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VEHICLE ATTITUDE
AN ANALYSIS OF FLIGHT 4.272 UA

CHARLES F. MILLER, JR.

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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AN ANALYSIS OF FLIGHT 4.272 UA

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Greenbelt, Maryland

ABSTRACT

This report gives a brief case history of the determination of sounding rocket attitude by means of solar aspect sensors and magnetometers, as applied to NASA Rocket Flight 4.272 UA.

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INTRODUCTION

Flight number 4.272 UA, an Aerobee 150 rocket, was fired February 4, 1969, at the Churchill Research Range in Canada. It was carrying equipment including two mass spectrometers, to perform an atmospheric composition experiment. The number of atmospheric particles detected by a mass spectrometer depends on the orientation of the spectrometer with respect to the direction of travel, or velocity vector. Consequently, value of spectrometer data depends on having accurate trajectory and attitude (direction of pointing) data over the period during which the measurements are being made. Trajectory data of Flight 4.272 UA were acquired by radar tracking, while the attitude data were provided by the methods described in this report.

DATA ACQUISITION

SOURCE OF ATTITUDE DATA

The source for attitude data depends on the type of sensors to be used. In this instance, the sun and the magnetic vector were used as sources and as reference points for the gathering of vehicle attitude data.

SENSORS

Two flux-gate magnetometers and two solar aspect sensors were mounted with the orientation illustrated in Figure 1, and specified in Table I. The orientation of the mass spectrometers are shown and specified in the same figure and table.

TABLE I

Sensor Orientation Specifications, NASA Rocket Flight 4.272 UA[1]

Sensor	Zenith[2]	Azimuth[3]
Mass Spectrometer 1	89° 20'	181° 52'
Mass Spectrometers 2, 3	89° 14'	0° 00'
Adcole Solar Sensor 1	69° 52'	114° 18'
Adcole Solar Sensor 2	110° 06'	249° 30'
Lateral Magnetometer	90° 00'	70° 34'
Longitudinal Magnetometer	179° 08'	320° 23'

1. From reference 1
2. Zenith angle measured from nose of rocket
3. Azimuth angles measured counterclockwise from mass spectrometers 2 and 3

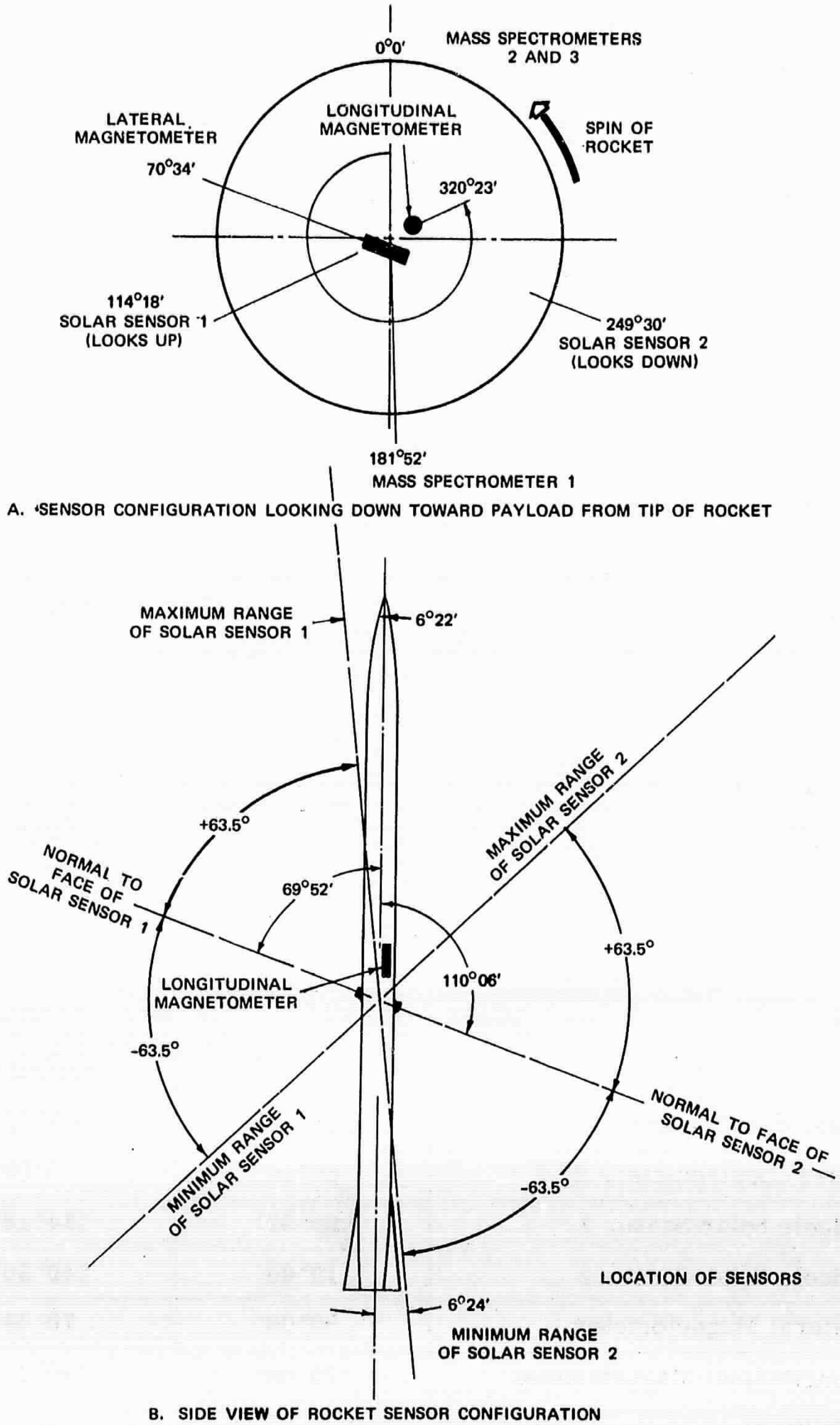


Figure 1. Sensor Orientation, NASA Rocket Flight 4.272 UA (Reference 1)

MAGNETOMETER. The Schonstedt RAM-5C Magnetometer senses the angular relationship between its longitudinal axis and the earth's magnetic field.

$$E = \hat{E} \cos\theta + E_0 \tag{1}$$

Where:

E is the output voltage of the magnetometer;

$\hat{E}$ is the peak output voltage, the magnetometer output voltage when its longitudinal axis is aligned with the magnetic field. This peak output is adjusted to be ±2.5 volts. One polarity of the voltage results from the pointing of one pole of the magnetometer in the direction of the south-seeking magnetic vector, the opposite polarity is the result of the opposite alignment;

θ is the angle between the longitudinal axis of the magnetometer and the magnetic field;

and:

E_0 is a bias voltage, +2.5 volts, whose purpose is to shift the magnetometer output voltage to the 0-to-+5-volt range.

SOLAR ASPECT SENSOR. The Adcole Solar Aspect Sensor Model 135, used in conjunction with Shift Register Model 235, produces binary coded words indicating the angle and the time of arrival of the solar beams that strike the sensor.

RAW DATA

The data were telemetered by an FM-FM system; the raw data are in the form of oscillograph records. Figure A-1 in Appendix A shows the telemetry record of the two magnetometer outputs. The modulation observed on the trace representing the output of the lateral magnetometer is the result of vehicle spin, and shows the spin rate. The peak positive output, during the spin cycle, occurs when the probe axis of the lateral magnetometer reaches its point of nearest approach to alignment with the magnetic vector in one direction. When, during the spin cycle, the orientation has changed 180 degrees, the instantaneous voltage at the output is peak negative. The output of the longitudinal magnetometer is similar, except that it does not have the sine-wave modulation. Its output is a function of the degree of alignment between the probe axis (which is parallel to the rocket longitudinal, or Z, axis) and the magnetic field. The magnetic aspect angle is equal to:

$$\text{ARC SIN } \frac{\hat{B}_{LAT}}{B_{TOTAL}}, \tag{2}$$

$$\text{ARC COS } \frac{B_{LONG}}{B_{TOTAL}}, \tag{3}$$

or

$$\text{ARC TAN } \frac{\hat{B}_{LAT}}{B_{LONG}}; \tag{4}$$

Where:

$\hat{B}_{LAT}$ = lateral sensor, peak flux density reading, milligauss;

B_{LONG} = longitudinal sensor, flux density reading, milligauss;

and B_{TOTAL} = total flux density, milligauss.

The solar sensor output tracing contains a pulse-code modulation that gives the solar aspect angle in degrees, whenever the solar sensor is rotated through the plane containing the sun and the rocket longitudinal axis. The angle in "spin degrees" between the solar sensor readout and the lateral magnetometer peak reading, when corrected for sensor orientation*, is known as the phase angle. (Another definition of phase angle, in this application, is given in the "Theory" paragraph of the Data Reduction section, on page 5.) The first step in data reduction is to read the magnitude of each parameter at the point on the record representing a readout, one time during each rotation, and to record the readings as a function of time, in tabular form. These are the figures which are punched on cards for computer entry.

*Note: The data-reduction procedure is simplified if the magnetic axis of the lateral magnetometer probe and the optical axis of the solar sensor point in the same direction, or lie in the same longitudinal plane of the rocket.

DATA REDUCTION

THEORY

The plane containing the longitudinal, or Z, axis of the rocket plus the center of the solar sensor, spins about the Z axis. As the plane intercepts the sun, the sensor generates a word which is a seven-bit Gray-Code number designating the angle between the direction of the sun and the rocket Z axis. This angle is defined as the solar aspect angle. The angle between the rocket Z axis and the earth's magnetic flux vector, at the launch site, is the magnetic aspect angle. The plane formed by the rocket Z axis and the magnetic vector intersects the plane formed by the Z axis and the sun. This intersection of the two planes coincides with the Z axis. The dihedral angle formed by the intersection of the two planes is defined as the phase angle. When corrected for any necessary sensor orientation, it is shown on the oscillograph recording as the rocket spin angle between the solar sensor readout and the peak voltage point on the lateral magnetometer readout. With these data, along with the latitude, longitude, and altitude of the rocket, the attitude of the rocket can be determined.

STEPS IN REDUCTION OF DATA

Most of the data reduction was performed, under contract, by the Physical Science Laboratory of New Mexico State University, and the data reduction was the subject of a report (Reference 1). The sequence of steps used in the data reduction are illustrated in the block diagram, Figure 2. Separating the procedure into definite steps enables the weeding out of data which is obviously erroneous, and makes it easier to avoid the temptation of integrating the program in such a way that it is not certain where an error has occurred in the program.

COMPUTER PROGRAM DESCRIPTION

There are two computerized methods of finding the attitude of the vehicle by spherical triangulation. The first method uses the solar aspect angle and magnetic aspect angle, with the sun and magnetic vector positions on the celestial sphere, as input parameters. The sun, the magnetic vector or south magnetic point, and the rocket axis form the apices of a spherical triangle, the solution of whose dimensions yields the attitude of the vehicle. Both the sun's position and the south magnetic point require computer programs for their determination. With the computerized solution of the triangle dimensions, the phase angle may theoretically be determined as part of the output. Table A-1 in the Appendix shows the computerized solution by this first method.

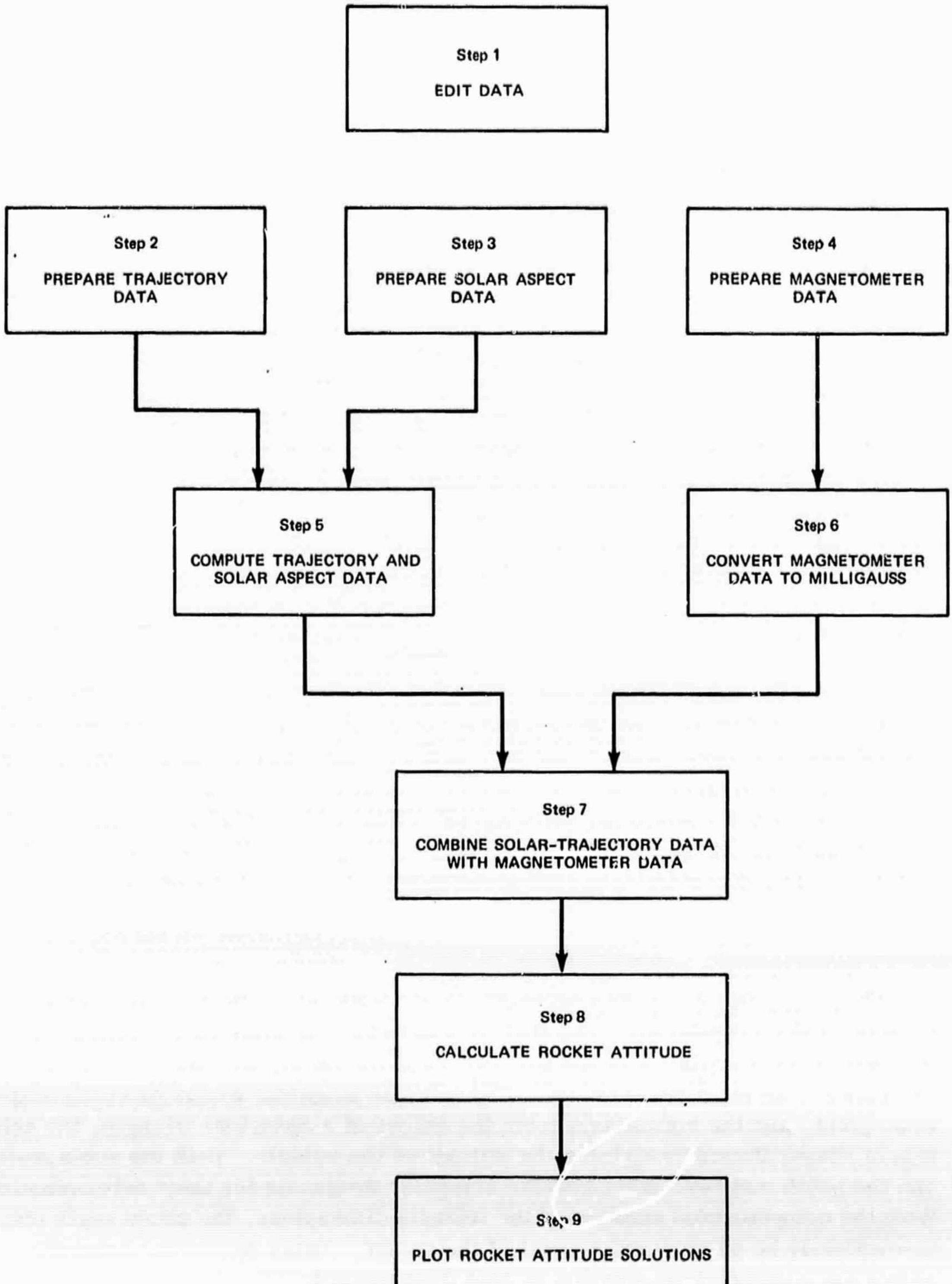


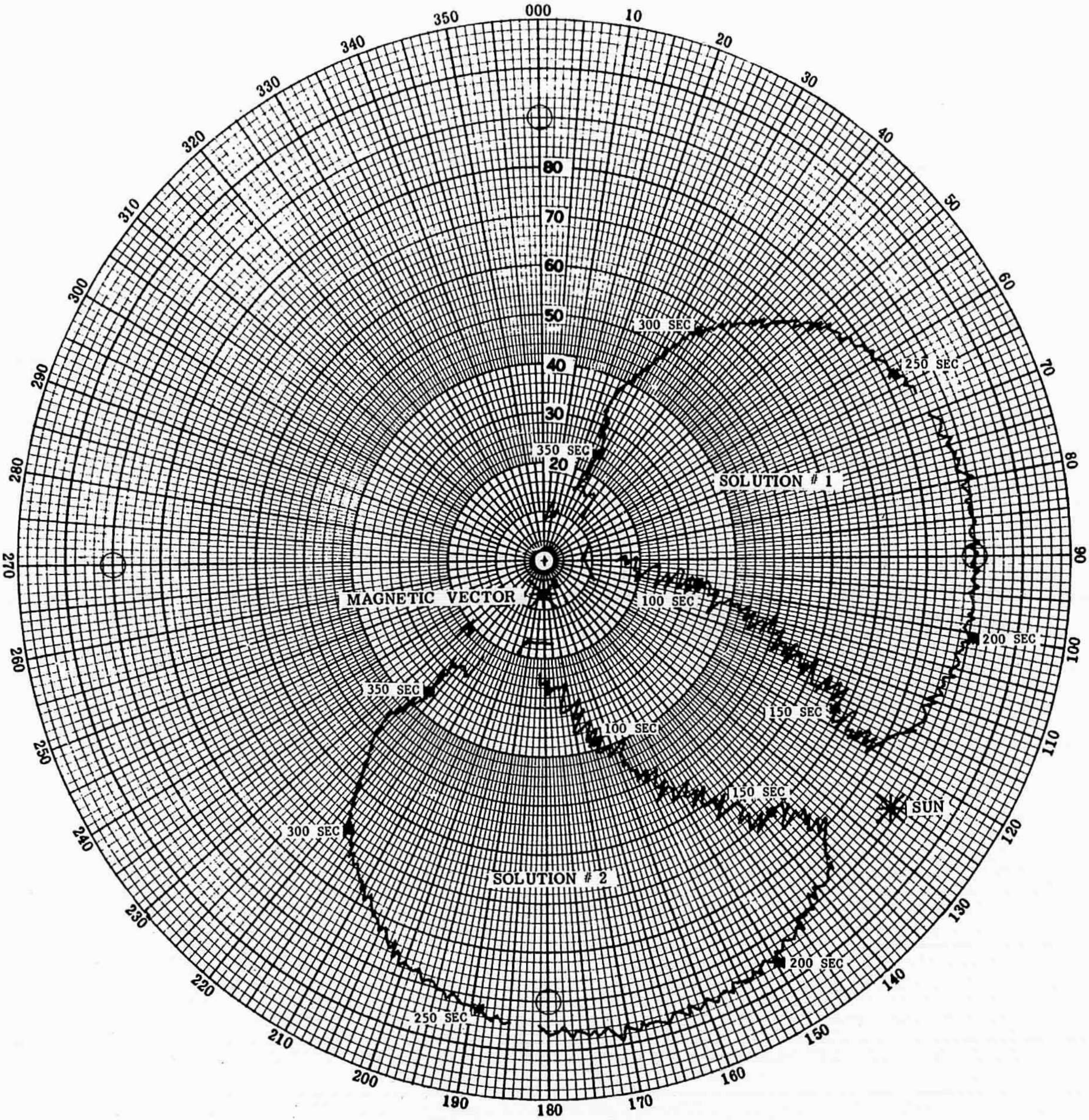
Figure 2. Flow Diagram for Rocket Attitude Data Reduction (Reference 1)

The alternate, or second, computerized method for finding the attitude uses the solar-aspect angle and the phase angle as inputs. When the nose of the vehicle points between the sun and the magnetic vector, this second method yields better resolution than the first.

POLAR GRAPH

Figure 3 shows a polar graph which is a representation of the hemispherical sky. There are small 1/4-inch circles on the circle which represents the horizon, at the points representing the directions, north, east, south, and west. The zenith angle designation is given to circles smaller than the horizon in 20-degree increments, through 80 degrees. The azimuth angles are marked in 10-degree increments, from true north or 0 degrees to 360 degrees, around the circle representing the horizon. The early morning sun is shown as having an altitude of 2 degrees, or a zenith angle of 88 degrees, and an azimuth of 126 degrees. The south-seeking direction of the magnetic vector has a zenith angle of 7 degrees and an azimuth of 182 degrees. Expressed in more conventional terms, the geomagnetic dip angle is 83 degrees, and the variation, or declination (deviation from a north-south direction) is 2 degrees east. The two solutions given in the tabulated output data were plotted on the graph and were made part of the attitude data-reduction report (Reference 1). It was stated in that report that the second solution was the correct one.

ROCKET ATTITUDE
AEROBEE 150 VEHICLE NUMBER 4.272 UA
FORT CHURCHILL, MANITOBA, CANADA 4 FEBRUARY 1969



LAUNCH DATA

TIME: 14H 35M 0.44 S GMT
LATITUDE: 58° 44' N
LONGITUDE: 93° 49' W
LAUNCHER SETTINGS:
ELEVATION: 82.6°
AZIMUTH: 162.4°
FLIGHT AZIMUTH: 166°

Figure 3. Mechanical Plot of Rocket Attitude Data (From Reference 1)

INTERPRETING THE TABULAR DATA

VEHICLE MOTION

Assuming that none of its parts move or oscillate with respect to one another, a spinning rocket can be mathematically represented in its motion. See Figure 4. During the early part of the flight the spin is imparted to the rocket by means of canted fins, for the purpose of stabilization of the vehicle, especially in the air, and while being propelled. It is usual to reduce spin rate, just before the gathering of the data. While falling freely in the vacuum of space, the vehicle spins and cones in a defined pattern about its center of gravity. The distribution of the masses within the vehicle determine its moment of inertia ellipsoid (a mathematical three-axis model for defining the motion of a body in terms of its absolute kinetic energy, T). If its linear velocity is defined as V, mass as M, spin angular velocity as ω_2, spin moment of inertia as I_2, coning angular velocity as ω_1, and coning moment of inertia, I_1, about the invariant line, then:

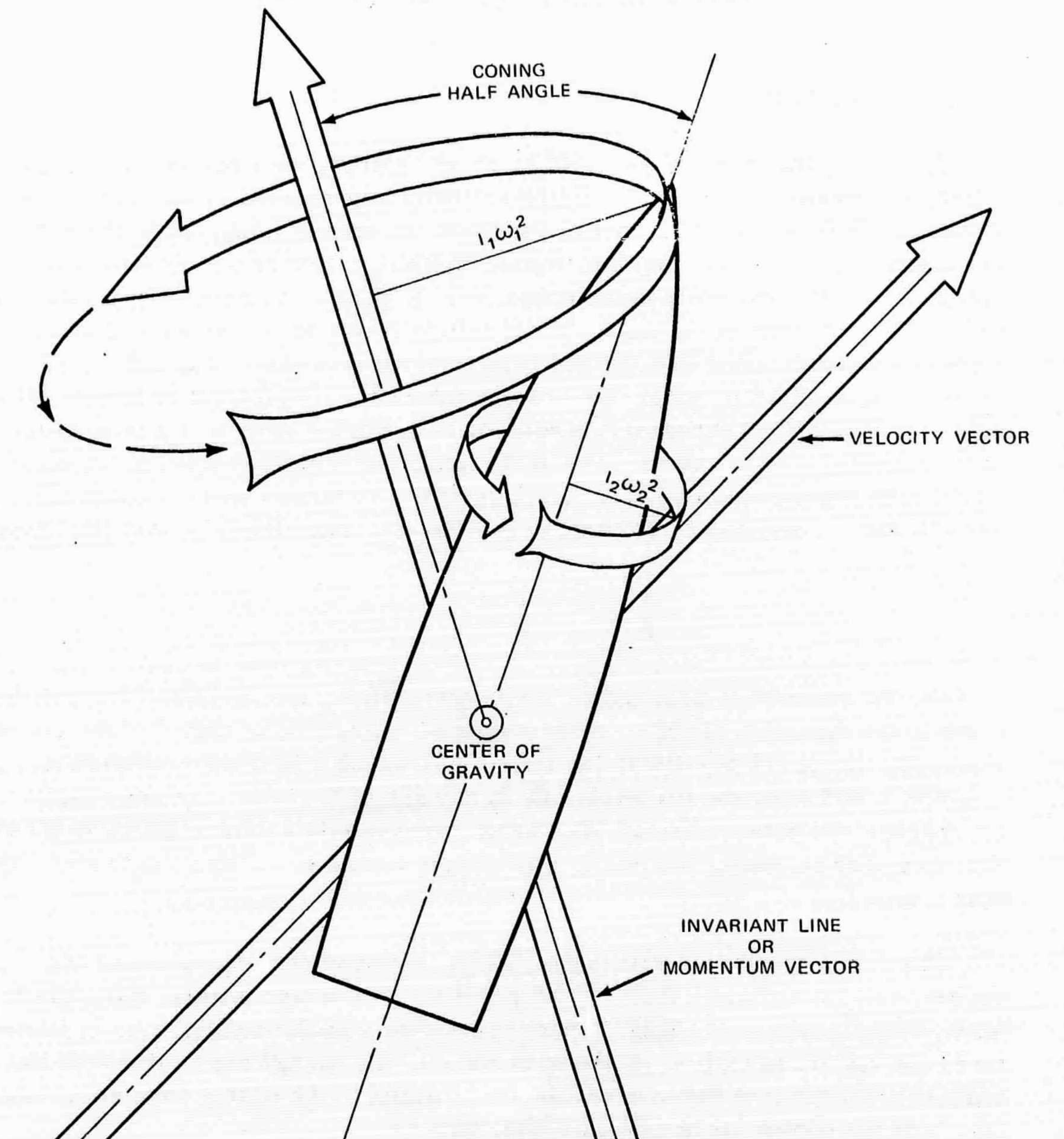
$$T = \frac{1}{2} MV^2 + \frac{1}{2} (I_1 \omega_1{}^2 + I_2 \omega_2{}^2). \tag{5}$$

During the earlier portions of the powered flight, the invariant line will be close to the direction of the velocity vector (the direction of travel of the rocket). However, thrust asymmetry in the rocket motor, or a poor separation of the booster, could alter the invariant line in any direction. Also, as the vehicle approaches and passes through its apogee, the velocity vector changes in direction up to 180 degrees. However, this change has no effect on vehicle stability during free fall in a vacuum.

One easily monitored parameter, the spin period and spin decay of the rocket, will immediately indicate its stability. If the spin angular momentum term, $I_2 \omega_2{}^2$, shows no change, there is no change in the coning, $I_1 \omega_1{}^2$; therefore, the vehicle is stable. If the spin decays, the energy associated with the angular momentum of the spin will be transferred to the coning angular momentum, and the coning angle will increase, as:

$$I_2 \omega_2{}^2 \longrightarrow I_1 \omega_1{}^2. \tag{6}$$

Under these conditions, the vehicle is unstable. It will develop a flat spin, and the acceleration forces at the ends of the vehicle will increase, sometimes to a point that the payload is destroyed.



The center of gravity of the rocket moves along the velocity vector in free space, while the vehicle spins about its longitudinal axis, and cones about a momentum vector with a coning half-angle as shown, at a particular precession rate. The spin, coning angle, and precession rate are all mathematically related. For more detail, see reference 2.

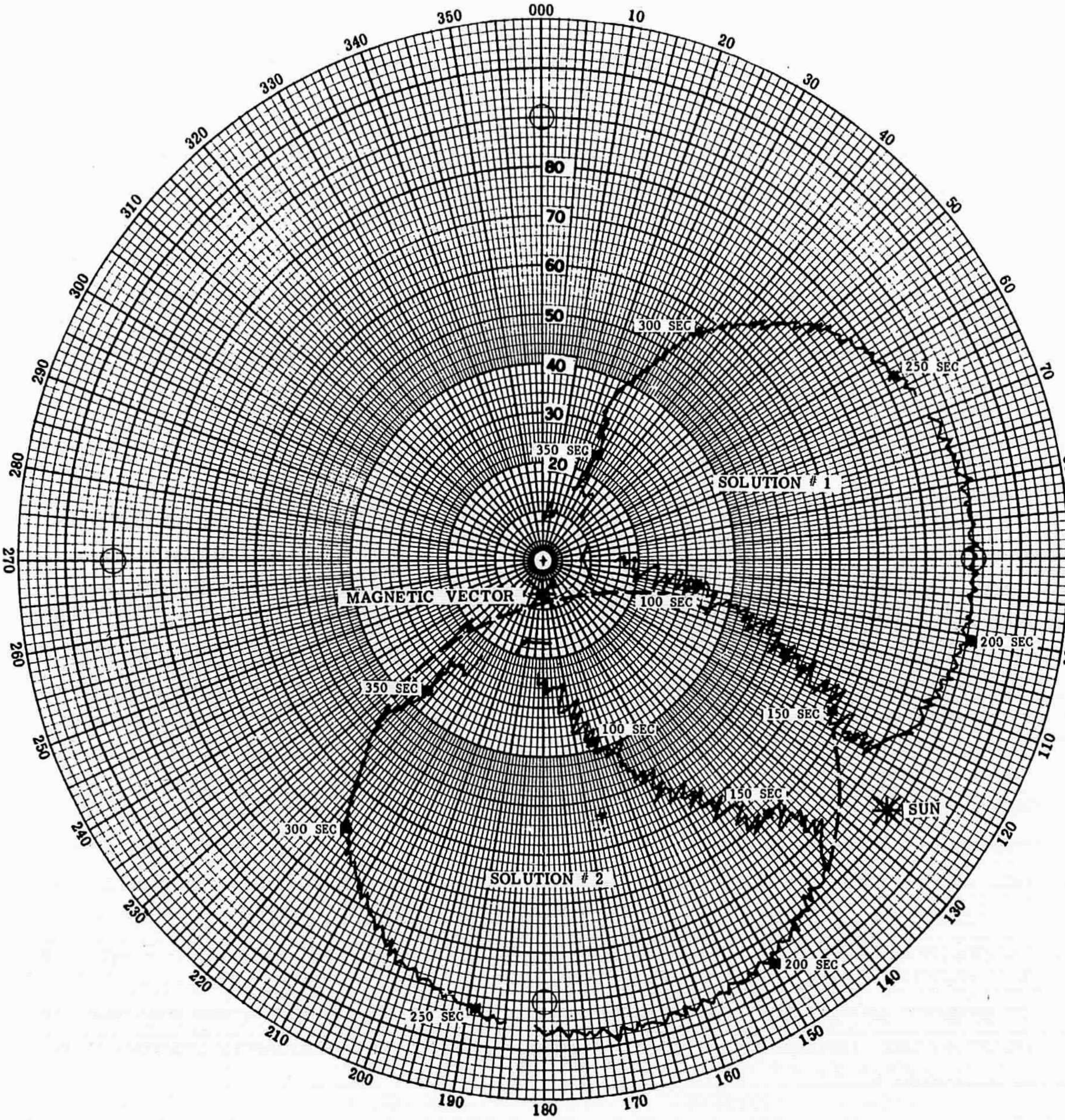
Figure 4. Vehicle Motion in Free Space

SPIN RATE AND SPIN RATE CHANGE

The spin rate and its changes were determined by noting, on the telemetry record, the exact time of the beginning of each solar signal. The spin period and the spin period change were computed and tabulated during 18 seconds to 376 seconds after lift-off. The spin rate increased from 0.735 revolutions per second at 17.9 seconds to 2.82 revolutions per second at 53 seconds after lift-off, and remained at a constant 2.813 revolutions per second until despin at 80.85 seconds. The spin rate then settled to an almost constant 0.3735 revolutions per second until 376 seconds after lift-off. The rocket history, as previously noted, is a very good index to be used in determining the vehicle stability. The only changes in spin rate, up to 376 seconds of flight, were caused by external forces, such as the acceleration of the sustainer, and the despin. Thus, it would be expected that any coning motion would have remained substantially constant during the free-fall part of the flight.

CORRECTLY INTERPRETING THE TABULAR DATA

Although it is not clear from an examination of the tabular data, the true attitude of the rocket during flight was a composite of the two solutions presented. In the light of the discussion on vehicle motion, an examination of the polar graph shown in Figure 5, makes it apparent that such is the case. It is from this plot, using the methods given in Reference 3, that the composite solution is determined. If that portion of solution Number 2 from 50 seconds to 180 seconds is omitted, and those portions of solution Number 1, from about 100 seconds to 160 seconds, and from 180 to 380 seconds are used, it is found that these portions of the curves form a circle about a point having a zenith angle of 53 degrees, and an azimuth angle of 167 degrees. This point represents the invariant line or momentum vector of the coning motion. The coning half-angle was 44 degrees, and the direction of the coning angular velocity was the same as that of the spin angular velocity. The coning motion, despite its rather large coning half-angle (see Figure 5) was confined to approximately one circle. The fact that the coning, once having begun, was almost unchanged throughout the remainder of the flight resulted from a good dynamic design of the payload. In other words, the distribution of the masses within the payload is critical to a good stable flight.



LAUNCH DATA

TIME: 14H 35M 0.44 S GMT
LATITUDE: 58° 44' N
LONGITUDE: 93° 49' W
LAUNCHER SETTINGS:
ELEVATION: 82.6°
AZIMUTH: 162.4°
FLIGHT AZIMUTH: 166°

THE "+" AT 53 DEGREES ZENITH DISTANCE AND 167 DEGREES AZIMUTH IDENTIFIES THE DIRECTION OF THE MOMENTUM VECTOR, OR INVARIANT LINE. THE CONING HALF-ANGLE IS 44 DEGREES.

Figure 5. Reconstructed Attitude Data Plot (Adapted from Reference 1)

PRECAUTIONS

There are some precautions that apply especially to rocket flights using solar sensors and magnetometers for attitude data. The experimenter should:

1. Know precisely the orientation of all sensors

2. Calibrate all sensors

3. To the extent permitted by the mission and range requirements, launch the rocket at a time and in a direction in which both the solar and the magnetic aspect angles will be relatively large. Also, it is better if the direction of the sun and the orientation of the magnetic vector make a relatively large angle with respect to each other. (In other words, calculate the Solar Flight Window, or time during which the direction of the sun is favorable to the acquisition of good aspect data.)

4. Design a payload whose moments of inertia are symmetrical about the longitudinal, or Z, axis, for best use of spin stabilization. With known moments of inertia, the degree of rocket stability can be mathematically predicted. This applies whether attitude sensing is required or not.

ACKNOWLEDGEMENTS

Most of the data reduction was performed under contract at New Mexico State University, the largest contributers being Mr. John Ward and Mr. John Byers. (See Reference 1.)

Calibrations of sensors and documentation of sensor orientations were made by Dr. Alfred Nier and Mr. David Hickman, of the University of Minnesota. The excellent performance by the team from the University of Minnesota contributed to the accuracy of the data reduction by New Mexico State University.

REFERENCES

1. John J. Ward and John Byers. "Rocket Attitude Determination, with Data from NASA 4.272 UA." PR00663, Physical Science Laboratory, New Mexico State University, Las Cruces, New Mexico, 88001. Contract Number NAS5-21002. 28 January, 1970

2. Joseph Sweetman Ames and Francis D. Murnagham. "Theoretical Mechanics, and Introduction to Mathematical Physics." Dover Publications, 180 Varick Street, New York, New York 10014. 1929, 1958. Library of Congress Card Number 58-11269

3. Charles F. Miller, Jr. "A Graphic Method for Determining Absolute Attitude of Sounding Rocket Vehicles" NASA/GSFC TN D 5172. May, 1969

APPENDIX

TABULATED OUTPUT DATA

Table A-1, in the Appendix, shows the computer printout of the attitude data for Flight 4.272 UA. Columns 1 through 3 show the Greenwich mean time in hours, minutes and seconds. Column 4 gives the time in seconds after lift-off. Columns 5, 6, and 7 contain the positional data of the rocket: latitude, longitude, and altitude. These three parameters were used by the computer, in a subroutine, to calculate the local magnetic field vector at the rocket. This is one of the inputs required for the computation of the magnetic aspect angle. Column 8 is the solar aspect angle, and column 9 is the magnetic aspect angle.

Columns 10, 11, and 12 represent one solution of the vehicle attitude. Column 10 shows the zenith distance, or angle between the Z axis and straight up; column 11 shows the angle from true north on the horizon; and column 12 shows the phase angle, or angle between the plane containing the sun and the plane containing the magnetic vector, measured at the rocket. Columns 13, 14, and 15 contain an alternate solution of the rocket attitude, using the same parameters.

Table A-1

COMPUTER PRINTOUT OF ROCKET ATTITUDE DATA (REFERENCE 1)

R O C K E T   A T T I T U D E

MISSILE: AEROBEE 150   VEHICLE NO. 4.272UA

LAUNCHED AT 14H 35M 00.440S GMT   FROM FORT CHURCHILL, CANADA   DATE 4 FEBRUARY 1969

UNIVERSAL TIME (GMT)	FLT_TM (SEC)	LAT (DEG)	LONG (DEG)	ALT (M)	S_ASP (DEG)	M_ASP (DEG)	R_ZD1 (DEG)	R_AZ1 (DEG)	R_PH_A1 (DEG)	R_ZD2 (DEG)	R_AZ2 (DEG)	R_PH_A2 (DEG)	N #SN
14H 35M 18.437S	18.000	58.73	93.82	5868.0	73.37	11.08	0.0	0.0	0.0	0.0	0.0	0.0	0
14H 35M 19.437S	19.000	58.73	93.82	6351.9	73.37	11.01	0.0	0.0	0.0	0.0	0.0	0.0	0
14H 35M 20.438S	20.000	58.73	93.82	6855.0	73.37	10.94	0.0	0.0	0.0	0.0	0.0	0.0	0
14H 35M 21.437S	21.000	58.73	93.82	7376.8	73.37	10.86	0.0	0.0	0.0	0.0	0.0	0.0	0
14H 35M 22.437S	22.000	58.73	93.81	7916.6	77.89	10.78	11.09	112.05	132.22	17.16	175.44	227.78	2
14H 35M 23.438S	23.000	58.73	93.81	8476.7	82.37	10.69	7.99	87.44	104.88	16.99	192.71	255.12	2
14H 35M 24.437S	24.000	58.73	93.81	9059.9	82.37	10.60	7.93	87.96	104.99	16.90	192.61	255.00	2
14H 35M 25.438S	25.000	58.72	93.81	9666.4	82.37	10.51	7.87	88.51	105.12	16.82	192.51	254.88	2
14H 35M 26.437S	26.000	58.72	93.81	10299.4	82.37	10.41	7.81	89.10	105.26	16.72	192.39	254.74	2
14H 35M 27.437S	27.000	58.72	93.81	10962.7	82.37	11.51	8.53	82.94	103.63	17.78	193.75	256.37	2
14H 35M 28.438S	28.000	58.72	93.81	11651.4	82.37	10.20	7.68	90.42	105.57	16.52	192.14	254.43	2
14H 35M 29.437S	29.000	58.72	93.81	12364.5	82.37	10.09	7.61	91.14	105.74	16.41	192.00	254.26	2
14H 35M 30.437S	30.000	58.72	93.81	13110.7	82.37	9.97	7.54	91.92	105.92	16.30	191.85	254.08	2
14H 35M 31.438S	31.000	58.72	93.81	13890.9	82.90	13.40	9.69	71.84	99.12	19.56	197.36	260.88	2
14H 35M 32.437S	32.000	58.72	93.81	14704.4	82.61	13.30	9.74	73.73	100.43	19.50	196.42	259.57	2

Table A-1 (Continued)

14H	36M	21.437S	81.000	58.61	93.75	84861.5	76.33	16.52	14.89	90.49	119.94	23.19	182.67	240.06	2
14H	36M	22.437S	82.000	58.61	93.75	86253.8	75.32	18.90	17.02	86.56	118.80	25.57	183.14	241.20	2
14H	36M	23.438S	83.000	58.61	93.75	87640.5	74.22	17.98	16.84	93.65	124.84	24.64	178.81	235.16	2
14H	36M	24.437S	84.000	58.61	93.75	89011.9	73.13	20.91	19.37	88.42	122.20	27.59	180.13	237.80	2
14H	36M	25.438S	85.000	58.61	93.75	90360.7	72.14	19.34	18.68	96.84	129.43	25.95	175.04	230.57	2
14H	36M	26.437S	86.000	58.60	93.75	91691.9	71.40	19.99	19.44	97.36	130.51	26.59	174.03	229.49	2

Table A-1 (Continued)

14H 36M 27.437S	87.000	58.60	93.74	93017.1	70.66	19.13	19.26	103.46	136.31	25.61	170.01	223.69	2
14H 36M 28.438S	88.000	58.60	93.74	94337.2	69.69	22.57	21.89	95.15	129.93	29.16	173.68	230.07	2
14H 36M 29.437S	89.000	58.60	93.74	95648.7	68.58	24.98	24.05	92.11	127.92	31.60	174.50	232.08	2
14H 36M 30.437S	90.000	58.59	93.74	96951.9	67.46	24.30	23.96	97.41	133.11	30.82	170.63	226.89	2
14H 36M 31.438S	91.000	58.59	93.74	98245.1	66.69	22.96	23.41	104.41	140.07	29.30	165.79	219.93	2
14H 36M 32.437S	92.000	58.59	93.74	99525.3	65.94	26.49	26.08	96.07	132.47	33.01	170.36	227.53	2
14H 36M 33.438S	93.000	58.59	93.74	100794.7	65.28	26.42	26.27	98.25	134.75	32.89	168.59	225.25	2
14H 36M 34.438S	94.000	58.58	93.73	102056.6	64.91	25.19	25.58	103.13	139.63	31.53	165.27	220.37	2
14H 36M 35.437S	95.000	58.58	93.73	103311.4	64.54	28.99	28.41	93.95	130.78	35.55	170.79	229.22	2
14H 36M 36.438S	96.000	58.58	93.73	104558.8	63.77	29.45	29.00	94.97	131.91	35.97	169.71	228.09	2
14H 36M 37.437S	97.000	58.58	93.73	105797.6	62.66	27.80	28.20	102.46	139.68	34.12	164.21	220.32	2
14H 36M 38.437S	98.000	58.58	93.73	107026.1	61.54	31.32	31.12	96.63	133.85	37.77	167.39	226.15	2
14H 36M 39.438S	99.000	58.57	93.73	108244.2	60.74	29.78	30.27	102.74	140.37	36.04	162.88	219.63	2
14H 36M 40.437S	100.000	58.57	93.73	109451.0	60.00	32.16	32.24	98.77	136.20	38.54	165.17	223.80	2
14H 36M 41.438S	101.000	58.57	93.73	110647.7	59.31	31.63	32.08	101.93	139.67	37.90	162.65	220.33	2
14H 36M 42.438S	102.000	58.57	93.73	111836.9	58.94	32.05	32.50	101.90	139.66	38.32	162.49	220.34	2
14H 36M 43.437S	103.000	58.56	93.73	113016.3	58.57	34.29	34.29	97.69	135.00	40.69	165.21	225.00	2
14H 36M 44.438S	104.000	58.56	93.72	114184.7	57.85	34.69	34.80	98.61	135.99	41.04	164.24	224.01	2
14H 36M 45.438S	105.000	58.56	93.72	115345.0	56.73	34.20	34.78	102.60	140.49	40.40	160.91	219.51	2
14H 36M 46.437S	106.000	58.56	93.72	116495.4	55.62	36.33	36.71	100.58	138.08	42.58	161.03	221.92	2
14H 36M 47.438S	107.000	58.56	93.72	117636.0	54.79	34.10	35.39	108.47	147.44	40.01	155.66	212.56	2
14H 36M 48.438S	108.000	58.55	93.72	118770.3	54.05	36.66	37.44	103.79	141.75	42.77	158.83	218.25	2
14H 36M 49.438S	109.000	58.55	93.72	119893.9	53.30	37.46	38.26	103.85	141.75	43.55	158.46	218.25	2
14H 36M 50.438S	110.000	58.55	93.72	121008.8	52.56	39.04	39.67	102.19	139.57	45.19	159.38	220.43	2
14H 36M 51.437S	111.000	58.55	93.72	122116.6	51.81	39.00	39.85	104.07	141.81	45.06	157.69	218.19	2
14H 36M 52.438S	112.000	58.54	93.72	123212.7	50.92	40.51	41.25	102.97	140.22	46.60	158.16	219.78	2
14H 36M 53.438S	113.000	58.54	93.71	124300.6	49.80	40.85	41.83	104.89	142.49	46.84	156.27	217.51	2
14H 36M 54.437S	114.000	58.54	93.71	125379.4	48.68	43.04	43.82	102.99	139.64	49.10	157.30	220.36	2
14H 36M 55.438S	115.000	58.54	93.71	126448.0	48.10	41.91	43.12	106.71	144.55	47.78	154.24	215.45	2
14H 36M 56.438S	116.000	58.54	93.71	127506.9	47.73	42.24	43.48	106.86	144.67	48.10	153.99	215.33	2
14H 36M 57.438S	117.000	58.53	93.71	128553.7	47.34	44.02	44.95	104.03	140.62	50.02	156.05	219.38	2
14H 36M 58.438S	118.000	58.53	93.71	129591.1	46.23	42.91	44.43	109.10	147.44	48.63	151.68	212.56	2
14H 36M 59.438S	119.000	58.53	93.71	130616.9	45.11	45.72	46.86	105.64	142.12	51.60	154.03	217.88	2
14H 37M 0.438S	120.000	58.53	93.71	131631.9	44.24	46.38	47.60	106.24	142.69	52.22	153.27	217.31	2
14H 37M 1.437S	121.000	58.52	93.71	132638.1	43.87	45.67	47.16	108.59	146.06	51.37	151.29	213.94	2
14H 37M 2.437S	122.000	58.52	93.71	133635.6	43.50	48.69	49.62	103.61	138.34	54.65	155.10	221.66	2
14H 37M 3.437S	123.000	58.52	93.70	134626.3	42.64	47.32	48.76	107.90	144.57	53.05	151.45	215.43	2
14H 37M 4.437S	124.000	58.52	93.70	135609.0	41.53	48.31	49.81	108.41	144.92	53.99	150.68	215.08	2
14H 37M 5.437S	125.000	58.52	93.70	136583.4	40.41	50.57	51.87	106.49	141.27	56.35	151.88	218.73	2
14H 37M 6.437S	126.000	58.51	93.70	137549.2	39.65	48.59	50.55	112.28	150.43	54.01	146.92	209.57	2
14H 37M 7.437S	127.000	58.51	93.70	138504.5	38.90	50.85	52.47	109.10	144.84	56.46	149.32	215.16	2
14H 37M 8.437S	128.000	58.51	93.70	139448.0	38.16	51.47	53.14	109.50	145.14	57.04	148.78	214.86	2
14H 37M 9.437S	129.000	58.51	93.70	140378.9	37.41	51.13	53.08	111.90	148.93	56.54	146.57	211.07	2
14H 37M 10.437S	130.000	58.50	93.70	141299.8	36.67	53.62	55.21	108.59	142.66	59.23	149.09	217.33	2
14H 37M 11.437S	131.000	58.50	93.70	142211.2	36.14	51.72	53.88	113.65	151.45	57.00	144.74	208.55	2
14H 37M 12.437S	132.000	58.50	93.70	143115.2	35.77	52.65	54.68	112.41	149.07	58.01	145.69	210.93	2
14H 37M 13.437S	133.000	58.50	93.69	144011.8	35.40	53.88	55.72	110.72	145.76	59.34	147.00	214.24	2
14H 37M 14.437S	134.000	58.49	93.69	144900.8	34.35	55.09	56.93	110.63	144.95	60.54	146.78	215.05	2
14H 37M 15.437S	135.000	58.49	93.69	145780.8	33.23	55.07	57.20	113.09	149.00	60.34	144.42	211.00	2
14H 37M 16.437S	136.000	58.49	93.69	146651.2	32.28	56.86	58.83	111.59	145.42	62.22	145.42	214.58	2
14H 37M 17.438S	137.000	58.49	93.69	147509.9	31.91	55.64	57.99	114.94	151.93	60.77	142.48	208.07	2

Table A-1 (Continued)

14H 37M 18.437S	138.000	58.49	93.69	148358.6	31.53	58.60	60.41	110.04	141.60	64.06	146.51	218.40	2
14H 37M 19.437S	139.000	58.48	93.69	149198.2	30.55	58.30	60.39	112.47	145.97	63.57	144.23	214.03	2
14H 37M 20.438S	140.000	58.48	93.69	150029.9	29.05	58.58	60.98	115.14	150.71	63.64	141.57	209.29	2
14H 37M 21.437S	141.000	58.48	93.69	150850.1	27.56	60.31	62.69	114.87	149.04	65.37	141.42	210.96	2
14H 37M 22.437S	142.000	58.48	93.69	151660.6	27.37	60.01	62.51	115.94	151.38	64.99	140.45	208.62	2
14H 37M 23.438S	143.000	58.47	93.68	152460.4	27.37	61.43	63.63	113.18	144.86	66.61	142.82	215.14	2
14H 37M 24.437S	144.000	58.47	93.68	153250.7	27.15	62.27	64.36	112.20	142.23	67.52	143.60	217.77	2
14H 37M 25.438S	145.000	58.47	93.68	154034.6	26.03	61.97	64.37	114.85	147.69	67.02	141.08	212.31	2
14H 37M 26.437S	146.000	58.47	93.68	154812.2	24.91	64.49	66.67	112.76	141.06	69.67	142.56	218.94	2
14H 37M 27.437S	147.000	58.47	93.68	155581.6	24.17	64.20	66.59	114.54	145.01	69.25	140.88	214.99	2
14H 37M 28.438S	148.000	58.46	93.68	156336.5	23.80	63.63	66.21	116.32	149.43	68.54	139.27	210.57	2
14H 37M 29.437S	149.000	58.46	93.68	157079.2	23.42	66.13	68.34	112.92	139.43	71.28	142.07	220.57	2
14H 37M 30.437S	150.000	58.46	93.68	157812.1	22.10	65.01	67.71	117.22	150.29	69.82	138.08	209.71	2
14H 37M 31.438S	151.000	58.46	93.68	158539.1	20.60	65.56	68.52	119.53	155.74	70.16	135.68	204.26	2
14H 37M 32.437S	152.000	58.45	93.68	159258.9	19.37	67.48	70.30	118.16	150.25	72.17	136.61	209.75	2
14H 37M 33.438S	153.000	58.45	93.67	159969.2	19.37	66.65	69.66	120.00	156.16	71.19	134.99	203.84	2
14H 37M 34.438S	154.000	58.45	93.67	160669.4	19.37	68.28	70.94	116.71	145.38	73.10	137.89	214.61	2
14H 37M 35.437S	155.000	58.45	93.67	161357.9	18.78	69.36	71.96	116.07	142.20	74.21	138.30	217.80	2
14H 37M 36.438S	156.000	58.45	93.67	162037.1	17.65	68.54	71.54	119.74	153.65	73.08	134.84	206.35	2
14H 37M 37.437S	157.000	58.44	93.67	162709.1	16.52	70.16	73.08	118.90	149.10	74.75	135.33	210.90	2
14H 37M 38.437S	158.000	58.44	93.67	163372.8	16.04	69.88	72.98	120.53	154.73	74.33	133.78	205.27	2
14H 37M 39.438S	159.000	58.44	93.67	164024.8	15.66	70.68	73.70	119.67	150.81	75.21	134.47	209.19	2
14H 37M 40.437S	160.000	58.44	93.67	164667.0	15.29	71.75	74.64	118.50	145.32	76.37	135.41	214.68	2
14H 37M 41.438S	161.000	58.43	93.67	165300.9	14.91	71.21	74.29	120.23	152.00	75.68	133.82	208.00	2
14H 37M 42.438S	162.000	58.43	93.67	165928.3	14.53	73.08	75.90	117.83	140.60	77.74	135.82	219.40	2
14H 37M 43.437S	163.000	58.43	93.66	166549.5	13.93	73.60	76.46	118.07	140.25	78.24	135.47	219.75	2
14H 37M 44.438S	164.000	58.43	93.66	167158.6	13.17	73.07	76.16	120.25	149.14	77.51	133.42	210.86	2
14H 37M 45.438S	165.000	58.43	93.66	167758.7	12.41	75.18	78.09	118.40	137.52	79.77	134.83	222.48	2
14H 37M 46.437S	166.000	58.42	93.66	168353.1	12.01	74.38	77.48	120.19	146.29	78.82	133.22	213.71	2
14H 37M 47.438S	167.000	58.42	93.66	168934.3	11.62	74.38	77.56	120.92	149.39	78.75	132.50	210.61	2
14H 37M 48.438S	168.000	58.42	93.66	169503.9	11.37	76.22	79.17	118.70	135.57	80.77	134.33	224.43	2
14H 37M 49.438S	169.000	58.42	93.66	170062.3	11.37	75.69	78.71	119.35	139.59	80.19	133.81	220.41	2
14H 37M 50.438S	170.000	58.41	93.66	170603.7	11.37	77.26	80.10	117.63	128.31	81.90	135.19	231.69	2
14H 37M 51.437S	171.000	58.41	93.66	171139.6	11.37	78.30	81.06	116.78	121.78	83.00	135.84	238.22	2
14H 37M 52.438S	172.000	58.41	93.66	171677.3	11.37	76.99	79.86	117.89	130.01	81.62	135.02	229.99	2
14H 37M 53.438S	173.000	58.41	93.65	172206.1	11.37	78.82	81.54	116.42	118.69	83.55	136.11	241.31	2
14H 37M 54.437S	174.000	58.41	93.65	172725.4	11.37	78.82	81.53	116.43	118.68	83.55	136.12	241.32	2
14H 37M 55.438S	175.000	58.40	93.65	173237.6	11.37	78.81	81.53	116.43	118.67	83.55	136.12	241.33	2
14H 37M 56.438S	176.000	58.40	93.65	173733.1	11.37	82.21	84.77	114.84	100.46	87.03	137.03	259.54	2
14H 37M 57.438S	177.000	58.40	93.65	174212.4	11.37	79.33	82.02	116.11	115.68	84.09	136.35	244.32	2
14H 37M 58.438S	178.000	58.40	93.65	174688.3	11.37	80.11	82.75	115.68	111.35	84.90	136.63	248.65	2
14H 37M 59.438S	179.000	58.39	93.65	175159.4	11.70	81.42	83.97	114.77	103.97	86.27	137.28	256.03	2
14H 38M 0.438S	180.000	58.39	93.65	175616.7	12.08	81.68	84.17	114.29	102.19	86.57	137.71	257.81	2
14H 38M 1.437S	181.000	58.39	93.65	176062.4	12.64	82.98	85.38	113.37	95.64	87.93	138.38	264.36	2
14H 38M 2.437S	182.000	58.39	93.65	176502.7	13.78	83.24	85.50	112.18	93.96	88.29	139.52	266.04	2
14H 38M 3.437S	183.000	58.39	93.65	176934.2	14.92	81.93	84.09	111.34	98.46	87.08	140.64	261.54	2
14H 38M 4.437S	184.000	58.38	93.65	177355.0	15.60	84.54	86.58	110.21	88.61	89.74	141.26	271.39	2
14H 38M 5.437S	185.000	58.38	93.64	177768.1	15.97	82.19	84.22	110.22	96.82	87.43	141.72	263.18	2
14H 38M 6.437S	186.000	58.38	93.64	178174.2	16.35	83.49	85.46	109.59	92.13	88.77	142.10	267.87	2
14H 38M 7.437S	187.000	58.38	93.64	178571.6	16.95	85.31	87.20	108.82	86.01	90.62	142.52	273.99	2
14H 38M 8.437S	188.000	58.37	93.64	178960.1	17.53	84.27	86.10	108.32	89.36	89.64	143.23	270.64	2

Table A-1 (Continued)

14H	38M	9.437S	189.000	58.37	93.64	179335.9	18.08	85.31	87.07	107.70	86.14	90.71	143.66	273.86	2
14H	38M	10.437S	190.000	58.37	93.64	179696.1	18.63	85.05	86.74	107.17	86.96	90.50	144.24	273.04	2
14H	38M	11.437S	191.000	58.37	93.64	180046.0	19.17	84.79	86.42	106.65	87.72	90.29	144.82	272.28	2
14H	38M	12.437S	192.000	58.37	93.64	180391.2	19.61	87.11	88.70	106.17	81.17	92.62	144.86	278.83	2
14H	38M	13.437S	193.000	58.36	93.64	180730.1	19.98	85.82	87.36	105.80	84.87	91.37	145.50	275.13	2
14H	38M	14.437S	194.000	58.36	93.64	181057.7	20.36	86.08	87.57	105.42	84.22	91.66	145.83	275.78	2
14H	38M	15.437S	195.000	58.36	93.64	181374.2	21.47	87.63	89.00	104.33	80.46	93.27	146.63	279.54	2
14H	38M	16.437S	196.000	58.36	93.64	181687.6	22.59	86.34	87.56	103.19	83.98	92.08	148.03	276.02	2
14H	38M	17.438S	197.000	58.35	93.64	182002.1	23.48	87.89	89.02	102.33	80.54	93.67	148.62	279.46	2
14H	38M	18.437S	198.000	58.35	93.63	182307.1	23.86	87.89	88.98	101.95	80.66	93.70	149.00	279.34	2
14H	38M	19.437S	199.000	58.35	93.63	182590.7	24.23	87.37	88.41	101.57	81.93	93.22	149.50	278.07	2
14H	38M	20.438S	200.000	58.35	93.63	182852.0	25.08	89.69	90.66	100.86	77.10	95.57	149.78	282.90	2
14H	38M	21.437S	201.000	58.35	93.63	183104.0	26.20	87.63	88.43	99.60	81.86	93.61	151.44	278.14	2
14H	38M	22.437S	202.000	58.34	93.63	183358.4	27.33	88.66	89.34	98.52	80.10	94.70	152.35	279.90	2
14H	38M	23.438S	203.000	58.34	93.63	183609.6	27.73	89.69	90.34	98.19	78.21	95.74	152.50	281.78	2
14H	38M	24.437S	204.000	58.34	93.63	183844.9	28.10	88.40	88.98	97.73	80.80	94.50	153.20	279.20	2
14H	38M	25.438S	205.000	58.34	93.63	184062.9	28.69	89.43	89.96	97.20	79.04	95.55	153.56	280.96	2
14H	38M	26.437S	206.000	58.33	93.63	184268.3	29.81	89.43	89.82	96.07	79.40	95.62	154.71	280.60	2
14H	38M	27.437S	207.000	58.33	93.63	184468.5	30.93	88.40	88.63	94.90	81.48	94.67	156.08	278.52	2
14H	38M	28.438S	208.000	58.33	93.63	184668.7	31.82	90.47	90.62	94.12	78.28	96.76	156.51	281.72	2
14H	38M	29.437S	209.000	58.33	93.62	184867.9	32.57	89.18	89.21	93.29	80.58	95.53	157.59	279.42	2
14H	38M	30.437S	210.000	58.33	93.62	185061.9	33.32	89.69	89.65	92.57	79.95	96.08	158.24	280.05	2
14H	38M	31.438S	211.000	58.32	93.62	185246.4	34.06	90.73	90.61	91.69	78.57	97.14	158.75	281.43	2
14H	38M	32.437S	212.000	58.32	93.62	185412.9	34.81	89.18	88.94	91.05	81.06	95.64	159.87	278.94	2
14H	38M	33.438S	213.000	58.32	93.62	185559.7	35.55	89.95	89.63	90.34	80.11	96.45	160.47	279.89	2
14H	38M	34.438S	214.000	58.32	93.62	185695.3	36.30	90.73	90.33	89.64	79.20	97.26	161.06	280.80	2
14H	38M	35.437S	215.000	58.32	93.62	185826.3	37.05	89.18	88.66	88.82	81.48	95.75	162.16	278.52	2
14H	38M	36.438S	216.000	58.31	93.62	185953.1	37.79	91.25	90.67	88.17	78.89	97.84	162.47	281.11	2
14H	38M	37.437S	217.000	58.31	93.62	186079.3	38.54	89.69	89.00	87.34	81.07	96.33	163.58	278.93	2
14H	38M	38.437S	218.000	58.31	93.62	186197.6	39.29	89.69	88.91	86.60	81.20	96.36	164.34	278.80	2
14H	38M	39.438S	219.000	58.31	93.62	186303.0	40.36	91.25	90.36	85.59	79.53	97.95	165.12	280.47	2
14H	38M	40.437S	220.000	58.30	93.61	186396.8	41.48	90.21	89.17	84.42	80.98	96.96	166.48	279.02	2
14H	38M	41.438S	221.000	58.30	93.61	186473.0	42.44	90.21	89.05	83.45	81.14	97.00	167.47	278.86	2
14H	38M	42.438S	222.000	58.30	93.61	186526.9	42.82	90.73	89.53	83.10	80.63	97.53	167.75	279.37	2
14H	38M	43.437S	223.000	58.30	93.61	186568.4	43.19	89.69	88.43	82.70	81.81	96.51	168.33	278.19	2
14H	38M	44.438S	224.000	58.29	93.61	186612.2	43.76	91.25	89.94	82.19	80.24	98.07	168.61	279.76	2
14H	38M	45.438S	225.000	58.29	93.61	186663.8	44.50	90.73	89.32	81.42	80.92	97.58	169.48	279.08	2
14H	38M	46.437S	226.000	58.29	93.61	186715.2	45.25	89.69	88.19	80.65	82.08	96.57	170.43	277.92	2
14H	38M	47.438S	227.000	58.29	93.61	186744.6	46.31	92.55	90.95	79.71	79.44	99.44	170.97	280.56	2
14H	38M	48.438S	228.000	58.29	93.61	186744.9	47.43	89.43	87.66	78.47	82.58	96.37	172.69	277.42	2
14H	38M	49.438S	229.000	58.28	93.61	186731.1	48.43	90.47	88.59	77.49	81.75	97.42	173.54	278.25	2
14H	38M	50.438S	230.000	58.28	93.61	186719.1	48.80	90.73	88.81	77.13	81.57	97.69	173.88	278.43	2
14H	38M	51.437S	231.000	58.28	93.60	186713.5	49.17	89.69	87.72	76.73	82.52	96.66	174.43	277.48	2
14H	38M	52.438S	232.000	58.28	93.60	186703.6	49.72	90.47	88.44	76.20	81.91	97.45	174.87	278.09	2
14H	38M	53.438S	233.000	58.28	93.60	186677.1	50.47	89.69	87.56	75.44	82.65	96.69	175.75	277.35	2
14H	38M	54.437S	234.000	58.27	93.60	186636.4	51.21	89.18	86.95	74.70	83.13	96.18	176.58	275.87	2
14H	38M	55.438S	235.000	58.27	93.60	186586.2	51.96	90.73	88.44	73.98	81.96	97.75	177.12	278.04	2
14H	38M	56.438S	236.000	58.27	93.60	186529.1	52.70	88.40	86.00	73.22	83.83	95.43	178.20	278.17	2
14H	38M	57.438S	237.000	58.27	93.60	186460.4	53.49	89.43	86.95	72.43	83.10	96.47	178.87	276.[illegible]	2
14H	38M	58.438S	238.000	58.27	93.60	186375.5	54.61	89.95	87.34	71.32	82.81	97.00	179.94	277.19	2
14H	38M	59.438S	239.000	58.26	93.60	186277.9	55.73	88.14	85.39	70.20	84.14	95.20	181.29	275.86	2

Table A-1 (Continued)

14H 39M 5.437S	245.000	58.25	93.59	185563.6	59.41	87.62	84.46	66.54	84.53	94.68	185.08	275.47	2
14H 39M 6.437S	246.000	58.25	93.59	185391.4	60.16	87.88	84.64	65.79	84.39	94.94	185.81	275.61	2
14H 39M 7.437S	247.000	58.24	93.59	185220.9	60.90	86.33	83.00	65.08	85.26	93.38	186.70	274.74	2
14H 39M 8.437S	248.000	58.24	93.59	185064.1	61.65	87.63	84.22	64.31	84.54	94.67	187.35	275.46	2
14H 39M 9.437S	249.000	58.24	93.59	184912.0	62.39	86.85	83.36	63.58	84.95	93.89	188.16	275.05	2
14H 39M 10.437S	250.000	58.24	93.59	184744.1	63.13	85.56	81.98	62.86	85.59	92.58	189.00	274.41	2
14H 39M 11.437S	251.000	58.24	93.59	184545.2	63.62	86.07	82.45	62.36	85.31	93.09	189.46	274.69	2
14H 39M 12.437S	252.000	58.24	93.59	184319.9	64.00	85.04	81.37	62.02	85.79	92.05	189.91	274.21	2
14H 39M 13.437S	253.000	58.23	93.59	184091.7	64.38	85.30	81.59	61.63	85.64	92.31	190.28	274.36	2
14H 39M 14.437S	254.000	58.23	93.58	183876.0	65.50	85.30	81.47	60.51	85.59	92.29	191.41	274.41	2
14H 39M 15.437S	255.000	58.23	93.58	183660.9	66.62	83.48	79.53	59.44	86.31	90.44	192.63	273.69	2
14H 39M 16.437S	256.000	58.23	93.58	183425.2	67.49	84.78	80.75	58.52	85.69	91.73	193.44	274.31	2
14H 39M 17.438S	257.000	58.22	93.58	183161.6	67.86	83.74	79.66	58.18	86.08	90.68	193.87	273.92	2
14H 39M 18.437S	258.000	58.22	93.58	182881.2	68.23	83.48	79.37	57.81	86.15	90.41	194.26	273.85	2
14H 39M 19.437S	259.000	58.22	93.58	182602.1	68.85	83.74	79.57	57.19	85.99	90.66	194.87	274.01	2
14H 39M 20.438S	260.000	58.22	93.58	182329.2	69.59	82.17	77.92	56.49	86.50	89.07	195.68	273.50	2
14H 39M 21.437S	261.000	58.22	93.58	182050.6	70.34	82.17	77.85	55.73	86.41	89.05	196.43	273.59	2
14H 39M 22.437S	262.000	58.21	93.58	181752.2	71.08	82.70	78.30	54.96	86.14	89.55	197.16	273.86	2
14H 39M 23.438S	263.000	58.21	93.58	181431.6	71.83	80.60	76.13	54.27	86.73	87.43	197.98	273.27	2
14H 39M 24.437S	264.000	58.21	93.58	181105.4	72.58	81.39	76.85	53.48	86.37	88.20	198.71	273.63	2
14H 39M 25.438S	265.000	58.21	93.58	180784.3	73.32	80.87	76.25	52.74	86.42	87.65	199.48	273.58	2
14H 39M 26.437S	266.000	58.20	93.58	180462.2	74.07	80.35	75.66	51.99	86.45	87.10	200.24	273.55	2
14H 39M 27.437S	267.000	58.20	93.57	180119.1	74.59	81.40	76.66	51.43	86.09	88.13	200.74	273.91	2
14H 39M 28.438S	268.000	58.20	93.57	179747.8	74.96	79.30	74.53	51.11	86.58	86.02	201.17	273.42	2
14H 39M 29.437S	269.000	58.20	93.57	179365.9	75.34	78.78	73.97	50.75	86.64	85.48	201.56	273.36	2
14H 39M 30.437S	270.000	58.20	93.57	178989.6	75.71	80.35	75.51	50.32	86.18	87.04	201.90	273.82	2
14H 39M 31.438S	271.000	58.19	93.57	178625.2	76.08	76.95	72.07	50.05	86.92	83.62	202.35	273.08	2
14H 39M 32.437S	272.000	58.19	93.57	178258.2	76.54	78.79	73.87	49.51	86.40	85.44	202.78	273.60	2
14H 39M 33.438S	273.000	58.19	93.57	177866.7	77.29	77.74	72.75	48.76	86.48	84.36	203.56	273.52	2
14H 39M 34.438S	274.000	58.19	93.57	177445.2	78.04	75.38	70.31	48.06	86.79	81.95	204.35	273.21	2
14H 39M 35.437S	275.000	58.19	93.57	177007.9	78.78	76.70	71.57	47.23	86.36	83.24	205.09	273.64	2
14H 39M 36.438S	276.000	58.18	93.57	176572.6	79.53	74.85	69.66	46.50	86.50	81.36	205.87	273.50	2
14H 39M 37.437S	277.000	58.18	93.56	176143.3	80.27	74.32	69.06	45.72	86.39	80.79	206.63	273.61	2
14H 39M 38.437S	278.000	58.18	93.56	175708.3	80.37	74.59	69.33	45.62	86.31	81.05	206.73	273.69	2
14H 39M 39.438S	279.000	58.18	93.56	175253.2	80.37	73.27	68.00	45.65	86.51	79.72	206.75	273.49	2
14H 39M 40.437S	280.000	58.17	93.56	174782.2	80.51	74.33	69.05	45.47	86.31	80.79	206.89	273.69	2
14H 39M 41.438S	281.000	58.17	93.56	174303.6	81.25	73.01	67.66	44.71	86.28	79.42	207.67	273.72	2
14H 39M 42.438S	282.000	58.17	93.56	173824.4	82.00	70.86	65.44	43.95	86.31	77.22	208.45	273.69	2
14H 39M 43.437S	283.000	58.17	93.56	173345.1	82.56	72.75	67.29	43.31	85.91	79.08	209.01	274.09	2
14H 39M 44.438S	284.000	58.17	93.56	172855.7	82.93	71.41	65.92	42.93	85.93	77.72	209.41	274.07	2
14H 39M 45.438S	285.000	58.16	93.56	172347.1	83.30	70.06	64.53	42.54	85.93	76.35	209.82	274.07	2
14H 39M 46.437S	286.000	58.16	93.56	171822.2	83.68	71.15	65.59	42.12	85.70	77.42	210.19	274.30	2
14H 39M 47.438S	287.000	58.16	93.56	171276.0	84.05	69.53	63.94	41.72	85.70	75.77	210.60	274.30	2
14H 39M 48.438S	288.000	58.16	93.56	170710.9	84.48	69.53	63.91	41.24	85.53	75.75	211.05	274.47	2
14H 39M 49.438S	289.000	58.15	93.56	170155.5	85.22	68.72	63.03	40.41	85.30	74.89	211.84	274.70	2
14H 39M 50.438S	290.000	58.15	93.56	169614.5	85.97	67.08	61.33	39.56	85.07	73.19	212.65	274.93	2

Table A-1 (Continued)

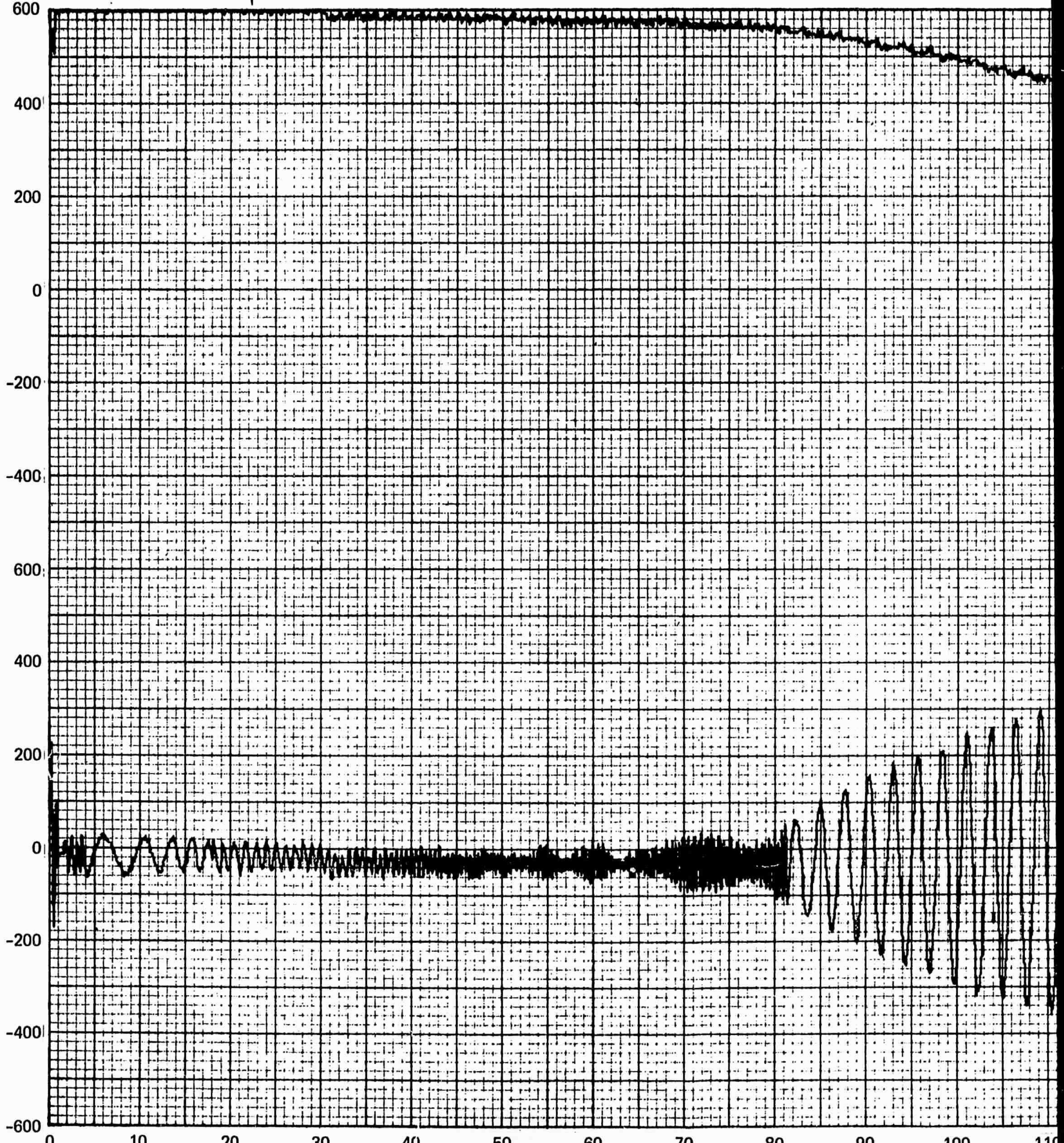
14H	39M	51.437S	291.000	58.15	93.56	169064.6	86.54	67.91	62.12	38.93	84.80	73.99	213.24	275.20	2
14H	39M	52.438S	292.000	58.15	93.56	168494.3	86.92	67.10	61.27	38.49	84.66	73.14	213.65	275.34	2
14H	39M	53.438S	293.000	58.15	93.56	167903.5	87.29	65.72	59.85	38.04	84.51	71.73	214.09	275.49	2
14H	39M	54.437S	294.000	58.14	93.55	167293.1	87.66	67.11	61.22	37.64	84.34	73.10	214.45	275.66	2
14H	39M	55.438S	295.000	58.14	93.55	166680.9	88.03	64.34	58.41	37.14	84.14	70.29	214.93	275.85	2
14H	39M	56.438S	296.000	58.14	93.55	166076.2	88.41	64.91	58.95	36.72	83.97	70.83	215.31	276.03	2
14H	39M	57.438S	297.000	58.14	93.55	165467.6	88.78	64.07	58.09	36.25	83.77	69.97	215.75	276.23	2
14H	39M	58.438S	298.000	58.13	93.55	164841.2	89.15	62.39	56.36	35.74	83.51	68.24	216.22	276.49	2
14H	39M	59.438S	299.000	58.13	93.55	164194.5	89.53	63.24	57.20	35.34	83.36	69.07	216.59	276.64	2
14H	40M	0.438S	300.000	58.13	93.55	163531.9	89.90	62.69	56.61	34.86	83.13	68.49	217.02	276.87	2
14H	40M	1.437S	301.000	58.13	93.55	162860.4	90.27	61.27	55.16	34.33	82.83	67.03	217.50	277.17	2
14H	40M	2.437S	302.000	58.13	93.55	162186.1	90.65	62.14	56.00	33.93	82.69	67.87	217.87	277.31	2
14H	40M	3.437S	303.000	58.12	93.55	161510.1	91.02	59.85	53.67	33.30	82.27	65.53	218.41	277.73	2
14H	40M	4.437S	304.000	58.12	93.55	160833.9	91.37	60.15	53.95	32.90	82.10	65.81	218.78	277.90	2
14H	40M	5.437S	305.000	58.12	93.54	160150.1	91.37	59.87	53.67	32.88	82.06	65.52	218.80	277.94	2
14H	40M	6.437S	306.000	58.12	93.54	159445.1	91.37	57.53	51.31	32.67	81.80	63.16	218.95	278.20	2
14H	40M	7.437S	307.000	58.12	93.54	158715.7	91.51	58.43	52.21	32.57	81.80	64.06	219.06	278.20	2
14H	40M	8.437S	308.000	58.11	93.54	157975.0	91.89	56.96	50.70	31.95	81.38	62.54	219.59	278.62	2
14H	40M	9.437S	309.000	58.11	93.54	157233.6	92.26	55.46	49.16	31.29	80.91	60.99	220.13	279.09	2
14H	40M	10.437S	310.000	58.11	93.54	156483.7	92.37	56.68	50.39	31.29	81.01	62.22	220.17	278.99	2
14H	40M	11.437S	311.000	58.11	93.54	155727.9	92.37	53.95	47.63	30.97	80.58	59.46	220.39	279.42	2
14H	40M	12.437S	312.000	58.10	93.54	154974.8	92.38	53.97	47.65	30.95	80.57	59.47	220.42	279.43	2
14H	40M	13.437S	313.000	58.10	93.54	154219.6	92.75	54.29	47.95	30.48	80.34	59.76	220.83	279.66	2
14H	40M	14.437S	314.000	58.10	93.54	153453.5	93.13	51.48	45.08	29.55	79.52	56.88	221.55	280.48	2
14H	40M	15.437S	315.000	58.10	93.54	152667.7	93.37	51.82	45.40	29.27	79.39	57.19	221.81	280.61	2
14H	40M	16.437S	316.000	58.10	93.54	151858.6	93.37	51.19	44.77	29.16	79.26	56.56	221.88	280.74	2
14H	40M	17.438S	317.000	58.09	93.54	151044.4	93.37	50.24	43.81	29.00	79.05	55.59	221.99	280.95	2
14H	40M	18.437S	318.000	58.09	93.54	150237.7	93.62	51.23	44.79	28.80	79.04	56.57	222.20	280.96	2
14H	40M	19.437S	319.000	58.09	93.53	149430.4	94.00	48.63	42.14	27.75	78.10	53.89	222.97	281.90	2
14H	40M	20.438S	320.000	58.09	93.53	148609.8	94.37	48.99	42.47	27.27	77.84	54.21	223.40	282.16	2
14H	40M	21.437S	321.000	58.08	93.53	147757.7	94.37	48.34	41.82	27.12	77.67	53.55	223.50	282.33	2
14H	40M	22.437S	322.000	58.08	93.53	146870.9	94.37	47.01	40.47	26.81	77.29	52.20	223.69	282.71	2
14H	40M	23.438S	323.000	58.08	93.53	145985.7	94.49	47.71	41.18	26.79	77.36	52.90	223.75	282.64	2
14H	40M	24.437S	324.000	58.08	93.53	145126.2	94.86	47.06	40.49	26.04	76.80	52.18	224.34	283.20	2
14H	40M	25.438S	325.000	58.08	93.53	144273.0	95.24	44.65	38.02	24.75	75.62	49.67	225.24	284.38	2
14H	40M	26.437S	326.000	58.07	93.53	143398.1	95.37	45.38	38.75	24.76	75.74	50.40	225.29	284.26	2
14H	40M	27.437S	327.000	58.07	93.53	142484.7	95.37	43.98	37.34	24.33	75.23	48.98	225.55	284.77	2
14H	40M	28.438S	328.000	58.07	93.53	141547.2	95.37	42.92	36.26	23.97	74.83	47.89	225.76	285.17	2
14H	40M	29.437S	329.000	58.07	93.53	140613.0	95.37	44.75	38.12	24.57	75.50	49.76	225.42	284.50	2
14H	40M	30.437S	330.000	58.06	93.53	139690.3	95.37	41.50	34.81	23.45	74.24	46.42	226.06	285.76	2
14H	40M	31.438S	331.000	58.06	93.53	138770.6	95.37	41.90	35.23	23.60	74.40	46.84	225.98	285.60	2
14H	40M	32.437S	332.000	58.06	93.53	137833.3	95.37	41.93	35.26	23.61	74.41	46.86	225.99	285.59	2
14H	40M	33.438S	333.000	58.06	93.52	136864.5	95.37	39.29	32.57	22.55	73.25	44.14	226.58	286.75	2
14H	40M	34.438S	334.000	58.06	93.52	135876.9	95.13	40.10	33.41	23.33	73.91	45.01	226.06	286.09	2
14H	40M	35.437S	335.000	58.05	93.52	134890.1	94.76	38.96	32.28	23.59	73.88	43.89	225.77	286.12	2
14H	40M	36.438S	336.000	58.05	93.52	133902.9	94.39	37.78	31.11	23.84	73.85	42.73	225.47	286.15	2
14H	40M	37.437S	337.000	58.05	93.52	132907.9	94.01	38.63	32.01	24.91	74.71	43.65	224.74	285.29	2
14H	40M	38.437S	338.000	58.05	93.52	131899.7	93.64	35.31	28.65	24.32	73.75	40.28	224.88	286.25	2
14H	40M	39.438S	339.000	58.04	93.52	130882.6	93.37	37.89	31.30	25.91	75.25	42.98	223.93	284.74	2
14H	40M	40.437S	340.000	58.04	93.52	129866.0	93.37	35.82	29.20	25.13	74.37	40.85	224.35	285.63	2
14H	40M	41.438S	341.000	58.04	93.52	128843.4	93.37	34.10	27.44	24.38	73.55	39.07	224.74	286.45	2

Table A-1 (Continued)

14H 40M 42.438S	342.000	58.04	93.52	127800.3	92.93	35.47	28.88	25.92	74.85	40.55	223.75	285.15	2
14H 40M 43.437S	343.000	58.04	93.52	126734.1	92.18	33.74	27.18	26.90	75.22	38.87	222.89	284.78	2
14H 40M 44.438S	344.000	58.03	93.52	125646.4	91.43	31.92	25.40	27.96	75.63	37.12	221.99	284.37	2
14H 40M 45.438S	345.000	58.03	93.52	124549.0	91.37	32.44	25.94	28.29	75.95	37.66	221.80	284.05	2
14H 40M 46.437S	346.000	58.03	93.52	123458.9	91.37	30.56	24.02	27.59	75.10	35.73	222.14	284.90	2
14H 40M 47.438S	347.000	58.03	93.52	122380.9	91.37	30.12	23.56	27.41	74.88	35.27	222.24	285.12	2
14H 40M 48.438S	348.000	58.02	93.51	121307.2	91.37	30.17	23.62	27.43	74.90	35.32	222.24	285.10	2
14H 40M 49.438S	349.000	58.02	93.51	120219.0	91.37	28.14	21.54	26.50	73.82	33.22	222.66	286.18	2
14H 40M 50.438S	350.000	58.02	93.51	119110.1	91.37	30.77	24.24	27.66	75.17	35.93	222.14	284.83	2
14H 40M 51.437S	351.000	58.02	93.51	117983.4	91.37	30.33	23.79	27.48	74.95	35.48	222.24	285.05	2
14H 40M 52.438S	352.000	58.01	93.51	116843.0	91.37	25.51	18.84	24.98	72.14	30.49	223.31	287.86	2
14H 40M 53.438S	353.000	58.01	93.51	115701.3	91.04	28.37	21.82	27.52	74.56	33.51	222.04	285.44	2
14H 40M 54.437S	354.000	58.01	93.51	114546.1	90.66	25.64	19.07	27.30	73.75	30.76	221.88	286.25	2
14H 40M 55.438S	355.000	58.01	93.51	113371.0	90.40	25.71	19.17	28.14	74.34	30.87	221.36	285.66	2
14H 40M 56.438S	356.000	58.01	93.51	112191.9	90.59	25.19	18.62	27.28	73.60	30.30	221.85	286.39	2
14H 40M 57.438S	357.000	58.00	93.51	111009.6	90.78	24.66	18.05	26.35	72.83	29.71	222.36	287.17	2
14H 40M 58.438S	358.000	58.00	93.51	109816.9	90.96	22.86	16.16	24.41	71.00	27.78	223.24	289.00	2
14H 40M 59.438S	359.000	58.00	93.51	108624.6	91.15	22.28	15.54	23.19	70.01	27.13	223.84	289.99	2
14H 41M 0.438S	360.000	58.00	93.51	107425.2	91.34	23.02	16.28	23.13	70.18	27.86	224.04	289.82	2
14H 41M 1.437S	361.000	57.99	93.50	106203.7	90.10	23.73	17.18	28.11	73.73	28.87	221.19	286.27	2
14H 41M 2.437S	362.000	57.99	93.50	104976.5	88.61	21.86	15.48	32.76	76.22	27.23	218.27	283.78	2
14H 41M 3.437S	363.000	57.99	93.50	103745.5	87.30	23.26	17.14	37.60	80.07	28.89	215.41	279.93	2
14H 41M 4.437S	364.000	57.99	93.50	102502.7	86.93	22.69	16.64	38.91	80.75	28.38	214.64	279.25	2
14H 41M 5.437S	365.000	57.99	93.50	101248.8	86.56	17.65	11.61	41.51	79.70	23.33	213.57	280.30	2

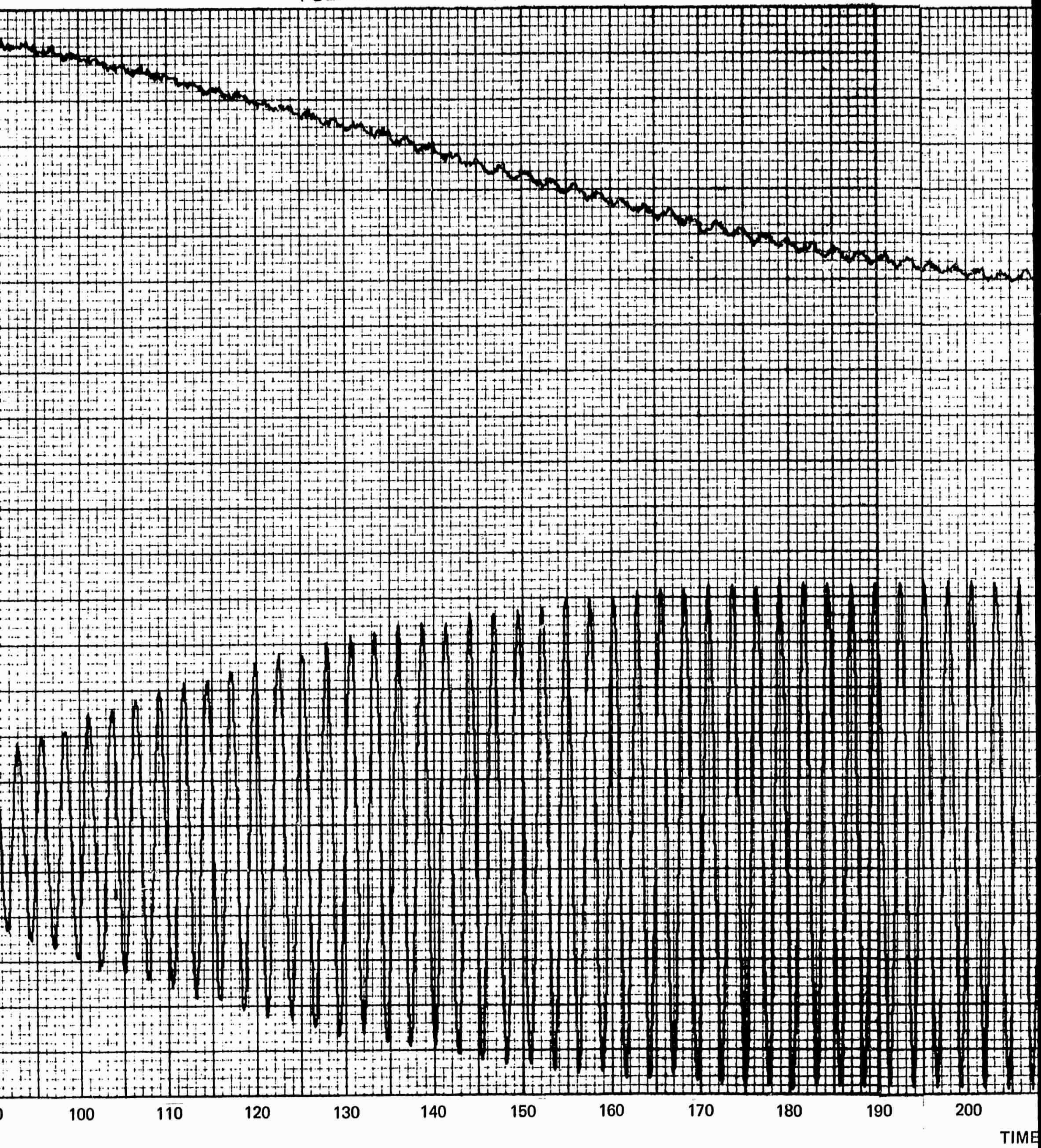
14H 41M 11.437S	371.000	57.97	93.50	93562.3	91.37	17.49	10.55	15.10	63.41	21.90	226.49	296.59	2
14H 41M 12.437S	372.000	57.97	93.50	92241.4	91.37	17.61	10.68	15.35	63.59	22.02	226.44	296.41	2
14H 41M 13.437S	373.000	57.97	93.50	90906.9	91.37	15.97	8.98	11.02	60.65	20.20	227.40	299.34	2
14H 41M 14.437S	374.000	57.97	93.50	89559.8	91.69	17.84	10.90	13.91	62.79	22.18	227.27	297.21	2
14H 41M 15.437S	375.000	57.96	93.49	88205.0	92.44	15.30	8.27	359.77	54.52	19.00	231.53	305.48	2
14H 41M 16.437S	376.000	57.96	93.49	86846.4	93.18	19.65	12.66	9.82	60.70	23.71	230.35	299.30	2

FOLDOUT FRAME 1



FOLDOUT FRAME 2

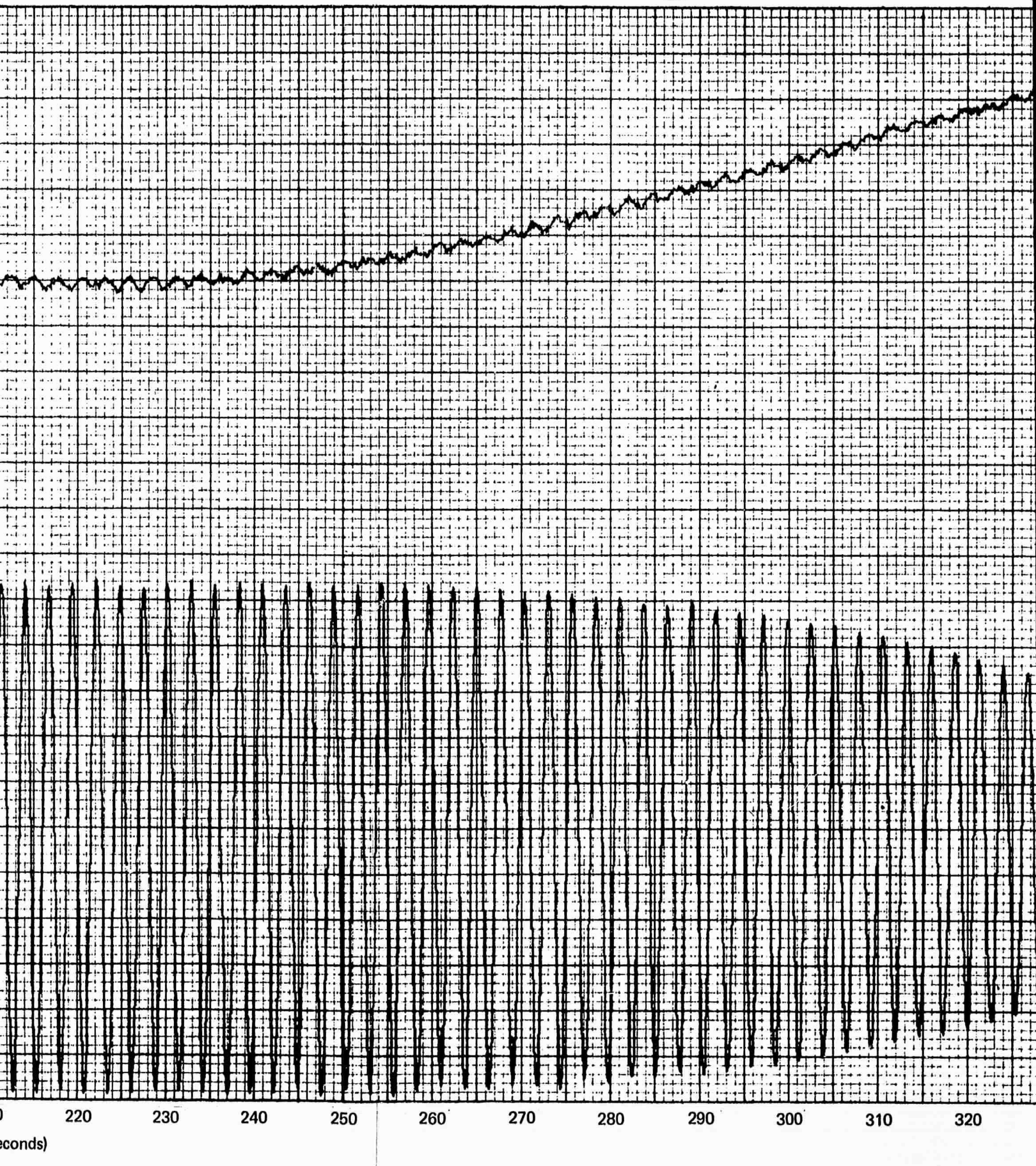
FO[redacted]



[redacted]E

FOLDOUT FRAME 3

FO[redacted]



FO[redacted]

FOLDOUT FRAME 4

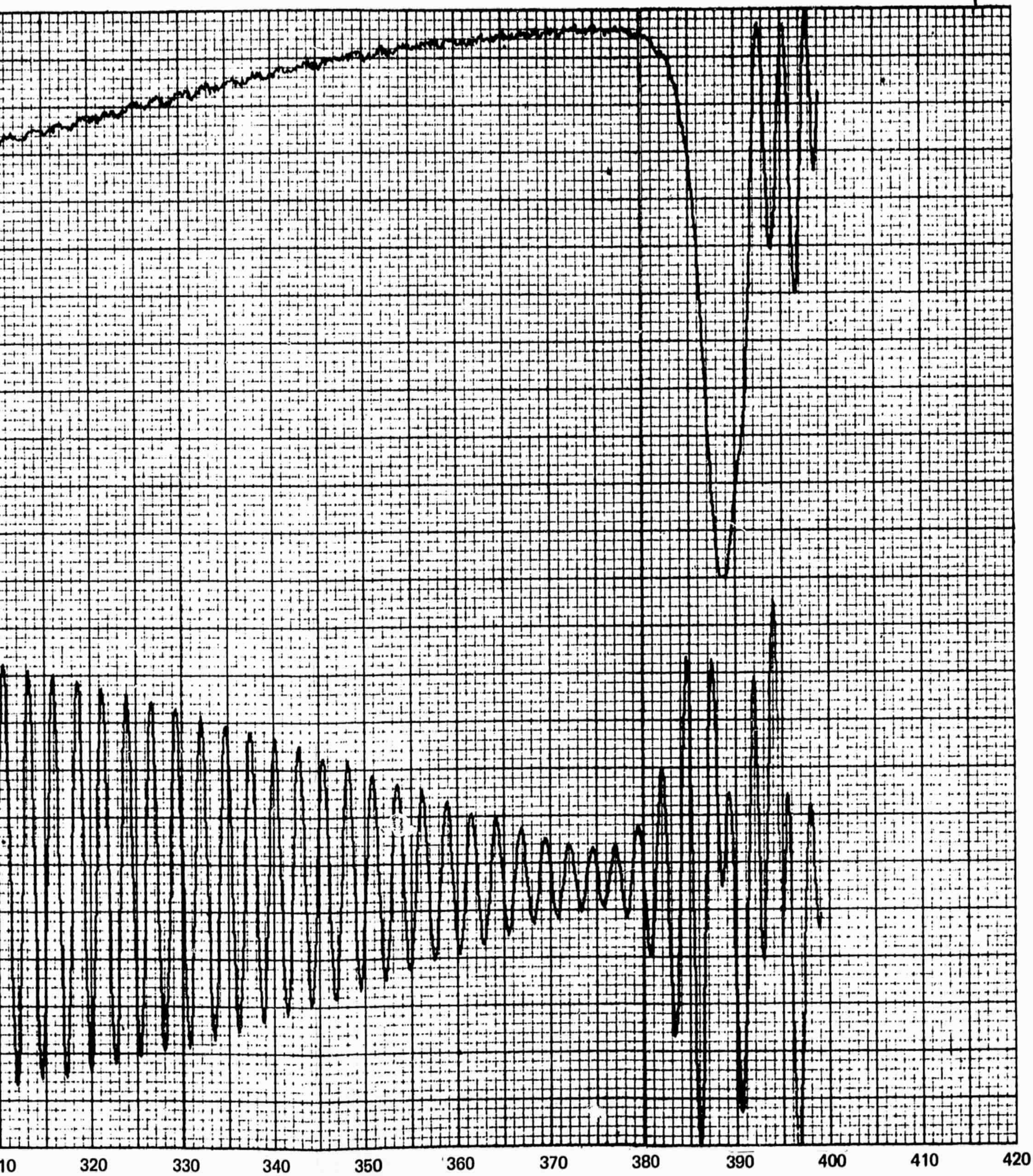


Figure A-1. Oscillograph Record of Magnetometer Outputs