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DATA PROCESSING SYSTEMS FOR ACCELEROMETER EXPERIMENTS ON AIR FO--ETC(U)
MAY 79 R W FIORETTI, E BARRY, S CIESZKA F19628-76-C-0244
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This report summarizes the data processing required to systematically extract meaningful data from accelerometer experiments flown aboard Air Force satellites. Drag data are extracted from the accelerometer output. These drag measurements are converted to atmospheric density.

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FOREWORD

The efforts described herein were performed under contract to the Atmospheric Structure Branch (LKB), Aeronomy Division of the Air Force Geophysics Laboratory (AFGL), Hanscom Air Force Base, Massachusetts. Frank A. Marcos was Contract Monitor.

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1. Introduction

The efforts described herein are part of a project to develop and implement data processing software systems for the management and analysis of data received from three accelerometer experiments. Two SETA (Satellite Electrostatic Triaxial Accelerometer) experiments were flown on the NAVPAC1 and NAVPAC2 satellites and one ROCA (Rotatable Calibration Accelerometer) experiment was flown on the S3-4 satellite.

Telemetry data were recorded at remote ground stations on analog tapes. Later accelerometer data and their associated temperature values were converted to digital pulses, stored on magnetic tapes and delivered to AFGL to be processed on the AFGL CDC6600 computer system.

Prior to the launch of the first NAVPAC satellite, simulated accelerometer measurements were generated to test the processing system and analysis techniques on expected flight results. The data processing systems developed prior to each satellite launch were capable of handling raw accelerometer data, editing, digital filtering and extracting atmospheric drag and neutral density values.

Post launch the data processing systems and analytical techniques were modified to process actual flight data.

This report will describe the accelerometer systems, flight summaries, and data processing systems for each experiment.

2. NAVPAC1 and NAVPAC2 SETA Accelerometer Systems

2.1 Experiment Description

The SETA (Satellite Electrostatic Triaxial Accelerometer) experiments on NAVPAC1 and NAVPAC2 were designed to determine neutral atmospheric density by measuring satellite deceleration caused by aerodynamic drag. The SETA experiment configuration consisted of a single electrostatically suspended proof mass which was also electrostatically rebalanced along three orthogonal axes. This design was based on the flight proven single proof mass/single axis MESA accelerometer which was modified by instrumenting both cross axes with precision constrainment loops. The SETA determined an applied acceleration along each axis from the electrostatic force required to recenter the proof mass. A thorough description of the SETA accelerometer system is given in Reference (1).

Both satellites were despun with the accelerometer axis generally along the flight direction. The x accelerometer axis was crosstrack, and the y accelerometer axis was the radial axis.

2.2 SETA Data Processing Systems

The SETA Data Processing System (DPS) was initially developed prior to the launch of NAVPAC1. The initial system was capable of processing raw accelerometer data; editing, calibrating, and temperature correcting them; and extracting drag values utilizing digital filtering techniques. In addition, power spectral representations of measured accelerations (before and/or after filtering) versus frequency could be displayed. This system was tested with simulated flight data prior to this first launch. A flow diagram of this system is given in Figure 1.

Post launch the data processing system was modified to process actual flight data. Digital filtering, math modelling, and multiple linear regression techniques were developed and applied to the flight data. Data were merged with satellite ephemeris parameters, and atmospheric model values were calculated and utilized in the post launch analysis. The programs written to perform these tasks were then added to our processing system as shown in the flow diagram given in Figure 2. The

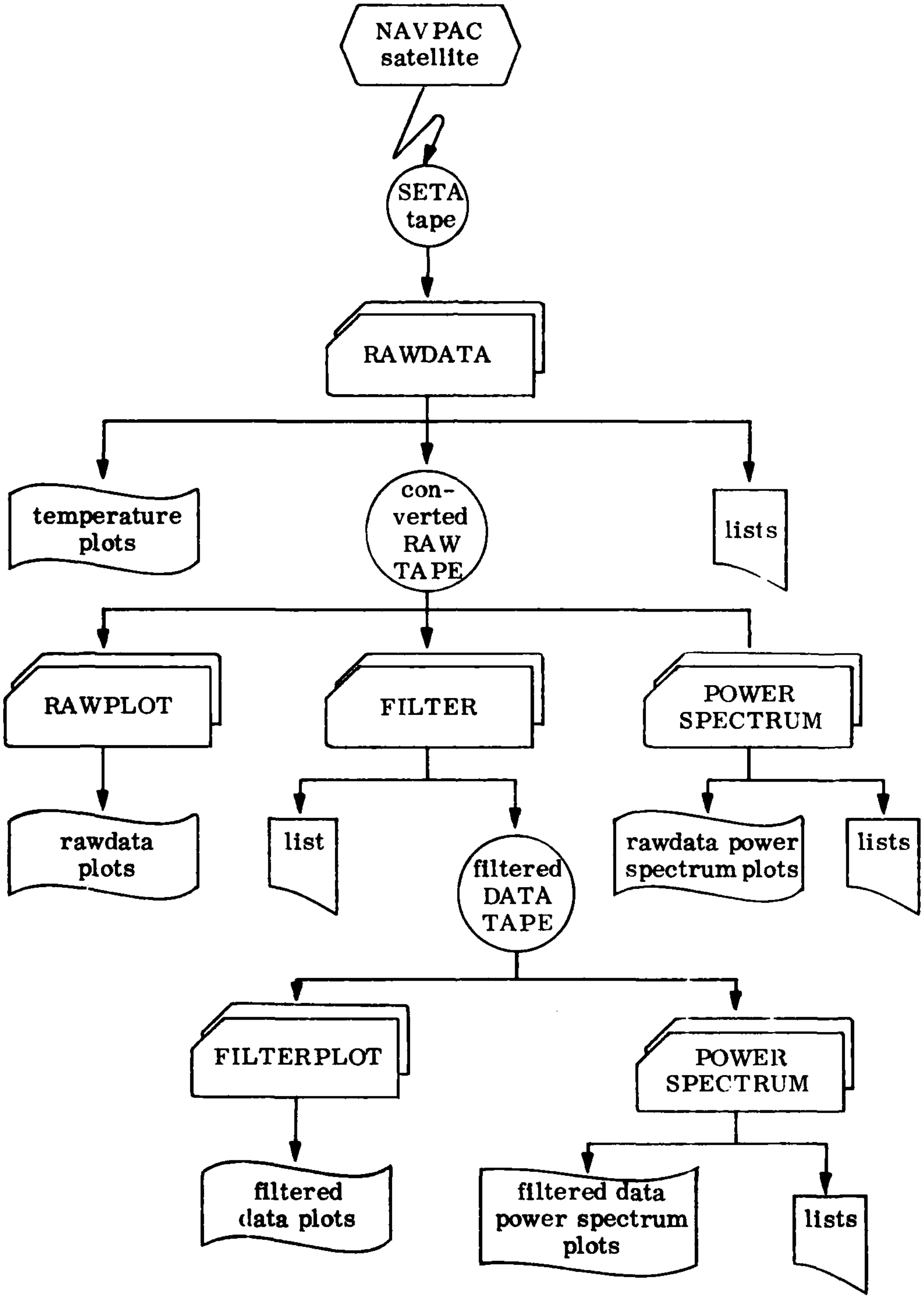


FIGURE 1. SETA PRE-LAUNCH DATA PROCESSING SYSTEM FLOW

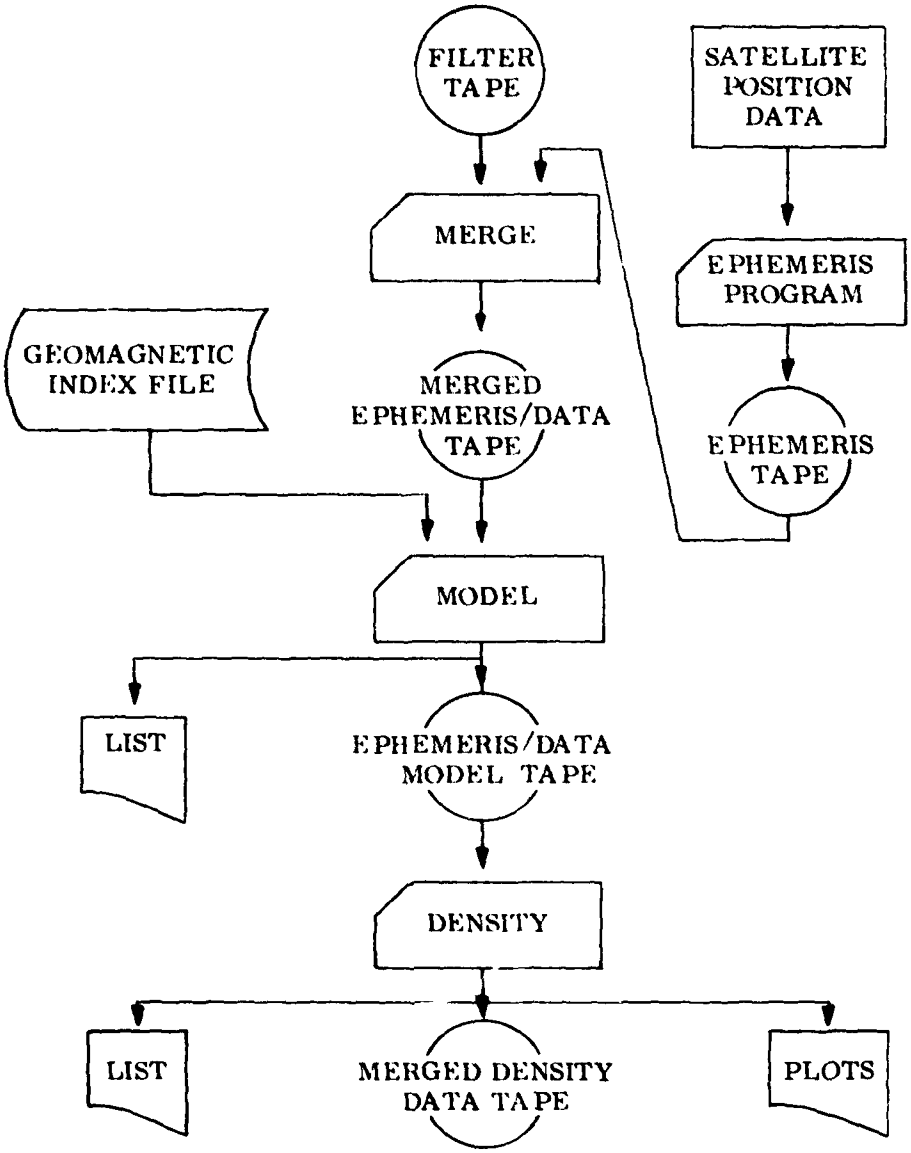


FIGURE 2. REMAINING SETA DATA PROCESSING SYSTEM FLOW

resultant system (Figures 1 and 2) was used to calculate atmospheric density profiles for selected orbits of SETA accelerometer data.

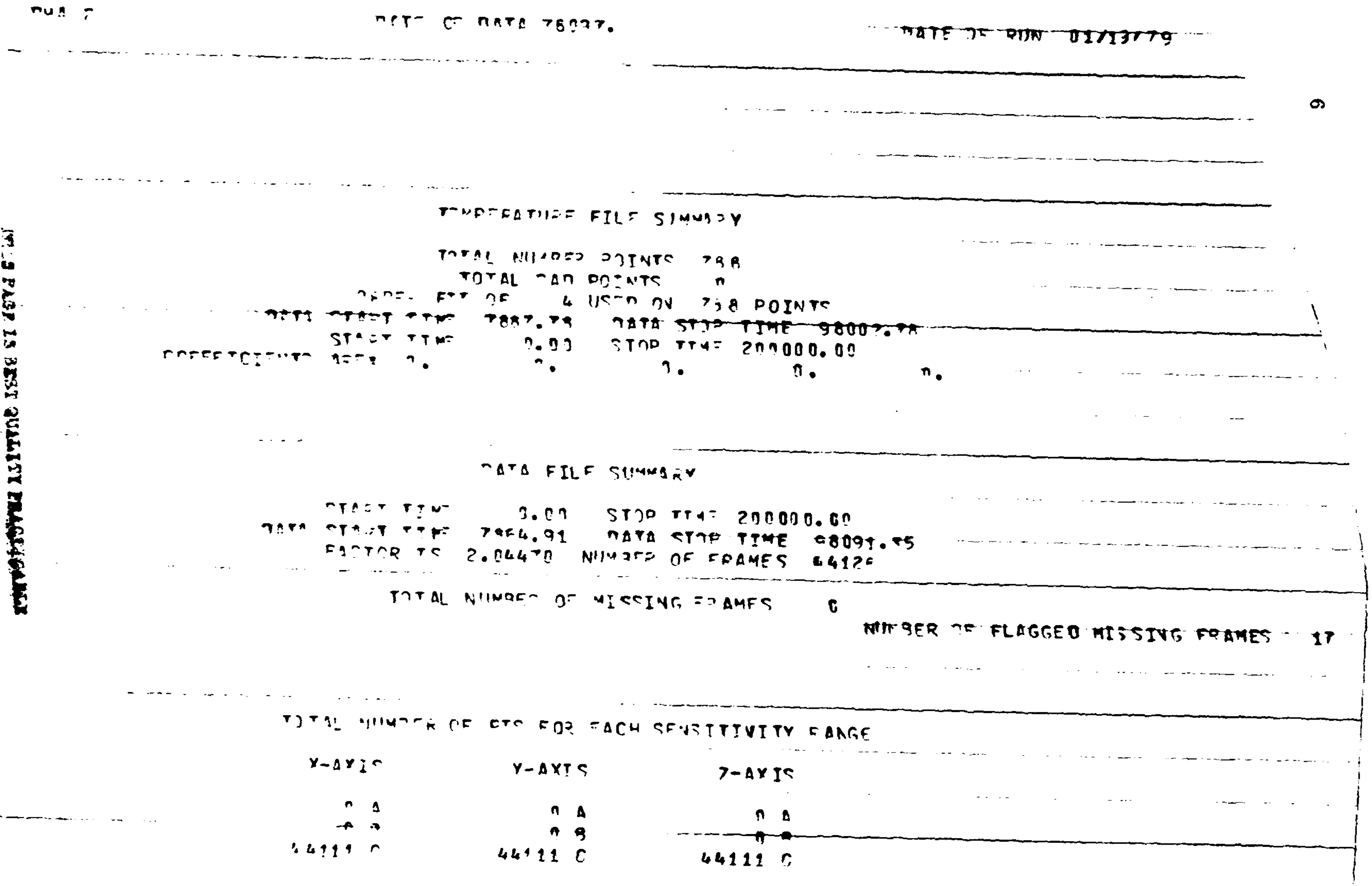
Following is a brief description of each main program in the SETA processing system.

2.2.1 RAWDATA – RAWDATA reads the SETA telemetry tape, extracts accelerometer temperature information and plots temperature values as a function of GMT for up to a day's worth of data. In addition, raw SETA telemetry data are unpacked, and acceleration values are constructed for each output (x, y, and z). Scale factor temperature corrections are made to the acceleration data, and missing data frames are flagged and reported upon. Acceleration and temperature data are written to an output file (or tape) for later use.

Printed output from RAWDATA includes temperature, acceleration and sensitivity range information for each accelerometer axis. Figure 3 is an example of the printed report generated by RAWDATA. Figure 4 is an example of the display capability of RAWDATA.

2.2.2 FILTER – This program reads the acceleration data output file created by RAWDATA, replaces any missing data frames by a special interpolation scheme, and then attempts to filter out unwanted frequencies from the acceleration data utilizing non-recursive digital filtering techniques (Reference (2)). Raw accelerations, filtered accelerations and temperature values are then written to an output file/tape for use by other analysis programs.

Printed output from FILTER is a one page report containing filter characteristics, start and end times, and data replacement statistics.



```
RUN 7                    DATE OF DATA 76037.                       DATE OF RUN 01/13/79

                             TEMPERATURE FILE SUMMARY

                             TOTAL NUMBER POINTS  758
                               TOTAL BAD POINTS     0
                        DEGREE FIT OF   4 USED ON  758 POINTS
                 DATA START TIME  7887.78   DATA STOP TIME  98007.78
                      START TIME     0.00   STOP TIME 200000.00
          COEFFICIENTS ARE  0.        0.        0.        0.        0.

                              DATA FILE SUMMARY

                      START TIME     0.00   STOP TIME 200000.00
                 DATA START TIME  7964.91   DATA STOP TIME  98091.95
                      FACTOR IS  2.04470  NUMBER OF FRAMES  44126

                         TOTAL NUMBER OF MISSING FRAMES     0
                                                    NUMBER OF FLAGGED MISSING FRAMES   17

                  TOTAL NUMBER OF PTS FOR EACH SENSITIVITY RANGE
                    X-AXIS          Y-AXIS          Z-AXIS

                       0 A             0 A             0 A
                       0 B             0 B             0 B
                   44111 C         44111 C         44111 C
```

FIGURE 3. SETA DPS RAW DATA PRINTER REPORT

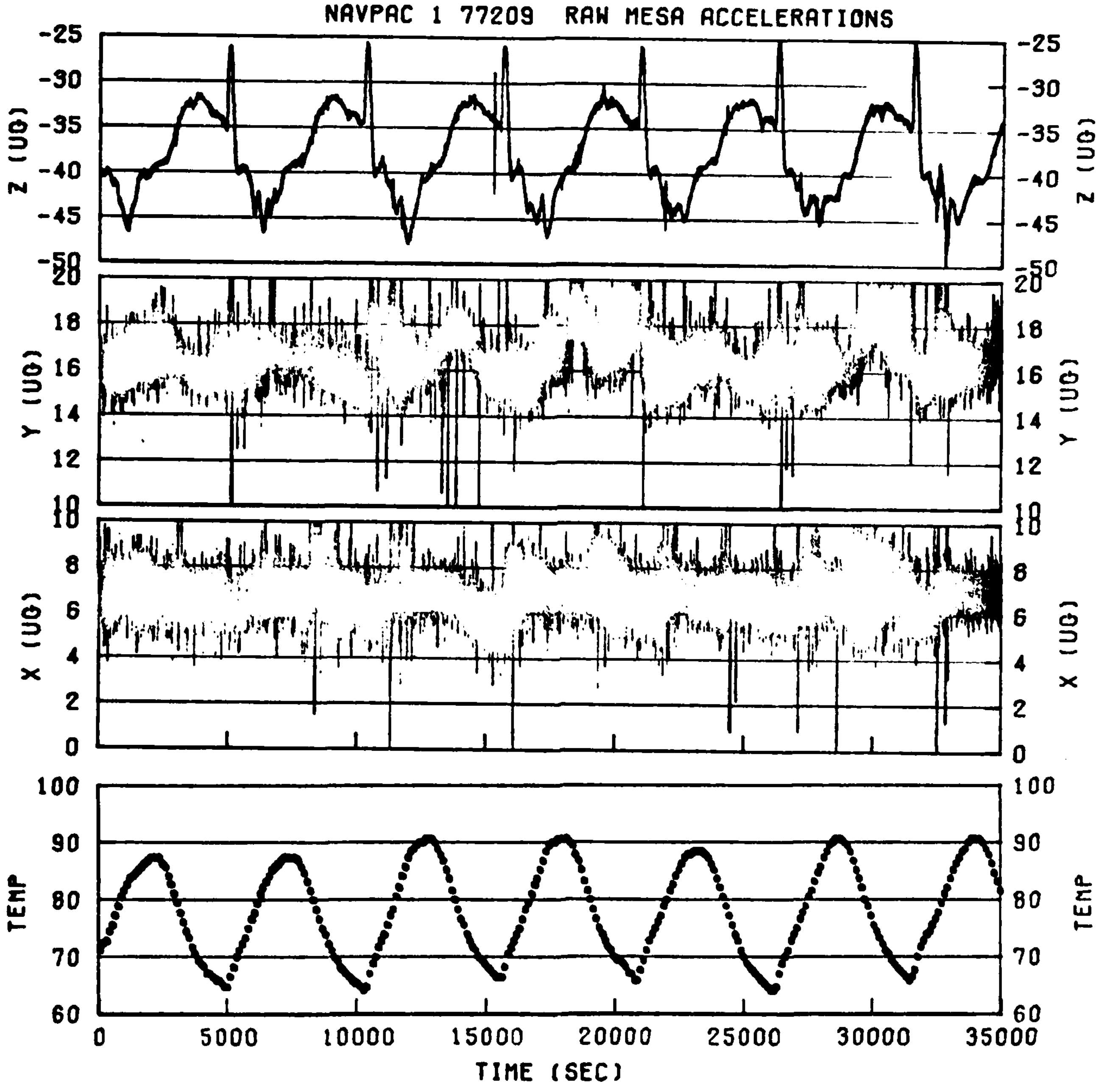


FIGURE 4. NAVPAC 1 RAW ACCELERATION DATA

In addition diagnostic output containing interpolation information may be obtained by special request.

Figure 5 illustrates the printer report generated by FILTER.

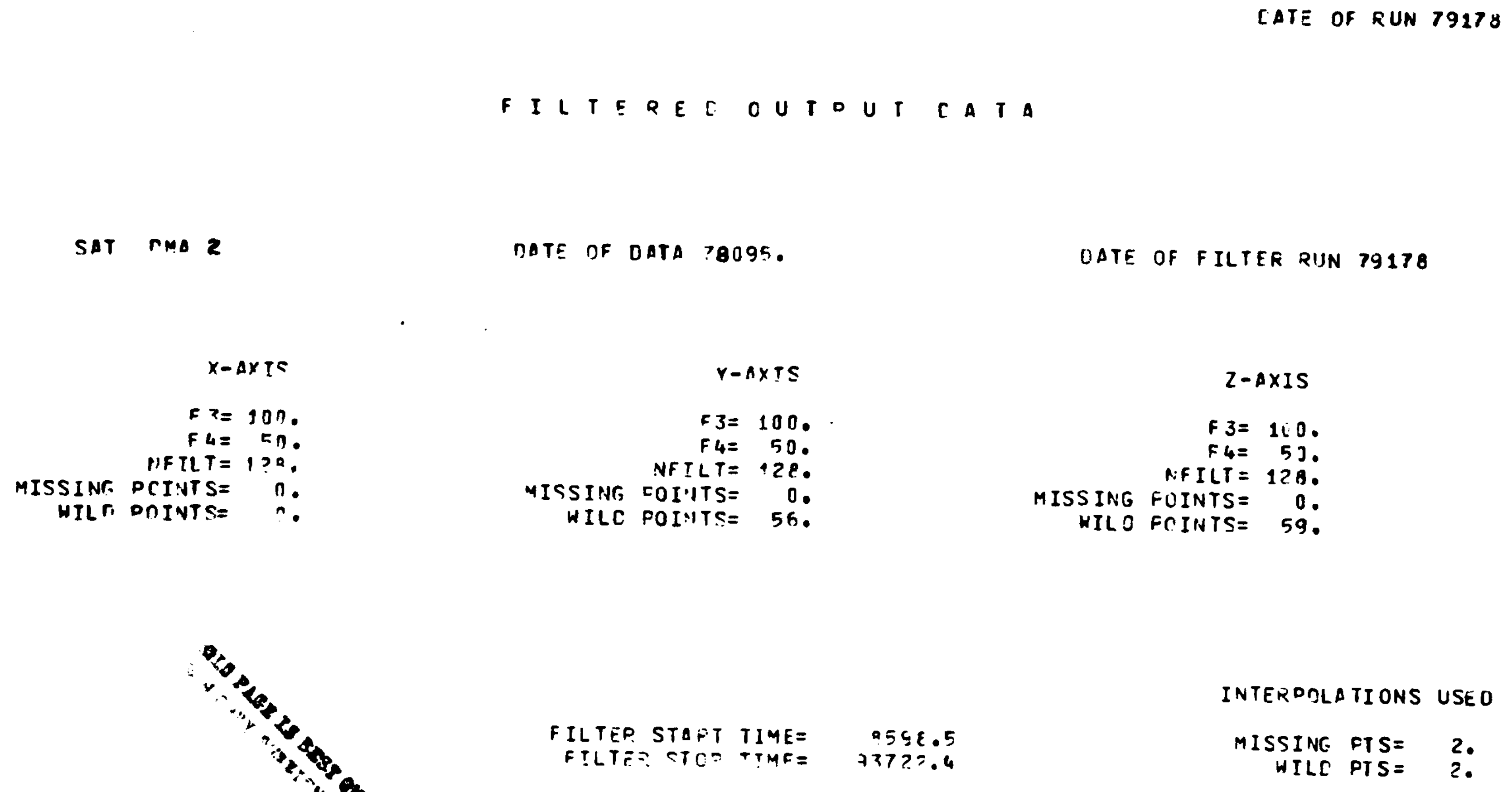
2.2.3 MERGE – The ephemeris/data MERGE program combines the accelerometer data from the file created by FILTER with satellite ephemeris information read from an ephemeris file/tape (created by the AFGL SUWA satellite ephemeris programs). Such ephemeris parameters as satellite altitude, latitude, longitude, and local solar time values are interpolated for the time of each SETA data value. Merged data/ephemeris information are written to an output file for later use.

2.2.4 MODEL – This program calculates model atmosphere density values utilizing Jacchia 71 and MSIS model atmosphere programs along with ephemeris, geomagnetic index and solar flux parameters. Model density values are used to aid in more accurate instrument bias determination, and are stored on an output file for later comparison to measured density values.

2.2.5 DENSITY – The DENSITY program reads the merged data/ephemeris/model output file, and for each acceleration value calculates atmospheric drag, satellite mass, cross sectional area, C_D value and atmospheric density. These data are stored on output files for later use.

Printer output consists of a listing of ephemeris, acceleration, density, and model values.

Altitude versus density profiles may be created from the output file.



```
                                                                          DATE OF RUN 79178

                              F I L T E R E D  O U T P U T  D A T A

      SAT  DMA 2                  DATE OF DATA 78095.                DATE OF FILTER RUN 79178

                 X-AXIS                        Y-AXIS                        Z-AXIS

               F3= 100.                      F3= 100.                      F3= 100.
               F4=  50.                      F4=  50.                      F4=  50.
            NFILT= 128.                   NFILT= 128.                   NFILT= 128.
   MISSING POINTS=   0.          MISSING POINTS=   0.          MISSING POINTS=   0.
      WILD POINTS=   0.             WILD POINTS=  56.             WILD POINTS=  59.

                                                                    INTERPOLATIONS USED

                                  FILTER START TIME=    9598.5        MISSING PTS=   2.
                                   FILTER STOP TIME=   33722.4           WILD PTS=   2.
```

FIGURE 5. SETA FILTER PRINTER REPORT

Figure 6 illustrates the format of the final merged ephemeris/density data file for NAVPAC satellites. These files may be stored on magnetic tapes at AFGL for later use by analysts.

2.3 Flight Summaries

2.3.1 NAVPAC 1 Data – The first SETA experiment was launched in mid-1977. Initial turnons indicated that acceleration data were being measured on all three axes. However, z-axis drag profiles were modulated by an anomalous response of the sensor to its varying operating temperature. A large anomaly was present on each orbit and additionally, excessive noise in both cross-axes (x and y axes) were observed.

After analysis the z-axis anomaly was correlated with the satellite's earth shadow exit time. In addition z-axis data was modulated with both low and high frequency variations. Figure 4 (previously given) illustrates the variability of the raw acceleration data on all three axes.

Concerning the z-axis (intrack) accelerometer data, analytical studies were performed in an attempt to determine the causes of the variability in the data. Digital filtering, math modelling and multiple linear regression techniques were applied to the z-axis data. These studies indicated that the non-drag variations had a strong dependence upon the instrument operating temperature. Utilizing these techniques on carefully selected orbits of data we were able to derive atmospheric drag and density profiles which were in good agreement with model profiles extracted from the AE/S3 data derived under contract F19628-76-C-0169 for similar atmospheric conditions (Reference (3)). However, variations due to temperature gradients across the instrument were in general difficult to model due to the relatively long time (114 sec.) between temperature samples. Because of this, the accuracy of our density profile results were limited and in general do not exceed the accuracy of available atmospheric models.

SETA Merged Ephemeris/Density Data Tape Format

1. Reader Record

Word	Description	Format
0.1	word count (=40)	I
0.2	group count (= 1)	I
1	SATID	A
2	year of data	F
3	day of year (of data)	F
4	blank	F
5	order of temperature fit polynomial	F
6	A0 $\left.\right\}$ fit = $\sum_{i=0}^{4} A_i T^i$	F
7	A1	F
8	A2	F
9	A3	F
10	A4	F
11	no. of temperature pts used in fit	F
12	start time of temp. fit	F
13	stop time of temp. fit	F
14	no. of missing data frames	F
15	frame increment factor	F
16	date of RAWDATA run (MM/DD/YY)	A
17	Julian date of RAWDATA run (YYDDD)	R
18	start time of accel. data	F
19	stop time of accel. data	F
20	total no. of frames	F
21	start time of data	F
22	stop time of data	F
23	Julian date of filter run (YYDDD)	R
24	filter length (NFILT)	F
25	F3 $\}$ x-axis filter parameters	F
26	F4	F
27	F3 $\}$ y-axis filter parameters	F
28	F4	F
29	F3 $\}$ z-axis filter parameters	F
30	F4	F
31	interpolation used – missing points	F
32	number of missing data frames	F
33	interpolation used – wild points	F
34	x-axis-number of wild points replaced	F
35	y-axis-number of wild points replaced	F
36	z-axis-number of wild points replaced	F
37	date of model run (YYDDD)	R
38	date of density run (YYDDD)	R

Figure 6. SETA Density Data Tape Format

Word	Description	Format
39	blank	F
40	blank	F

2. Data Records

Word	Description	Format
0.1	word count (= 30)	I
0.2	group count (= 64)	I
1	blank	F
2	blank	F
3	blank	F
4	GMT (sec)	F
5	altitude (km)	F
6	latitude (± 90°)	F
7	longitude (+E)	F
8	velocity (v) (km/sec)*	F
9	velocity (v_r) (km/sec)*	F
10	local time (sec)	F
11	rev. no.	F
12	angle (rotating atmosphere).*	
13	sun/shade (0 = shade, 1 = sun)	
14	invariant latitude	
15	blank (fixed zero)	F
16	J71 model density	F
17	MSIS model density	F
18	NAVPAC density	F
19	NAVPAC x-raw data	F
20	NAVPAC y-raw data	F
21	NAVPAC z-raw data	F
22	NAVPAC x-filtered	F
23	NAVPAC y-filtered	F
24	NAVPAC z-filtered	F
25	NAVPAC Temperature	F
26-30	blank	F
31-1920	same as 1-30	F

---

* $v_x = \dot{x} + Ey$

$v_y = \dot{y} + Ex$

$v_z = \dot{z}$

$$v_r = \left(v_x^2 + v_y^2 + v_z^2\right)^{1/2}$$

$$v = \left(\dot{x}^2 + \dot{y}^2 + \dot{z}^2\right)^{1/2}$$

$$\text{ANGLE} = \text{ACOS}\left(\frac{\dot{x}v_x + \dot{y}v_y + \dot{z}v_z}{vv_r}\right)$$

Figure 6. SETA Density Data Tape Format

2.3.2 NAVPAC2 Data – The second SETA experiment was launched in early 1978. For this experiment initial turnons indicated that acceleration data were again being measured on all three axes but high frequency noise variations were of the same order as NAVPAC1 data. In addition, the temperature related anomalies observed on the first flight were observed in the NAVPAC2 data, but were reduced by about a factor of three. This reduction was due to placement of a solar radiation shield around the NAVPAC2 instrument. Figure 7 illustrates this reduction by displaying NAVPAC1 and NAVPAC2 raw acceleration data.

Utilizing many of the techniques developed for NAVPAC1-digital filtering, math modelling and regression analyses – and the fact that the temperature variations on NAVPAC2 were much smaller than the first flight, it was possible to develop an improved mathematical model for the thermal effects on NAVPAC2. We were able to evaluate our thermal effect model by means of another experiment on the satellite.

Due to these techniques atmospheric drag and density results were obtained for selected orbits of NAVPAC2. Merged ephemeris/model/density data for these orbits were stored on magnetic tapes as described in 2.2.5.

3. S3-4 Satellite ROCA Accelerometer System

3.1 Experiment Description

The ROCA experiment flown on the S3-4 satellite consisted of a single axis accelerometer mounted on a rotatable platform. The rotating platform provided the capability of aligning the sensitive axis with the satellite velocity vector (position X) for density measurements and rotating the sensitive axis 90° (position Y) for bias determination.

ROCA measurements on S3-4 were taken in two data collecting modes, called format A and format C. Format A was the normal data collecting

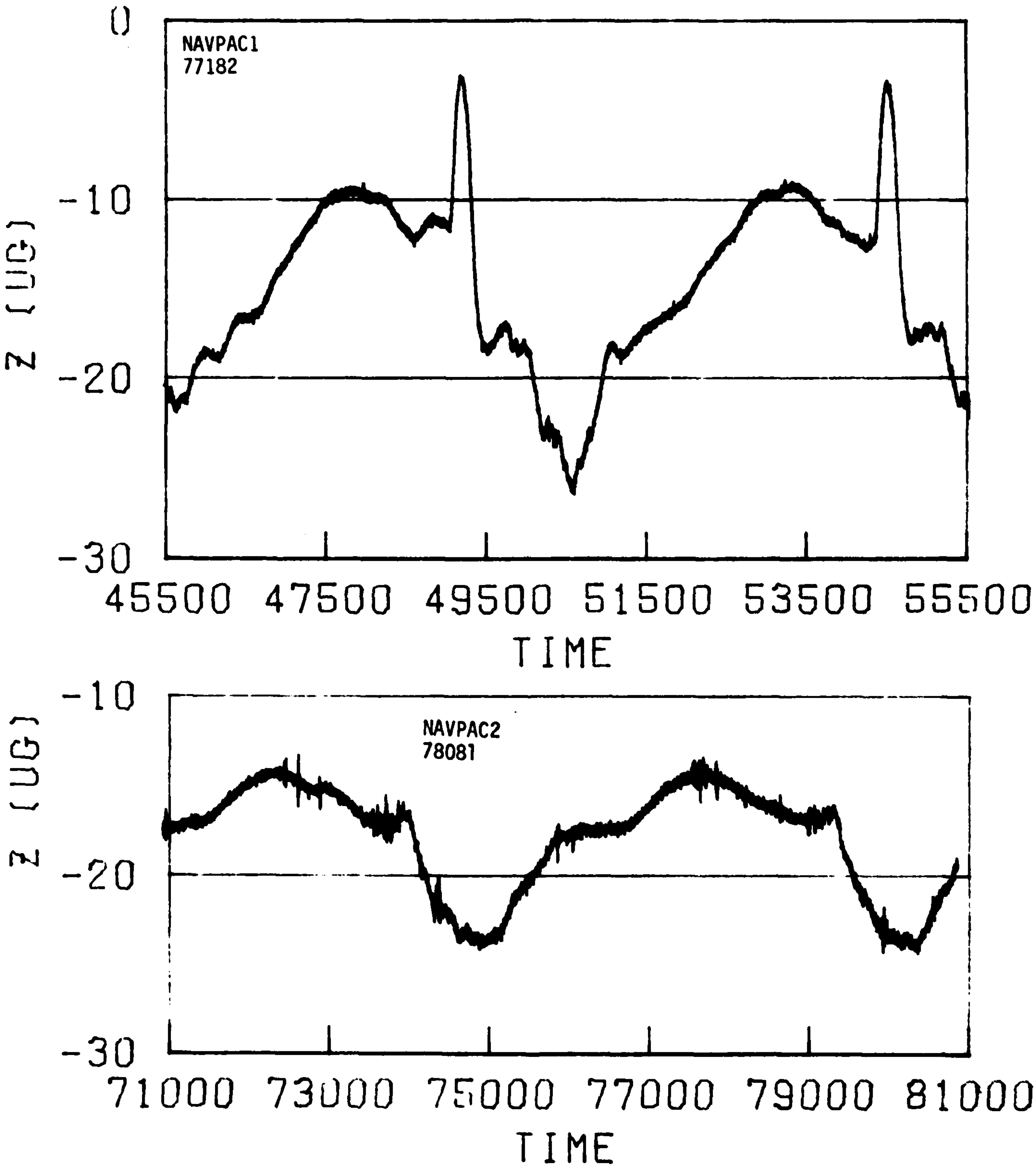


FIGURE 7. NAVPAC1 AND NAVPAC2 RAW ACCELERATION DATA

mode and provided acceleration measurements for 90 minutes over about one orbital period. Format C was a high data rate mode (needed for another experiment on the satellite), and it provided acceleration measurements (for 90 minutes) over about one-half the orbital period.

Due to the 90 minute tape recorder capacity, the high data rates and the short station acquisitions of S3-4, up to four acquisitions were required to recover the recorded data for each orbit. These acquisitions were copied to separate files on the ROCA telemetry tapes. Our data processing system was required to piece together these files to construct each orbit of recorded data. This is presented below.

Detailed experiment description and flight results have been given in Reference (4). Following is a description of the ROCA software data processing system which provided these reduced data.

3.2 ROCA Data Processing System

The S3-4 ROCA accelerometer Data Processing System (DPS) was constructed from two sources. First, new programs were designed and written prior to satellite launch. These programs were capable of processing and displaying raw accelerometer data, editing, calibrating, and temperature correcting them, and providing useful printer reports concerning data status. Secondly, programs which were written for the SETA processing system (Section 2.2) were utilized, when applicable, and modified to make up the remainder of the ROCA processing system. These programs were capable of extracting atmospheric drag values from the ROCA data by utilizing digital filtering and math modelling techniques.

Post launch the processing system was modified to process actual flight data. After initial evaluation, modification and checkout the processing system was used to process density data on selected orbits. Model atmosphere programs were used for density evaluation and linear regression techniques aided in instrument bias value and bias/temperature coefficient determinations. As density profiles were calculated for each orbit of data, a history data base program was developed to allow for useful storage of density values in a common data bank.

When completed the ROCA processing system was capable of calculating and saving atmospheric density profiles for selected orbits of the ROCA accelerometer data on S3-4.

Figure 8 gives a flow diagram of the ROCA processing system. Following is a brief description of each main program in the system.

3.2.1 RAWDATA/QCKLIST - The RAWDATA program reads the ROCA telemetry tape, extracts each frame of accelerometer measured data, measured temperature values and rotation information parameters. Accelerometer data are then converted to acceleration values. For each accelerometer data frame, raw data, acceleration values, temperature values, rotation information, GMT and telemetry frame indicators are tabulated in a computer listing. In addition, master frame time differences are calculated and displayed for each master frame of data.

Although this listing is very useful in evaluating telemetry data quality, it would be very cumbersome to generate a listing of each ROCA orbit, since this program would list each frame of data. Hence, we developed the QCKLIST program.

QCKLIST provides a condensed version of the RAWDATA listing. It disdisplays GMT, acceleration values and master frame time differences for the first minor frame of each master frame. This listing is then used to evaluate telemetry data quality. If the data appears suspect, then a more detailed RAWDATA listing may be provided. Figures 9 and 10 are examples of RAWDATA and QCKLIST printed outputs, respectively.

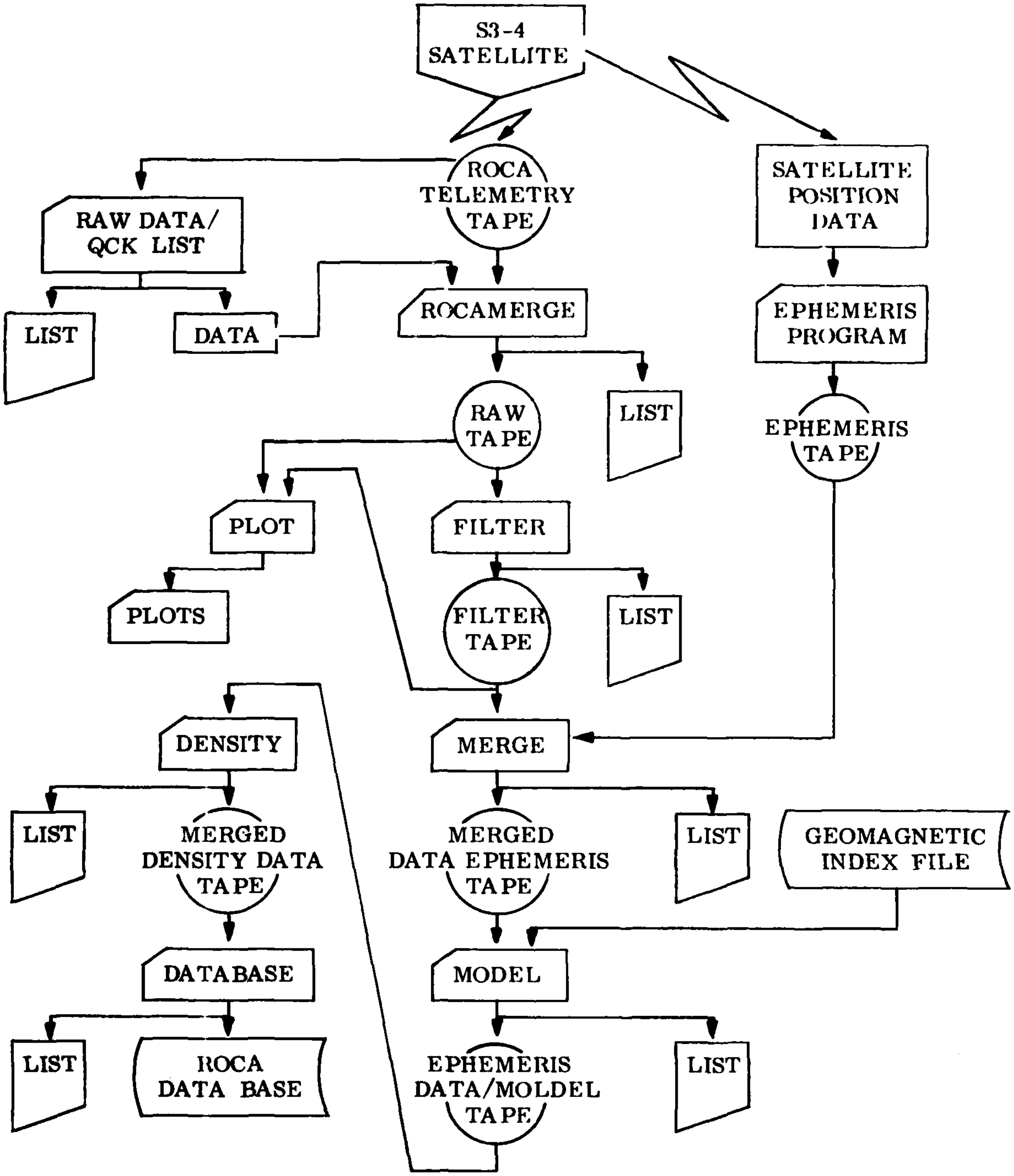
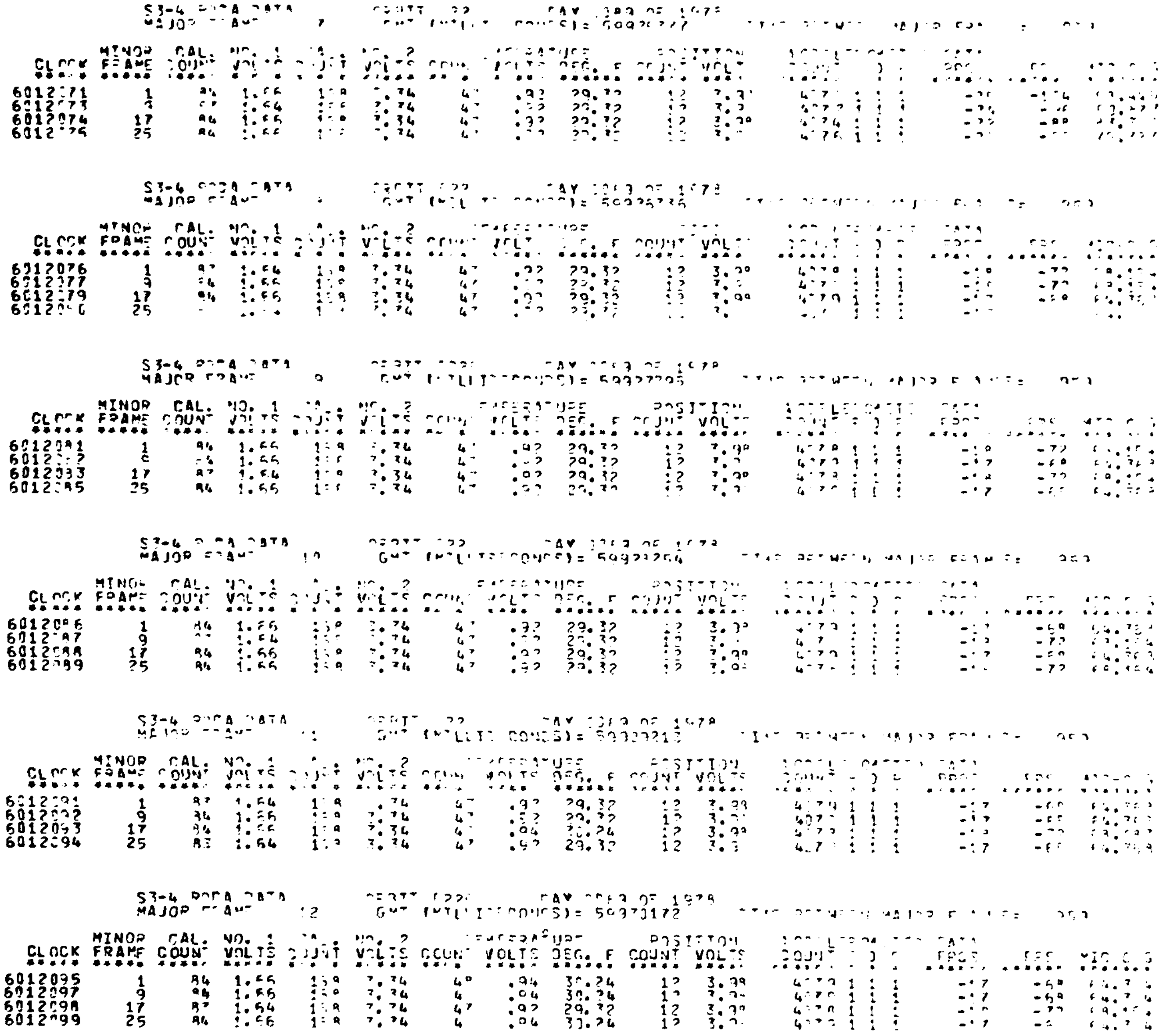


FIGURE 8. ROCA DATA PROCESSING SYSTEM FLOW



```
S3-4 ROCA DATA        ORBIT [illegible]       DAY [illegible] OF 1978
MAJOR FRAME    7      GMT (MILLISECONDS)= [illegible]      TIME BETWEEN MAJOR FRAMES = [illegible]

        MINOR  CAL.  NO. 1        NO. 2        TEMPERATURE       POSITION     ACCELEROMETER DATA
 CLOCK  FRAME COUNT  VOLTS COUNT  VOLTS COUNT  VOLTS DEG. F  COUNT VOLTS   COUNT          [illegible]
6012[illegible]71   1   [illegible]  1.66  [illegible]  [illegible]  4[illegible]  .92  29.[illegible]  12  [illegible]  [illegible] 1 1 1  [illegible]
6012[illegible]73   9   [illegible]  1.64  [illegible]  [illegible]  4[illegible]  [illegible]  [illegible]  12  [illegible]  [illegible]  [illegible]
6012074  17   84  1.66  [illegible]  [illegible]  4[illegible]  .92  [illegible]  12  [illegible]  [illegible]  [illegible]
6012[illegible]75  25   84  [illegible]  [illegible]  [illegible]  4[illegible]  [illegible]  [illegible]  12  [illegible]  [illegible]  [illegible]

S3-4 ROCA DATA        ORBIT [illegible]       DAY [illegible] OF 1978
MAJOR FRAME    [illegible]      GMT (MILLISECONDS)= [illegible]      TIME BETWEEN MAJOR FRAMES = [illegible]

        MINOR  CAL.  NO. 1        NO. 2        TEMPERATURE       POSITION     ACCELEROMETER DATA
 CLOCK  FRAME COUNT  VOLTS COUNT  VOLTS COUNT  VOLTS DEG. F  COUNT VOLTS   COUNT          [illegible]
6012076   1   [illegible]  1.64  [illegible]  [illegible]  47  .92  29.32  12  [illegible]  [illegible]  [illegible]
6012077   9   [illegible]  1.66  [illegible]  [illegible]  4[illegible]  [illegible]  [illegible]  12  [illegible]  [illegible]  [illegible]
6012079  17   [illegible]  1.66  158  [illegible]  47  .92  29.32  12  [illegible]  [illegible]  [illegible]
6012[illegible]0  25   [illegible]  [illegible]  [illegible]  [illegible]  47  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]

S3-4 ROCA DATA        ORBIT [illegible]       DAY [illegible] OF 1978
MAJOR FRAME    9      GMT (MILLISECONDS)= 59927795     TIME BETWEEN MAJOR FRAMES = [illegible]

        MINOR  CAL.  NO. 1        NO. 2        TEMPERATURE       POSITION     ACCELEROMETER DATA
 CLOCK  FRAME COUNT  VOLTS COUNT  VOLTS COUNT  VOLTS DEG. F  COUNT VOLTS   COUNT          [illegible]
6012081   1   84  1.66  158  [illegible]  4[illegible]  .92  29.32  12  [illegible]  [illegible]  [illegible]
6012[illegible]2   9   [illegible]  1.66  [illegible]  [illegible]  4[illegible]  [illegible]  29.32  12  [illegible]  [illegible]  [illegible]
6012083  17   87  1.64  [illegible]  [illegible]  4[illegible]  .92  29.32  12  [illegible]  [illegible]  [illegible]
6012[illegible]85  25   84  1.66  [illegible]  [illegible]  4[illegible]  [illegible]  [illegible]  12  [illegible]  [illegible]  [illegible]

S3-4 ROCA DATA        ORBIT [illegible]       DAY [illegible] OF 1978
MAJOR FRAME   10      GMT (MILLISECONDS)= 59921256     TIME BETWEEN MAJOR FRAMES = [illegible]

        MINOR  CAL.  NO. 1        NO. 2        TEMPERATURE       POSITION     ACCELEROMETER DATA
 CLOCK  FRAME COUNT  VOLTS COUNT  VOLTS COUNT  VOLTS DEG. F  COUNT VOLTS   COUNT          [illegible]
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6012[illegible]87   9   [illegible]  1.64  [illegible]  [illegible]  47  [illegible]  [illegible]  12  [illegible]  [illegible]  [illegible]
6012088  17   84  1.66  158  [illegible]  47  .92  29.32  12  [illegible]  [illegible]  [illegible]
6012[illegible]89  25   84  1.66  158  [illegible]  47  .92  29.32  12  [illegible]  [illegible]  [illegible]

S3-4 ROCA DATA        ORBIT [illegible]       DAY [illegible] OF 1978
MAJOR FRAME   [illegible]      GMT (MILLISECONDS)= [illegible]     TIME BETWEEN MAJOR FRAMES = [illegible]

        MINOR  CAL.  NO. 1        NO. 2        TEMPERATURE       POSITION     ACCELEROMETER DATA
 CLOCK  FRAME COUNT  VOLTS COUNT  VOLTS COUNT  VOLTS DEG. F  COUNT VOLTS   COUNT          [illegible]
6012[illegible]91   1   87  1.64  158  [illegible]  47  .92  29.32  12  [illegible]  [illegible] 1 1 1  [illegible]
6012[illegible]92   9   [illegible]  1.66  [illegible]  [illegible]  47  [illegible]  [illegible]  12  [illegible]  [illegible] 1 1 1  [illegible]
6012093  17   84  [illegible]  158  [illegible]  4[illegible]  .94  [illegible]  12  [illegible]  [illegible]  [illegible]
6012094  25   83  1.64  [illegible]  [illegible]  47  .92  29.32  12  [illegible]  [illegible]  [illegible]

S3-4 ROCA DATA        ORBIT [illegible]       DAY [illegible] OF 1978
MAJOR FRAME   12      GMT (MILLISECONDS)= 59970172     TIME BETWEEN MAJOR FRAMES = [illegible]

        MINOR  CAL.  NO. 1        NO. 2        TEMPERATURE       POSITION     ACCELEROMETER DATA
 CLOCK  FRAME COUNT  VOLTS COUNT  VOLTS COUNT  VOLTS DEG. F  COUNT VOLTS   COUNT          [illegible]
6012095   1   84  1.66  159  [illegible]  4[illegible]  .94  30.24  12  3.98  [illegible] 1 1 1  -[illegible]7  -[illegible]  [illegible]
6012097   9   [illegible]  1.66  [illegible]  [illegible]  4[illegible]  .94  30.24  12  [illegible]  [illegible] 1 1 1  -[illegible]7  -[illegible]  [illegible]
6012098  17   87  1.64  158  [illegible]  47  .92  29.32  12  [illegible]  [illegible] 1 1 1  [illegible]  [illegible]  [illegible]
6012[illegible]99  25   84  1.66  158  [illegible]  4[illegible]  .94  30.24  12  [illegible]  [illegible] 1 1 1  -[illegible]7  [illegible]  [illegible]
```

FIGURE 9. ROCA RAW DATA PRINTER REPORT

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```
                ST-6 ROCA DATA        ORBIT 1665     FILE 1         DAY 0116 OF 1978
FRME GMT-MSEC TEMP  DATA  DIFF     FRME GMT-MSEC TEMP  DATA  DIFF     FRME GMT-MSEC TEMP  DATA  DIFF     FRME GMT-MSEC TEMP  DATA  DIFF
   1 64146590   3.    0.********BAD    2 64147550  39.   87.   960        3 64148510  39.   51.   960        4 64149470  39.   47.   960
   5 64150430  40.   51.   960        6 64151390  40.   51.   960        7 64152350  39.   51.   960        8 64153310  40.   47.   960
~~   9 64154270  40.   47.   960~~       10 64155230  39.   47.   960       11 64156190  40.   51.   960       12 64157150  40.   55.   960
  13 64158110  39.   55.   960       14 64159070  40.   58.   960       15 64160030  40.   55.   960       16 64160990  40.   29.   960
  17 64161950  40.   55.   960       18 64162910  40.   53.   960       19 64163870  40.   52.   960       20 64164830  40.   52.   960
  21 64165790  40.   52.   960       22 64166750  40.   53.   960       23 64167710  40.   53.   960       24 64168670  40.   53.   960
  25 64169630  40.   53.   960       26 64170590  40.   53.   960       27 64171550  40.   53.   960       28 64172510  40.   53.   960
  29 64173470  40.   53.   960       30 64174430  40.   53.   960       31 64175390  40.   53.   960       32 64176350  40.   53.   960
~~  33 64177310  40.   53.   960~~       34 64178270  40.   53.   960       35 64179230  40.   53.   960       36 64180190  40.   54.   960
  37 64181150  40.   53.   960       38 64182110  40.   53.   960       39 64183070  40.   54.   960       40 64184030  40.   53.   960
  41 64184990  40.   53.   960       42 64185950  40.   54.   960       43 64186910  40.   54.   960       44 64187870  39.   54.   960
  45 64188830  40.   54.   960       46 64189790  40.   54.   960       47 64190750  40.   54.   960       48 64191710  40.   54.   960
  49 64192670  40.   54.   960       50 64193630  40.   54.   960       51 64194590  40.   54.   960       52 64195550  40.   54.   960
  53 64196510  40.   54.   960       54 64197470  40.   54.   960       55 64198430  40.   54.   960       56 64199390  40.   54.   960
  57 64200350  40.   54.   960       58 64201310  40.   54.   960       59 64202270  40.   54.   960       60 64203230  40.   54.   960
  61 64204190  40.   54.   960       62 64205150  40.   54.   960       63 64206110  40.   54.   960       64 64207070  40.   54.   960
  65 64208030  40.   54.   960       66 64208990  40.   54.   960       67 64209950  40.   54.   960       68 64210910  40.   54.   960
  69 64211870  40.   54.   960       70 64212830  40.   54.   960       71 64213790  40.   54.   960       72 64214750  40.   54.   960
  73 64215710  40.   54.   960       74 64216670  40.   54.   960       75 64217630  40.   54.   960       76 64218590  40.   54.   960
  77 64219550  40.   54.   960       78 64220510  40.   54.   960       79 64221470  40.   54.   960       80 64222430  40.   54.   960
  81 ~~64223390~~  40.   54.   960       82 64224350  40.   54.   960       83 64225310  40.   54.   960       84 64226270  40.   54.   960
  85 64227230  40.   54.   960       86 64228190  40.   54.   960       87 64229150  41.   54.   960       88 64230110  40.   54.   960
  89 64231070  41.   54.   960       90 64232030  41.   54.   960       91 64232990  40.   54.   960       92 64233950  40.   54.   960
  93 64234910  41.   54.   960       94 64235870  40.   54.   960       95 64236830  41.   54.   960       96 64237790  41.   54.   960
  97 64238750  40.   54.   960       98 64239710  41.   54.   960       99 64240670  41.   54.   960      100 64241630  40.   54.   960
 101 64242590  41.   54.   960      102 64243550  41.   54.   960      103 64244510  40.   54.   960      104 64245470  41.   54.   960
 105 64246430  41.   54.   960      106 64247390  40.   54.   960      107 64248350  41.   54.   960      108 64249310  41.   54.   960
 109 64250270  40.   54.   960      110 64251230  41.   54.   960      111 64252190  41.   54.   960      112 64253150  40.   54.   960
 113 64254110  41.   54.   960      114 64255070  41.   54.   960      115 64256030  40.   54.   960      116 64256990  41.   54.   960
 117 64257950  41.   54.   960      118 64258910  40.   54.   960      119 64259870  41.   54.   960      120 64260830  41.   54.   960
 121 64261790  40.   54.   960      122 64262750  41.   54.   960      123 64263710  41.   54.   960      124 64264670  40.   54.   960
 125 64265630  41.   54.   960      126 64266590  41.   54.   960      127 64267550  40.   54.   960      128 64268510  41.   54.   960
~~ 129 64269470  41.   54.   960~~      130 64270430  40.   54.   960      131 64271390  41.   54.   960      132 64272350  41.   54.   960
 133 64273310  40.   54.   960      134 64274270  41.   54.   960      135 64275230  41.   54.   960      136 64276190  40.   54.   960
 137 64277150  41.   54.   960      138 64278110  41.   54.   960      139 64279070  40.   54.   960      140 64280030  41.   54.   960
 141 64280990  41.   54.   960      142 64281950  40.   54.   960      143 64282910  41.   54.   960      144 64283870  41.   54.   960
 145 64284830  40.   54.   960      146 64285790  41.   54.   960      147 64286750  41.   54.   960      148 64287710  40.   54.   960
 149 64288670  41.   54.   960      150 64289630  41.   54.   960      151 64290590  40.   54.   960      152 64291550  41.   54.   960
~~ 153 64292510  41.   54.   960~~      154 64293470  40.   54.   960      155 64294430  41.   54.   960      156 64295390  41.   54.   960
 157 64296350  40.   54.   960      158 64297310  41.   54.   960      159 64298270  41.   54.   960      160 64299230  40.   54.   960
 161 64300190  41.   53.   960      162 64301150  41.   54.   960      163 64302110  40.   53.   960      164 64303070  41.   53.   960
 165 64304030  41.   54.   960      166 64304990  40.   54.   960      167 64305950  41.   54.   960      168 64306910  41.   54.   960
 169 64307870  40.   54.   960      170 64308830  41.   54.   960      171 64309790  41.   54.   960      172 64310750  40.   54.   960
 173 64311710  41.   54.   960      174 64312670  41.   54.   960      175 64313630  40.   54.   960      176 64314590  41.   54.   960
 177 64315550  41.   54.   960      178 64316510  40.   54.   960      179 64317470  41.   54.   960      180 64318430  41.   54.   960
 181 64319390  40.   54.   960      182 64320350  41.   54.   960      183 64321310  41.   54.   960      184 64322270  41.   54.   960
 185 64323230  41.   54.   960      186 64324190  41.   54.   960      187 64325150  40.   54.   960      188 64326110  41.   54.   960
 189 64327070  41.   53.   960      190 64328030  41.   54.   960      191 64328990  41.   54.   960      192 64329950  41.   54.   960
 193 64330910  40.   54.   960      194 64331870  41.   54.   960      195 64332830  41.   54.   960      196 64333790  41.   54.   960
 197 64334750  41.   54.   960      198 64335710  41.   54.   960      199 64336670  41.   54.   960      200 64337630  41.   54.   960
 201 64338590  41.   54.   960      202 64339550  41.   54.   960      203 64340510  41.   54.   960      204 64341470  41.   54.   960
 205 64342430  41.   54.   960      206 64343390  41.   54.   960      207 64344350  41.   54.   960      208 64345310  41.   54.   960
 209 64346270  41.   54.   960      210 64347230  41.   53.   960      211 64348190  41.   54.   960      212 64349150  41.   54.   960
 213 64350110  41.   54.   960      214 64351070  41.   54.   960      215 64352030  41.   54.   960      216 64352990  41.   54.   960
 217 64353950  41.   54.   960      218 64354910  41.   54.   960      219 64355870  41.   53.   960      220 64356830  41.   54.   960
 221 64357790  41.   54.   960      222 64358750  41.   54.   960      223 64359710  41.   54.   960      224 64360670  41.   54.   960
 225 64361630  41.   54.   960      226 64362590  41.   54.   960      227 64363550  41.   54.   960      228 64364510  41.   54.   960
```

FIGURE 10. ROCA QCKLIST PRINTER REPORT

These listings also provide necessary inputs (such as start time, end time, number of files for each orbit, etc.) to the ROCAMERGE program.

3.2.2 ROCAMERGE – Utilizing inputs generated from the QCKLIST program, ROCAMERGE reads the ROCA telemetry tape, extracts each frame of measured accelerometer data, and converts ROCA outputs to acceleration units by first determining instrument range and then applying the associated scale factor. In addition, missing data frames are flagged and reported upon. For each orbit of ROCA data the required number of telemetry data files are processed. Data from each file are concatenated, and one continuous data file for each orbit is generated with missing data frames appropriately flagged. Acceleration and temperature data are written to an output file (or tape) for later use.

The format of this file is consistent with the format of the SETA RAWDATA output files (Section 2.2). This allowed us to utilize the FILTER, PLOT, MERGE, MODEL, and DENSITY programs written for SETA. These programs were then modified for the specific requirements of the ROCA data analysis.

Figure 11 is an example of the printed report generated by ROCAMERGE.

3.2.3 FILTER – FILTER reads the continuous acceleration data output file for each orbit created by ROCAMERGE, replaces any missing data frames by a special interpolation scheme, and then attempts to filter our unwanted frequencies from the acceleration data utilizing non-recursive digital filtering techniques. Raw accelerations, filtered accelerations, and temperature values are then written to an output file/tape for use by other analysis programs.

Printed output from FILTER is a one page report similar to the one given in Figure 5.

```
FILE  1  START TIME=64148511      STOP TIME= 65346590

              THE FOLLOWING OPTIONS WERE SELECTED

FILE  2  START TIME=65355153      STOP TIME= 67342350

              THE FOLLOWING OPTIONS WERE SELECTED

FILE  3  START TIME=67373753      STOP TIME= 69513130

              THE FOLLOWING OPTIONS WERE SELECTED
              DELETE     67777190  67778159


FILE 1 - HEADER RECORD VALUES -  DAY 75116  ORBIT 1666   START TIME 064147  STOP TIME 065345
                                 DATA FORMAT 32K   DATA RATE 30.000  (ACTUAL DATA RATE USED=30.00)
END-OF-FILE 1


FILE 2 - HEADER RECORD VALUES -  DAY 75116  ORBIT 1666   START TIME 065354  STOP TIME 067341
                                 DATA FORMAT 32K   DATA RATE 30.000  (ACTUAL DATA RATE USED=30.00)
9 MISSING FRAMES FOLLOWING FRAME NUMBER 1249 AT 65345570
END-OF-FILE 2


FILE 3 - HEADER RECORD VALUES -  DAY 75116  ORBIT 1666   START TIME 067373  STOP TIME 069522
                                 DATA FORMAT 32K   DATA RATE 30.000  (ACTUAL DATA RATE USED=30.00)
32 MISSING FRAMES FOLLOWING FRAME NUMBER 3327 AT 67341790
2 MISSING FRAMES FOLLOWING FRAME NUMBER 3363 AT 67775230
END-OF-FILE 3

5511 FRAMES PROCESSED  -  END OF FILE ENCOUNTERED
 THERE WERE 43 MISSING MAJOR FRAMES

                                                                                   9 MAJOR FRAMES MISSING
                                                                                  32 MAJOR FRAMES MISSING
                                                                                   2 MAJOR FRAMES MISSING
```

FIGURE 11. ROCA ROCAMERGE PRINTER REPORT

In addition, diagnostic output containing interpolation information may be obtained by special request.

3.2.4 PLOT – This plot program displays either raw measured acceleration data or filtered acceleration data as a function of GMT values. In addition, it has the capability of plotting ROCA temperature data versus GMT. Figures 12-15 are examples of these plots for orbits 1348 and 1351.

3.2.5 MERGE – The ephemeris/data MERGE program combines the accelerometer data from the file created by FILTER with satellite ephemeris information read from an ephemeris file/tape (created by the AFGL SUA satellite ephemeris programs). Such ephemeris parameters as satellite altitude, latitude, longitude, satellite position, velocity, and local solar time values are interpolated for the time of each ROCA data value. Merged data/ephemeris information are written to an output file for later use.

3.2.6 MODEL – This program calculates model atmosphere density values utilizing Jacchia 71 and MSIS model atmosphere programs along with ephemeris, geomagnetic index and solar flux parameters. Model density values are used to aid in more accurate instrument bias determination, and are stored on an output file for later comparison to measured density values.

3.2.7 DENSITY – The DENSITY program reads the merged data/ephemeris/model output file and calculates atmospheric density. Bias and bias/temperature coefficient are applied to the acceleration data (as previously described), and for each acceleration output, atmospheric drag, satellite mass, cross-sectional area, C_D and density are determined. These data are stored in an output file/tape for later use.

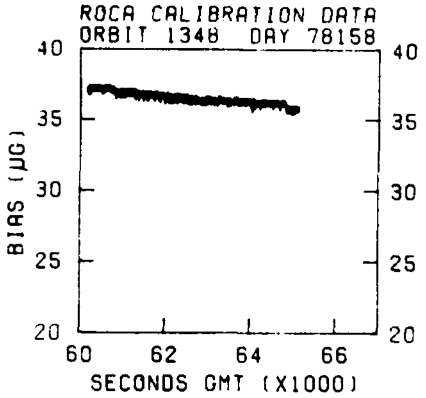

FIGURE 12. ROCA RAW DATA VERSUS GMT FOR ORBIT 1348

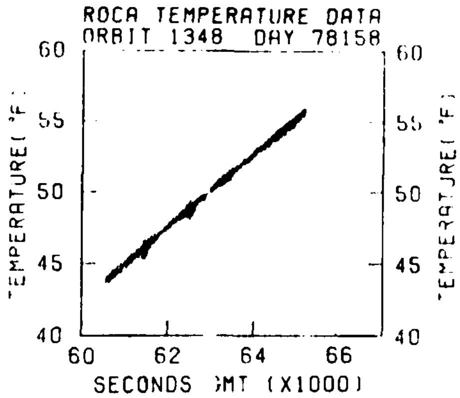

FIGURE 13. ROCA TEMPERATURE VERSUS GMT FOR ORBIT 1348

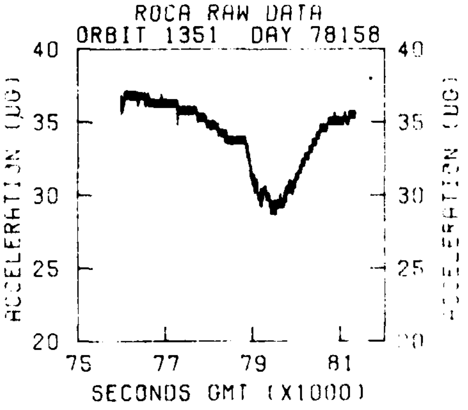

FIGURE 14. ROCA RAW DATA VERSUS GMT FOR ORBIT 1351

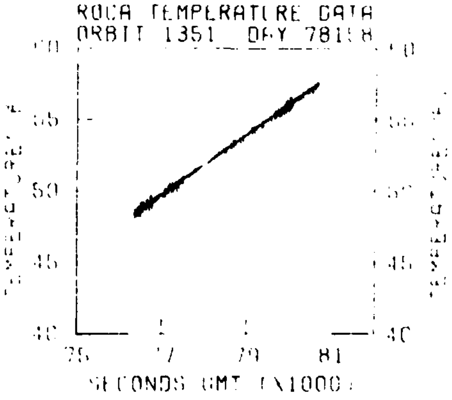

FIGURE 15. ROCA TEMPERATURE VERSUS GMT FOR ORBIT 1351

Density versus altitude profiles may be created from the output file. Figure 17 displays such a density profile for orbit 1351 data.

3.2.8 DATABASE – The ROCA DATABASE program provides the opportunity to store data from many orbits into a common history file or data bank which is structured to allow for global density studies to be performed. For each orbit of reduced density data every 10th value and its associated ephemeris/model parameters are saved and reordered into the standard time ordered accelerometer data base format as described in Reference (3). Once created this data base may be used alone or in conjunction with other similar data bases to aid in studies of the neutral atmosphere. Existing data base analysis programs may then be directly applied to these data.

Figure 18 illustrates the format of the ROCA data base tapes.

3.3 Flight Summary[1]

The S3-4 satellite was launched in March 1978 into a near polar orbit with perigee about 165 km and apogee at 270 km. An orbit-adjust propulsion system was used to maintain this orbit for a six-month period.

The ROCA experiment in position Y provided a successful inflight calibration of instrument bias and bias/temperature coefficients. The position Y ROCA acceleration output (A_Y) is:

$$A_Y = B + BT_C + N_Y \ , \qquad (1)$$

---

[1] Portions of this section were taken directly from Reference (4).

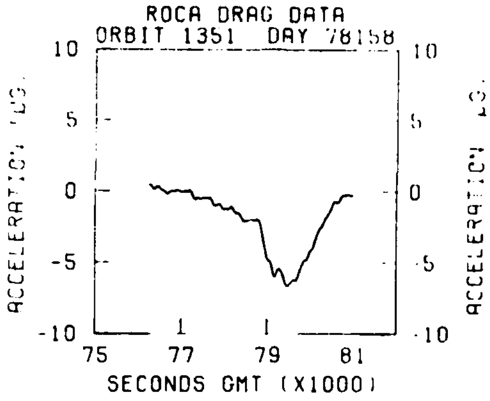

FIGURE 16. ROCA FILTERED DRAG VERSUS GMT FOR ORBIT 1351

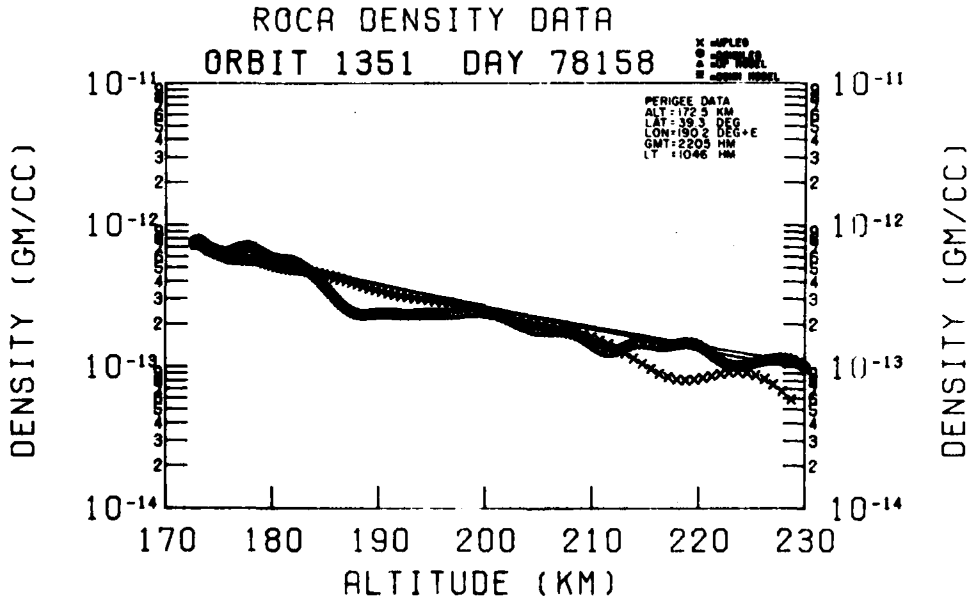

FIGURE 17. ROCA DENSITY VERSUS ALTITUDE PROFILE FOR ORBIT 1351

ROCA Data Base Tape Format

The data base history file is stored by orbit and time in 16 seconds intervals. Each tape contains one file containing two types of records-header and data records. The tapes are blocked, binary, 800 BPI.

1. Header Record

The first record is a header record in the following format:

Word	Description	Format
0.1	word count (IWD=40)	I
0.2	group count (JGP=1)	I
1	satellite ID	A
2	experimental name ('ROCA')	A
3	blank	I
4	Run date (YYDDD)	I
5	#files*100 + file#	I
6-40	blank	R

2. Data Records

The remaining records of each file are data records in the following format:

Word	Description	Format
0.1	word count (IWD=40)	I
0.2	group count (JGP=12)	I
1	orbit number	I
2	date – YYDDD	I
3	GMT – total seconds	I
4	GMT – hours	I
5	GMT – minutes	I
6	GMT – sec.	I
7	local time – hours	I
8	local time – minutes	I
9	local time – sec.	I
10	LEG (U=upleg, D=downleg)	A
11	day/night (D=day, N=night)	A
12	Spin/despun (S=spin, D=despun)	A
13	geographic latitude	F
14	geographic longitude (+E)	I

Figure 18. ROCA Data Base File Format

Word	Description	Format
15	geomagnetic latitude	F
16	geomagnetic longitude (+E)	I
17	blank	F
18	density – gm/cc	F
19	J71 model density	F
20	normalized density (180 km)	F
21	MSIS model density	F
22	ratio (measured/J71)	F
23	blank	F
24	ratio (measured/MSIS)	F
25	Ap – daily	F
26	Ap (6.7 hr lag)	I
27	Kp (6.7 hr lag)	F
28	F7 (day lag)	F
29	FB7 (81 day average)	F
30	altitude	F
31-39	blank	F
40	normalized density	F

3. An EOF follows the last data record.

Figure 18. ROCA Data Base File Format

where B is instrument bias,

BT_C is bias/temperature coefficient,

N_Y is vehicle and/or instrument noise accelerations.

For position X, the ROCA acceleration output A_X is:

$$A_X = A_D + B + BT_C + N_X \ , \qquad (2)$$

where A_D is the drag acceleration,

N_X is vehicle and/or instrument noise accelerations along the X-axis.

Then by subtracting A_Y from A_X, we have

$$A_X - A_Y = A_D + N_X - N_Y \ . \qquad (3)$$

In determining atmospheric drag accelerations, (A_D), N_X, and N_Y are largely removed by numerical filtering techniques as described in Reference (2). Atmospheric density (ρ) is then calculated by:

$$\rho = \frac{2MA_D}{C_D A V^2} \ , \qquad (4)$$

where C_D is satellite drag coefficient,

A is satellite cross-sectional area,

M is satellite mass,

V is satellite velocity.

Flight data were scheduled for acquisition in Position X only for the first month of operation. After this period bias calibration data were taken for one day each week in Position Y. Orbital operations for ROCA were normal for the next few months. During orbit 2472 (August 1978) a short circuit in the rotation motor caused the instrument to malfunction following a rotation command. No meaningful data were acquired after that malfunction. However, during its lifetime, ROCA acquired many orbits of valuable atmospheric drag acceleration data. Density results were obtained for selected orbits over the useful lifetime of ROCA.

Data obtained in the Position Y mode for orbit 1348 are given in Figures 12 and 13. These data were used to provide bias and bias/temperature coefficient information. Figures 14 and 15 display data obtained in the normal Position X mode on orbit 1351. Utilizing Equation (3) along with digital filtering techniques the drag profile derived from orbit 1351 using orbit 1348 calibration data is given in Figure 16. Atmospheric density results for orbit 1351 are given in Figure 17.

Merged ephemeris/model/density parameters for the selected orbits of reduced ROCA data were stored in a data base as described in 3.2.8.

4. Summary

Data processing software systems were developed for the management and analysis of satellite accelerometer data. Telemetry data from two SETA and one ROCA accelerometer experiments flown on three satellites were processed. Flight data were merged with satellite ephemeris parameters. Atmospheric drag and density values were obtained and were compared to two commonly used atmospheric models, Jacchia 71 and MSIS. Reduced data were stored in databases for future use.

5. References

(1) Development, Test, and Calibration of a Three-Axis Accelerometer System, William G. Lange, AFGL-TR-78-0003, December 1977.

(2) Digital Filtering Analysis Applied to the Atmosphere Explorer-C Satellite MESA Accelerometer Data, J.P. Noonan, R.W. Fioretti, and B. Hass, AFCRL-75-0293, 1975.

(3) Atmosphere Explorer MESA Accelerometer Density Data Base, R.W. Fioretti and L.D. Cox, AFGL-TR-79-0062, June 1978.

(4) Satellite Density Measurements with the Rotatable Calibration Accelerometer (ROCA), F.A. Marcos and K.S.W. Champion, AFGL-TR-0005, January 1979.