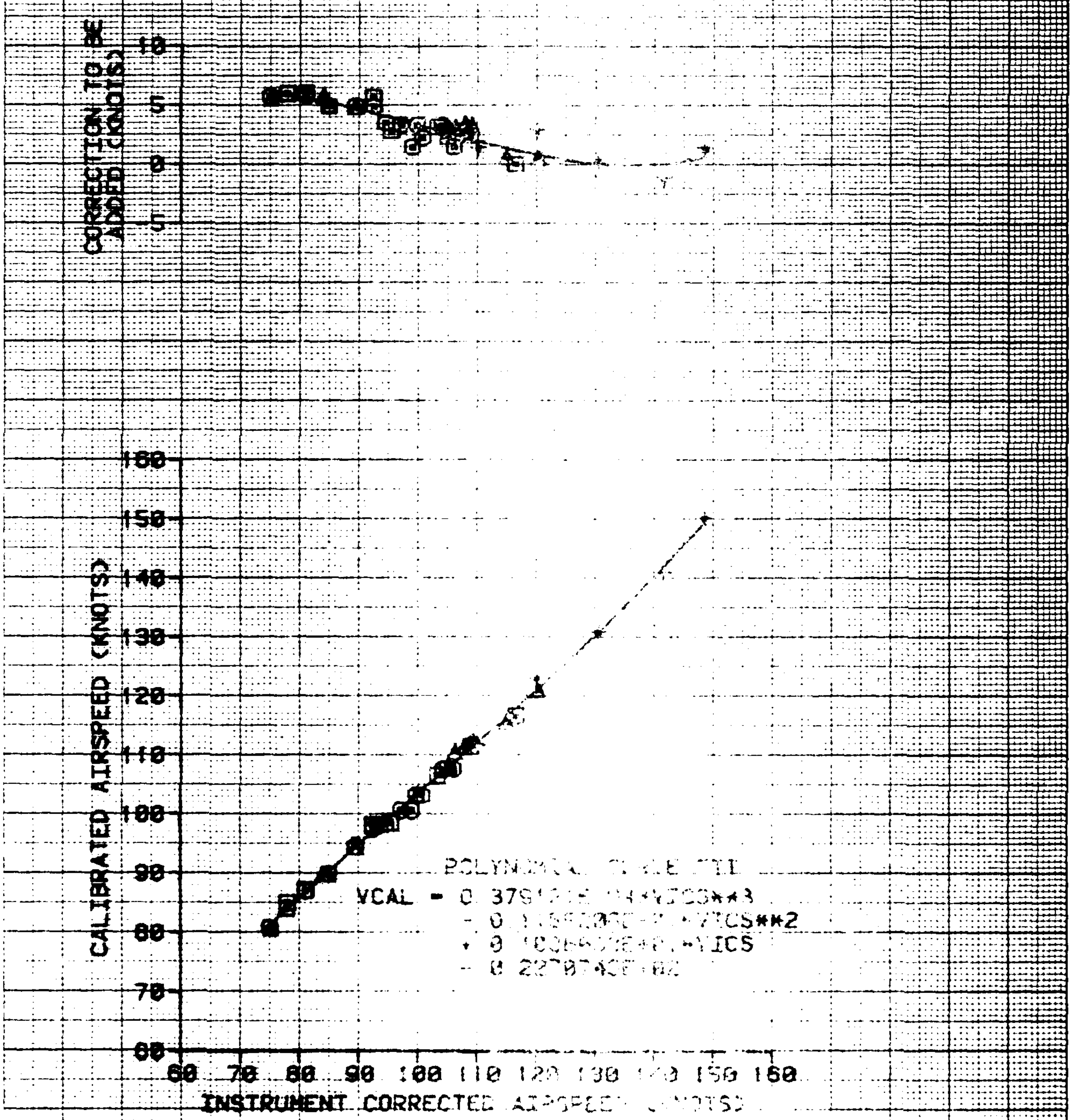
FIGURE 4[illegible]

AIRSPEED CALIBRATION

LONG-EZ USA S/N 82-1241 (N1241)

SHIP SYSTEM POSITION ERROR

SYM	AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (C)	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
□	1330	100.7 (MID)	5140	4.5	GEAR UP	CRUISE
⊙	1340	100.2 (MID)	4740	7.0	GEAR UP	CLIMB
△	1330	100.1 (MID)	4780	6.5	GEAR DOWN	DESCENT
+	1320	101.2 (MID)	5600	1.5	GEAR DOWN	DESCENT



APPENDIX F. DEFINITIONS, ABBREVIATIONS, AND SYMBOLS

This list includes most of the symbols used in this report. However, certain portions of the report use special or unusual abbreviations and symbols. The meaning of these is made clear in the text of the report and, when that is the case, the abbreviation or symbol will not be found in this list. Also, certain symbols have more than one meaning; however, the context should make the meaning clear.

Symbols and Abbreviations	Definitions	Unit
b	Wing span	feet
C_{Do}	Minimum coefficient of dray of the propeller-feathered drag polar	--
C_D	Coefficient of drag	--
$C_{D_{BL}}$	Base-line coefficient of drag	--
$C_{D_{PF}}$	Powered flight coefficient of drag	--
C_P	Coefficient of power	--
C_L	Coefficient of lift	--
Cont	Continuous	--
D	Drag	--
e	Oswald's span efficiency factor	--
f	Equivalent flat plate area	ft^2
g	Acceleration of gravity	ft/sec^2
H_D	Density altitude	feet
H_{Pi}	Indicated pressure altitude	feet
H_P	Pressure altitude	feet
H_{Pic}	Instrument corrected pressure altitude	feet
L	Lift	pounds
MAC	Mean aerodynamic chord	--

Symbols and Abbreviations	Definitions	Unit
Max	Maximum	--
MCP	Maximum continuous power	--
Min	Minimum, minute	--
N_P	Propeller speed	rpm
NU	Nose up	--
ND	Nose down	--
OAT	Outside air temperature	°C
p	Roll rate	radians/sec
P_a	Ambient pressure	in. of mercury
P_o	Standard-day, sea level pressure	in. of mercury
Psi	Pounds per square inch	lb/in.^{2}
q	Dynamic pressure	lb/ft^2
ref	Referred, reference	--
R/C	Rate of climb	ft/min
S	Wing area	ft^2
SHP	Shaft horsepower	--
SL	Sea level	--
S/N	Serial number	--
STD	Standard	--
T_a	Ambient air temperature	°C
T_C	Coefficient of thrust	--
T_i	Indicated air temperature	°C

Symbols and Abbreviations	Definitions	Unit
T	Thrust	lb
T_{ie}	Instrument corrected on temperature	°C
THP	Thrust horsepower	HP
T_o	Sea-level, standard-day static temperature	°K
V_{cal}	Calibrated airspeed	knot
VHF	Very high frequency	--
V_i	Indicated airspeed	knot
V_{ic}	Instrument corrected airspeed	knot
V_T	True airspeed	knot
V_{MC}	Airspeed for minimum control	knot
V_S	Stall airspeed	knot
V_H	Maximum airspeed for level flight	knot
V_{MO}	Maximum operating airspeed	knot
V	True airspeed	ft/sec
W_a	Engine airflow	lb/hr
W	Weight	pounds
°C	Degrees Centigrade	degrees
°F	Degrees Fahrenheit	degrees
°K	Degrees Kelvin	degrees
Δ	Difference	--
$\Delta C_{D_{PF-BL}}$	Difference in coefficient of drag due to thrust effect	--
ΔV_{PC}	Airspeed position error correction	--

Symbols and Abbreviations	Definitions	Unit
ζ	Damping ratio	--
θ	Temperature ratio, descent angle	degrees
δ	Pressure ratio	--
σ	Density ratio	--
ρ	Air mass density	slug/sec^3
ω_d	Damped natural frequency	radians/sec
ω_n	Undamped natural frequency	radians/sec
a	Angle of attack	degrees
ϕ	Roll of bank angle	degrees
η_p	Propeller efficiency	--
ϕ/β	Roll-to-yaw ratio	--
dh/dt	Tapeline rate of descent	ft/min
π	3.14159	--
$\eta_{in.}$	Inlet duet efficiency	percent

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Deputy Chief of Staff for Research Development and Acquisition (DAMA-PPM-T, DAMA-RA, DAMA-WSA)	3
Comptroller of the Army (DACA-EA)	1
US Army Materiel Development and Readiness Command (DRCDE-SA, DRCQA-E, DRCDE-I, DRCDE-P, DRCQA-SA, DRCSM-WA)	6
US Army Training and Doctrine Command (ATTG-U, ATCD-T, ATCD-ET, ATCD-B)	4
US Army Aviation Systems Command (DRSAV-ED, DRSAV-EI, DRSAV-EL, DRSAV-EA, DRSAV-EP, DRSAV-ES, DRSAV-Q, DRSAV-MC, DRSAV-ME)	16
US Army Test and Evaluation Command (DRSTE-CT-A, DRSTE-TO-O)	2
US Army Logistics Evaluation Agency (DALO-LEI)	1
US Army Materiel Systems Analysis Agency (DRXSY-R, DRXSY-MP)	2
US Army Operational Test and Evaluation Agency (CSTE-POD)	1
US Army Armor Center (ATZK-CD-TE)	1
US Army Aviation Center (ATZQ-D-T, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-U)	4
US Army Combined Arms Center (ATZLCA-DM)	1
US Army Safety Center (IGAR-TA, IGAR-Library)	2

US Army Research and Technology Laboratories (AVSCOM) (SAVDL-AS, SAVDL-POM (Library))	2
US Army Research and Technology Laboratories/Applied Technology Laboratory (SAVDL-ATL-D, SAVDL-Library)	2
US Army Research and Technology Laboratories/Aeromechanics Laboratory (AVSCOM) (SAVDL-AL-D)	2
US Army Research and Technology Laboratories/Proplusion Laboratory (AVSCOM) (SAVDL-PL-D)	1
Defense Technical Information Center (DDR)	12
US Military Academy, Department of Mechanics (Aero Group Director)	1
MTMC-TEA (MTT-TRC)	1
ASD/AFXT	1
US Naval Post Graduate School, Department Aero Engineering (Professor Donald Layton)	1
US Army 9th Cavalry Brigade (Air Attack) (AFVO-CB-XO, MAJ Kreutz)	5
US Army Aviation Systems Command (DRSAV-WZ)	3
Rutan Aircraft Factory, Inc.	3

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