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Ground Vibration Test Results for Drones for Aerodynamic and Structural Testing (DAST)/ Aeroelastic Research Wing (ARW-1R) Aircraft

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INTRODUCTION

Accurate structural modeling becomes increasingly important as designers continue to develop more efficient aircraft designs. In particular, if active controls are to be used on a wing to control structural modes, accurate knowledge of the model is imperative to meet the design goals. One objective of the NASA program on drones for aerodynamic and structural testing (DAST) is to investigate aeroelastic effects in the high subsonic speed range and, in so doing, to develop and demonstrate the use of state-of-the-art analytical techniques. The DAST program is a joint effort of NASA Langley Research Center (LaRC) and Dryden Flight Research Facility of Ames Research Center (Ames-Dryden).

The aircraft for the DAST program, a modified Firebee II target drone vehicle fuselage with a NASA-designed research wing, is flown in a remotely piloted mode. The first aeroelastic research wing that was tested in the DAST program and designated the ARW-1 was a sweptback, supercritical airfoil with a performance design point of Mach 0.98 at 13,716 m (45,000 ft). During its third flight, the ARW-1 encountered flutter and was severely damaged on ground impact. An overview of the DAST program and results of ARW-1 flight testing can be found in references 1 to 5. The vehicle was subsequently rebuilt retaining the same basic wing design and designated ARW-1R (fig. 1).

As a result of some discrepancies between analytical and ground vibration test (GVT) results and their associated effects on the ARW-1, a major objective of the ARW-1R was to produce the best possible structural model for flutter analysis. This report presents details of the complete vehicle, GVT configuration, test setup, test procedure, analysis methods, and natural frequency and mode shape results. These results were used to update the structural model for the final design analysis.

NOMENCLATURE

ARW-1	aeroelastic research wing no. 1
ARW-1R	aeroelastic research wing no. 1, rebuilt
DAST	drones for aerodynamic and structural testing
FSS	flutter suppression system
f	frequency, cycles/sec
GVT	ground vibration test
g	acceleration due to gravity
K	multiplication factor
MARS	midair recovery system

s	Laplace variable
X, Y, Z	conventional coordinate system
Δ	difference between measurements
ξ	damping ratio
ϕ	phase angle, deg
ω	angular frequency, rad/sec
ω_n	natural frequency, rad/sec

AIRCRAFT TEST CONFIGURATION

To obtain the most accurate modal frequencies and mode shapes possible during the GVT, the ARW-1 vehicle was configured as closely as possible to its flight configuration. The nosecone, noseboom, engine, external fuel tank, wingtip masses, and the aft section – which contains the midair recovery system (MARS) – were installed for the test. In addition, a speed brake, designed for use as an emergency deceleration device, was installed in the aft area of the vehicle (fig. 2). Small, lightweight fixtures were used to prevent aileron motion (fig. 3), and heavy tape was wrapped around the speed brake to minimize interference with basic aircraft response; however, the tape did not touch the fuselage. The vehicle was unfueled for all test configurations.

TEST ELEMENTS

Structural Support System

An overhead structural support stand (fig. 4) was constructed; the vehicle was suspended using the system air springs and 0.952-cm (3/8-in) cables. The cables were connected to the two hook attachment points located on the top centerline of the fuselage and used to carry the vehicle in its launch configuration.

Air Spring Isolation System

The vehicle was isolated from the support structure by two nitrogen-pressurized air springs (fig. 5) that were manufactured by LaRC and had a natural frequency of ω_n = 2.39 rad/sec. The total length of the air spring and cable support system was 2.44 m (8 ft).

Test Equipment

Structural analysis system. – A GenRad 2508 structural test and analysis system was used for the test procedure. The testing was performed with single-point, random excitation.

The actual data generation was a two-step process. First, an excitation signal was generated and recorded on magnetic tape. This process (fig. 6) was initialized by programming a flat force spectrum, specified over a frequency range of 5 to 100 Hz, into the GenRad 2508. The system was used in a closed loop to generate the random drive shaker signal so that the desired flat force spectrum was produced. When the system converged and produced the desired spectrum, a 30-min recording was made of the drive signal. Because of different vehicle response characteristics, a different drive signal was generated for each new shaker location.

The second step consisted of replaying the recorded signal through an amplifier to drive the shaker while simultaneously recording the vehicle response data. The amplifier gain was adjusted to produce the desired rms force level. When the vehicle reached a steady-state excitation condition, the system initiated data collection.

Sensors. - The test and analysis system has a four-channel input capability; typically, one force measurement and three accelerometer measurements that provide three-transfer-function analysis capability for each run. The force was measured by a force link that had a sensitivity of approximately 222.4 mV/N (50 mV/lb). Figure 7 illustrates a typical shaker and vehicle connection. In addition to a narrow diameter fuse-type rod connected to the shaker, the force link is isolated electrically from both the shaker and the aircraft.

The three acceleration signals were measured by accelerometers that had sensitivities of approximately 10 mV/g. The accelerometers were usually attached directly to the aircraft with double-backed tape. However, in areas of significant curvature, balsa wedges were used to maintain a normal coordinate system (fig. 8).

Shaker equipment. - Two different types of shakers were used throughout the ARW-1R testing. A 44.48-N (10-lb) shaker was used in the vertical axis at the right wingtip, but a 222.40-N (50-lb) shaker was required in both the vertical and horizontal axes to obtain adequate excitation at the nose.

VIBRATION DATA

Test Coordinates

The wing and body test coordinates of the ARW-1R vehicle are listed in table 1 and illustrated in figures 9 to 11. Both spanwise rows on the left wing and the two middle spanwise rows on the right wing (fig. 9) were above the forward and aft spars. The chordwise rows were above the ribs.

Test Conditions

Three major tests were conducted to determine basic modal parameters and shapes. The shaker locations were: (1) right wingtip (location 14 in Z direction), (2) horizontal at the base of the nosecone (location 78 in Y direction), and (3) vertical at the base of the nose (location 78 in Z direction), where X, Y, and Z are axes in the conventional coordinate system.

Data Collection

The majority of the collected data consisted of single-axis measurements when the primary modes consisted of single-axis responses. To verify anticipated axis coupling, acceleration responses were recorded in two axes at selected test coordinates for certain excitation locations.

A schematic of the collection process is shown in figure 12. When the aircraft reached a steady-state excitation condition, the data collection process was initiated. The system has many data collection options that control the data actually stored for analysis processing. The aircraft was randomly excited over a frequency range of 5 to 100 Hz. The basic data analysis block size was 1024; data were collected at 128 samples/sec, which produced an ensemble (record) length of 8 sec. Each test run consisted of 100 ensembles using an overlap factor of 7/8. With a record length of 8 sec, each new ensemble consisted of 7 sec from the previous ensemble plus 1 sec of new data. Therefore, 100 ensembles with a 7/8 overlap factor resulted in 107 sec of data collected for each test. Anti-aliasing filters of 50 Hz were used on all data collected. When a test was completed and the data stored, the three accelerometers were moved to new locations and the data collection process was reinitiated.

Data Analysis

The analysis of a desired mode at a particular excitation point consists of first identifying the modal frequency and damping from a transfer function obtained from a test coordinate with good response characteristics. The mode shape data are obtained by performing a single-degree-of-freedom fit of the remaining transfer functions for the mode of interest. The result of this fit produces amplitude coefficients for all the test points relative to the test point used to identify the modal frequency. The fitting algorithm assumes normal modes.

RESULTS AND DISCUSSION

All identifiable modes were analyzed for their respective mode shapes. The symmetric wing model results were determined from the right-wing vertical excitation location. Also included with the symmetric results are the vertical body bending modes that were determined from the nose vertical excitation location. The antisymmetric wing results were determined from the right-wing vertical excitation location. Included with the antisymmetric results are the lateral body bending modes and the vertical tail mode that were determined from the nose horizontal excitation location.

Table 2 summarizes the frequency and damping of the identified modes, together with the most prominent modal description. The symmetric mode shapes are presented in figures 13 to 17, and the antisymmetric mode shapes are presented in figures 18 to 23. The tabulated mode shapes (amplitude coefficients) are presented in tables 3 and 4 for the symmetric and antisymmetric modes, respectively.

The mode shape data have units of cm/N (in/lb) and result directly from the transfer function analysis; the data were not normalized in any other respect.

Therefore, magnitude comparisons should not be made from one mode to another unless the same excitation point was used for the identification of each mode.

Symmetric

The symmetric first wing bending mode is presented in figure 13. The node line is near the line where the glove fairing merges into the basic wing. Amplitudes increase with increasing wing station to the outer wing area, where data points in front of the front spar and aft of the rear spar have some apparent scatter. The maximum deflection occurs on the wingtip mass. Although this mode is the most pronounced of all identified modes, it was the most difficult to fit and its mode shape quality is poorer than nearly all other mode shapes presented.

The primary cause of the poor fit quality is that a fixed frequency increment, Δf, was used in collecting the data. The lower the frequency of data, the poorer the quality of fit. The problem is best illustrated in figure 24 where two second-order modes are presented, each with the same damping, but with the second mode having a natural frequency larger than the first by a factor, K. Thus, for equivalent magnitude levels,

$$\Delta\omega_2 = K(\Delta\omega_1)$$

If a constant frequency resolution of Δw is assumed, the respective number of samples in resonance peak is

$$\frac{\Delta\omega_1}{\Delta\omega} = \text{number of samples}$$

and

$$\frac{\Delta\omega_2}{\Delta\omega} = K \times \text{number of samples}$$

Hence, for a fixed $\Delta\omega$, the number of data points over the range of interest decrease as modal frequencies decrease. In general, improvement in this mode can only be obtained by reducing Δf, which requires an increase in the ensemble time and therefore total test time.

The second symmetric wing bending/torsion mode is presented in figure 14. The mode shape definition is good with node lines appearing near the wing root and in a lateral direction on the outer wing proceeding to the wingtip. The outer wing node line is very close to the flutter suppression system (FSS) accelerometer location (see table 1 for coordinates). Because this mode interacts with the first symmetric wing bending mode to produce flutter for closed-loop flutter control, the accelerometer location is critical. Again, the maximum deflection is observed on the wingtip mass.

It should be noted that, although mode shape definition is good, an apparent asymmetry was detected near this mode, as evidenced by a second mode appearing 0.30 Hz higher. From a detailed analysis of this area, it was concluded that a wing asymmetry caused this problem. The left wing dominates at the higher frequency, and the right wing dominates at the lower frequency. The mode shape results that are given are also representative for the higher frequency mode.

The first vertical fuselage bending mode is presented in figure 15. The node lines are immediately forward of the engine inlet duct and near the root midchord of the vertical tail. Nearly equal maximum deflections occur at both ends of the fuselage. The second vertical fuselage bending mode is presented in figure 16.

Antisymmetric

The antisymmetric first wing bending mode is presented in figure 18. The mode shape definition is good, and although the frequency is relatively low, the mode shape fitting proceeded well and did not encounter the same degree of difficulty as it did for the first wing symmetric mode. The wing node line runs laterally across the midsection of the wing with a maximum displacement occurring at the wingtip mass.

The antisymmetric second wing bending/torsion mode is presented in figure 19. The mode shape is well defined with wing node lines near the wing root and laterally across the outer section of the wing proceeding to the wingtip. The overall mode shape is similar to the symmetric second wing bending/torsion mode of figure 14. Again, a node line is near the FSS accelerometer location.

The antisymmetric first lateral fuselage bending mode is presented in figure 20. The node lines are immediately in front of the engine inlet duct and near the root midchord of the vertical tail. The node line locations are very similar to the vertical mode of figure 18.

CONCLUDING REMARKS

A ground vibration test (GVT) was conducted to determine the resonant frequencies and mode shapes of the rebuilt aeroelastic research wing vehicle (ARW-1R). The results were then used to update the structural model. The aircraft was excited at three test locations – at the nose vertically, at the nose horizontally, and at the right wingtip vertically – to ensure adequate excitation of all modes. The results provided accurate modal frequency and mode shape information, with the possible exception of the 9.30-Hz mode. The fit of this mode could have been improved by increasing the test duration to produce a smaller change in frequency (Δf).

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TABLE 1. — AIRCRAFT TEST POINT LOCATIONS

(a) Right-wing test point locations

Test point	X	Y	Z
1	221.0	10.0	0
2	229.6	13.1	0
3	239.5	16.3	0
4	248.2	19.2	0
5	256.4	27.8	0
6	264.5	36.6	0
7	272.9	45.3	0
8	281.1	54.0	0
9	285.1	58.2	0
10	289.2	62.9	0
11	293.2	67.1	0
12	297.3	71.3	0
13	301.6	75.9	0
14	304.8	79.2	0
15	235.0	10.0	0
16	244.3	10.0	0
17	250.6	17.0	0
18	258.7	25.9	0
19	266.7	34.8	0
20	274.8	43.6	0
21	282.9	52.5	0
22	286.9	57.0	0
23	291.0	61.4	0
24	295.0	65.9	0
25	299.0	70.3	0
26	303.3	74.7	0
27	307.1	79.2	0
28	256.2	10.0	0
29	264.7	20.4	0
30	272.3	29.8	0
31	279.9	39.1	0
32	287.4	48.4	0
33	291.2	53.1	0
34	295.0	57.7	0
35	298.8	62.4	0
36	302.6	67.1	0
37	306.4	71.7	0
38	312.3	79.2	0
39	262.6	10.0	0

TABLE 1. — Continued

(a) Continued

Test point	X	Y	Z
40	268.1	17.3	0
41	275.2	27.0	0
42	282.8	36.8	0
43	290.0	46.2	0
44	293.4	50.9	0
45	297.2	55.7	0
46	300.8	60.3	0
47	304.2	65.2	0
48	314.9	79.2	0
49	322.4	80.7	0
50	306.0	79.2	0
FSS accel-erometer	311.68	76.26	0

(b) Left-wing test point locations

Test point	X	Y	Z
51	250.6	-17.0	0
52	258.7	-25.9	0
53	266.7	-34.8	0
54	274.8	-43.6	0
55	282.9	-52.5	0
56	291.0	-61.4	0
57	299.0	-70.3	0
58	307.1	-79.2	0
59	256.2	-10.0	0
60	264.7	-20.4	0
61	272.3	-29.8	0
62	279.9	-39.1	0
63	287.4	-48.4	0
64	295.0	-57.7	0
65	302.6	-67.1	0
66	312.3	-79.2	0

TABLE 1. — Concluded

(c) Horizontal tail test point locations

Test point	X	Y	Z
67	359.6	14.0	0
68	363.9	20.0	0
69	368.6	26.0	0
70	373.1	32.0	0
71	359.6	-14.0	0
72	363.9	-20.0	0
73	368.6	-26.0	0
74	373.1	-32.0	0

(d) Vertical tail test point locations

Test point	X	Y	Z
75	348.1	0	9.0
76	356.0	0	18.0
77	366.1	0	29.5

(e) Fuselage test point locations

Test point	X	Y	Z
78	118.5	0	0
79	150.5	0	0
80	182.5	0	0
81	215.0	0	0
82	241.5	0	0
83	275.5	0	0
84	295.5	0	0
85	324.5	0	0
86	340.0	0	0
87	369.0	0	0
88	409.0	0	0
89	241.5	0	-34.4
90	258.0	0	-34.4
91	275.5	0	-34.4
92	295.9	0	-33.1
93	325.0	0	-26.9

TABLE 2. – FREQUENCY AND DAMPING OF MODE SHAPES

Frequency, Hz	Damping	Mode shape
		Symmetric
9.30	0.00588	First wing bending
16.09	0.01782	First vertical fuselage bending
27.77	0.01177	Second vertical fuselage bending
30.30	0.00937	Second wing bending/torsion
30.69	0.00684	Second wing bending/torsion
38.96	0.01447	Unidentified (significant wing torsion)
		Antisymmetric
13.56	0.00882	First wing bending
18.18	0.00704	First lateral fuselage bending
28.50	0.00710	Vertical tail
31.51	0.01497	Second lateral fuselage bending
32.72	0.01943	Second wing bending/torsion
48.91	0.02010	Second wing torsion

TABLE 3. — SYMMETRIC MODE SHAPE COEFFICIENTS
(Mode shape location is the same as
test point in table 1.)

(a) First wing bending mode, 9.30 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	-1.6841E-02
2	0.0000E-01	0.0000E-01	-1.4841E-02
3	0.0000E-01	0.0000E-01	-1.3553E-02
4	0.0000E-01	0.0000E-01	2.3995E-03
5	0.0000E-01	0.0000E-01	3.5104E-02
6	0.0000E-01	0.0000E-01	1.1269E-01
7	0.0000E-01	0.0000E-01	1.9040E-01
8	0.0000E-01	0.0000E-01	3.6072E-01
9	0.0000E-01	0.0000E-01	5.0616E-01
10	0.0000E-01	0.0000E-01	5.7317E-01
11	0.0000E-01	0.0000E-01	7.3815E-01
12	0.0000E-01	0.0000E-01	7.9996E-01
13	0.0000E-01	0.0000E-01	8.9057E-01
14	0.0000E-01	0.0000E-01	1.0519E 00
15	0.0000E-01	0.0000E-01	-1.7152E-02
16	0.0000E-01	0.0000E-01	-2.4217E-02
17	0.0000E-01	0.0000E-01	-4.7990E-03
18	0.0000E-01	0.0000E-01	3.6081E-02
19	0.0000E-01	0.0000E-01	8.5226E-02
20	0.0000E-01	0.0000E-01	2.1062E-01
21	0.0000E-01	0.0000E-01	3.3766E-01
22	0.0000E-01	0.0000E-01	4.4355E-01
23	0.0000E-01	0.0000E-01	5.9112E-01
24	0.0000E-01	0.0000E-01	6.3102E-01
25	0.0000E-01	0.0000E-01	7.3500E-01
26	0.0000E-01	0.0000E-01	9.6224E-01
27	0.0000E-01	0.0000E-01	1.1682E 00
28	0.0000E-01	0.0000E-01	-2.4262E-02
29	0.0000E-01	0.0000E-01	2.6750E-02
30	0.0000E-01	0.0000E-01	8.5982E-02
31	0.0000E-01	0.0000E-01	2.2773E-01
32	0.0000E-01	0.0000E-01	3.6477E-01
33	0.0000E-01	0.0000E-01	4.8034E-01
34	0.0000E-01	0.0000E-01	6.4262E-01
35	0.0000E-01	0.0000E-01	6.8914E-01
36	0.0000E-01	0.0000E-01	8.0685E-01
37	0.0000E-01	0.0000E-01	1.0940E 00
38	0.0000E-01	0.0000E-01	1.0656E 00
39	0.0000E-01	0.0000E-01	-3.5326E-02
40	0.0000E-01	0.0000E-01	2.0174E-02
41	0.0000E-01	0.0000E-01	8.5804E-02
42	0.0000E-01	0.0000E-01	2.4142E-01
43	0.0000E-01	0.0000E-01	3.9325E-01
44	0.0000E-01	0.0000E-01	5.1345E-01
45	0.0000E-01	0.0000E-01	6.8203E-01
46	0.0000E-01	0.0000E-01	7.5628E-01
47	0.0000E-01	0.0000E-01	8.6982E-01
48	0.0000E-01	0.0000E-01	1.1570E 00
49	0.0000E-01	0.0000E-01	1.4492E 00
51	0.0000E-01	0.0000E-01	-5.3322E-03
52	0.0000E-01	0.0000E-01	2.7105E-02
53	0.0000E-01	0.0000E-01	9.4424E-02
54	0.0000E-01	0.0000E-01	2.1013E-01
55	0.0000E-01	0.0000E-01	3.3397E-01
56	0.0000E-01	0.0000E-01	5.4420E-01
57	0.0000E-01	0.0000E-01	8.2942E-01
58	0.0000E-01	0.0000E-01	1.1611E 00
59	0.0000E-01	0.0000E-01	-2.2218E-02
60	0.0000E-01	0.0000E-01	1.9196E-02
61	0.0000E-01	0.0000E-01	9.4069E-02
62	0.0000E-01	0.0000E-01	2.8058E-01
63	0.0000E-01	0.0000E-01	3.8139E-01
64	0.0000E-01	0.0000E-01	6.2542E-01
65	0.0000E-01	0.0000E-01	9.4975E-01
66	0.0000E-01	0.0000E-01	1.4560E 00
67	0.0000E-01	0.0000E-01	-6.0298E-02
68	0.0000E-01	0.0000E-01	-7.0829E-02
69	0.0000E-01	0.0000E-01	-7.3851E-02
70	0.0000E-01	0.0000E-01	-8.4782E-02
71	0.0000E-01	0.0000E-01	-6.1187E-02
72	0.0000E-01	0.0000E-01	-7.1585E-02
73	0.0000E-01	0.0000E-01	-7.9850E-02
74	0.0000E-01	0.0000E-01	-8.0961E-02
75	0.0000E-01	0.0000E-01	0.0000E-01
76	0.0000E-01	0.0000E-01	0.0000E-01
77	0.0000E-01	0.0000E-01	0.0000E-01
78	0.0000E-01	0.0000E-01	-3.7459E-02
79	0.0000E-01	0.0000E-01	-3.1815E-02
80	0.0000E-01	0.0000E-01	-2.6394E-02
81	0.0000E-01	0.0000E-01	-2.2129E-02
82	0.0000E-01	0.0000E-01	-1.9329E-02
83	0.0000E-01	0.0000E-01	-2.2884E-02
84	0.0000E-01	0.0000E-01	-3.1327E-02
85	0.0000E-01	0.0000E-01	-4.4968E-02
86	0.0000E-01	0.0000E-01	-5.7366E-02
87	0.0000E-01	0.0000E-01	-6.6875E-02
88	0.0000E-01	0.0000E-01	-1.0264E-01
89	0.0000E-01	0.0000E-01	-1.7863E-02
90	0.0000E-01	0.0000E-01	-2.0307E-02
91	0.0000E-01	0.0000E-01	-2.3728E-02
92	0.0000E-01	0.0000E-01	-2.9327E-02
93	0.0000E-01	0.0000E-01	-3.8970E-02
50	0.0000E-01	0.0000E-01	1.0562E 00
94	0.0000E-01	0.0000E-01	-1.0775E-01

TABLE 3. — Continued

(b) First vertical fuselage bending mode, 16.09 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	-7.1465E-03
2	0.0000E-01	0.0000E-01	-8.6179E-03
3	0.0000E-01	0.0000E-01	-9.6197E-03
4	0.0000E-01	0.0000E-01	-8.8696E-03
5	0.0000E-01	0.0000E-01	-9.3120E-03
6	0.0000E-01	0.0000E-01	-9.5612E-03
7	0.0000E-01	0.0000E-01	-7.3847E-03
8	0.0000E-01	0.0000E-01	-7.7466E-03
9	0.0000E-01	0.0000E-01	-8.5704E-03
10	0.0000E-01	0.0000E-01	-5.3574E-03
11	0.0000E-01	0.0000E-01	0.0000E-01
12	0.0000E-01	0.0000E-01	0.0000E-01
13	0.0000E-01	0.0000E-01	5.2828E-03
14	0.0000E-01	0.0000E-01	6.5821E-03
15	0.0000E-01	0.0000E-01	-6.8821E-03
16	0.0000E-01	0.0000E-01	-7.9263E-03
17	0.0000E-01	0.0000E-01	-7.4677E-03
18	0.0000E-01	0.0000E-01	-6.9016E-03
19	0.0000E-01	0.0000E-01	-6.7346E-03
20	0.0000E-01	0.0000E-01	-6.0201E-03
21	0.0000E-01	0.0000E-01	-5.5989E-03
22	0.0000E-01	0.0000E-01	-5.3785E-03
23	0.0000E-01	0.0000E-01	-5.2311E-03
24	0.0000E-01	0.0000E-01	0.0000E-01
25	0.0000E-01	0.0000E-01	2.9181E-03
26	0.0000E-01	0.0000E-01	5.1158E-03
27	0.0000E-01	0.0000E-01	9.0594E-03
28	0.0000E-01	0.0000E-01	-8.4340E-03
29	0.0000E-01	0.0000E-01	-7.9322E-03
30	0.0000E-01	0.0000E-01	-7.2118E-03
31	0.0000E-01	0.0000E-01	-6.2125E-03
32	0.0000E-01	0.0000E-01	-5.5514E-03
33	0.0000E-01	0.0000E-01	-4.5556E-03
34	0.0000E-01	0.0000E-01	0.0000E-01
35	0.0000E-01	0.0000E-01	0.0000E-01
36	0.0000E-01	0.0000E-01	2.8808E-03
37	0.0000E-01	0.0000E-01	7.4686E-03
38	0.0000E-01	0.0000E-01	1.0546E-02
39	0.0000E-01	0.0000E-01	-8.0017E-03
40	0.0000E-01	0.0000E-01	-7.7678E-03
41	0.0000E-01	0.0000E-01	-7.4449E-03
42	0.0000E-01	0.0000E-01	-6.2117E-03
43	0.0000E-01	0.0000E-01	-5.9328E-03
44	0.0000E-01	0.0000E-01	-4.4166E-03
45	0.0000E-01	0.0000E-01	0.0000E-01
46	0.0000E-01	0.0000E-01	0.0000E-01
47	0.0000E-01	0.0000E-01	3.5461E-03
48	0.0000E-01	0.0000E-01	1.2962E-02
49	0.0000E-01	0.0000E-01	2.1345E-02
51	0.0000E-01	0.0000E-01	-9.3001E-03
52	0.0000E-01	0.0000E-01	-1.0647E-02
53	0.0000E-01	0.0000E-01	-9.6663E-03
54	0.0000E-01	0.0000E-01	-8.8272E-03
55	0.0000E-01	0.0000E-01	-5.2751E-03
56	0.0000E-01	0.0000E-01	-1.0688E-03
57	0.0000E-01	0.0000E-01	8.7442E-03
58	0.0000E-01	0.0000E-01	1.5477E-02
59	0.0000E-01	0.0000E-01	-1.0952E-02
60	0.0000E-01	0.0000E-01	-1.0653E-02
61	0.0000E-01	0.0000E-01	-1.0630E-02
62	0.0000E-01	0.0000E-01	-8.1839E-03
63	0.0000E-01	0.0000E-01	-5.0734E-03
64	0.0000E-01	0.0000E-01	0.0000E-01
65	0.0000E-01	0.0000E-01	9.9511E-03
66	0.0000E-01	0.0000E-01	2.1635E-02
67	0.0000E-01	0.0000E-01	7.5381E-03
68	0.0000E-01	0.0000E-01	1.1959E-02
69	0.0000E-01	0.0000E-01	1.3328E-02
70	0.0000E-01	0.0000E-01	1.6815E-02
71	0.0000E-01	0.0000E-01	4.4022E-03
72	0.0000E-01	0.0000E-01	6.5100E-03
73	0.0000E-01	0.0000E-01	8.6628E-03
74	0.0000E-01	0.0000E-01	9.6341E-03
75	0.0000E-01	0.0000E-01	0.0000E-01
76	0.0000E-01	0.0000E-01	0.0000E-01
77	0.0000E-01	0.0000E-01	0.0000E-01
78	0.0000E-01	0.0000E-01	2.3780E-02
79	0.0000E-01	0.0000E-01	9.9044E-03
80	0.0000E-01	0.0000E-01	0.0000E-01
81	0.0000E-01	0.0000E-01	-5.2412E-03
82	0.0000E-01	0.0000E-01	-8.3373E-03
83	0.0000E-01	0.0000E-01	-8.6840E-03
84	0.0000E-01	0.0000E-01	-7.9212E-03
85	0.0000E-01	0.0000E-01	-3.7928E-03
86	0.0000E-01	0.0000E-01	0.0000E-01
87	0.0000E-01	0.0000E-01	8.6026E-03
88	0.0000E-01	0.0000E-01	2.4915E-02
89	0.0000E-01	0.0000E-01	-9.5078E-03
90	0.0000E-01	0.0000E-01	-7.8051E-03
91	0.0000E-01	0.0000E-01	-7.6720E-03
92	0.0000E-01	0.0000E-01	-6.6516E-03
93	0.0000E-01	3.4139E-03	-3.2987E-03
50	0.0000E-01	0.0000E-01	7.5110E-03
94	0.0000E-01	1.8403E-02	2.7772E-02

TABLE 3. — Continued

(c) Second vertical fuselage bending, 27.77 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	0.0000E-01
2	0.0000E-01	0.0000E-01	0.0000E-01
3	0.0000E-01	0.0000E-01	0.0000E-01
4	0.0000E-01	0.0000E-01	0.0000E-01
5	0.0000E-01	0.0000E-01	0.0000E-01
6	0.0000E-01	0.0000E-01	0.0000E-01
7	0.0000E-01	0.0000E-01	0.0000E-01
8	0.0000E-01	0.0000E-01	0.0000E-01
9	0.0000E-01	0.0000E-01	0.0000E-01
10	0.0000E-01	0.0000E-01	0.0000E-01
11	0.0000E-01	0.0000E-01	0.0000E-01
12	0.0000E-01	0.0000E-01	0.0000E-01
13	0.0000E-01	0.0000E-01	0.0000E-01
14	0.0000E-01	0.0000E-01	0.0000E-01
15	0.0000E-01	0.0000E-01	0.0000E-01
16	0.0000E-01	0.0000E-01	0.0000E-01
17	0.0000E-01	0.0000E-01	0.0000E-01
18	-3.1065E-02	2.0157E-02	-6.3674E-02
19	0.0000E-01	0.0000E-01	0.0000E-01
20	-2.0170E-02	1.0286E-02	-4.0313E-02
21	0.0000E-01	0.0000E-01	0.0000E-01
22	0.0000E-01	0.0000E-01	0.0000E-01
23	-1.0532E-02	9.8579E-04	-4.0469E-02
24	0.0000E-01	0.0000E-01	0.0000E-01
25	-6.3687E-03	-1.7122E-03	-4.6150E-02
26	0.0000E-01	0.0000E-01	0.0000E-01
27	-2.3219E-03	-4.6565E-03	-5.3903E-02
28	0.0000E-01	0.0000E-01	0.0000E-01
29	-2.8160E-02	9.9876E-03	-3.0092E-02
30	0.0000E-01	0.0000E-01	0.0000E-01
31	-2.1493E-02	2.5034E-03	-7.7177E-03
32	0.0000E-01	0.0000E-01	0.0000E-01
33	0.0000E-01	0.0000E-01	0.0000E-01
34	-1.1881E-02	-5.0586E-03	7.8474E-03
35	0.0000E-01	0.0000E-01	0.0000E-01
36	-7.5491E-03	-8.3014E-03	-9.4947E-03
37	0.0000E-01	0.0000E-01	0.0000E-01
38	-1.5565E-03	-1.4579E-02	-2.2829E-02
39	0.0000E-01	0.0000E-01	0.0000E-01
40	0.0000E-01	0.0000E-01	0.0000E-01
41	0.0000E-01	0.0000E-01	0.0000E-01
42	0.0000E-01	0.0000E-01	0.0000E-01
43	0.0000E-01	0.0000E-01	0.0000E-01
44	0.0000E-01	0.0000E-01	0.0000E-01
45	0.0000E-01	0.0000E-01	0.0000E-01
46	0.0000E-01	0.0000E-01	0.0000E-01
47	0.0000E-01	0.0000E-01	0.0000E-01
48	0.0000E-01	0.0000E-01	0.0000E-01
49	0.0000E-01	0.0000E-01	0.0000E-01
51	0.0000E-01	0.0000E-01	0.0000E-01
52	-3.5852E-02	-6.2131E-03	-8.1665E-02
53	0.0000E-01	0.0000E-01	0.0000E-01
54	-3.2207E-02	-4.8906E-03	-6.8292E-02
55	0.0000E-01	0.0000E-01	0.0000E-01
56	-3.1934E-02	1.0766E-03	-7.0043E-02
57	-3.0157E-02	1.7900E-03	-6.9407E-02
58	-3.1467E-02	2.2050E-03	-5.5502E-02
59	0.0000E-01	0.0000E-01	0.0000E-01
60	-2.9574E-02	1.1155E-03	-3.8005E-02
61	0.0000E-01	0.0000E-01	0.0000E-01
62	-3.1753E-02	-1.3619E-03	-2.7330E-02
63	0.0000E-01	0.0000E-01	0.0000E-01
64	-3.0546E-02	-1.6732E-03	-2.5638E-02
65	-3.1195E-02	-1.8678E-03	-1.8976E-02
66	-2.8782E-02	1.5176E-03	0.0000E-01
67	0.0000E-01	0.0000E-01	0.0000E-01
68	0.0000E-01	0.0000E-01	2.5870E-01
69	0.0000E-01	0.0000E-01	0.0000E-01
70	0.0000E-01	0.0000E-01	4.2502E-01
71	0.0000E-01	0.0000E-01	0.0000E-01
72	0.0000E-01	0.0000E-01	2.3049E-01
73	0.0000E-01	0.0000E-01	0.0000E-01
74	0.0000E-01	0.0000E-01	3.0709E-01
75	0.0000E-01	0.0000E-01	0.0000E-01
76	0.0000E-01	0.0000E-01	0.0000E-01
77	0.0000E-01	0.0000E-01	0.0000E-01
78	0.0000E-01	0.0000E-01	2.5367E-01
79	0.0000E-01	0.0000E-01	-5.3816E-02
80	0.0000E-01	0.0000E-01	-2.3054E-01
81	0.0000E-01	0.0000E-01	-1.9362E-01
82	0.0000E-01	0.0000E-01	-1.4634E-01
83	0.0000E-01	0.0000E-01	5.2052E-02
84	0.0000E-01	0.0000E-01	1.2278E-01
85	0.0000E-01	0.0000E-01	2.3598E-01
86	0.0000E-01	0.0000E-01	2.4501E-01
87	0.0000E-01	0.0000E-01	1.0058E-01
88	0.0000E-01	0.0000E-01	-3.8620E-01
89	0.0000E-01	0.0000E-01	0.0000E-01
90	0.0000E-01	0.0000E-01	0.0000E-01
91	0.0000E-01	0.0000E-01	0.0000E-01
92	0.0000E-01	0.0000E-01	0.0000E-01
93	0.0000E-01	0.0000E-01	0.0000E-01
50	0.0000E-01	0.0000E-01	0.0000E-01
94	0.0000E-01	0.0000E-01	0.0000E-01

TABLE 3. — Continued

(d) Second wing bending/torsion mode, 30.30 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	-1.7301E-02
2	0.0000E-01	0.0000E-01	-1.0993E-02
3	0.0000E-01	0.0000E-01	-2.6821E-03
4	0.0000E-01	0.0000E-01	2.6141E-02
5	0.0000E-01	0.0000E-01	9.4931E-02
6	0.0000E-01	0.0000E-01	2.2224E-01
7	0.0000E-01	0.0000E-01	3.2227E-01
8	0.0000E-01	0.0000E-01	4.6555E-01
9	0.0000E-01	0.0000E-01	5.3192E-01
10	0.0000E-01	0.0000E-01	5.1005E-01
11	0.0000E-01	0.0000E-01	5.3355E-01
12	0.0000E-01	0.0000E-01	5.2743E-01
13	0.0000E-01	0.0000E-01	4.4402E-01
14	0.0000E-01	0.0000E-01	3.8059E-01
15	0.0000E-01	0.0000E-01	-9.7462E-03
16	0.0000E-01	0.0000E-01	-2.0135E-02
17	0.0000E-01	0.0000E-01	1.5904E-02
18	0.0000E-01	0.0000E-01	8.2502E-02
19	0.0000E-01	0.0000E-01	1.7974E-01
20	0.0000E-01	0.0000E-01	3.0663E-01
21	0.0000E-01	0.0000E-01	4.1478E-01
22	0.0000E-01	0.0000E-01	4.4398E-01
23	0.0000E-01	0.0000E-01	4.7178E-01
24	0.0000E-01	0.0000E-01	4.7409E-01
25	0.0000E-01	0.0000E-01	4.3786E-01
26	0.0000E-01	0.0000E-01	3.8826E-01
27	0.0000E-01	0.0000E-01	2.9688E-01
28	0.0000E-01	0.0000E-01	-1.7037E-02
29	0.0000E-01	0.0000E-01	5.5682E-02
30	0.0000E-01	0.0000E-01	1.3648E-01
31	0.0000E-01	0.0000E-01	2.3701E-01
32	0.0000E-01	0.0000E-01	3.0988E-01
33	0.0000E-01	0.0000E-01	3.1792E-01
34	0.0000E-01	0.0000E-01	3.1150E-01
35	0.0000E-01	0.0000E-01	2.6232E-01
36	0.0000E-01	0.0000E-01	2.0161E-01
37	0.0000E-01	0.0000E-01	5.5002E-02
38	0.0000E-01	0.0000E-01	-2.1918E-01
39	0.0000E-01	0.0000E-01	-3.2336E-02
40	0.0000E-01	0.0000E-01	3.7776E-02
41	0.0000E-01	0.0000E-01	1.1136E-01
42	0.0000E-01	0.0000E-01	2.0067E-01
43	0.0000E-01	0.0000E-01	2.5831E-01
44	0.0000E-01	0.0000E-01	2.5812E-01
45	0.0000E-01	0.0000E-01	2.5068E-01
46	0.0000E-01	0.0000E-01	1.9047E-01
47	0.0000E-01	0.0000E-01	9.2777E-02
48	0.0000E-01	0.0000E-01	-4.7084E-01
49	0.0000E-01	0.0000E-01	-1.2378E 00
51	0.0000E-01	0.0000E-01	1.9039E-02
52	0.0000E-01	0.0000E-01	9.0322E-02
53	0.0000E-01	0.0000E-01	1.7709E-01
54	0.0000E-01	0.0000E-01	3.2147E-01
55	0.0000E-01	0.0000E-01	4.1557E-01
56	0.0000E-01	0.0000E-01	4.6408E-01
57	0.0000E-01	0.0000E-01	4.2475E-01
58	0.0000E-01	0.0000E-01	2.5246E-01
59	0.0000E-01	0.0000E-01	-1.3977E-03
60	0.0000E-01	0.0000E-01	5.9535E-02
61	0.0000E-01	0.0000E-01	1.4374E-01
62	0.0000E-01	0.0000E-01	2.3549E-01
63	0.0000E-01	0.0000E-01	3.1966E-01
64	0.0000E-01	0.0000E-01	3.1656E-01
65	0.0000E-01	0.0000E-01	1.8310E-01
66	0.0000E-01	0.0000E-01	-1.8480E-01
67	0.0000E-01	0.0000E-01	-3.2185E-02
68	0.0000E-01	0.0000E-01	-7.9254E-02
69	0.0000E-01	0.0000E-01	-1.0827E-01
70	0.0000E-01	0.0000E-01	-1.6602E-01
71	0.0000E-01	0.0000E-01	-1.6470E-02
72	0.0000E-01	0.0000E-01	-2.5763E-02
73	0.0000E-01	0.0000E-01	-3.7058E-02
74	0.0000E-01	0.0000E-01	-4.7560E-02
75	0.0000E-01	-1.3033E-02	0.0000E-01
76	0.0000E-01	-3.3885E-02	0.0000E-01
77	0.0000E-01	-1.2753E-01	0.0000E-01
78	0.0000E-01	3.3998E-03	1.4846E-02
79	0.0000E-01	1.8510E-03	-1.2013E-02
80	0.0000E-01	1.3977E-03	-2.3610E-02
81	0.0000E-01	-9.0662E-04	-2.1721E-02
82	0.0000E-01	3.2487E-03	-1.3184E-02
83	0.0000E-01	1.1333E-03	-1.1106E-02
84	0.0000E-01	-1.1333E-03	-1.1031E-02
85	0.0000E-01	2.6821E-03	-1.5979E-02
86	0.0000E-01	2.0777E-03	-1.6281E-02
87	0.0000E-01	2.0021E-03	-1.0653E-02
88	0.0000E-01	6.8374E-03	1.7679E-02
89	0.0000E-01	7.0263E-03	-1.3070E-02
90	0.0000E-01	-2.0399E-03	-1.3335E-02
91	0.0000E-01	-1.0539E-02	-1.5941E-02
92	0.0000E-01	-9.7462E-03	-1.7075E-02
93	0.0000E-01	1.6432E-02	-1.7490E-02
50	0.0000E-01	0.0000E-01	3.0194E-01
94	0.0000E-01	6.1575E-03	2.9994E-02

TABLE 3. — Continued

(e) Unidentified mode (significant wing torsion), 38.96 Hz

Mode shape loc	X real	X imag	Y real	Y imag	Z real	Z imag
1	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	3.468E-03
2	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	5.039E-03
3	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	4.777E-03
4	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	2.896E-03
5	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.669E-03
6	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	5.579E-03
7	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.888E-02
8	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	3.109E-02
9	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	4.331E-02
10	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	6.037E-02
11	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	9.730E-02
12	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.095E-01
13	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.245E-01
14	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.569E-01
15	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	7.673E-03
16	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	4.957E-03
17	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	4.009E-03
18	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-4.336E-03
19	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-9.473E-03
20	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.013E-02
21	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.697E-02
22	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	2.752E-02
23	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	3.498E-02
24	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	4.988E-02
25	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	7.336E-02
26	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	8.187E-02
27	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.219E-01
28	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.103E-02
29	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-7.166E-03
30	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-2.448E-02
31	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-3.985E-02
32	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-3.807E-02
33	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-3.547E-02
34	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-2.940E-02
35	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-2.137E-02
36	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.757E-02
37	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	7.951E-03
38	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	3.015E-02
39	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	2.444E-02
40	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-6.250E-03
41	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-4.319E-02
42	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-6.626E-02
43	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-7.928E-02
44	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-7.981E-02
45	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-6.781E-02
46	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-7.776E-02
47	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-5.657E-02
48	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-2.502E-02

TABLE 3. — Concluded

(e) Concluded

Mode shape loc	X real	X imag	Y real	Y imag	Z real	Z imag
49	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-8.455E-02
51	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	6.970E-03
52	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-7.051E-03
53	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	4.630E-03
54	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	7.820E-03
55	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	2.197E-02
56	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	4.583E-02
57	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.016E-01
58	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.240E-01
59	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	6.691E-03
60	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-1.381E-02
61	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-3.216E-02
62	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-4.118E-02
63	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-4.525E-02
64	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-2.834E-02
65	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-1.811E-02
66	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	3.377E-02
67	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-7.689E-04
68	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-7.542E-03
69	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.337E-02
70	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.994E-02
71	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-5.000E-02
72	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-1.753E-01
73	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-3.773E-01
74	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	-5.361E-01
75	0.000E-01	0.000E-01	0.000E-01	1.243E-03	0.000E-01	0.000E-01
76	0.000E-01	0.000E-01	0.000E-01	2.487E-03	0.000E-01	0.000E-01
77	0.000E-01	0.000E-01	0.000E-01	5.514E-03	0.000E-01	0.000E-01
78	0.000E-01	0.000E-01	0.000E-01	-4.810E-03	0.000E-01	-2.585E-03
79	0.000E-01	0.000E-01	0.000E-01	-4.761E-03	0.000E-01	-8.671E-04
80	0.000E-01	0.000E-01	0.000E-01	-3.681E-03	0.000E-01	1.407E-03
81	0.000E-01	0.000E-01	0.000E-01	3.403E-03	0.000E-01	4.614E-03
82	0.000E-01	0.000E-01	0.000E-01	3.338E-03	0.000E-01	2.340E-03
83	0.000E-01	0.000E-01	0.000E-01	3.436E-03	0.000E-01	2.520E-03
84	0.000E-01	0.000E-01	0.000E-01	3.387E-03	0.000E-01	2.111E-03
85	0.000E-01	0.000E-01	0.000E-01	1.292E-03	0.000E-01	1.162E-03
86	0.000E-01	0.000E-01	0.000E-01	2.290E-03	0.000E-01	4.908E-04
87	0.000E-01	0.000E-01	0.000E-01	1.914E-03	0.000E-01	-4.630E-03
88	0.000E-01	0.000E-01	0.000E-01	-6.479E-03	0.000E-01	7.689E-04
89	0.000E-01	0.000E-01	0.000E-01	1.585E-02	0.000E-01	4.270E-03
90	0.000E-01	0.000E-01	0.000E-01	1.378E-02	0.000E-01	2.683E-03
91	0.000E-01	0.000E-01	0.000E-01	1.782E-02	0.000E-01	2.683E-03
92	0.000E-01	0.000E-01	0.000E-01	1.911E-02	0.000E-01	-4.401E-03
93	0.000E-01	0.000E-01	0.000E-01	8.017E-04	0.000E-01	-2.192E-03
50	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.107E-01
94	0.000E-01	0.000E-01	0.000E-01	5.203E-03	0.000E-01	-6.741E-03

TABLE 4. – ANTISYMMETRIC MODE SHAPE COEFFICIENTS
(Mode shape location is the same
as test point in table 1.)

(a) First wing bending mode, 13.56 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	-8.2668E-02
2	0.0000E-01	0.0000E-01	-1.1486E-01
3	0.0000E-01	0.0000E-01	-1.4442E-01
4	0.0000E-01	0.0000E-01	-1.4230E-01
5	0.0000E-01	0.0000E-01	-1.8028E-01
6	0.0000E-01	0.0000E-01	-1.9692E-01
7	0.0000E-01	0.0000E-01	-1.2915E-01
8	0.0000E-01	0.0000E-01	-4.8640E-02
9	0.0000E-01	0.0000E-01	2.3119E-02
10	0.0000E-01	0.0000E-01	1.0192E-01
11	0.0000E-01	0.0000E-01	2.0974E-01
12	0.0000E-01	0.0000E-01	3.6942E-01
13	0.0000E-01	0.0000E-01	4.3520E-01
14	0.0000E-01	0.0000E-01	5.7379E-01
15	0.0000E-01	0.0000E-01	-7.1679E-02
16	0.0000E-01	0.0000E-01	-7.9901E-02
17	0.0000E-01	0.0000E-01	-1.1340E-01
18	0.0000E-01	0.0000E-01	-1.5488E-01
19	0.0000E-01	0.0000E-01	-1.6135E-01
20	0.0000E-01	0.0000E-01	-1.3253E-01
21	0.0000E-01	0.0000E-01	-2.8085E-02
22	0.0000E-01	0.0000E-01	3.9116E-02
23	0.0000E-01	0.0000E-01	1.2716E-01
24	0.0000E-01	0.0000E-01	2.0718E-01
25	0.0000E-01	0.0000E-01	3.3336E-01
26	0.0000E-01	0.0000E-01	4.6239E-01
27	0.0000E-01	0.0000E-01	6.6033E-01
28	0.0000E-01	0.0000E-01	-8.0470E-02
29	0.0000E-01	0.0000E-01	-1.2984E-01
30	0.0000E-01	0.0000E-01	-1.2980E-01
31	0.0000E-01	0.0000E-01	-8.6617E-02
32	0.0000E-01	0.0000E-01	2.6254E-02
33	0.0000E-01	0.0000E-01	1.0212E-01
34	0.0000E-01	0.0000E-01	2.0335E-01
35	0.0000E-01	0.0000E-01	3.0397E-01
36	0.0000E-01	0.0000E-01	4.3321E-01
37	0.0000E-01	0.0000E-01	6.1690E-01
38	0.0000E-01	0.0000E-01	8.2583E-01
39	0.0000E-01	0.0000E-01	-9.5571E-02
40	0.0000E-01	0.0000E-01	-1.1910E-01
41	0.0000E-01	0.0000E-01	-1.1401E-01
42	0.0000E-01	0.0000E-01	-6.5492E-02
43	0.0000E-01	0.0000E-01	5.5438E-02
44	0.0000E-01	0.0000E-01	1.3912E-01
45	0.0000E-01	0.0000E-01	2.4271E-01
46	0.0000E-01	0.0000E-01	3.5831E-01
47	0.0000E-01	0.0000E-01	5.0342E-01
48	0.0000E-01	0.0000E-01	9.4212E-01
49	0.0000E-01	0.0000E-01	1.3337E 00
51	0.0000E-01	0.0000E-01	1.1214E-01
52	0.0000E-01	0.0000E-01	1.7234E-01
53	0.0000E-01	0.0000E-01	1.5862E-01
54	0.0000E-01	0.0000E-01	1.3986E-01
55	0.0000E-01	0.0000E-01	2.8330E-02
56	0.0000E-01	0.0000E-01	-1.2797E-01
57	0.0000E-01	0.0000E-01	-3.7887E-01
58	0.0000E-01	0.0000E-01	-6.0086E-01
59	0.0000E-01	0.0000E-01	1.0050E-01
60	0.0000E-01	0.0000E-01	1.3693E-01
61	0.0000E-01	0.0000E-01	1.4608E-01
62	0.0000E-01	0.0000E-01	8.6983E-02
63	0.0000E-01	0.0000E-01	-2.8167E-02
64	0.0000E-01	0.0000E-01	-2.1898E-01
65	0.0000E-01	0.0000E-01	-4.3996E-01
66	0.0000E-01	0.0000E-01	-8.7504E-01
67	0.0000E-01	0.0000E-01	-1.3953E-01
68	0.0000E-01	0.0000E-01	-2.3649E-01
69	0.0000E-01	0.0000E-01	-2.9050E-01
70	0.0000E-01	0.0000E-01	-3.8904E-01
71	0.0000E-01	0.0000E-01	1.3253E-01
72	0.0000E-01	0.0000E-01	2.1390E-01
73	0.0000E-01	0.0000E-01	3.0975E-01
74	0.0000E-01	0.0000E-01	3.3271E-01
75	0.0000E-01	1.9672E-01	0.0000E-01
76	0.0000E-01	3.1110E-01	0.0000E-01
77	0.0000E-01	5.5120E-01	0.0000E-01
78	0.0000E-01	1.1299E-01	7.7743E-03
79	0.0000E-01	9.6548E-02	1.9945E-03
80	0.0000E-01	1.0717E-01	7.4487E-03
81	0.0000E-01	9.1216E-02	5.0065E-03
82	0.0000E-01	7.5301E-02	0.0000E-01
83	0.0000E-01	8.2384E-02	4.9658E-03
84	0.0000E-01	7.5260E-02	6.5125E-03
85	0.0000E-01	7.5952E-02	-9.3618E-04
86	0.0000E-01	9.5734E-02	2.0352E-03
87	0.0000E-01	1.0587E-01	1.1478E-02
88	0.0000E-01	1.0274E-01	0.0000E-01
89	0.0000E-01	-2.7866E-01	1.8317E-03
90	0.0000E-01	-2.5627E-01	-3.6633E-03
91	0.0000E-01	-2.9872E-01	1.6403E-02
92	0.0000E-01	-2.6510E-01	1.9619E-02
93	0.0000E-01	-2.0189E-02	-8.1407E-03
50	0.0000E-01	0.0000E-01	5.6692E-01
94	0.0000E-01	-9.2804E-03	-1.9782E-01

TABLE 4. — Continued

(b) First lateral fuselage bending mode, 18.18 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	-8.8903E-04
2	0.0000E-01	0.0000E-01	-1.2749E-03
3	0.0000E-01	0.0000E-01	-1.4922E-03
4	0.0000E-01	0.0000E-01	-2.8488E-03
5	0.0000E-01	0.0000E-01	-2.2693E-03
6	0.0000E-01	0.0000E-01	-3.9539E-03
7	0.0000E-01	0.0000E-01	-2.9766E-03
8	0.0000E-01	0.0000E-01	-3.9960E-03
9	0.0000E-01	0.0000E-01	-3.8762E-03
10	0.0000E-01	0.0000E-01	0.0000E-01
11	0.0000E-01	0.0000E-01	-1.7636E-03
12	0.0000E-01	0.0000E-01	3.5996E-03
13	0.0000E-01	0.0000E-01	3.2361E-03
14	0.0000E-01	0.0000E-01	5.2854E-03
15	0.0000E-01	0.0000E-01	6.0981E-04
16	0.0000E-01	0.0000E-01	-1.0062E-03
17	0.0000E-01	0.0000E-01	-9.9044E-04
18	0.0000E-01	0.0000E-01	-2.0336E-03
19	0.0000E-01	0.0000E-01	-3.1676E-03
20	0.0000E-01	0.0000E-01	-3.4929E-03
21	0.0000E-01	0.0000E-01	-3.7603E-03
22	0.0000E-01	0.0000E-01	-3.1333E-03
23	0.0000E-01	0.0000E-01	0.0000E-01
24	0.0000E-01	0.0000E-01	0.0000E-01
25	0.0000E-01	0.0000E-01	-2.5103E-03
26	0.0000E-01	0.0000E-01	2.8976E-03
27	0.0000E-01	0.0000E-01	5.3012E-03
28	0.0000E-01	0.0000E-01	-7.1912E-04
29	0.0000E-01	0.0000E-01	-2.7316E-03
30	0.0000E-01	0.0000E-01	-3.7550E-03
31	0.0000E-01	0.0000E-01	-4.5874E-03
32	0.0000E-01	0.0000E-01	-3.4705E-03
33	0.0000E-01	0.0000E-01	-2.9858E-03
34	0.0000E-01	0.0000E-01	-2.3971E-03
35	0.0000E-01	0.0000E-01	-2.7645E-03
36	0.0000E-01	0.0000E-01	2.2074E-03
37	0.0000E-01	0.0000E-01	5.2380E-03
38	0.0000E-01	0.0000E-01	9.0365E-03
39	0.0000E-01	0.0000E-01	-1.0550E-03
40	0.0000E-01	0.0000E-01	-3.3783E-03
41	0.0000E-01	0.0000E-01	-3.8261E-03
42	0.0000E-01	0.0000E-01	-4.3740E-03
43	0.0000E-01	0.0000E-01	-3.8590E-03
44	0.0000E-01	0.0000E-01	-2.8897E-03
45	0.0000E-01	0.0000E-01	-2.2351E-03
46	0.0000E-01	0.0000E-01	-2.7158E-03
47	0.0000E-01	0.0000E-01	3.3809E-03

Mode Shape loc	X coeff	Y coeff	Z coeff
48	0.0000E-01	0.0000E-01	9.8662E-03
49	0.0000E-01	0.0000E-01	1.8049E-02
51	0.0000E-01	0.0000E-01	2.1613E-03
52	0.0000E-01	0.0000E-01	3.3888E-03
53	0.0000E-01	0.0000E-01	4.0632E-03
54	0.0000E-01	0.0000E-01	4.9101E-03
55	0.0000E-01	0.0000E-01	4.4623E-03
56	0.0000E-01	0.0000E-01	2.2417E-03
57	0.0000E-01	0.0000E-01	-3.2150E-03
58	0.0000E-01	0.0000E-01	-5.5515E-03
59	0.0000E-01	0.0000E-01	2.9805E-03
60	0.0000E-01	0.0000E-01	4.6414E-03
61	0.0000E-01	0.0000E-01	5.4290E-03
62	0.0000E-01	0.0000E-01	5.4962E-03
63	0.0000E-01	0.0000E-01	4.4926E-03
64	0.0000E-01	0.0000E-01	-1.4817E-03
65	0.0000E-01	0.0000E-01	-2.7171E-03
66	0.0000E-01	0.0000E-01	-9.6700E-03
67	0.0000E-01	0.0000E-01	-4.7362E-03
68	0.0000E-01	0.0000E-01	-1.1133E-02
69	0.0000E-01	0.0000E-01	-1.5083E-02
70	0.0000E-01	0.0000E-01	-1.8263E-02
71	0.0000E-01	0.0000E-01	5.4290E-03
72	0.0000E-01	0.0000E-01	8.6901E-03
73	0.0000E-01	0.0000E-01	1.3147E-02
74	0.0000E-01	0.0000E-01	1.5569E-02
75	0.0000E-01	-3.4586E-03	0.0000E-01
76	0.0000E-01	-4.0724E-03	0.0000E-01
77	0.0000E-01	-8.5083E-03	0.0000E-01
78	0.0000E-01	-2.0758E-02	-3.9078E-03
79	0.0000E-01	-7.9486E-03	-1.5239E-03
80	0.0000E-01	-1.4620E-03	3.9117E-04
81	0.0000E-01	4.7718E-03	1.0747E-03
82	0.0000E-01	7.0556E-03	1.0339E-03
83	0.0000E-01	1.9332E-02	1.1406E-03
84	0.0000E-01	8.7915E-03	1.0984E-03
85	0.0000E-01	3.4060E-03	-2.5156E-04
86	0.0000E-01	-1.2196E-03	0.0000E-01
87	0.0000E-01	-1.3532E-02	-9.9966E-04
88	0.0000E-01	-2.4569E-02	-2.3194E-03
89	0.0000E-01	3.6839E-03	1.3237E-03
90	0.0000E-01	3.4679E-03	8.2449E-04
91	0.0000E-01	2.7593E-03	9.5225E-04
92	0.0000E-01	2.9753E-03	0.0000E-01
93	0.0000E-01	-3.2268E-04	0.0000E-01
50	0.0000E-01	0.0000E-01	4.8666E-03
94	0.0000E-01	-4.3155E-02	1.5609E-02

TABLE 4. — Continued

(c) Vertical tail mode, 28.50 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	3.3843E-03
2	0.0000E-01	0.0000E-01	5.3987E-03
3	0.0000E-01	0.0000E-01	7.6280E-03
4	0.0000E-01	0.0000E-01	1.1523E-02
5	0.0000E-01	0.0000E-01	2.1434E-02
6	0.0000E-01	0.0000E-01	3.7576E-02
7	0.0000E-01	0.0000E-01	4.5016E-02
8	0.0000E-01	0.0000E-01	5.8741E-02
9	0.0000E-01	0.0000E-01	6.4462E-02
10	0.0000E-01	0.0000E-01	5.9869E-02
11	0.0000E-01	0.0000E-01	5.9198E-02
12	0.0000E-01	0.0000E-01	5.4014E-02
13	0.0000E-01	0.0000E-01	4.0155E-02
14	0.0000E-01	0.0000E-01	3.0055E-02
15	0.0000E-01	0.0000E-01	4.2975E-03
16	0.0000E-01	0.0000E-01	3.4648E-03
17	0.0000E-01	0.0000E-01	9.0516E-03
18	0.0000E-01	0.0000E-01	1.8399E-02
19	0.0000E-01	0.0000E-01	3.1989E-02
20	0.0000E-01	0.0000E-01	4.5070E-02
21	0.0000E-01	0.0000E-01	5.2644E-02
22	0.0000E-01	0.0000E-01	5.5357E-02
23	0.0000E-01	0.0000E-01	5.4820E-02
24	0.0000E-01	0.0000E-01	5.3584E-02
25	0.0000E-01	0.0000E-01	4.3512E-02
26	0.0000E-01	0.0000E-01	3.6072E-02
27	0.0000E-01	0.0000E-01	2.1326E-02
28	0.0000E-01	0.0000E-01	3.4380E-03
29	0.0000E-01	0.0000E-01	1.4182E-02
30	0.0000E-01	0.0000E-01	2.6295E-02
31	0.0000E-01	0.0000E-01	3.7522E-02
32	0.0000E-01	0.0000E-01	4.2169E-02
33	0.0000E-01	0.0000E-01	4.1739E-02
34	0.0000E-01	0.0000E-01	3.7925E-02
35	0.0000E-01	0.0000E-01	3.0217E-02
36	0.0000E-01	0.0000E-01	1.8667E-02
37	0.0000E-01	0.0000E-01	3.3305E-03
38	0.0000E-01	0.0000E-01	-3.7684E-02
39	0.0000E-01	0.0000E-01	-1.4773E-03
40	0.0000E-01	0.0000E-01	1.1603E-02
41	0.0000E-01	0.0000E-01	2.3502E-02
42	0.0000E-01	0.0000E-01	3.4031E-02
43	0.0000E-01	0.0000E-01	3.7818E-02
44	0.0000E-01	0.0000E-01	3.6287E-02
45	0.0000E-01	0.0000E-01	3.3574E-02
46	0.0000E-01	0.0000E-01	2.4173E-02
47	0.0000E-01	0.0000E-01	8.7561E-03
48	0.0000E-01	0.0000E-01	-6.6611E-02
49	0.0000E-01	0.0000E-01	-1.5492E-01
51	0.0000E-01	0.0000E-01	-1.0797E-02
52	0.0000E-01	0.0000E-01	-2.3663E-02
53	0.0000E-01	0.0000E-01	-3.8462E-02
54	0.0000E-01	0.0000E-01	-6.1024E-02
55	0.0000E-01	0.0000E-01	-7.3191E-02
56	0.0000E-01	0.0000E-01	-7.5152E-02
57	0.0000E-01	0.0000E-01	-6.1911E-02
58	0.0000E-01	0.0000E-01	-2.9008E-02
59	0.0000E-01	0.0000E-01	-6.5805E-03
60	0.0000E-01	0.0000E-01	-1.7888E-02
61	0.0000E-01	0.0000E-01	-3.3171E-02
62	0.0000E-01	0.0000E-01	-4.7433E-02
63	0.0000E-01	0.0000E-01	-5.8902E-02
64	0.0000E-01	0.0000E-01	-5.2537E-02
65	0.0000E-01	0.0000E-01	-2.6080E-02
66	0.0000E-01	0.0000E-01	4.0880E-02
67	0.0000E-01	0.0000E-01	-2.4899E-02
68	0.0000E-01	0.0000E-01	-7.4803E-02
69	0.0000E-01	0.0000E-01	-1.1042E-01
70	0.0000E-01	0.0000E-01	-1.6833E-01
71	0.0000E-01	0.0000E-01	1.9177E-02
72	0.0000E-01	0.0000E-01	4.1256E-02
73	0.0000E-01	0.0000E-01	6.6262E-02
74	0.0000E-01	0.0000E-01	8.2968E-02
75	0.0000E-01	8.9737E-02	0.0000E-01
76	0.0000E-01	2.5226E-01	0.0000E-01
77	0.0000E-01	8.8010E-01	0.0000E-01
78	0.0000E-01	-9.6693E-03	0.0000E-01
79	0.0000E-01	-3.7603E-03	0.0000E-01
80	0.0000E-01	-1.4235E-03	0.0000E-01
81	0.0000E-01	-6.9834E-04	0.0000E-01
82	0.0000E-01	-1.3967E-03	-4.5661E-04
83	0.0000E-01	0.0000E-01	0.0000E-01
84	0.0000E-01	2.0682E-03	8.0578E-04
85	0.0000E-01	2.0144E-03	-1.2892E-03
86	0.0000E-01	1.3430E-03	-2.2562E-03
87	0.0000E-01	-8.7024E-03	1.3698E-03
88	0.0000E-01	-2.0628E-02	-3.4648E-03
89	0.0000E-01	9.9111E-03	0.0000E-01
90	0.0000E-01	7.3326E-03	0.0000E-01
91	0.0000E-01	7.4669E-03	0.0000E-01
92	0.0000E-01	5.0764E-03	1.9876E-03
93	0.0000E-01	-2.2830E-03	1.9339E-03
50	0.0000E-01	0.0000E-01	2.3072E-02
94	0.0000E-01	2.0217E-01	4.6950E-02

TABLE 4. — Continued

(d) Second lateral fuselage bending mode, 31.51 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	0.0000E-01
2	0.0000E-01	0.0000E-01	0.0000E-01
3	0.0000E-01	0.0000E-01	0.0000E-01
4	0.0000E-01	0.0000E-01	0.0000E-01
5	9.5823E-03	8.3474E-03	-2.0651E-03
6	0.0000E-01	0.0000E-01	0.0000E-01
7	1.8401E-02	2.5058E-03	-1.5409E-02
8	0.0000E-01	0.0000E-01	0.0000E-01
9	0.0000E-01	0.0000E-01	0.0000E-01
10	3.0894E-02	-9.3005E-03	-2.8245E-02
11	0.0000E-01	0.0000E-01	0.0000E-01
12	0.0000E-01	0.0000E-01	0.0000E-01
13	0.0000E-01	0.0000E-01	0.0000E-01
14	4.8711E-02	-1.8924E-02	-3.2903E-02
15	0.0000E-01	0.0000E-01	0.0000E-01
16	0.0000E-01	0.0000E-01	0.0000E-01
17	0.0000E-01	0.0000E-01	0.0000E-01
18	0.0000E-01	0.0000E-01	0.0000E-01
19	0.0000E-01	0.0000E-01	0.0000E-01
20	0.0000E-01	0.0000E-01	0.0000E-01
21	0.0000E-01	0.0000E-01	0.0000E-01
22	0.0000E-01	0.0000E-01	0.0000E-01
23	0.0000E-01	0.0000E-01	0.0000E-01
24	0.0000E-01	0.0000E-01	0.0000E-01
25	0.0000E-01	0.0000E-01	0.0000E-01
26	0.0000E-01	0.0000E-01	0.0000E-01
27	4.6118E-02	-1.9720E-02	-3.2452E-02
28	0.0000E-01	0.0000E-01	0.0000E-01
29	0.0000E-01	0.0000E-01	0.0000E-01
30	0.0000E-01	0.0000E-01	0.0000E-01
31	0.0000E-01	0.0000E-01	0.0000E-01
32	0.0000E-01	0.0000E-01	0.0000E-01
33	0.0000E-01	0.0000E-01	0.0000E-01
34	0.0000E-01	0.0000E-01	0.0000E-01
35	0.0000E-01	0.0000E-01	0.0000E-01
36	0.0000E-01	0.0000E-01	0.0000E-01
37	0.0000E-01	0.0000E-01	0.0000E-01
38	4.7440E-02	-2.9464E-02	-4.4735E-03
39	0.0000E-01	0.0000E-01	0.0000E-01
40	5.6418E-03	2.3264E-03	-6.4565E-04
41	0.0000E-01	0.0000E-01	0.0000E-01
42	1.4789E-02	-7.1586E-03	-3.5665E-03
43	0.0000E-01	0.0000E-01	0.0000E-01
44	0.0000E-01	0.0000E-01	0.0000E-01
45	2.6477E-02	-1.6756E-02	-7.0458E-03
46	0.0000E-01	0.0000E-01	0.0000E-01
47	0.0000E-01	0.0000E-01	0.0000E-01
48	4.4284E-02	-2.7543E-02	7.4763E-03
49	0.0000E-01	0.0000E-01	0.0000E-01
51	0.0000E-01	0.0000E-01	0.0000E-01
52	-8.5933E-03	7.7427E-03	3.2488E-03
53	0.0000E-01	0.0000E-01	0.0000E-01
54	-2.0548E-02	-2.9823E-03	1.2462E-02
55	0.0000E-01	0.0000E-01	0.0000E-01
56	-3.2944E-02	-1.7059E-02	2.1240E-02
57	0.0000E-01	0.0000E-01	0.0000E-01
58	-4.9449E-02	-2.9142E-02	2.1927E-02
59	0.0000E-01	0.0000E-01	0.0000E-01
60	-6.4873E-03	3.2026E-03	1.3169E-03
61	0.0000E-01	0.0000E-01	0.0000E-01
62	-1.6490E-02	-7.1432E-03	3.7304E-03
63	0.0000E-01	0.0000E-01	0.0000E-01
64	-3.1022E-02	-2.0953E-02	6.6359E-03
65	0.0000E-01	0.0000E-01	0.0000E-01
66	-4.9121E-02	-3.8611E-02	-3.8585E-03
67	0.0000E-01	0.0000E-01	0.0000E-01
68	0.0000E-01	0.0000E-01	5.8519E-02
69	0.0000E-01	0.0000E-01	0.0000E-01
70	0.0000E-01	0.0000E-01	1.6791E-01
71	0.0000E-01	0.0000E-01	0.0000E-01
72	0.0000E-01	0.0000E-01	-3.1668E-02
73	0.0000E-01	0.0000E-01	0.0000E-01
74	0.0000E-01	0.0000E-01	-8.2326E-02
75	0.0000E-01	9.6848E-04	0.0000E-01
76	0.0000E-01	8.4909E-03	0.0000E-01
77	0.0000E-01	4.3351E-02	0.0000E-01
78	0.0000E-01	-3.0392E-02	-4.5708E-03
79	0.0000E-01	8.0450E-04	-5.3804E-04
80	0.0000E-01	1.6146E-02	2.2034E-03
81	0.0000E-01	1.8765E-02	1.7986E-03
82	0.0000E-01	1.1396E-02	1.6551E-03
83	0.0000E-01	2.3213E-03	0.0000E-01
84	0.0000E-01	-2.8747E-03	-1.1068E-03
85	0.0000E-01	-5.5905E-03	-1.6756E-03
86	0.0000E-01	-3.7407E-03	-1.1734E-03
87	0.0000E-01	5.6777E-03	0.0000E-01
88	0.0000E-01	1.4322E-02	1.9575E-03
89	0.0000E-01	1.8099E-02	1.3169E-03
90	0.0000E-01	1.1427E-02	0.0000E-01
91	0.0000E-01	4.6169E-03	-1.9985E-04
92	0.0000E-01	-8.7112E-04	0.0000E-01
93	0.0000E-01	-6.8460E-03	-8.0450E-04
50	0.0000E-01	0.0000E-01	0.0000E-01
94	0.0000E-01	0.0000E-01	0.0000E-01

TABLE 4. — Continued

(e) Second wing bending/torsion mode, 32.72 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	-8.6193E-03
2	0.0000E-01	0.0000E-01	-1.0458E-02
3	0.0000E-01	0.0000E-01	-1.1829E-02
4	0.0000E-01	0.0000E-01	-8.2426E-03
5	0.0000E-01	0.0000E-01	1.1332E-02
6	0.0000E-01	0.0000E-01	4.0038E-02
7	0.0000E-01	0.0000E-01	7.3551E-02
8	0.0000E-01	0.0000E-01	1.1580E-01
9	0.0000E-01	0.0000E-01	1.4089E-01
10	0.0000E-01	0.0000E-01	1.5011E-01
11	0.0000E-01	0.0000E-01	1.7624E-01
12	0.0000E-01	0.0000E-01	1.8902E-01
13	0.0000E-01	0.0000E-01	1.7114E-01
14	0.0000E-01	0.0000E-01	1.7076E-01
15	0.0000E-01	0.0000E-01	-6.3289E-03
16	0.0000E-01	0.0000E-01	-7.2029E-03
17	0.0000E-01	0.0000E-01	-6.7207E-03
18	0.0000E-01	0.0000E-01	7.0371E-03
19	0.0000E-01	0.0000E-01	2.7953E-02
20	0.0000E-01	0.0000E-01	5.7111E-02
21	0.0000E-01	0.0000E-01	9.2839E-02
22	0.0000E-01	0.0000E-01	9.8791E-02
23	0.0000E-01	0.0000E-01	1.2522E-01
24	0.0000E-01	0.0000E-01	1.2314E-01
25	0.0000E-01	0.0000E-01	1.4749E-01
26	0.0000E-01	0.0000E-01	1.5052E-01
27	0.0000E-01	0.0000E-01	1.3310E-01
28	0.0000E-01	0.0000E-01	-7.3083E-03
29	0.0000E-01	0.0000E-01	5.1837E-03
30	0.0000E-01	0.0000E-01	1.1950E-02
31	0.0000E-01	0.0000E-01	2.6702E-02
32	0.0000E-01	0.0000E-01	5.0510E-02
33	0.0000E-01	0.0000E-01	5.2319E-02
34	0.0000E-01	0.0000E-01	6.3439E-02
35	0.0000E-01	0.0000E-01	5.8346E-02
36	0.0000E-01	0.0000E-01	6.1465E-02
37	0.0000E-01	0.0000E-01	3.3061E-02
38	0.0000E-01	0.0000E-01	-2.2543E-02
39	0.0000E-01	0.0000E-01	-7.6700E-03
40	0.0000E-01	0.0000E-01	-9.4933E-03
41	0.0000E-01	0.0000E-01	3.9782E-03
42	0.0000E-01	0.0000E-01	1.8685E-03
43	0.0000E-01	0.0000E-01	2.2920E-02
44	0.0000E-01	0.0000E-01	2.5135E-02
45	0.0000E-01	0.0000E-01	2.9640E-02
46	0.0000E-01	0.0000E-01	1.6093E-02
47	0.0000E-01	0.0000E-01	9.7344E-03
48	0.0000E-01	0.0000E-01	-1.1815E-01
49	0.0000E-01	0.0000E-01	-3.4247E-01
51	0.0000E-01	0.0000E-01	-3.0288E-03
52	0.0000E-01	0.0000E-01	-2.1066E-02
53	0.0000E-01	0.0000E-01	-5.3440E-02
54	0.0000E-01	0.0000E-01	-1.0830E-01
55	0.0000E-01	0.0000E-01	-1.6115E-01
56	0.0000E-01	0.0000E-01	-1.9371E-01
57	0.0000E-01	0.0000E-01	-2.1568E-01
58	0.0000E-01	0.0000E-01	-1.6027E-01
59	0.0000E-01	0.0000E-01	5.4097E-03
60	0.0000E-01	0.0000E-01	-4.4604E-03
61	0.0000E-01	0.0000E-01	-2.6958E-02
62	0.0000E-01	0.0000E-01	-6.1963E-02
63	0.0000E-01	0.0000E-01	-9.7600E-02
64	0.0000E-01	0.0000E-01	-1.1190E-01
65	0.0000E-01	0.0000E-01	-6.9527E-02
66	0.0000E-01	0.0000E-01	4.3036E-02
67	0.0000E-01	0.0000E-01	5.1294E-02
68	0.0000E-01	0.0000E-01	2.0503E-01
69	0.0000E-01	0.0000E-01	3.0784E-01
70	0.0000E-01	0.0000E-01	4.9376E-01
71	0.0000E-01	0.0000E-01	2.0358E-02
72	0.0000E-01	0.0000E-01	5.2816E-02
73	0.0000E-01	0.0000E-01	9.0729E-02
74	0.0000E-01	0.0000E-01	1.2310E-01
75	0.0000E-01	-5.9823E-03	0.0000E-01
76	0.0000E-01	-4.6623E-02	0.0000E-01
77	0.0000E-01	-2.4749E-01	0.0000E-01
78	0.0000E-01	1.8173E-02	2.0192E-03
79	0.0000E-01	8.3180E-03	3.6466E-03
80	0.0000E-01	1.1934E-02	5.8919E-03
81	0.0000E-01	1.1633E-02	2.5918E-03
82	0.0000E-01	1.4722E-02	6.0275E-04
83	0.0000E-01	2.5677E-02	-7.8358E-04
84	0.0000E-01	2.4487E-02	-1.1151E-03
85	0.0000E-01	1.4662E-02	1.2507E-03
86	0.0000E-01	1.3471E-02	1.4014E-03
87	0.0000E-01	1.6967E-02	1.9137E-03
88	0.0000E-01	1.4888E-02	-4.4151E-03
89	0.0000E-01	-2.7606E-02	6.4796E-04
90	0.0000E-01	-2.6385E-02	-6.7809E-04
91	0.0000E-01	-3.8697E-02	2.1247E-03
92	0.0000E-01	-4.1680E-02	1.2658E-03
93	0.0000E-01	-2.1096E-03	-1.9589E-03
50	0.0000E-01	0.0000E-01	1.4564E-01
94	0.0000E-01	2.1955E-02	2.9459E-02

TABLE 4. — Concluded

(f) Second wing torsion mode, 48.91 Hz

Mode shape loc	X coeff	Y coeff	Z coeff
1	0.0000E-01	0.0000E-01	3.8713E-02
2	0.0000E-01	0.0000E-01	4.7999E-02
3	0.0000E-01	0.0000E-01	4.9748E-02
4	0.0000E-01	0.0000E-01	2.2371E-02
5	0.0000E-01	0.0000E-01	-8.6289E-02
6	0.0000E-01	0.0000E-01	-1.7107E-01
7	0.0000E-01	0.0000E-01	-1.8808E-01
8	0.0000E-01	0.0000E-01	-3.1658E-02
9	0.0000E-01	0.0000E-01	1.4032E-01
10	0.0000E-01	0.0000E-01	3.4703E-01
11	0.0000E-01	0.0000E-01	6.8006E-01
12	0.0000E-01	0.0000E-01	1.1233E 00
13	0.0000E-01	0.0000E-01	1.5690E 00
14	0.0000E-01	0.0000E-01	1.9759E 00
15	0.0000E-01	0.0000E-01	3.9014E-02
16	0.0000E-01	0.0000E-01	3.4853E-02
17	0.0000E-01	0.0000E-01	-2.8100E-02
18	0.0000E-01	0.0000E-01	-1.3236E-01
19	0.0000E-01	0.0000E-01	-3.1597E-01
20	0.0000E-01	0.0000E-01	-3.4829E-01
21	0.0000E-01	0.0000E-01	-2.7979E-01
22	0.0000E-01	0.0000E-01	-1.2325E-01
23	0.0000E-01	0.0000E-01	1.0914E-01
24	0.0000E-01	0.0000E-01	5.0923E-01
25	0.0000E-01	0.0000E-01	9.2205E-01
26	0.0000E-01	0.0000E-01	1.3999E 00
27	0.0000E-01	0.0000E-01	1.8991E 00
28	0.0000E-01	0.0000E-01	2.6653E-02
29	0.0000E-01	0.0000E-01	-2.1738E-01
30	0.0000E-01	0.0000E-01	-6.5504E-01
31	0.0000E-01	0.0000E-01	-9.4550E-01
32	0.0000E-01	0.0000E-01	-1.1859E 00
33	0.0000E-01	0.0000E-01	-1.0861E 00
34	0.0000E-01	0.0000E-01	-9.1234E-01
35	0.0000E-01	0.0000E-01	-8.2539E-01
36	0.0000E-01	0.0000E-01	-3.7205E-01
37	0.0000E-01	0.0000E-01	-2.5507E-02
38	0.0000E-01	0.0000E-01	6.2766E-01
39	0.0000E-01	0.0000E-01	4.4200E-02
40	0.0000E-01	0.0000E-01	-2.4349E-01
41	0.0000E-01	0.0000E-01	-9.3369E-01
42	0.0000E-01	0.0000E-01	-1.3639E 00
43	0.0000E-01	0.0000E-01	-1.7645E 00
44	0.0000E-01	0.0000E-01	-1.7418E 00
45	0.0000E-01	0.0000E-01	-1.4952E 00
46	0.0000E-01	0.0000E-01	-1.4995E 00
47	0.0000E-01	0.0000E-01	-1.0809E 00
48	0.0000E-01	0.0000E-01	2.2251E-01
49	0.0000E-01	0.0000E-01	-7.8420E-01
51	0.0000E-01	0.0000E-01	2.4663E-02
52	0.0000E-01	0.0000E-01	6.9767E-02
53	0.0000E-01	0.0000E-01	1.3091E-01
54	0.0000E-01	0.0000E-01	1.7149E-01
55	0.0000E-01	0.0000E-01	1.1457E-01
56	0.0000E-01	0.0000E-01	-6.5848E-02
57	0.0000E-01	0.0000E-01	-4.0793E-01
58	0.0000E-01	0.0000E-01	-8.2810E-01
59	0.0000E-01	0.0000E-01	2.5748E-02
60	0.0000E-01	0.0000E-01	1.1035E-01
61	0.0000E-01	0.0000E-01	2.8787E-01
62	0.0000E-01	0.0000E-01	4.3163E-01
63	0.0000E-01	0.0000E-01	5.4192E-01
64	0.0000E-01	0.0000E-01	4.3621E-01
65	0.0000E-01	0.0000E-01	1.7125E-01
66	0.0000E-01	0.0000E-01	-4.1921E-01
67	0.0000E-01	0.0000E-01	7.3144E-02
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69	0.0000E-01	0.0000E-01	-9.5817E-02
70	0.0000E-01	0.0000E-01	-2.2389E-01
71	0.0000E-01	0.0000E-01	-4.7818E-02
72	0.0000E-01	0.0000E-01	9.9495E-02
73	0.0000E-01	0.0000E-01	2.9595E-01
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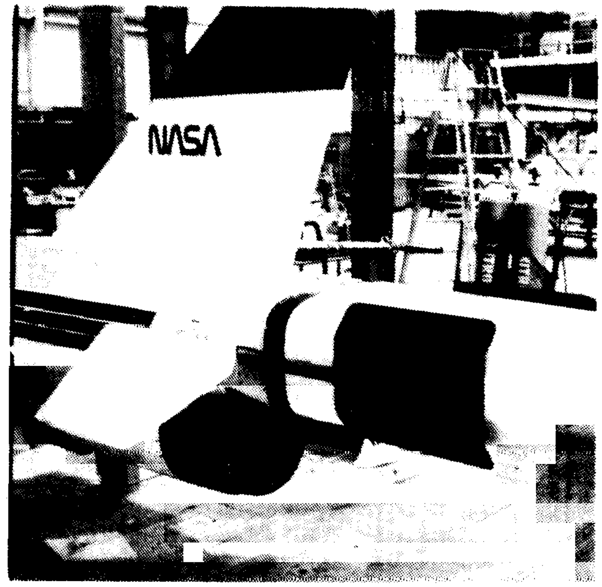
91	0.0000E-01	1.5835E-01	1.9417E-02
92	0.0000E-01	1.3815E-01	-1.0794E-02
93	0.0000E-01	2.5447E-02	-2.2673E-02
50	0.0000E-01	0.0000E-01	1.9386E 00
94	0.0000E-01	-1.2808E-01	9.5093E-02

ECN 20817A

Figure 1. Aeroelastic research wing (ARW-1R) on modified Firebee II drone vehicle.

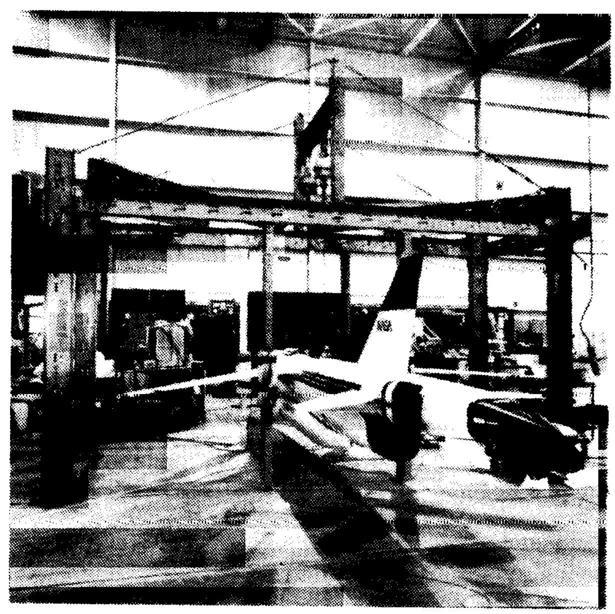


ECN 18473

Figure 2. Speed brakes installed on ARW-1R vehicle.

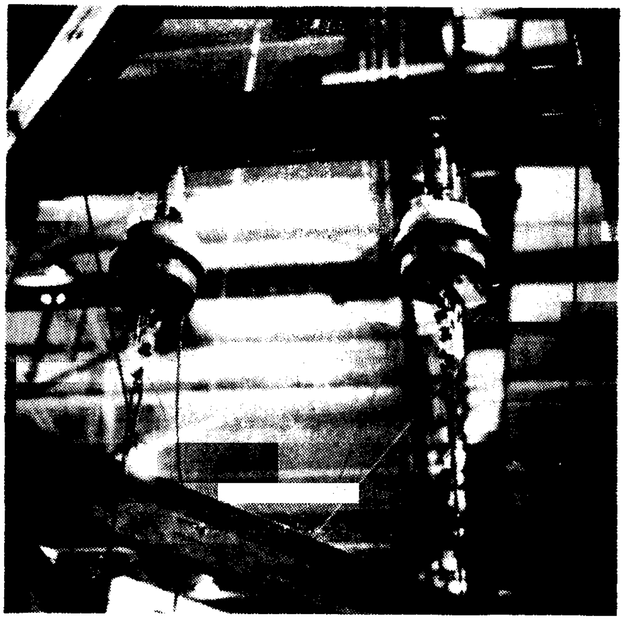
ECN 18476

Figure 3. Aileron restraint fixtures installed on ARW-1R vehicle.



ECN 18477

Figure 4. Overhead vehicle support system.



ECN 18474

Figure 5. Nitrogen-pressurized air springs used to isolate vehicle from support structure.

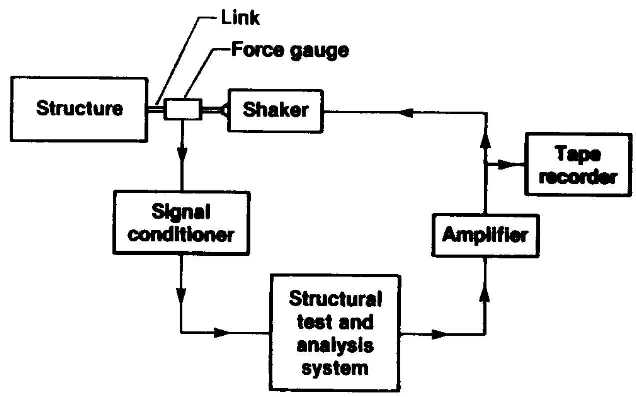
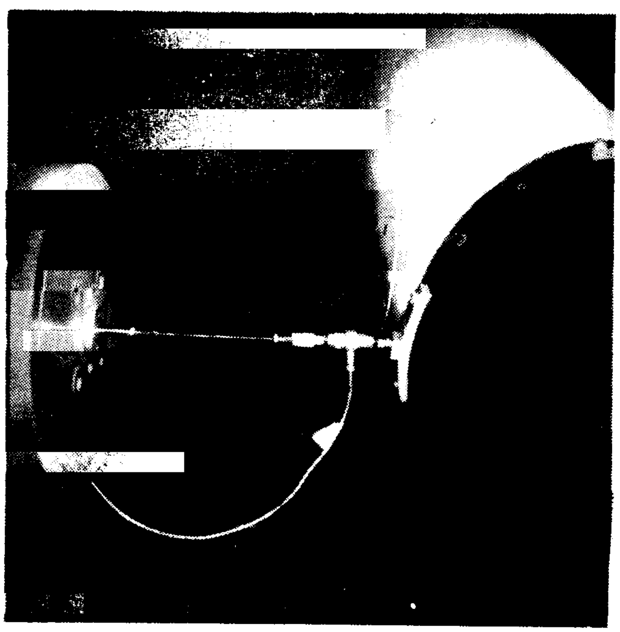


Figure 6. Schematic of excitation signal generation.



ECN 18463

Figure 7. Connection between aircraft and shaker.

ECN 18458

Figure 8. Wedges used to maintain normal coordinate system in wing glove area.

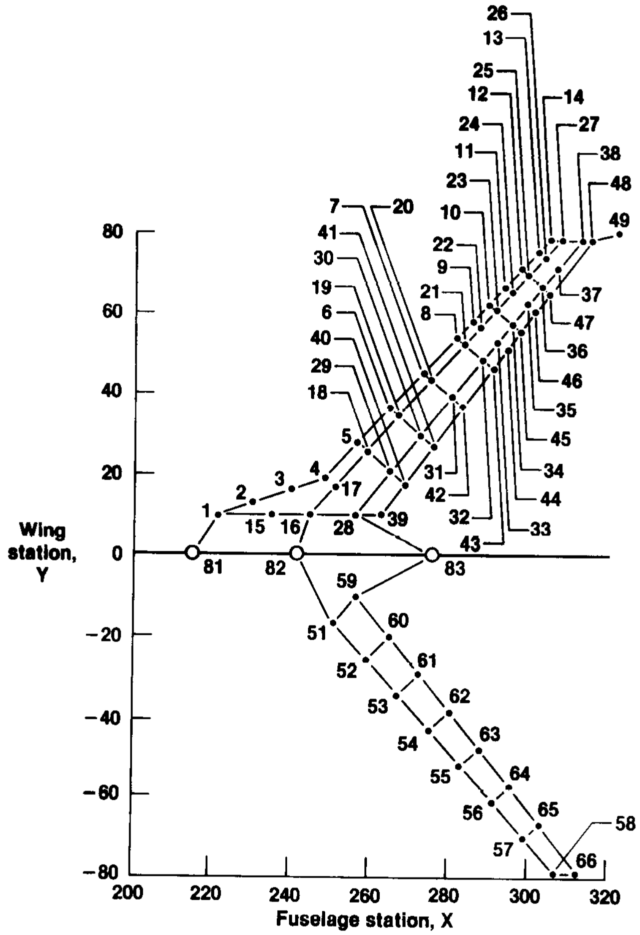


Figure 9. Test coordinates of right and left wings.

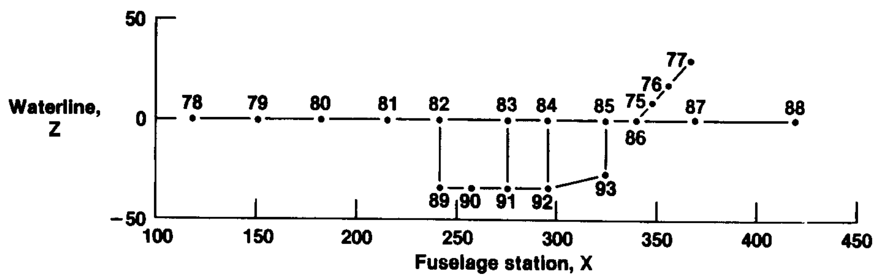


Figure 10. Test coordinates of fuselage and vertical tail.

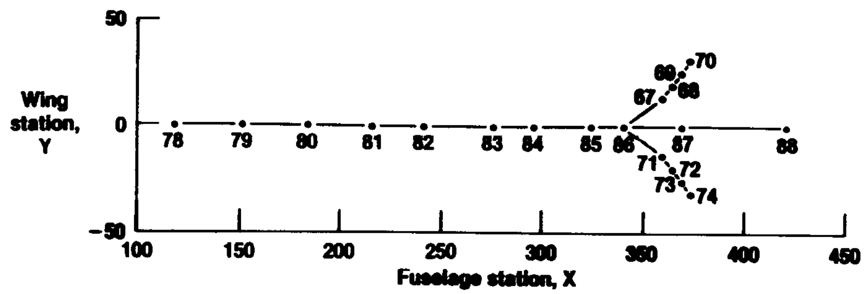


Figure 11. Test coordinates of fuselage and horizontal tail.

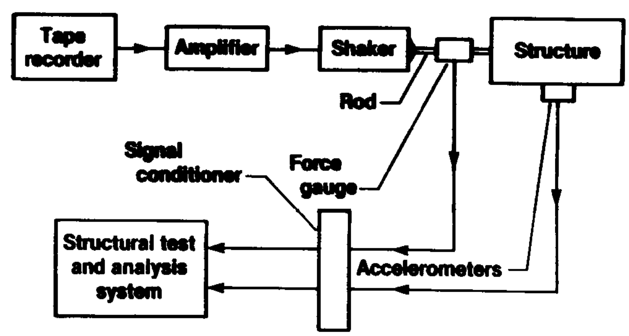


Figure 12. Data collection process.

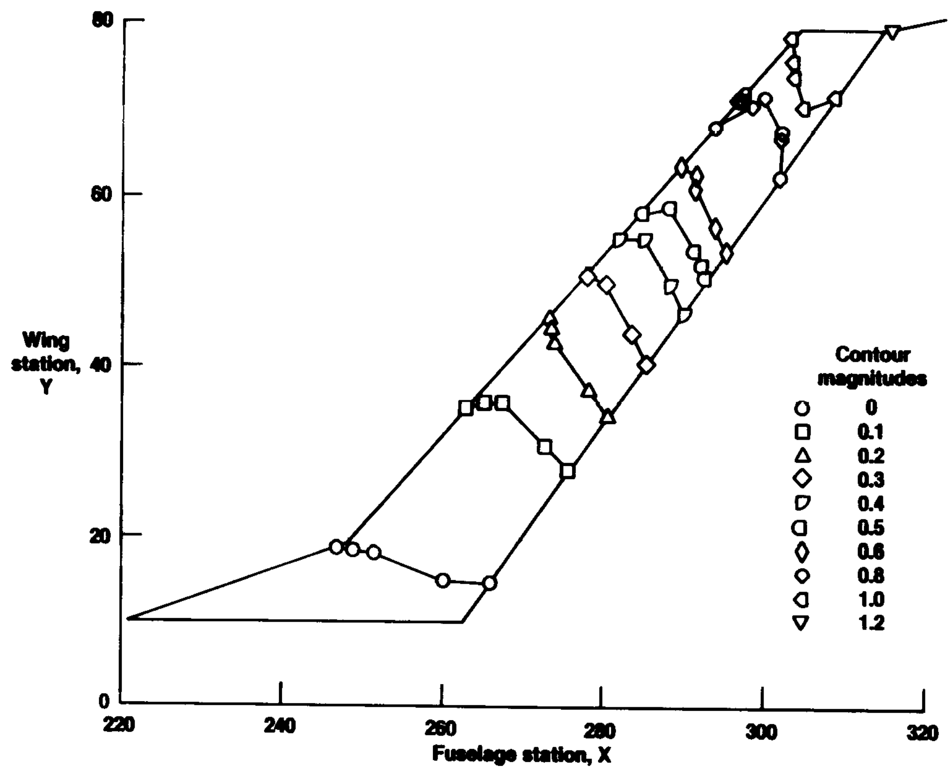


Figure 13. First symmetric wing bending mode.

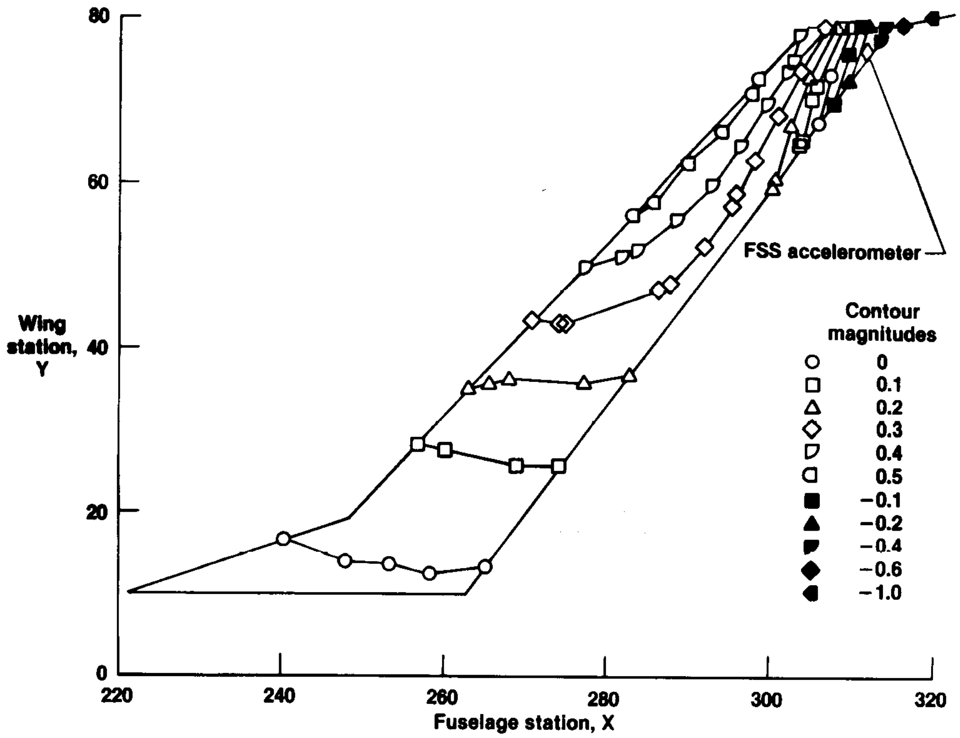


Figure 14. Second symmetric wing bending/torsion mode.

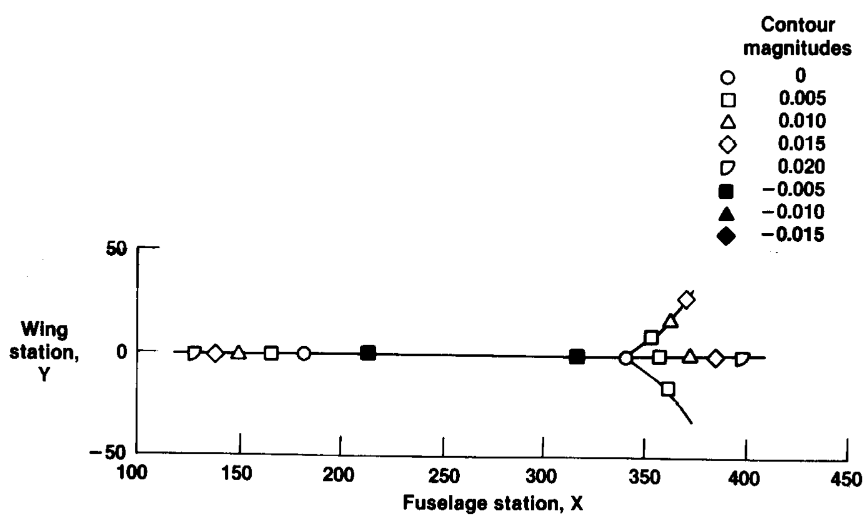


Figure 15. First symmetric vertical fuselage bending mode.

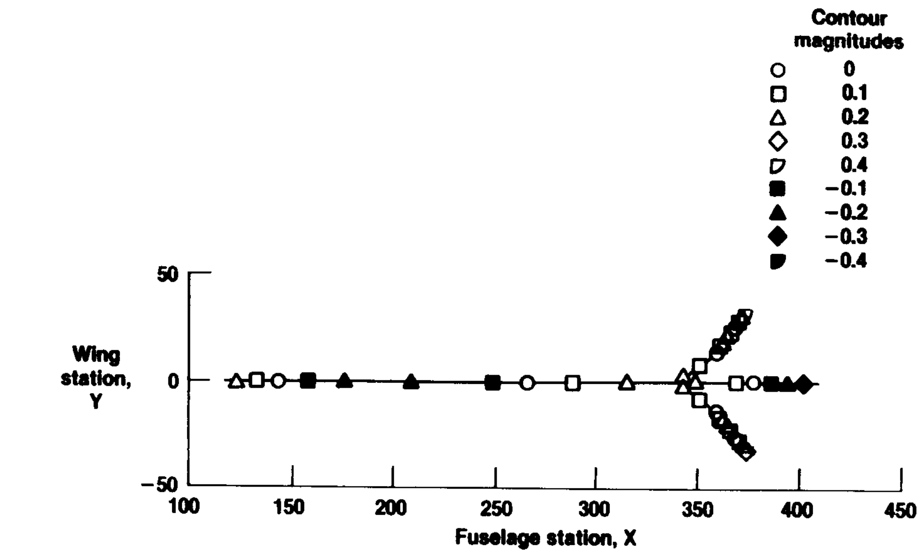


Figure 16. Second symmetric vertical fuselage bending mode.

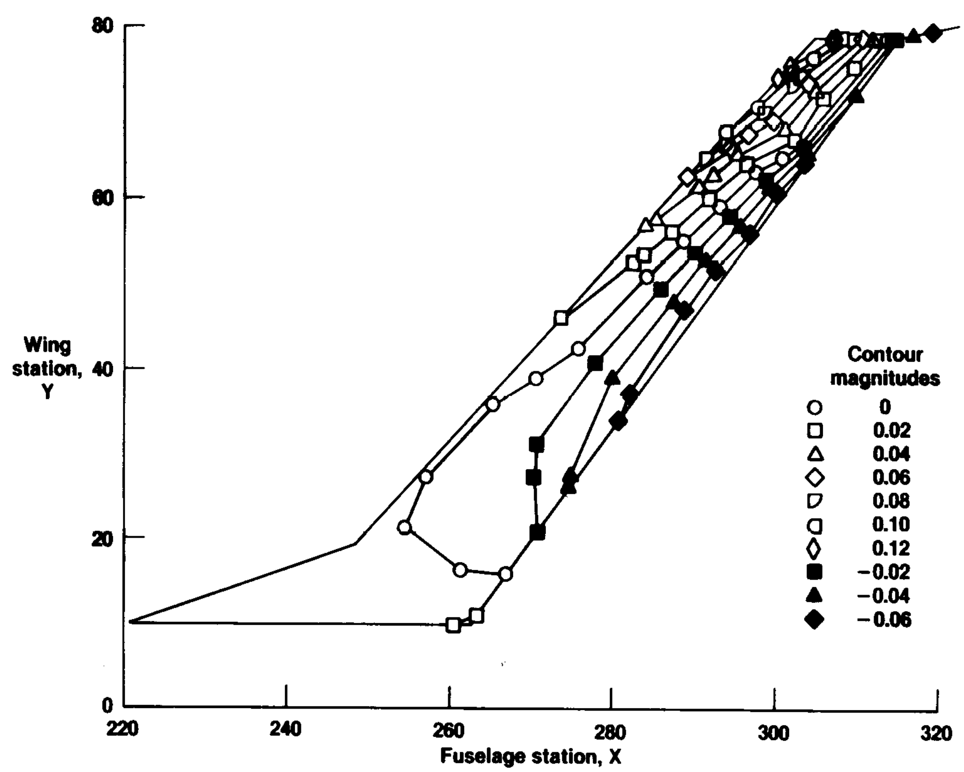


Figure 17. Unidentified symmetric mode (significant wing torsion).

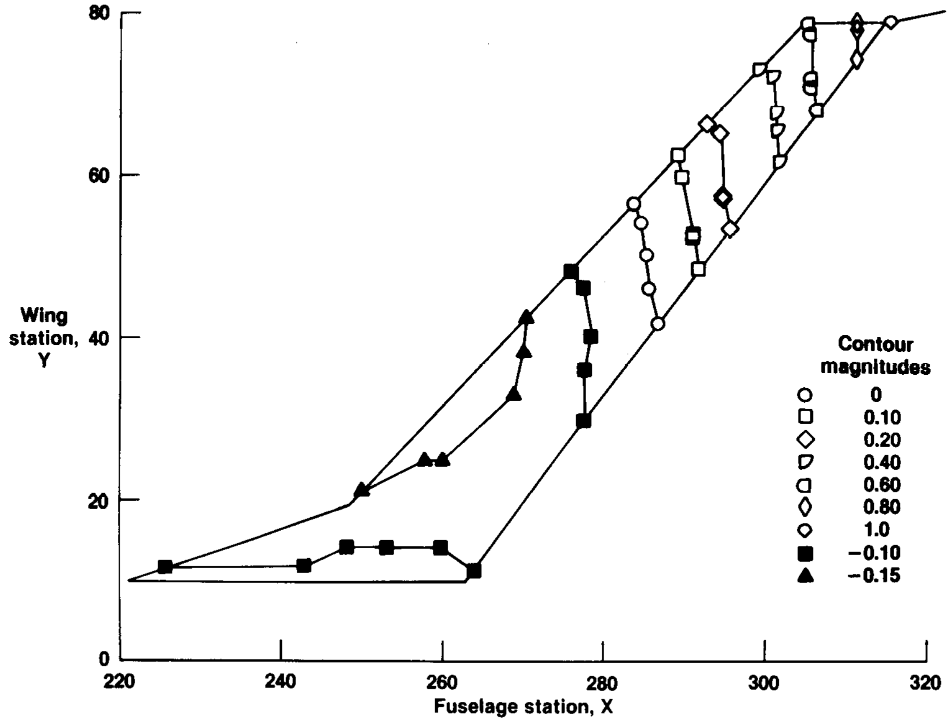


Figure 18. Antisymmetric first wing bending/torsion mode.

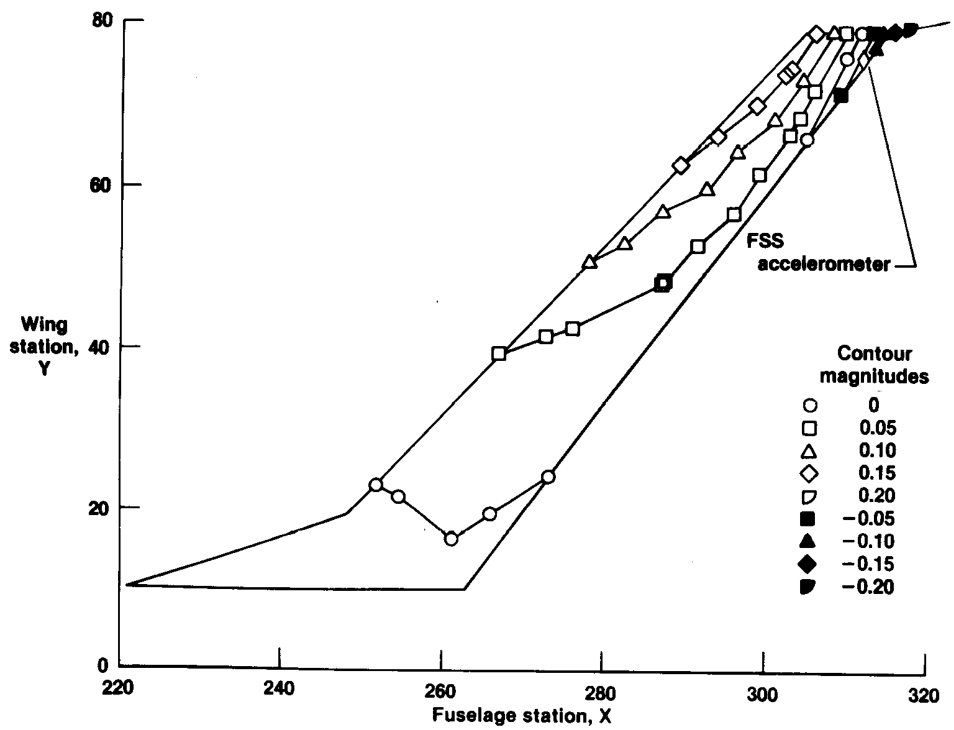


Figure 19. Antisymmetric second wing bending/torsion mode.

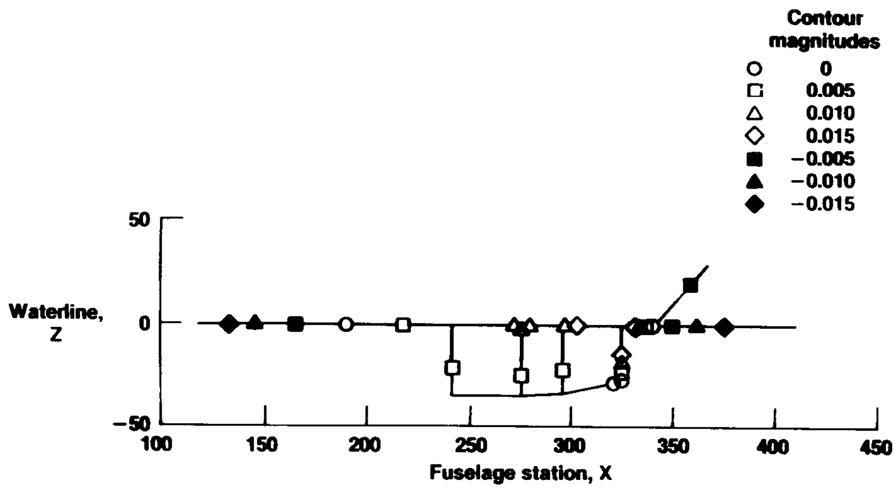


Figure 20. Antisymmetric first lateral fuselage bending mode.

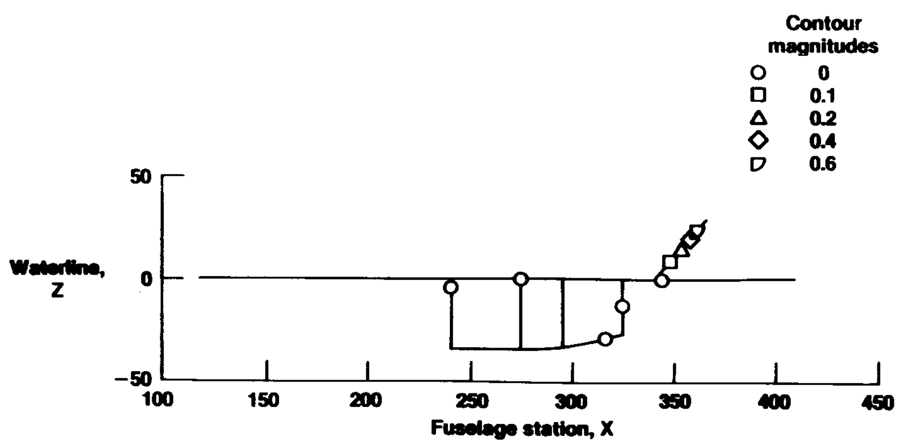


Figure 21. Vertical tail mode.

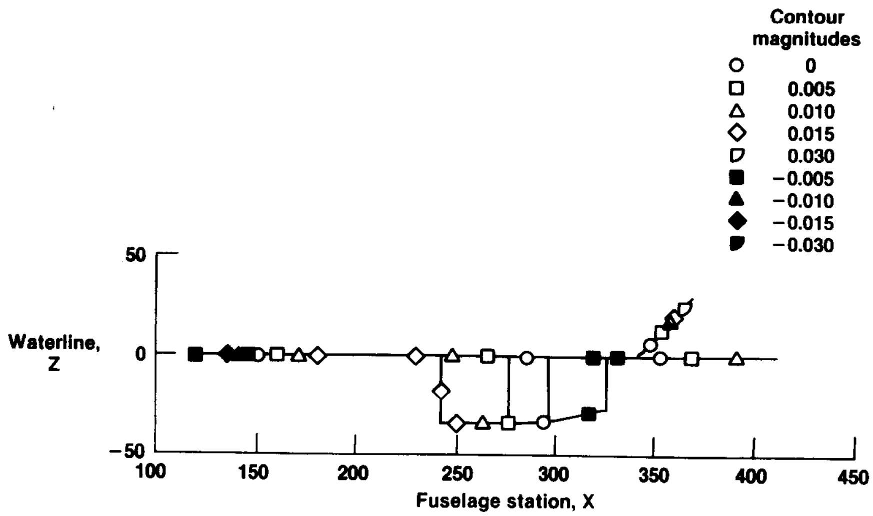


Figure 22. Second antisymmetric lateral fuselage bending mode.

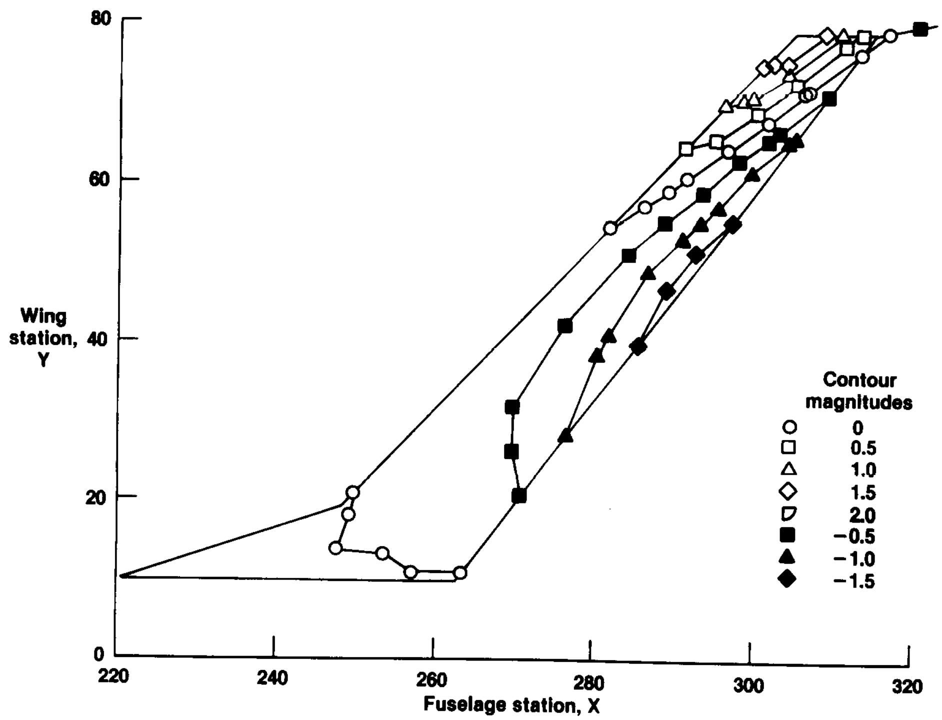


Figure 23. Second antisymmetric wing bending/torsion mode.

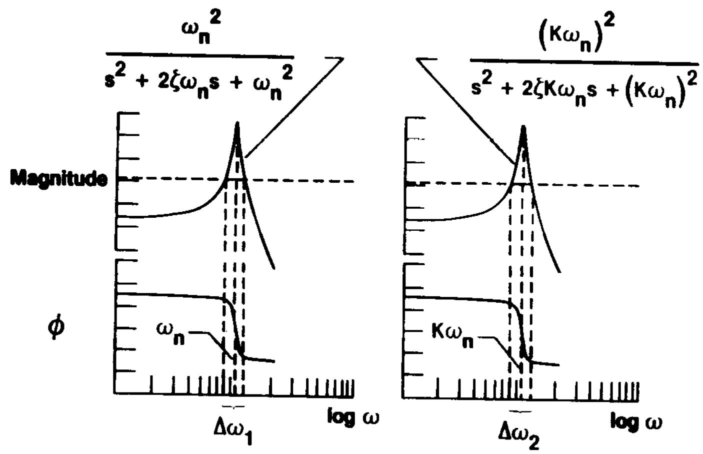


Figure 24. Effect of natural frequency on amount of data available for analysis.

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15. Supplementary Notes

16. Abstract

The drones for aerodynamic and structural testing (DAST) project was designed to control flutter actively at high subsonic speeds. Accurate knowledge of the structural model was critical for the successful design of the control system. A ground vibration test was conducted on the DAST vehicle to determine the structural mode characteristics. This report presents and discusses the vibration and test equipment, the test setup and procedures, and the antisymmetic and symmetric mode shape results. The modal characteristics were subsequently used to update the structural model employed in the control law design process.

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