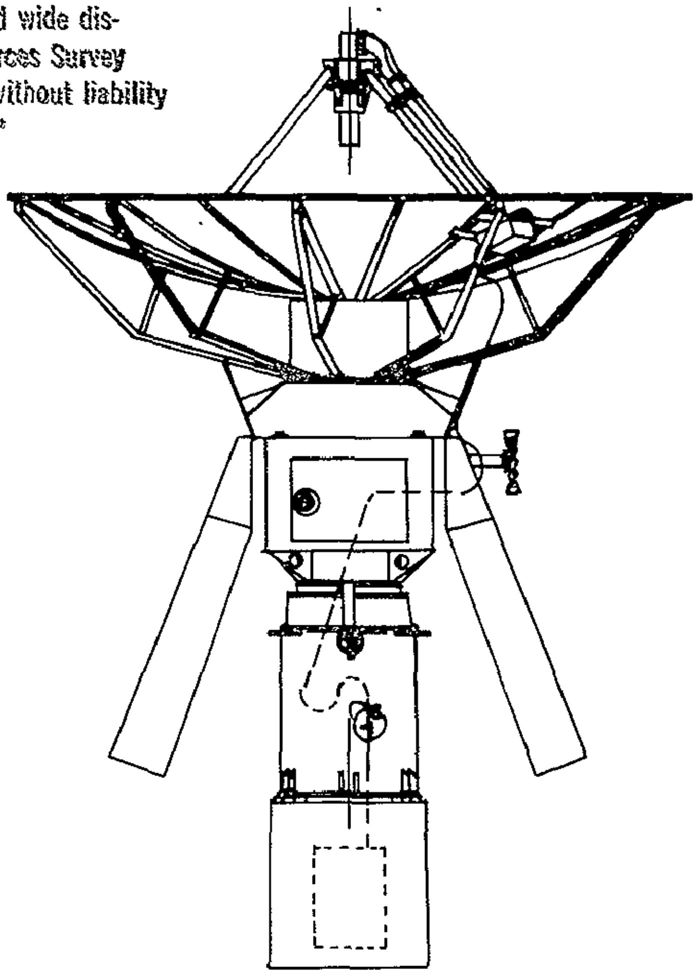
OPERATION OF THE LANDSAT AUTOMATIC TRACKING SYSTEM



NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

MAY 1976

Operation of LANDSAT

Automatic Tracking System

Saul Cooper — P.I.

New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

by

Timothy D. Buckelew

March 1976

TABLE OF CONTENTS

Foreword ii

List of Figures iii

I. Automatic Tracking System Overview 1

II. Routine to Power Up the NOVA 3

III. Setting NOVA's Real Time Clock 5

IV. How to Enter Orbital Elements into Tracking System 7

V. Powering Up Tracking Equipment 9

VI. If Something Fails 10

VII. System Design and Operation, In-depth View 13

Appendices 28

FOREWORD

The purpose of this manual is to document the procedures and theory of operation of the LANDSAT tracking system at New England Division, U.S. Army Corps of Engineers, Waltham, Massachusetts.

The manual is arranged generally by degree of detail, with the simplest operating procedures first; instructions for normal day-to-day operation are given in Section I, while information needed for program modification, file maintenance, and trouble-shooting is in Sections II - VII and the Appendices. All figures referred to in the text are in Appendix B.

List of Figures

1. Subsystems Diagram

2. LANDSAT Tracking Pedestal and Parabolic Antenna

3. Simplified Flowchart of Events Associated with LANDSAT Tracking

4. Complete Flowchart of Events Associated with LANDSAT Tracking

5. Format of Orbital Elements Provided by NORADC

6. Dialogue Between Operator and Computer during Execution of ELW. Note: "↲" Stands for "RETURN".

7. Power Switches on Computer and Command Equipment

8. Bit mapping Between NOVA Software and DG4065 Interface Controlling 1848 Digital Comparator.

9. LANDSAT DCP Sitelist

I. AUTOMATIC TRACKING SYSTEM OPERATION - OVERVIEW

The Automatic Tracking System for receiving LANDSAT data at New England Division, Waltham, consists of a 15-foot dish antenna, a tracking pedestal, some pedestal control equipment, and a Data General NOVA minicomputer with various accessories. The relationship of all these parts is shown in the subsystems diagram, Figure 1. Most day-to-day operation of the system will require very little action by operators, but full control of it and the handling of unusual situations require some knowledge of the programs and various information files that are kept on disc. Most operator action is taken at the computer terminal (Figure 7). (No card decks are needed, and the system is almost entirely separate from the IBM 1130 and Motorola equipment which are in the same room.) The operator may have to power up the NOVA computer (see section II) and start execution of the programs which track the LANDSAT and store incoming data. Once the NOVA has the correct time of day and is executing the tracking programs, it should do so continually until the operator interrupts it. These programs are cyclical, and if one of them is interrupted, it may be restarted later; that is, the operator may re-enter the cycle at one of several points.

The simplest procedure for tracking is as follows (refer to Figure 3):

1. Power up the NOVA (see Section II).

2. Set the NOVA's real time clock precisely (see Section III).

3. Turn on all required control equipment (see Section V).

4. Execute the program TRACK by typing "TRACK" followed by a carriage return.

II. ROUTINE TO POWER UP THE NOVA

SWITCHES ARE LABELLED WITH RED TAPES. (SEE FIGURE 7).

1. TURN CONSOLE POWER SWITCH TO "ON".

2. TURN ON POWER SWITCH ON TEKTRONIX TERMINAL

3. TURN TELETYPE SWITCH TO "LINE".

4. TURN DISC POWER SWITCH TO "ON" (clockwise).

5. PUSH WHITE KEY ("POWER ON") ON MOVING HEAD DISC CABINET

6. SET CONSOLE SWITCHES 0, 11, 12, 14, and 15 UP; ALL OTHER NUMBERED SWITCHES STAY DOWN.

7. WHEN GREEN LIGHT ON DISC CABINET COMES ON, LIFT "RESET" SWITCH AND THEN "PROGRAM LOAD" SWITCH ON THE CONSOLE. THE FOLLOWING DIALOGUE ENSUES:

```
FILENAME ? ANTSYS↓

RDOS REV 3.02
DATE (M/D/Y) ? 3 15 76↓
TIME (H:M:S) ? 13 15 0 ↓
R
CLEAR/A/V↓
DIR USER↓
CLEAR/A/V↓
SYS.DR
R
R
SYS.DR
R
```

NOTES:

1. "↓" means "RETURN". You type in the underlined characters.

2. WHEN RDOS SYSTEM CRASHES, PUSH WHITE KEY ON DISC CABINET (OFF) AND GO TO STEP 5 ABOVE.

ROUTINE TO POWER DOWN THE NOVA (SEE FIGURE 7)

1. TYPE RELEASE DPØ ↲ . ("Ø" IS A ZERO: "↲" IS A RETURN).
2. PUSH WHITE KEY ON DISC CABINET (WHITE LIGHT GOES OUT).
3. TURN OFF FHD SWITCH.
4. TURN DISC POWER SWITCH TO OFF (counter clockwise).
5. TURN TELETYPE SWITCH FROM "LINE" TO "OFF".
6. TURN TEKTRONIX TERMINAL SWITCH TO "OFF".

NOTE: NOVA IS NORMALLY LEFT RUNNING ALL THE TIME.

III. SETTING NOVA's REAL TIME CLOCK

To track LANDSAT accuratley the NOVA's Real Time clock must be set to Coordinated Universal Time (UTC). Accuracy of one-fourth second is sufficient. Two methods may be used; a manual one and (eventually) an automatic one.

Automatic Method. Execute the program CL. Within 2-3 minutes the computer will signify completion by typing "R". If it doesn't it means that it probably won't. In this case, use the manual method.

Manual Method. The NOVA provides for its clock to be set by the teletype command STOD hh mm ss ↵

Where hh, mm, and ss stand for hour, minute, and second.

Dial up the FTS number 8-323-4245 to get the National Bureau of Standards' audio time signal. When you have found out what time mark will be coming soon (e.g., the next minute), use the STOD command to prepare to enter that upcoming time, and hit CARRIAGE RETURN exactly when the time marker occurs.

Before hanging up the telephone, you may check the NOVA's time by executing the program PU which will send an audible pulse to the terminal every 15 seconds.

This annotated sample of operator/computer dialog illustrates the method:

<u>STOD 13 1Ø 3Ø</u> ↲ *	At this time, NBS signal is coming in by telephone. Return is pressed at exactly 13:10:30.
R	
<u>PU</u> ↲	
IT'S NOW 13:1Ø:34	Continue listening to NBS and compare teletype pulses to telephone signal.
45	
6Ø	
INT	
R	
<u>PU</u> ↲	
IT'S NOW 13:11:12	
15	
INT	
R	
<u>LSI</u> ↲	
NEXT PASS AT 14:28:1Ø	

IV. HOW TO ENTER ORBITAL ELEMENTS INTO TRACKING SYSTEM

To track LANDSAT, the system must be able to predict when the satellite will rise over the horizon and what azimuth and elevation angles to send to the tracking pedestal. To predict those times and angles the system is given a description of LANDSAT's orbit by means of the teletype or CRT terminal. This orbital information is contained in the element set provided by the North American Air Defense Command, Ent AFB, Colorado.* The element set comes via TWX twice a week and looks like the example in Figure 5. Eight of the elements in Figure 5 are important to our system. Their meanings, formats, and units are as follows:

1. EPOCH - - An arbitrarily chosen recent instant expressed as a Julian date, at which the rest of this element set was determined.

XXX.XXXXXXXX (DAYS)

2. NDOTØ** - - First derivative of mean motion + or - .XXXXXXXX (REVS/DAY/DAY)

---

*Questions about NORDADC elements can be addressed to:

SPACE DEFENSE CENTER
(Cheyenne Mountain Office)
ENT AFB, Colorado

As of 9 December 1975, our contact person there was Capt. Tohlen, FTS 8-327-0111 635-8911, ask for ext. 3549

** "Ø" stands for zero; "O" is the 15th character of the alphabet.

3. IØ - - Inclination. XX.XXXX (DEGREES)

4. NODEØ - - Right Ascension of the Ascending Node, XX.XXXX (DEGREES)

5. EØ - - Eccentricity. XXXXXXX (NO UNITS)

Notice that the decimal point is not printed on NORAD message, but must be supplied to system when you type it in.

6. OMEGØ - - Argument of Perigee. XXX.XXXX (DEGREES)

7. MØ - - Mean Anomaly. XXX.XXXX (DEGREES)

8. NØ - - Mean Motion. XX.XXXXXXXX(REVS/DAY)

The orbital element set is entered into the system by executing a program called "ELW", which stands for "Element Writer". ELW is an interactive program which guides the operator in entering the numbers correctly. Because the numbers have many digits, it is easy to mistype them on the teletype keyboard. Therefore, ELW echoes each number as it is entered and allows revision of that one number. If no correction is needed, the operator types Y after "OK?" and enters the next number. If a correction is needed, the operator types N and retypes the same number. An example of the operator/computer dialog for the element set of Figure 5 is given in Figure 6.

V. POWERING UP TRACKING EQUIPMENT

Power switches for the Data General equipment, the Scientific/Atlanta equipment and associated devices are shown on the photographs in Figure 7. The order of turning switches ON is as follows:

Data General:

1. Console power
2. Disk power on console
3. Disk power on disk cabinet
4. CRT } reversible
5. Teletype } reversible
6. Decoder

Scientific/Atlanta:

7. Receiver
8. Synchro Display
9. Servo Control
10. Digital Comparator

In addition, the main power switch on the antenna pedestal concrete foundation must be ON, and any interlock switches in the pedestal itself must be closed.

There is one power switch on a plug strip inside the S/A cabinet of which you should be aware.

VI. IF SOMETHING FAILS ...

Occasionally, a device will malfunction and cause tracking to cease. Here are a few things to notice as you recover from the malfunction:

1. Is the computer still up and running?

   If the lights are glowing softly, it is probably still running and should respond to commands from the terminal. If the console lights have stopped with some on and some off,or if no lights are on it has crashed. Go to Section II, Step 2, in the footnotes.

2. Is the dish in the stow position (pointed straight up)?

   If not, tracking is either in progress or has ended abnormally. If it has ended abnormally, the command equipment must be returned to STANDBY mode. Go to next item.

3. Are the two tiny (5/16") red lights (LED'S) on the Servo Control Unit lit?

   If so, the equipment is in PROGRAM mode. Put it in STANDBY, by typing "OFF" at the terminal followed by carriage return. The tiny red lights should go off. If that doesn't work, turn off the power switch on the DECODER (see Section IV) for 2 or 3 seconds.

To put the antenna in the stow position, use the manual command unit, the cabinet immediately above the Servo Control Unit. Push the two square buttons on the manual command unit. The antenna should go to the position indicated on the two round dials on this unit. If it doesn't respond to the manual commands, something has blown out - probably a fuse. Finally, push the STANDBY buttons on the Servo Control Unit.

4. If it looks like a fuse has blown, zero in on the difficulty by the equipment's behavior and appearance (e.g., lights out, movement in azimuth but not elevation, or vice versa), lost power in Servo Amps, etc.). Most commonly the center (30 amp) fuse on the concrete foundation supply box is the one that is blown.

Fuses have also blown in the Digital Synchro Display Unit (back panel) and in the Servo Amplifier in the pedestal itself.

5. The root cause of these fuse troubles seems to be back in the NOVA computer. When it sends bad data, the pedestal equipment gets overloaded. The NOVA runs into difficulties when RDOS is not functioning right, and recently it has appeared that RDOS gives problems when the files CLI.OL and TLOG are not "cleared". That is, their user counts in the system directory are greater than zero. This is remedied by the commands "CLEAR TLOG" and "CLEAR CLI.OL" at the terminal.

6. If the equipment all seems to work, but no signal comes in during a satellite pass, the system time may be set wrong. Also, check the system date. Perhaps the satellite has not been turned on by NASA at Goddard Space Flight Center. Usually, they turn it on by the time it reaches 10° elevation.

7. If the equipment has failed so badly that it can't be fixed by NED, the following service groups are available:

Data General Corporation
Field Service
237 Riverview
Waltham, MA 02154
891-7024

Tektronix, Inc.
Field Service
482 Bedford
Lexington, MA
861-6800

Scientific/Atlanta
Bud Lydon, Fred Leavett, or Dan Pioli
Burlington, MA
272-1256

VII. SYSTEM DESIGN AND OPERATION, IN-DEPTH VIEW

The LANDSAT tracking system integrates a set of about twenty programs or subroutines (software), about ten disk data files, and several pieces of equipment (hardware). The inter-relationships of the programs and data files can be seen in the flowchart in Figure 4. The hardware configuration is shown in Figure 1. In the flowchart, an information flow can be seen as well as a cycle of program executions. Essentially, the system predicts the satellite's position, tracks the satellite, stores and prints the data, returns to the predicting program, and so forth. This cycle can be entered by the method given in Section I. However, from time to time, other operator action will be necessary.

For example, the computer's real-time clock must be accurately set (see Section III). As of this writing, only a manual method is available, and it has to be performed at least once a day for various reasons such as clock inaccuracy and system crashes. A better, automatic method of imputting time from a standard clock is being developed by the writer.

The operator must also inform the tracking system of the latest description of the LANDSAT's orbit. This must be stored in a file called "ELEMENTS". The orbital information is contained in an eight-number set which is supplied to WCB under a standing arrangement with the North American Air Defence Command (NORADC) in

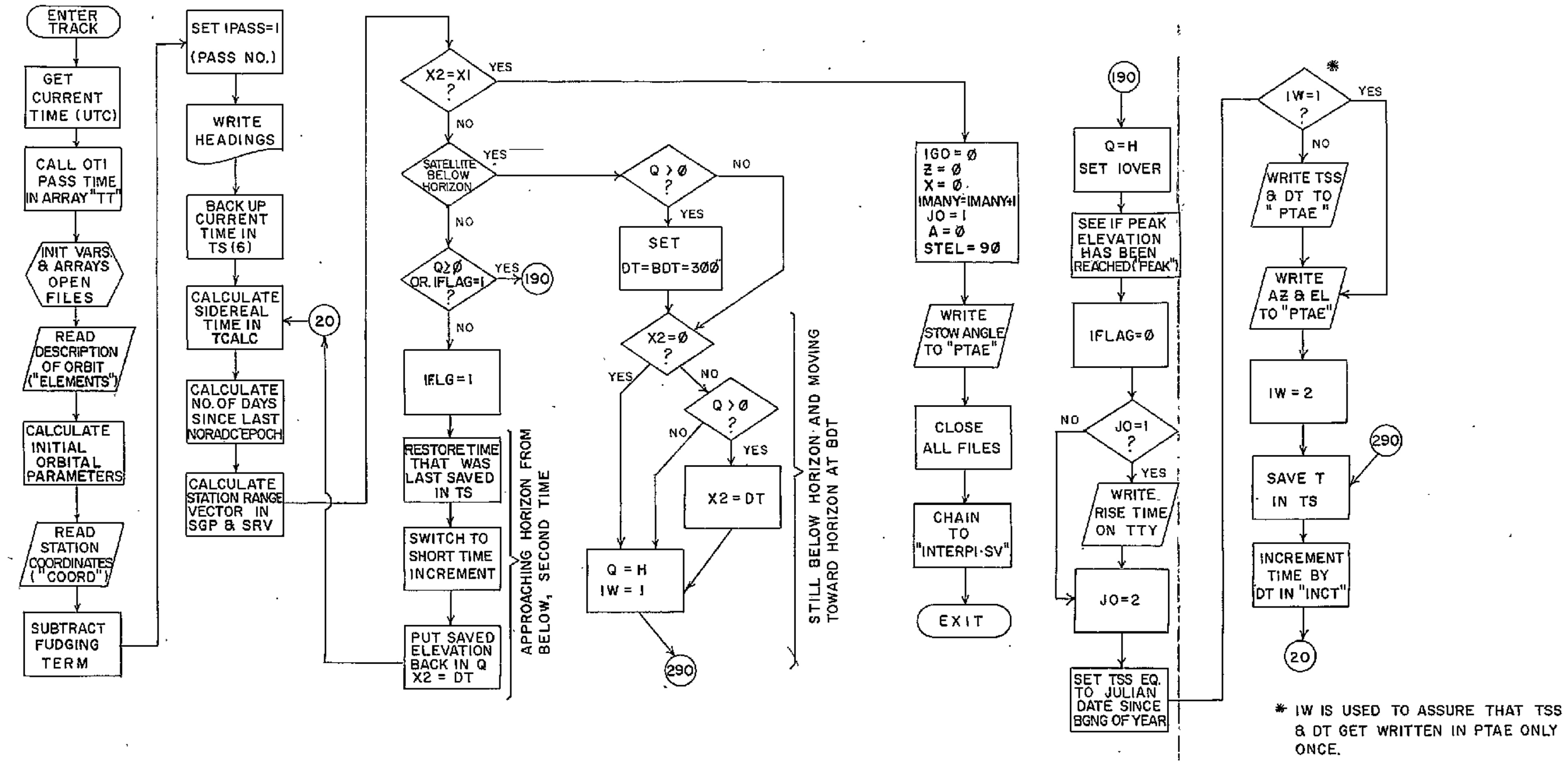
Colorado. Twice a week, NORADC sends the element set to the TWX machine in Building 115S. A detailed description of how to enter the elements into the system is given in Section IV.

Normally, entry to the tracking system is by execution of the program TRACK, a FORTRAN program which calculates pairs of azimuth and elevation angles to LANDSAT from NED. TRACK starts with the current time and keeps incrementing it until it calculates that the satellite would be above the horizon. In other words, it projects into the future from the current time in the computer's real-time clock.

After the current date and time are input to TRACK, they are converted to Sideral time. This is done by a subroutine called TCALC. Sidereal time is a relationship between the constellation ARIES (γ) and the Greenwich prime meridian. Specifically, it is an angle between the Greenwich prime meridian and the inertial X-axis which points toward the first point of ARIES (Escobal, p. 20)*. This angle is denoted by θ. This angle is called the local sidereal time. Knowing the east longitude (λe) of an observer's station and, θg (Greenwich Sidereal time) θ can be easily determined. This is given by $\theta = \theta g - \lambda e$, where $\emptyset < \theta \leq 2\pi$ (Escobal, p. 20, Eq. 1.26).

---

*See Appendix F for literature cited.



TRACK FLOW CHART

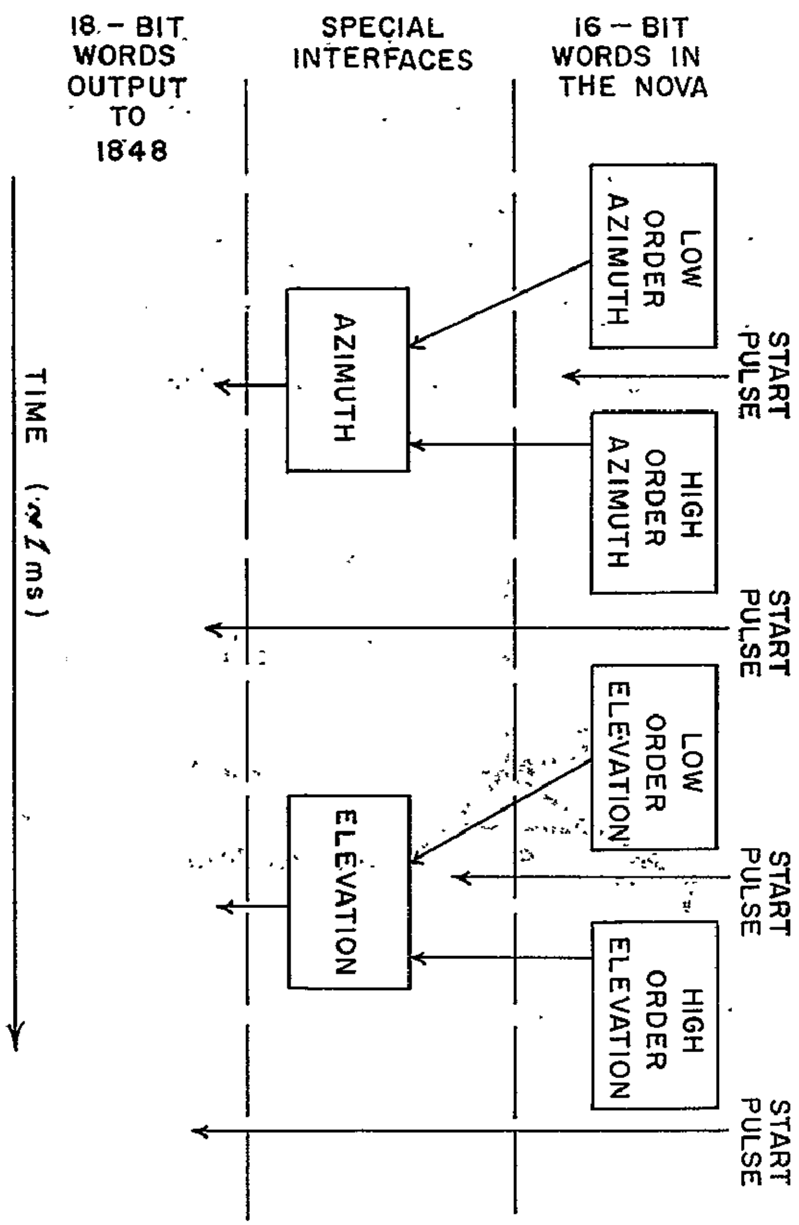
To find the sidereal time, the Julian Date (J.D.) must be calculated. The Julian Date is a continuing count of each day elapsed since some arbitrarily selected epoch. The epoch selected for LANDSAT orbital predictions in TCALC is January 1, 4713 B.C. Each Julian Date is measured from noon to noon; hence, it is an integer 12 hours after every midnight (Escobal, page 17). After the Julian Date and sidereal time are calculated, the next thing found is TSINCE, the number of days since the most recent NORAD EPOCH. TSINCE is then used to determine the unit vector pointing toward the satellite (see SGP of this text). These unit vectors are in turn converted to azimuth and elevation angles at the observer's station (degrees clockwise from north and degrees above the horizon, respectively) (see SRV of this text). These two values and the times at which they occur are then written on the disc under the file name PTAE. The Time of interest is then incremented seconds or minutes by the routine INCT, and the next values of AZ and EL are determined, etc. In this incremental fashion, the computer is able to predict the path of the satellite across the sky at the observer's site.

The name PTAE stands for Paper Tape Azimuth Elevation. The file can be transferred as it is to the paper tape punch by the teletype command, "XFER/A PTAE $TTP". This will cause a paper tape to be generated that is suitable for input to the paper tape reader on the pedestal control equipment.

PTAE is a disk file which comprises a time, a time increment, and many pairs of azimuth and elevation angles. The file is ended with a special file terminator. An example of PTAE is shown in Appendix C.

TRACK calculates azimuths and elevations at 10-second increments, so the angle pairs in PTAE are pointing angles for instants 10 seconds apart. If these angles were fed to the tracking pedestal, the antenna would jump quickly to the next position every 10 seconds. The progress of the satellite is smoother than this jumpy motion, and it has been found that one-second incrementing is sufficiently small for constant satellite acquisition. Therefore, the program INTERP1 is executed right after TRACK to interpolate ten angle pairs for every one pair in PTAE. Furthermore, INTERP1 recodes the angles from ASCII characters to a binary coded decimal (BCD) format suitable for the electronic interface enroute to the command equipment. The new angles are stored in a binary file called BCDAZEL, and the number of angles in BCDAZEL is stored in the file NANGLES.

The recoding is done by bit-mapping in the program INTERP1 (q.v.); the assignment of angular values to bit positions is shown in Figure 8. A set of special interfaces, built by Robert Snyder of NASA Wallops, is used to route the BCD angles from the NOVA to the 1848 Digital Comparator (see Figure 1). Input to the 1848 is in the form of Two 18-bit BCD words representing azimuth and elevation. However, the NOVA can output only 16-bit words, by way of the 4065 Digital Interface. For this reason, it was necessary to concatenate two pairs of 16-bit words into two 18-bit words as shown below (see also Figure 8):



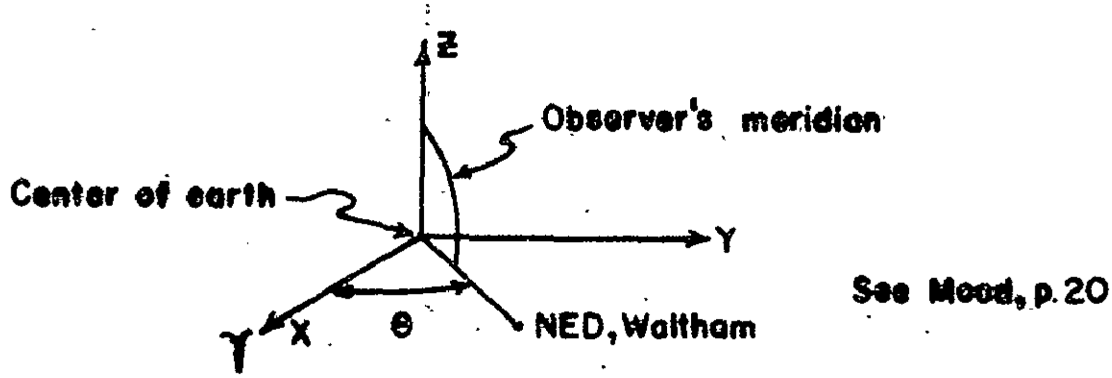
TCALC

TCALC is a time handling routine which calculates the following three variables:

1. XJD - No. Julian days; it is used to find TSINCE and THETA (Escobal ; Pgs. 20, 21, 22).

2. TSINCE - No. of days since most recent NORAD EPOCH. This is used by SGP to find the unit vector pointing toward the satellite (RDOT).

3. THETA, θ - Sidereal time (measured in radians) - the angle between a line from the center of the earth to the first point of the constellation ARIES (Υ), and the plane of observer's meridian.



THETA is used by SRV in determining Azimuth (A) and elevation (H).

EXPLANATION OF TCALC VARIABLES

EP = 2442413.5 = Number of Julian days from an original EPOCH to January 1, 1975. This EPOCH is January 1, 4713 B.C. (days).

TWOPI = 2π = 6.2831853072 (no units).

LAMBDA E = East longitude from Greenwich to NED = 288.784332° (degrees). (λ_e)

DTHDT = .25068447 - Constant used to account for one extra sidereal day for every tropical year (degrees/mim).

EPYR = DFLOAT (75) = An arbitrary year used as a reference (years).

XJD = Number of Julian days (days).

N = T(2)-1 = Number of months in year up to last month (months).

DAYS IN MO (I) = Number of days in each month (days).

N = T(1)-1= Number of years up to last year (years).

TSINCE = Number of Julian days at INSTANT, the time of interest (days).

INSTANT = Future prediction times, or the times of interest (year, month, day, hour, minute, second).

DT = The number of hours, minutes, seconds which T, the time of interest, is incremented for successive executions of TRACK.

TU = Time since January 1, 4713 B.C.; used to find THETA G Ø (centuries).

THETA GØ = Greenwich Sidereal time at Ø hour of a particular date (degrees).

THETA G = Greenwich Sidereal time (degrees).

THETA - Sidereal time at NED, Waltham (degrees).

SAMPLE CALCULATION OF SIDEREAL TIME

August 23, 1975, at 10 hours, 15 minutes, Ø seconds; Number of hours, minutes, seconds expressed in minutes: DT = 615 minutes.

XJD = 2442648.5 DTHDT = .25068447

TU = (XJD-2415Ø2Ø)/36525 = .7564271Ø47227926

THETA GØ = 99.6909833 + (36ØØØ.7689) (TU) + (.ØØØ38708) $(TU)^2$ = 331.6485916Ø15490

THETA G = THETAGØ + (DT) (DTHDT) = 125.81954Ø6515490°

THETA = (THETA G + LAMBDAE) ($2\pi/360$) = .9530184529430946 radians

SGP

SGP is a FORTRAN subroutine embodying a truncated simplified general perturbation theory for use in the determination of LANDSAT pointing elements. SGP computes osculating position, velocity and mean classical elements. SGP is a first order analytical integration of the equations of motion including perturbations caused by the first two zonal harmonics of the geopotential. The zonal harmonic constants account for the effects of the non-circularity of the meridian cross sections of the earth. The perturbations caused by these harmonics are independent of the longitude of the satellite. SGP is based on the orbital elements a, AXN, Ayn, i, Ω , and L which are well defined for all elliptic orbits except those that are nearly equatorial. For equatorial satellites, the elements Axn and Ayn are ill-defined because of the indeterminacy of the node angle Ω to which they are referred. The SGP mathematical model is adequate to handle a majority of routine cataloguing. Accuracy is said to be better than one part in 10^9.

SRV

SRV (Slant Range Vector) is a FORTRAN subroutine of TRACK which transforms the orthogonal vectors and the time angle, THETA, from subroutine SGP into an azimuth/elevation coordinate system with the observer's station as the origin. Files of azimuth and elevation angles in this coordinate system describe the path of LANDSAT over a particular station during some interval.

TRACKING THE SATELLITE: PROGRAM LS1

After TRACK has predicted the satellite's path across the sky and prepared a file of pointing angles, it chains automatically to the program LS1 which will perform any of over six main functions. It is a complex multi-tasking program which defies flowcharting, because program internal control shifts according to time as counted down by the Real Time Disc Operating System (RDOS) and according to real events in the outside world.

Typically, LS1 carries out the following main tasks:

1. Schedules itself by looking at the starting time of the upcoming pass. This time is the first number stored in the disk file BCDAZEL.

2. Orients the antenna 1-1/2 minutes before the satellite rises.

3. Starts repositioning the antenna second by second beginning at the instant the satellite rises; and simultaneously logs any data that arrives by way of the antenna/receiver/decoder pathway (see Figure 1); and also simultaneously will accept corrections from the terminal to advance or retard some number of seconds. These corrections are made to improve antenna position.

4. Restores the antenna to the stow (upright) position when the last angle pair in file BCDAZEL has been sent.

5. Dumps the field data that have come in from core buffer to a temporary disk file called "SDF" (Satellite Data File).

6. Finally chains to a program called QD3 which will decode field data from binary to an octal format similar to one used by NASA at Goddard.

Note that once TRACK and INTERP1 have been executed for an upcoming pass, LS1 can be run at any time up to one minute, 40 seconds before satellite rise time. Execution of LS1 after that causes problems which are signalled by a "W" being printed at the terminal. One then has to quickly reset the system clock; execute LS1; and when the computer eventually types ":", enter positive corrections that stand for numbers of seconds to enable LS1 to catch up with real time.

If further knowledge of LS1 is desired, the program itself is the best source. The original source code is copiously annotated with explanations of individual steps.

OUTPUTTING DATA: QD3 and P3

QD3 and P3 are programs that condition the raw field data received by the ground receive antenna for disk storage or legible output.

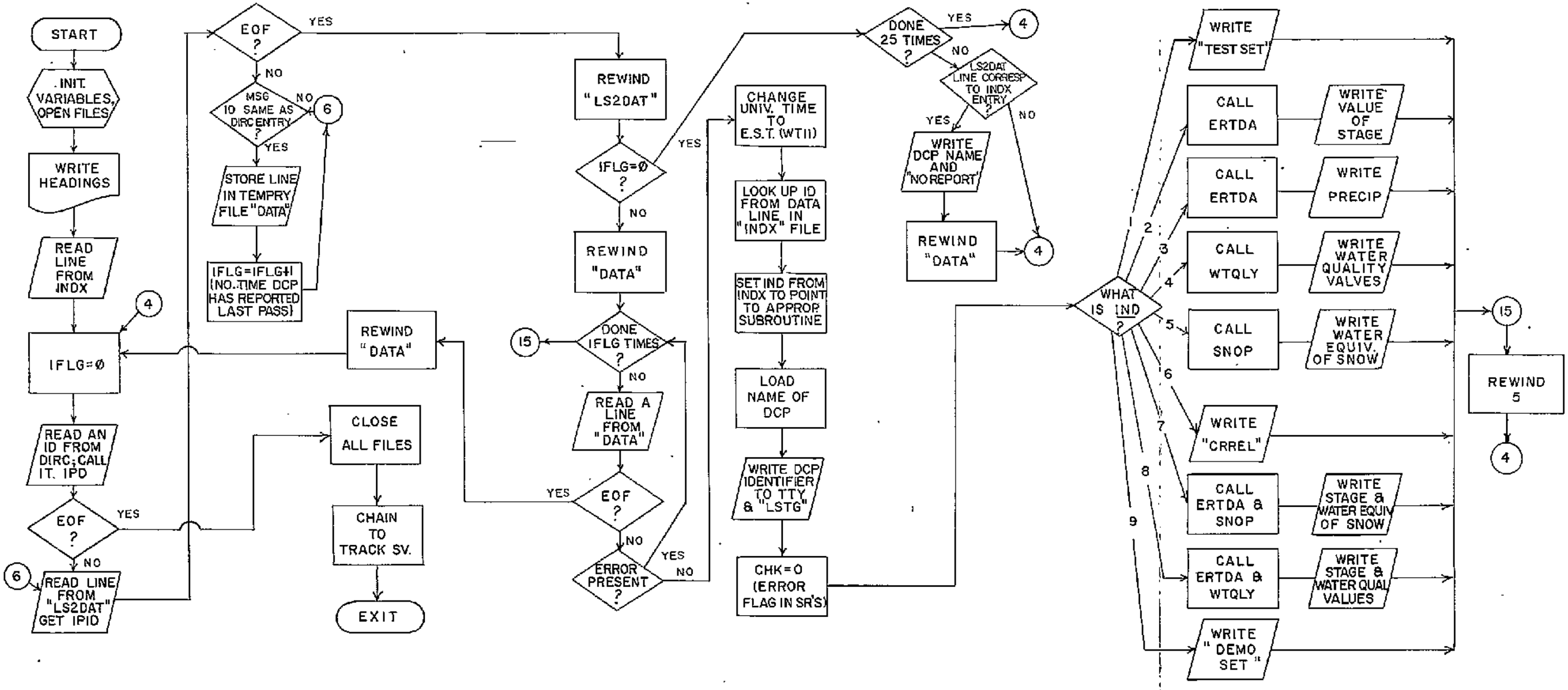
QD3

Output to QD3 is the disk file "SDF" which was produced by LS1 immediately after the last satellite pass. Output from QD3 goes to a temporary file "LS2DAT" and a permanent file "STORAGE". These file formats are shown in Appendix C.

The arrival time of each DCP message is recorded by LS1 by storing a seconds counter with each message. This number of seconds is accumulated from the beginning of each pass, and QD3 calculates a message arrival time by adding the number of elapsed seconds to the starting time. The arrival time (Y, M, D, H, M, S) is then stored with each message. The time used is Coordinated Universal Time.

P3

Legible output of DCS data is obtained by executing P3. Input to P3 is from temporary disk file "LS2DAT". Essentially, the program examines each message for the platform ID number. looks up the ID in a table, and decides how to interpret the data on the basis of indices in the table. These indices then direct program control to appropriate subroutines for calculating decimal numbers and attaching labels. The kinds of parameters handled by P3 are shown in the sitelist, Figure 9.



P3 FLOW CHART

APPENDICES

A. History and Background of LANDSAT Program at NED

B. Figures

C. Computer File Formats

D. Glossary

E. Program Listings

F. Literature Cited and Related Documents

APPENDIX A

HISTORY AND BACKGROUND OF LANDSAT PROGRAM AT NED

Since the Industrial Revolution in the 1800's, the rivers of New England have been developed to supply water for power and transportation. As new means of transportation became more economical, both railroad and highway systems were built along the banks of the rivers to service the expanding needs of the industrial, commercial and urban centers. Structures, such as buildings, roads, bridges and dams have restricted floodways to such an extent that considerable property and environmental damages have occurred during moderate and major floods. Notable floods of November 1927, March 1936, September 1938 and August 1955 have demonstrated the need for flood control to prevent these natural catastrophes.

At the direction of Congress, the U.S. Army Corps of Engineers developed a comprehensive plan of protection for each river basin after a careful analysis of all water resources. Protective works generally consist of a combination of channel improvements, dikes and/or floodwalls at major damage centers augmented by upstream flood control reservoirs. Many of these reservoirs contain additional storage reserved for other uses such as water supply, conservation and recreation. The Corps has built 35 flood control reservoirs, 37 local protection projects and four hurricane barriers in New England at a total investment of some $300 million.

To achieve optimum operating benefits from this comprehensive protection system, the New England Division requires hydrologic data such as river, reservoir and tidal levels, wind velocity and direction, barometric pressure and precipitation.

In the past this data was collected from field observation and relayed via telephone or voice radio. It took several hours to compile and assess the data in this manner. With the need for timely and reliable information increasing, the Corps began development of new methods of data collection.

In 1970, the Automatic Hydrologic Radio Reporting Network was placed in operation. This ground-based radio relay system consists of 41 remote reporting stations, and a central control at Division Headquarters in Waltham, Massachusetts. This network, under computer programmed control, collects and analyzes, in real time mode, information which is essential for flood regulation. The remote reporting stations are strategically located in five major river basins and at key coastal points, with each contributing to a detailed, comprehensive hydrologic picture.

LANDSAT

In June 1972, NASA entered into a contract with the Corps for an experiment to study the feasibility of using the Earth Resources Technology Satellite (ERTS or LANDSAT) for collection environmental data from Data Collection Platforms (DCP's) which are installed at 27 locations throughout New England. Many are situated at existing U.S. Geological Survey gaging stations.

Since July 1972, LANDSAT has been relaying river stage, precipitation, and water quality data from DCP's via the Goddard Space Flight Center to the U.S. Army Corps of Engineers, New England Division, in near real time. This is the first resources satellite designed to obtain data from the planet Earth exclusively for planning, design, operations and research of land and water resources.

THE NED GROUND RECEIVE STATION

Since any operational satellite configuration serving an urgent function like flood control should include ground receiving stations at all major user locales, NED, with NASA support, constructed and is now operating an inexpensive semiautomatic and easily maintained ground receive station as a follow-up to its original study. The Division is now able to receive hydro-meteorological data from data collection platforms in the field directly at its headquarters in Waltham, Massachusetts with no time delays. The software to drive the antenna system has been developed with the intention that the antenna operate in an unattended mode automatically over nights and during weekends and holidays, with a computer controlling all processes.

The major objective of the program has been to compare the effectiveness of the LANDSAT Data Collection System (DCS) with existing systems in aiding our watershed management functions.

Data collection platforms tested by the Corps have performed successfully in all seasons including the winter months and also during significant flood events, transmitting near real time operationally useful data for our flood fighting missions.

The satellite proved invaluable in April and early May of 1973 and 1974, monitoring flooding in Maine Rivers. LANDSAT relayed data from five river points in that State to aid the New England Division in the coordination of the flood emergencies.

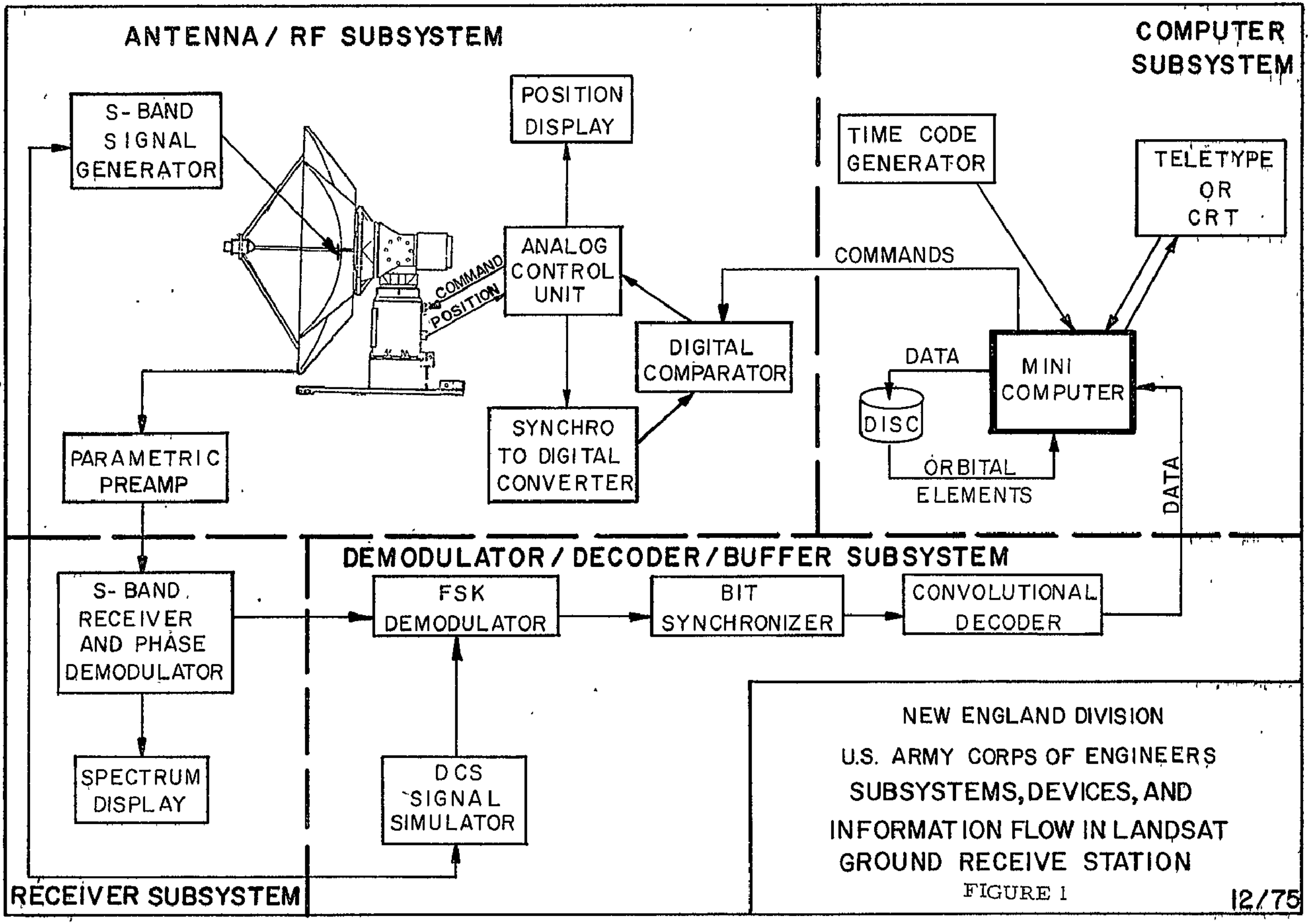
The successful testing of the LANDSAT Data Collection System at the New England Division should encourage serious consideration of the institution of an operational satellite data relay system on a Corps-wide basis. Such a system appears to be more cost-effective than conventional ground-based data relay.

The New England Division is also making a study of satellite imagery to determine its usefulness in planning, designing and managing water resource systems. To obtain an overall broad coverage of ground conditions, imagery studies and measurements are being made of fluctuations in river, lake, and reservoir stages as well as tidal changes, icing of water surfaces, location and depth of snow cover, moisture content of the soil, and water quality parameters.

FLOOD CONTROL OPERATIONS

Data received at the New England Division's Reservoir Control Center from either the Automatic Hydrologic Radio Reporting Network or the LANDSAT Data Collection System is compiled by computer. This is augmented by information from other sources such as the National Weather Service Meteorologic and River Forecast Offices and the U.S. Geological Survey. Experienced engineers and hydrologists at the Reservoir Control Center analyze the data for timely operation of dams and hurricane barriers, and then issue instructions to operating field personnel.

Flood Control reservoirs, local protection projects and hurricane barriers built by the Corps in New England have been responsible for prevention of almost $300 million in flood and storm damage.



NEW ENGLAND DIVISION

U.S. ARMY CORPS OF ENGINEERS

SUBSYSTEMS, DEVICES, AND INFORMATION FLOW IN LANDSAT GROUND RECEIVE STATION

FIGURE 1

12/75

ORIGINAL PAGE IS
OF POOR QUALITY

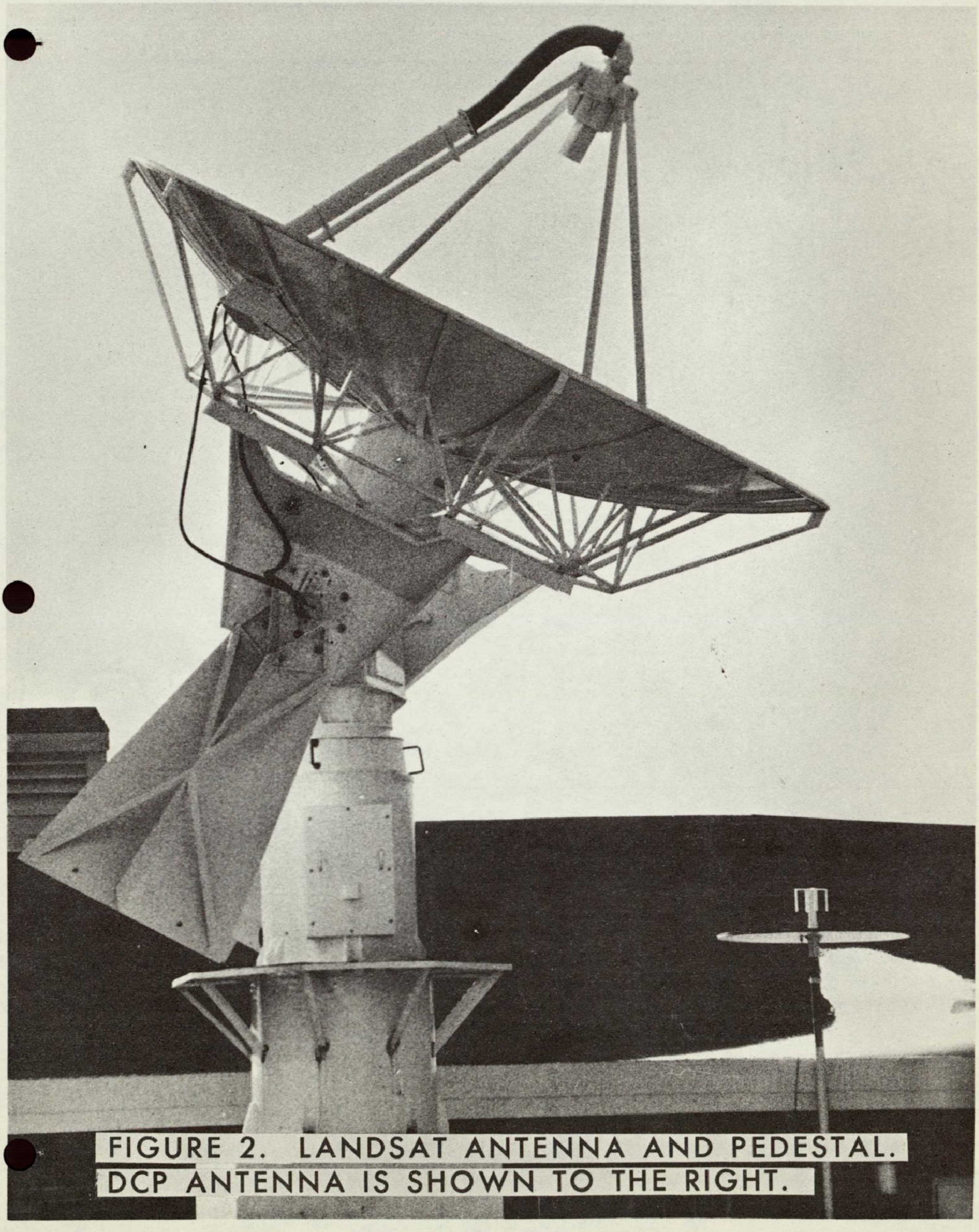


FIGURE 2. LANDSAT ANTENNA AND PEDESTAL. DCP ANTENNA IS SHOWN TO THE RIGHT.

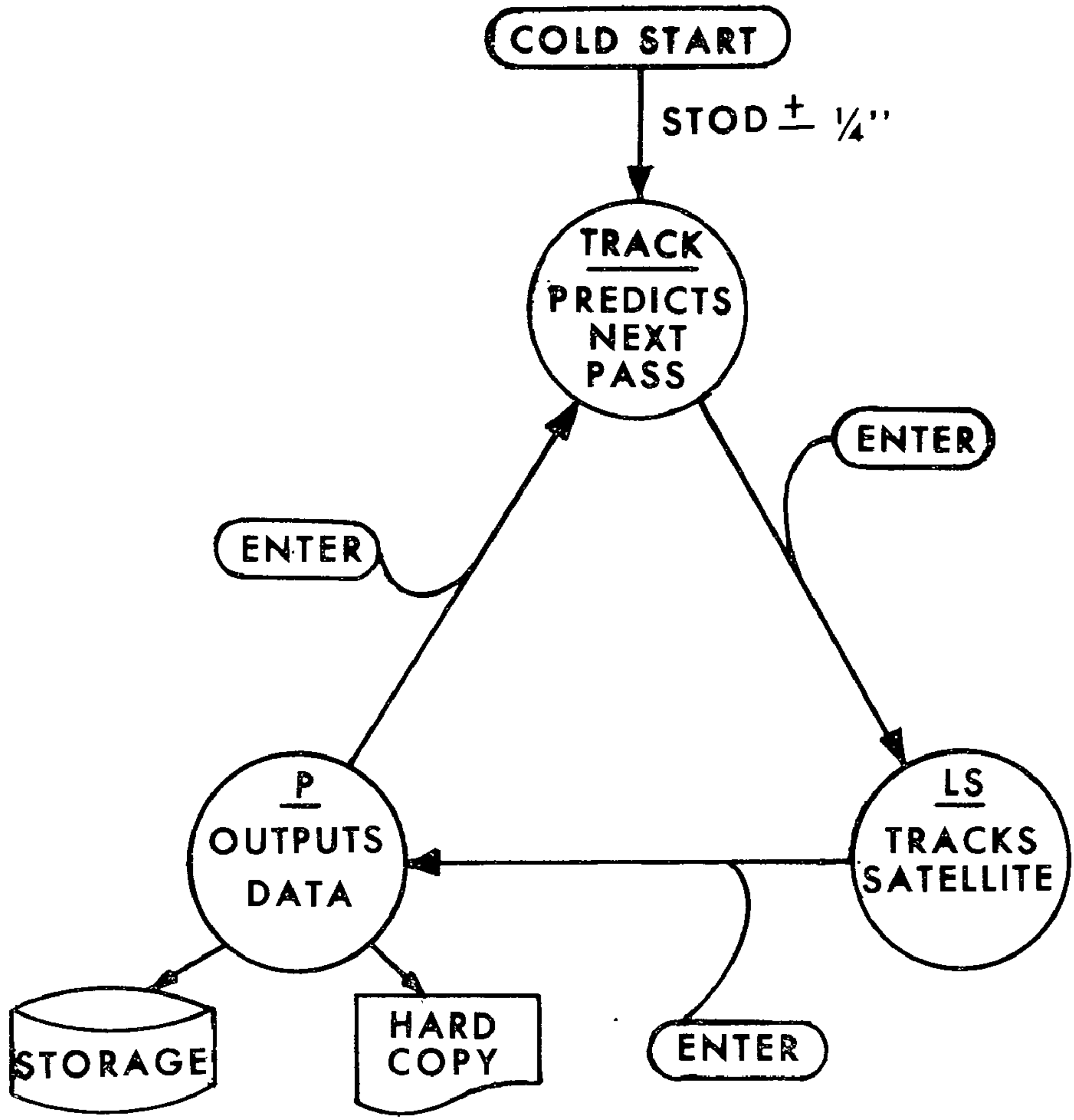
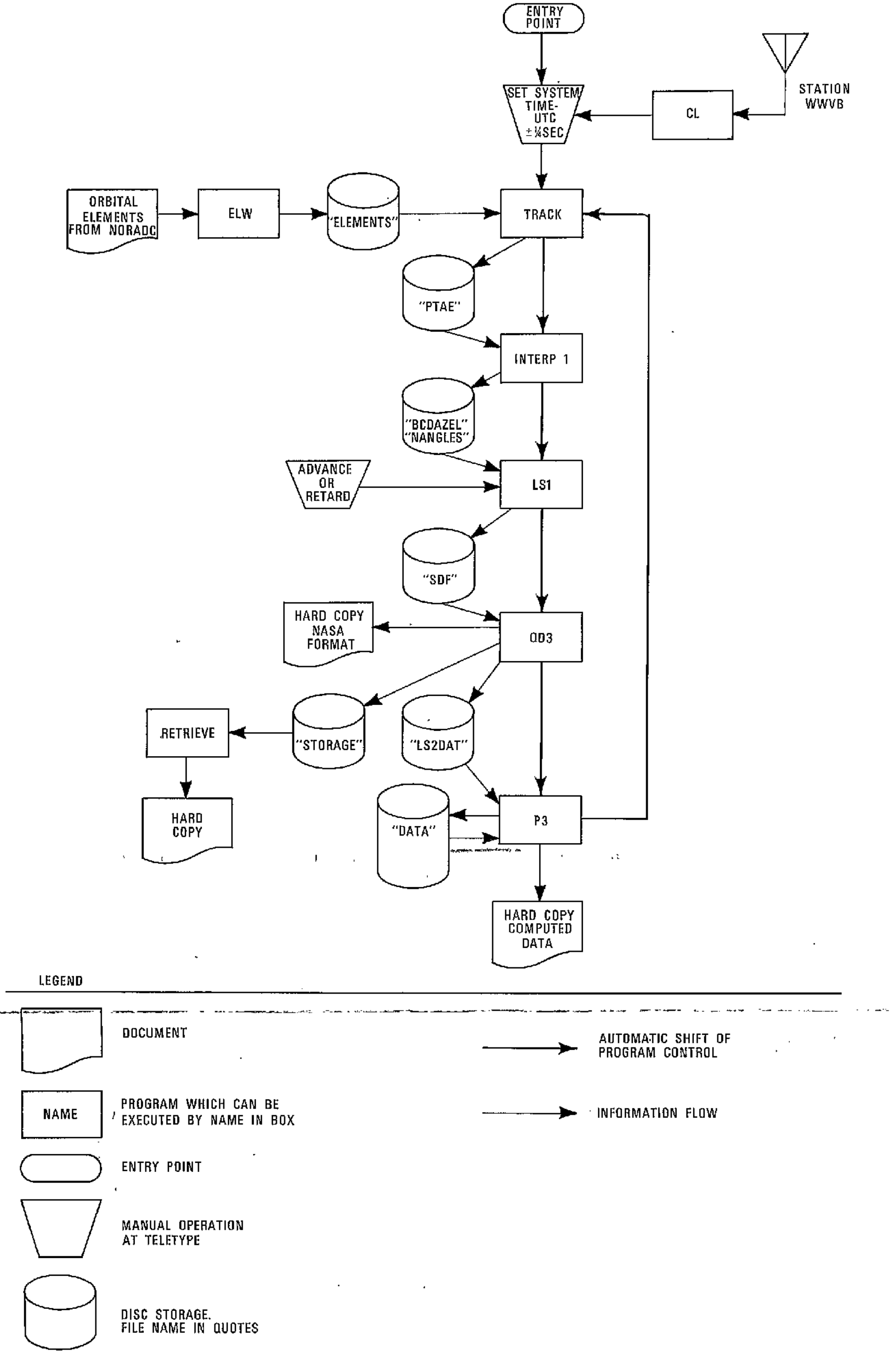

COLD START
STOD ± ¼''
TRACK
PREDICTS NEXT PASS
ENTER
ENTER
LS
TRACKS SATELLITE
P
OUTPUTS DATA
ENTER
STORAGE
HARD COPY

FIGURE 3

FOLDOUT FRAME 1

28-B-4



28-B-4a FOLDOUT FRAME 2

HOW TO ENTER ORBITAL ELEMENTS INTO SYSTEM

ARMY ENGRS WAL

GRIFFISS ROME
S-9
710-324-6949 VIA 315-337-6275 MSG NBR 050857
R 050857Z DEC 75
FM SPACE DEFENSE CENTER ENT AFB COLO
TO USA ENDE WALTHAM MA
BT
UNCLAS SDC-0 F050851 0819 DEC 75
NEDED-W/ATTN COOPER

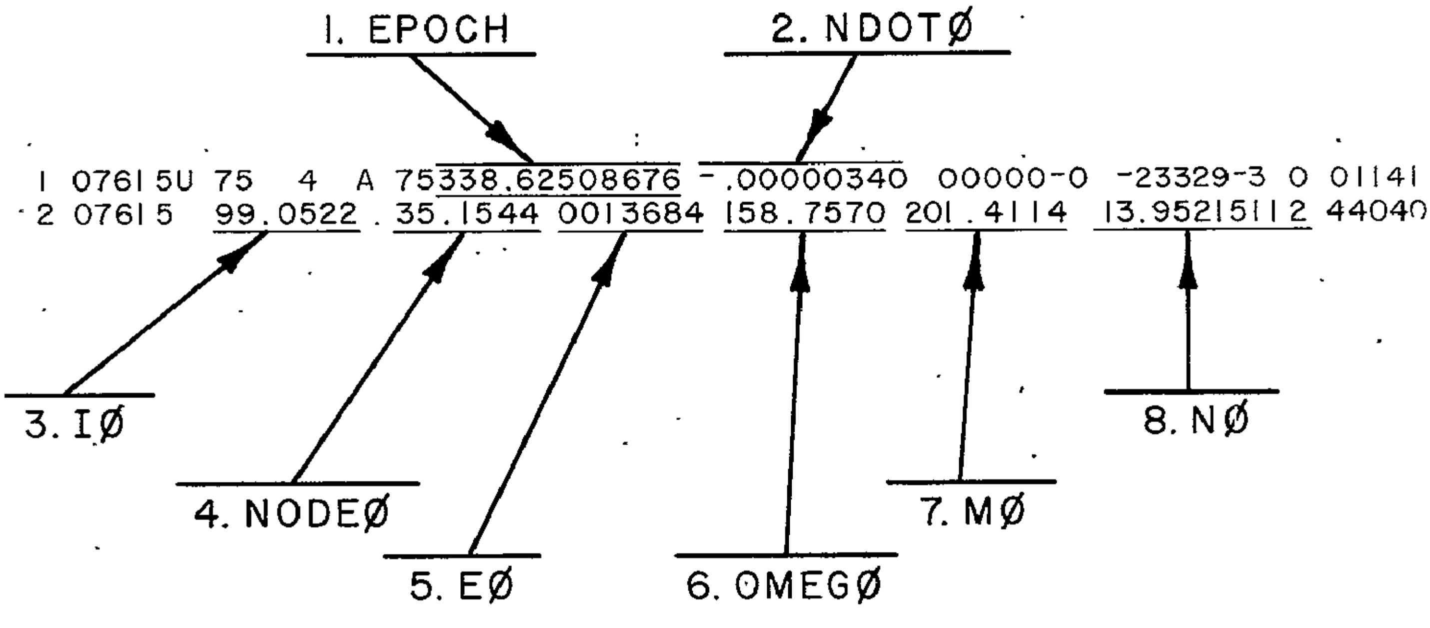
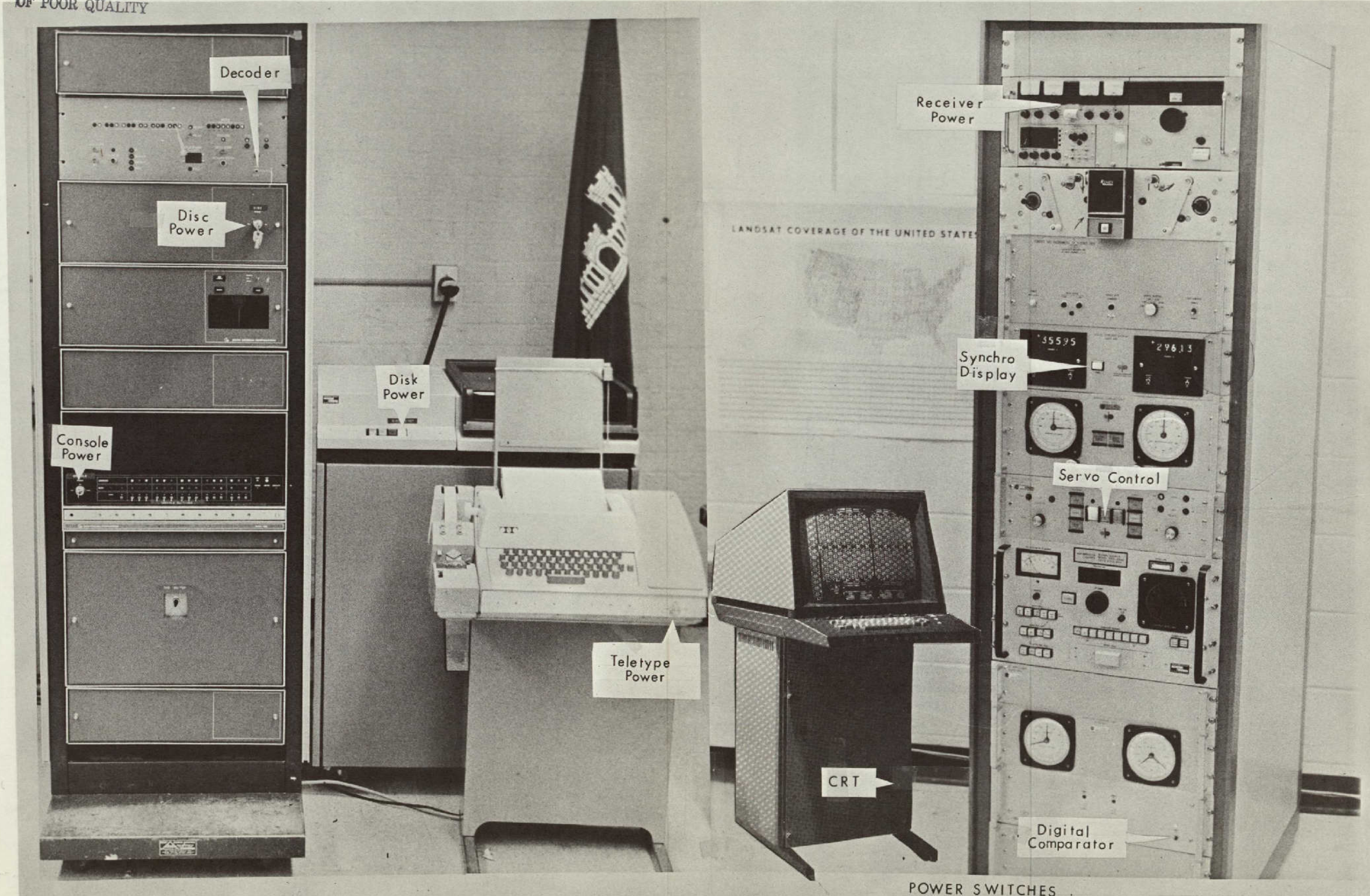


FIGURE 5 FORMAT OF ORBITAL ELEMENTS PROVIDED BY NORADC.

```
ELW↓
ENTER EPOCH,NDOTØ,IØ,NODEØ,EØ,OMEGØ,MØ,NØ
DO YOU NEED FURTHER EXPLANATION? YES OR NO N↓
ANSWER YES(Y) OR NO(N) TO OK?
71.22545099 ↓
        71.225450990  OK?Y↓
-.00000327↓
        -0.000003270  OK?Y↓
99.0355↓
        99.035500000  OK?Y↓
130.8772↓
       130.877200000  OK?Y↓
.0011596↓
         0.001159600  OK?Y↓
260.7835↓
       260.783500000  OK?Y↓
99.1966↓
        99.196600000  OK?Y↓
13.95212232↓
        13.952122320  OK?Y↓
R
```

FIGURE 6.

DIALOGUE BETWEEN OPERATOR AND COMPUTER DURING EXECUTION OF ELW.
NOTE: "↓" STANDS FOR RETURN.



POWER SWITCHES

27·Sept 49

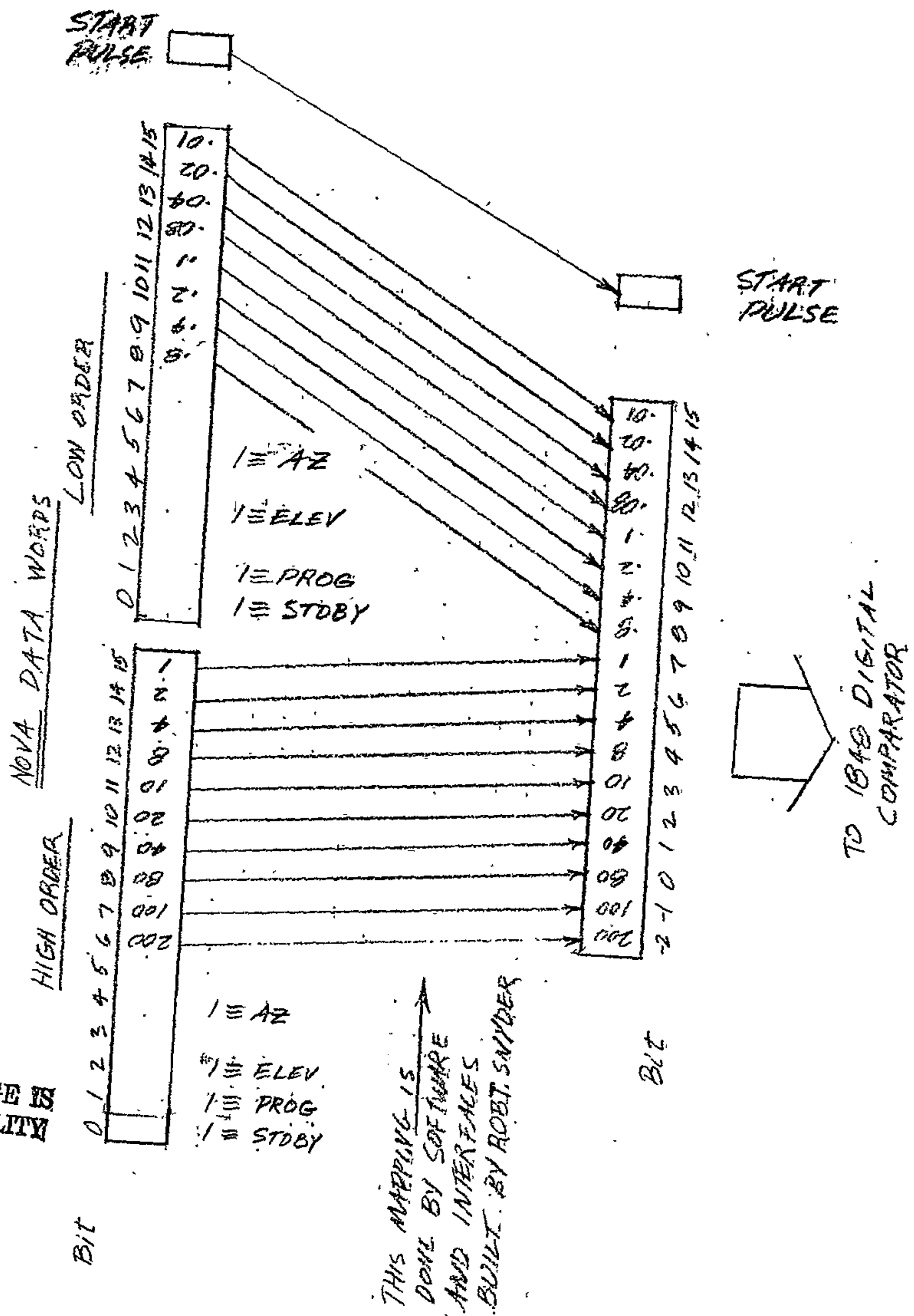
CORPS OF ENGINEERS, U.S ARMY

SUBJECT FIGURE B. BIT MAPPING BETWEEN NOVA SOFTWARE AND

~~COMPUTATION~~ 4065 INTERFACE CONTROLLING 1848 DIGITAL COMPARATOR

PAGE

COMPUTED BY CHECKED BY DATE 2 MARCH 76



LANDSAT-2 - DCP INFORMATION SHEET
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DIVISION 15 APRIL 1976

DCP NO.	STATION NAME	PARA-METER(S)*	LAT	LONG
7147	ST. JOHN RIVER AT NINEMILE BRIDGE, ME.	RS WES	46 42 00	69 42 59
7101	ST. JOHN RIVER AT DICKEY, ME.	RS WQ	47 06 44	69 05 25
7355	MICHAUD FARM AT ALLAGASH FALLS, ME.	WES	46 57 05	69 11 43
7273	ST. JOHN RIVER AT FORT KENT, ME.	RS	47 15 27	68 35 35
7071	PENOBSCOT RIVER AT WEST ENFIELD, ME.	RS	45 14 12	68 38 56
7272	CARABASSETT RIVER NEAR NORTH ANSON, ME.	RS	44 52 09	69 57 20
7356	SACO RIVER AT CORNISH, ME.	RS	43 48 35	70 46 53
7271	STINSON MOUNTAIN, N.H.	P	43 50 06	71 46 49
7127	SOUTH MOUNTAIN, N.H.	P	42 58 59	71 35 21
7201	PEMIGEWASSET RIVER AT PLYMOUTH, N.H.	RS	43 45 33	71 41 10
7233	MERRIMACK RIVER NEAR GOFFS FALLS, N.H.	RS	42 56 54	71 27 52
7214,7331	COLD REGIONS LAB, HANOVER,N.H.	T	VARIABLE	
7246	WACHUSETT MOUNTAIN, MA.	P	42 29 24	71 53 15
6063	IPSWICH RIVER NEAR IPSWICH, MA. (1)	RS	42 39 35	70 53 39
7106	NORTH NASHUA RIVER AT FITCHBURG, MA.	RS	42 34 34	71 47 19
7142	CHICOPEE RIVER AT CHICOPEE FALLS, MA.	WQ	42 09 37	72 34 52
7021	WESTFIELD RIVER AT WEST SPRINGFIELD,MA.	WQ	42 05 59	72 38 28
7207	FRENCH RIVER AT WEBSTER, MA.	WQ	42 03 03	71 53 08
----	NED HEADQUARTERS, WALTHAM, MA.	T	42 23 46	71 12 56
7012	BRANCH RIVER AT FORESTDALE, R.I.	RS	41 59 47	71 33 47
7345	PAUTUXET RIVER AT CRANSTON, R.I.	RS	41 45 03	71 26 44
7254	CONNECTICUT RIVER AT HARTFORD, CT.	RS	41 46 10	72 40 04
7242	CONNECTICUT RIVER NEAR MIDDLETOWN, CT.	RS	41 33 40	72 36 45
7206	PORTER BROOK NEAR MANCHESTER,CT.(2)	RS	41 45 55	72 30 12
7124,6216		(3) RL AT GST GT WP		
7042,7325		(3,4)		
7010,7304,7171,7220,7207,7335		SPARES		

* P - PRECIPITATION
WES - WATER EQUIVALENT OF SNOWPACK
RS - RIVER STAGE
RL - RESERVOIR LEVEL
WQ - WATER QUALITY (TEMPERATURE, CONDUCTIVITY, PH AND DISSOLVED OXYGEN)

AT - AIR TEMPERATURE(S)
GST - GROUND SURFACE TEMPERATURE
GT - GROUND TEMPERATURE(S)
WP - WIND PASSAGE
PV - PARAMETERS VARIABLE
T - TEST SET

(1) DCP BELONGS TO U.S. GEOLOGICAL SURVEY, BOSTON, MA.
(2) DCP ON LOAN TO U.S. GEOLOGICAL SURVEY, HARTFORD, CT.--ON DEMONSTRATION AT THE MANCHESTER NATURE CENTER
(3) DCP ON LOAN TO U.S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LAB, HANOVER, N.H.
(4) NOT YET INSTALLED

FIGURE 9

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U.S ARMY

SUBJECT FIGURE 7a. FILE FORMATS. FILE "PTAE."

COMPUTATION

COMPUTED BY ______ CHECKED BY ______ DATE 8 MARCH 76

```
TYPE PTAE
 64.649159815
 10.0
A   4.82E   0.27;
A   4.42E   0.82;
A   4.00E   1.35;
A   3.57E   1.94;
A   3.11E   2.52;
A   2.64E   3.10;
A   2.14E   3.70;
A   1.63E   4.31;
A   1.09E   4.92;
A   0.53E   5.55;
A359.94E   6.20;
A359.33E   6.85;
A358.68E   7.52;
A358.01E   8.20;
A357.30E   8.89;
A356.55E   9.60;
A355.77E  10.33;
A354.95E  11.06;
A354.09E  11.82;
A353.18E  12.59;
       .
       .
A299.79E  32.49;
A296.44E  32.59;
A293.07E  32.58;
A289.71E  32.46;
       .
       .
A231.57E   7.94;
A230.89E   7.26;
A230.23E   6.59;
A229.61E   5.93;
A229.01E   5.29;
A228.43E   4.66;
A227.88E   4.05;
A227.35E   3.44;
A226.85E   2.84;
A226.36E   2.26;
A225.89E   1.68;
A225.44E   1.12;
A225.00E   0.56;
A224.58E   0.02;
A   0.00E  90.00;
```

JULIAN DATE OF SATELLITE RISE TIME, MEASURED FROM BEGINNING OF CALENDAR YEAR. (points to 64.649159815)

DT, TIME INTERVAL (IN SECONDS) BETWEEN THE FOLLOWING ANGLE PAIRS. (points to 10.0)

PAIRS OF AZIMUTH AND ELEVATION ANGLES

PEAK ELEVATION FOR THIS PASS (points to A296.44E 32.59;)

PAIR OF STOW ANGLES; SENDS ANTENNA TO STOW POSITION (points to last line)

ORIGINAL PAGE IS OF POOR QUALITY

NED FORM 225
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: FIGURE 76. FILE FORMATS. FILE "BCDAZEL"

COMPUTATION

COMPUTED BY ____ CHECKED BY ____ DATE 5 MARCH 76

```
OEDIT BCDAZEL

A
W 6
000001 4
000002 64
000003 91
000004 59
000005 51
000006 5
000007
000010 1.
000011 0<015>
0
12/000202
000013 000004
000014 000047
000015 000000
000016 000170
000017 000004
000020 000062
000021 000000
000022 000164
000023 000004
000024 000070
000025 000000
000026 000151
000027 000004
000030 000103
000031 000000
000032 000145
000033 000004
000034 000111
000035 000000
000036 000141
000037 000004
000040 000124
000041 000000
000042 000127
000043 000004 HOME
```

(000001–000007) JULIAN DATE OF SATELLITE RISE TIME MEASURED FROM BEGINNING OF YEAR

(000010–000011) DT, TIME INTERVAL (IN SECONDS) BETWEEN THE FOLLOWING ANGLE PAIRS

(12/000202) LOW ORDER AZIMUTH
$202_8 = 10000010_2 = 1 \times 8 + 1 \times 10^2 =$ [illegible]$_{10}$

(000013) HIGH ORDER AZIMUTH
$4_8 = 100_2 = 4_{10}$

(000014) LOW ORDER ELEVATION
$47_8 = 100111_2 = 1 \times .2 + 1 \times .04 + 1 \times .02$ [illegible]
$= .27_{10}$

(000015) HIGH ORDER ELEVATION
$0_8 = 0_2 = 0_{10}$

NED FORM 223,
27 Sept 49

NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U.S ARMY

PAGE 3

SUBJECT FIGURE 7c. . FILE FORMATS. FILE "INDX"

COMPUTATION

COMPUTED BY CHECKED BY DATE 8 MAY '76

```
TYPE INDX
7147 7 NINEMILE BRIDGE, ME.
7101 2 DICKEY, ME.
7355 5 ALLAGASH FALLS, ME.
7220 2 FORT KENT, ME.
7071 2 WEST ENFIELD, ME.
7272 2 NORTH ANSON, ME.
7356 2 CORNISH, ME.
7170 3 STINSON MT., N.H.
7127 3 SOUTH MT., N.H.
7201 2 PLYMOUTH, N.H.
7233 2 GOFFS FALLS, N.H.
7331 6 CRREL, HANOVER, N.H.
7246 3 WACHUSETT MT., MA.
6063 2 IPSWICH, MA.
7106 2 FITCHBURG, MA.
7214 1 ERT, LEXINGTON, MA.
7142 4 CHICOPEE, MA.
7021 4 WESTFIELD, MA.
7207 2 NED, WALTHAM, MA.
7010 1 NED, WALTHAM, MA.
7304 2 FORESTDALE, R.I.
7345 2 CRANSTON, R.I.
7254 2 HARTFORD, CT.
7335 2 MIDDLETOWN, CT.
7206 2 MANCHESTER, CT.
R
```

PLATFORM NAME (12A2)

INDEX USED IN "P3" TO DIRECT PROGRAM CONTROL (I1)

PLATFORM ID NO. (I4)

YEAR (LAST DIGIT)

MONTH

DAY

HOUR

MINUTE

SECOND

ERROR CODE

DCP NUMBER

DATA

```
\
\
\
\
TYPE LS2DAT
6 323154149 7220237 633773773773773773377
6 323154415 712737732337737737737737377
6 3231545 2 7355377377377377377350 64377
6 3231545 5 735613712337737737737737377
6 323154510 606333723537737737737737377
6 323154511 7220237 63377377377377377377
6 323154531 7106377314120  0224  0  0  0
6 323154545 7201267 233773773773773773377
6 323154547 720627733737737737737737377
6 323154645 7355377377377377377350 64377
6 323154719 712737732337737737737737377
6 323154725 714237737737727627327633634
6 3231548 6 606333723537737737737737377
6 323154825 735613712337737737737737377
6 323154827 7355377377377377377350 64377
6 323154831 720627733737737737737737377
6 323154832 722023712337737737737737377
6 323154851 7106377314120  0224  0  0  0
6 323154852 7201267 233773773773773773377
6 323155023 712737732337737737737737377
6 323155041E6504  4344 21 17162345300221
6 3231551 2 606333723537737737737737377
6 323155114 720627733737737737737737377
6 323155146 735613712337737737737737377
6 323155154 722023712337737737737737377
6 323155159 7201267 233773773773773773377
6 323155211 7106377314120  0224  0  0  0
6 323155433 714237737737727627327633634
R
```

APPENDIX D - GLOSSARY

ADR - Anlog to digital recorder. Typically a Fisher-Porter or Leupold-Stevens recorder, equipped with a telekit.

Azimuth - Horizontal angle measured clockwise from north.

BCD - Binary Coded Decimal.

Chain - in programming, a call from one program to execute another, thereby terminating its own execution.

Coordinated Universal Time - an observer's local mean solar time plus the number of time zones the observer is west of Greenwich observatory, corrected for aberrations in the spin of the Earth.

Crash - (v.i.) - to cease functioning. Syn. bomb.

CRT - Cathode Ray Tube - Specifically, the Tektronix 4014 terminal connected to the NOVA.

DCP - Data Collection Platform - Field installation used for sensing parameters, encoding data, and transmitting data to satellite.

Disc (or disk) - medium for storage of data in the Data General Computer. Refers to twenty-surface disc pack and drive which is a peripheral device to the computer. Files on the disk are divided into two directories, "DPØ" and "USER". Most system programs are in DPØ, and most user programs are in USER.

Elevation - angle above the plane of the observer's horizon.

Flowchart - diagram that shows flow of control in a computer program. Elements shown are input, output, initializations, processes, decisions, and connectors.

Julian Date - an arbitrary benchmark that is a continuing count of each day elapsed since some particular epoch.

Multi-tasking - in a computer several program tasks competing for devices and the contral processor on a priority or queued basis.

Octal - refers to a number system that has 8 as a base.

Sidereal Time - the relationship between an observer's meridian and some inertial coordinate system, for example, one based on the constellation ARIES.

Real Time Clock - device in the Data General Nova Computer that consists of a crystal controlled clock and associated DG system software that are used (1) to keep track of date and time of day and (2) to provide for low resolution timing.

Tracking - keeping the antenna pointed at the satellite, and in conjunction with that, logging any incoming data.

Universal Time - see Coordinated Universal Time.

ORIGINAL PAGE IS
OF POOR QUALITY

```
TYPE LS1LOAD
RLDR S/K 16/C LS1 T1 T2 T3 T5 WG ANT GARB/L TASKCALL FMT.LB ^
FORT.LB;DELETE/C GARB
R
TYPE LS1
C     LS1   CALLED BY INTERP1 OR EXEC'D BY ITSELF
C     WAITS FOR SATELLITE RISE TIME - ZMIN,
C     ORIENTS ANTENNA, TRACKS SATELLITE, LOGS DATA
C     ACCEPTS CORRECTIONS, DUMPS DATA AT END OF
C     PASS, STOWS ANTENNA IN UPRIGHT POSITION
C     TURNS ON AND OFF CIRCUITRY IN COMMAND
C     EQUIPMENT, CHAINS TO OD3
C  TDB 14 NOV 75
        COMPILER DOUBLE PRECISION
        DIMENSION ID(3),IT(3),IT2(11),IT3(11),IT5(11)
        COMMON/KBLK/IT1(11)
        EXTERNAL T1,T2,T3,T5
        COMMON/KEY/KEY1,KEY2,KEY3,KEY4

C     KEY-'S ARE USED TO PASS MESSAGES AS FOLLOWS:
C         KEY1     T1 TO LS1
C         KEY2     T1 TO WG
C                  WG BACK TO T1
C         KEY3     T5 TO T1
C         KEY4     T1 TO WG         TIME COUNTER

        COMMON/IBLK/DAYSINMO(12)
        DATA DAYSINMO/31.,28.,31.,30.,31.,30.,31.,31.,30.,31.,
     *30.,31./
        ZMIN=1.5/1440.
        CALL DFILW("SDF",IER)
        CALL CFILW("SDF",2,IER)
        CALL OPEN(5,"BCDAZEL",1,IER)
        CALL APPEND(15,"TLOG",3,IER)
        CALL OPEN(12,"STARTANGLE",1,IER)
        CALL OPEN(7,"NANGLES",1,IER)
        CURDATE=0.
        CURTIME=0.
        KEY2=0
        KEY4=0
        CALL TIME(IT,IER)
        IF(IER.NE.1)TYPE "TIMERR",IER
        CURTIME=DFLOAT(IT(1))+(DFLOAT(IT(2))/60.)+(DFLOAT(IT(3))/
     *3600.)
        CALL DATE(ID,IER)
        IF(IER.NE.1)TYPE "DE",IER
        II=ID(1)-1
        DO 6 J=1,II
6       CURDTE=CURDTE+DAYSINMO(J)
        CURDTE=CURDTE+DFLOAT(ID(2))
        IF((ID(3)/4*4.EQ.ID(3)).AND.(ID(1).GT.2))CURDTE=CURDTE+1.
        CURDTE=CURDTE+CURTIME/24.  ;CURRENT JUL TIME SINCE 1 JAN
        READ(5,10,END=100)TSINCE,DT
10      FORMAT(F13.9,F6.1)
        IF(CURDTE.GT.364.)TYPE "RESET EP AND EPYR IN TCALC ON
     *JAN. 1 .SEE MOOD PAGE   FOR MORE INFO"
        IF(CURDTE.LE.(TSINCE-ZMIN))GO TO 50 ;TASK SCHEDULING
        TYPE "U"  ;TOO LATE FOR CURRENT PASS
        CALL CHAIN("TRACK.SV",IER)
        IF(IER.NE.1)TYPE "LS1RD",IER
        CALL EXIT

C       TASKER  T1 SENDS ANGLES,T2 ORIENTS,T3 GATHERS DATA
C       T5 ACCEPTS CORRECTIONS
50      READ(7,51)IT1(2)  ;NO. TIMES TO EXECUTE
C       NOTE THAT IT1(2) IS THE LOC THAT IS MODIFIED BY T5
51      FORMAT(I6)
        XTIME=(TSINCE-IDINT(TSINCE))*24.
        IT1(4)=XTIME  ;STARTING HOUR
        IT1(5)=(XTIME-DFLOAT(IT1(4)))*3600.  ;SECOND WITHIN HOUR
        IT1(6)=3
        IT1(7)=DT
        IT1(11)=100
        CALL FQTASK(DUM,T1,IT1,IER,-1)
        IF(IER.NE.1)TYPE "FQ1",IER
        IMIN=IT1(5)/60
        ISEC=IT1(5)-IMIN*60+.1
        WRITE(10,60)IT1(4),IMIN,ISEC
        WRITE(15,60)IT1(4),IMIN,ISEC
60      FORMAT(" NEXT PASS AT "I2,":",I2,":",I2)
        IT2(2)=1  ;ORIENT ANTENNA ONCE
        XTIME=((TSINCE-ZMIN)-IDINT(TSINCE-ZMIN))*24.
        IT2(4)=IDINT(XTIME)
        IT2(5)=(XTIME-DFLOAT(IT2(4)))*3600.
        IT2(6)=3
        IT2(7)=0
        IT2(11)=200
        CALL FQTASK(DUM,T2,IT2,IER,-1)
        IF(IER.NE.1)TYPE "FQ2",IER
        IT3(2)=1
        IT3(4)=IT1(4)
        IT3(5)=IT1(5)
        IT3(6)=0
        IT3(7)=0
        IT3(11)=300
        CALL FQTASK(DUM,T3,IT3,IER,-1)
        IF(IER.NE.1)TYPE "FQ3",IER
        IT5(2)=1
        IT5(4)=IT1(4)
        IT5(5)=IT1(5)
        IT5(6)=10
        IT5(7)=0
        IT5(11)=500
        CALL FQTASK(DUM,T5,IT5,IER,-1)
        IF(IER.NE.1)TYPE "FQ5",IER
        IONE=0
        CALL REC(KEY1,IONE)
        CALL FDELY(120)  ;WAIT FOR ANT TO RCH STOW POS.
        II=1
        CALL ANT(II,II,II,II,II)  ;TURN OFF CIRCUITRY
        CALL CLOSE(5,IER)
        CALL CLOSE(7,IER)
        CALL CLOSE(12,IER)
        WRITE(10,70)
        WRITE(15,70)
70      FORMAT(/)
        CALL CHAIN("OD3.SV",IER)
        IF(IER.NE.1)TYPE "CHER",IER
100     CALL EXIT
        CALL CLOSE(15,IER)
        END
R
```

28-E-1

```
TYPE T1
C TDB 9 DEC 75
        TASK T1
        COMMON/KEY/KEY1,KEY2,KEY3,KEY4
        COMMON/KBLK/IT1(11)
        DIMENSION I(4)
        I0=0
        KEY4=KEY4+1
        IF(KEY3.GE.0)GO TO 10
        KEY3=KEY3+1
        IT1(2)=IT1(2)+1
        GO TO 25
10      READ BINARY(5)I(1)
        IF(I(1).EQ.-1)GO TO 30  ;END OF FILE?
        READ BINARY(5)(I(J),J=2,4)  ;NO, GET 3 MORE #'S
        CALL ANT(I(1),I(2),I(3),I(4),I0)  ;SEND THEM TO ANT
        IF(KEY3.LE.0)GO TO 25  ;ADJUST IF NECESSARY
        KEY3=KEY3-1
        IT1(2)=IT1(2)-1
        GO TO 10
25      CALL KILL
30      CALL XMT(KEY2,1,$50)  ;TELL WG TO DUMP TO DISC
        IONE=0
        CALL REC(KEY2,IONE)  ;WAIT FOR WG TO FINISH
        CALL XMT(KEY1,1,$50)    ;TELL LS1 EOF HAS BEEN REACHED
        CALL KILL
50      TYPE "XMTERR1"
        CALL EXIT
        END
R
TYPE T2
C TDB 8/7/75
        TASK T2
        DIMENSION J(4)
        CALL APPEND(15,"TLOG",3,IER)
        I0=0
        READ BINARY(12)J  ;GET FIRST ANGLE PAIR
C                          FROM "STARTANGLE"
        IPOINT=1
        GO TO 100  ;GO SEND  PAIR
10      CALL FDELY(30)  ;WAIT FOR ANTENNA TO GET THERE
        DO 20 I=1,21  ;SEND ANTENNA CCW TWICE
        READ BINARY(12)J
        IPOINT=2
        GO TO 100
15      CALL FDELY(21)
20      CONTINUE
        GO TO 21

100     CALL ANT(J(1),J(2),J(3),J(4),I0)
        WRITE(15,120)
        WRITE(10,120)
120     FORMAT(" .",Z)
        GO TO (10,15,25,35),IPOINT
21      DO 30 I=1,9  ;SEND ANTENNA CW ONCE
        READ BINARY(12)J
        IPOINT=3
        GO TO 100
25      CALL FDELY(21)
30      CONTINUE
        READ BINARY(5)J  ;FIRST LOOK ANGLE,
C                         THEN CONTROL GOES TO T1
        IPOINT=4
        GO TO 100
35      WRITE(10,130)
        WRITE(15,130)
130     FORMAT(" !")
        CALL KILL
        CALL CLOSE(15,IER)
        END
R
TYPE T3
        TASK T3
        CALL WG
        CALL KILL
        END
R
TYPE ANT
.TITL ANT
.ENT ANT
.EXTD .CPYL,.FRET
.NREL
I=-167  ;LO AZ
J=I+1   ;HI AZ
K=I+2   ;LO EL
L=I+3   ;HIEL
M=I+4
FS.=5  ;PROG/STDBY SWITCH
FS.
ANT:JSR @.CPYL
STA 3 RTN
LDA 0 @M 3
MOV 0 0 SZR  ;TURN OFF PEDESTAL?
JMP OFF  ;YES
LDA 0 ATB  ;NO, SEND ANGLES
STA 0 TTB
LDA 2 CN4
MOR: LDA 0 @I 3
LDA 1 @TTB
COM 0 0
AND 1 0
COM 0 0
ISZ TTB

DOAS 0 DUC
INC 3 3
INC 2 2 SZR
JMP MOR
BK: LDA 3 RTN
JSR @.FRET

OFF: LDA 0 B0
DOAS 0 DUC
JMP BK

;DATA AREA-------------------
DUC=42
ATB:.+1
B5: 135777  ;0B1+0B5
B4: 133777  ;0B1+0B4
B3: 127777  ;0B1+0B3
B2: 117777  ;0B1+0B2
B0: 1B0+1B2

RTN:.-.
CN4: -4
TTB:.-.
;-----------------------
```

E-28

```
TYPE UG
.TITL UG
.ENT UG
.EXTN .UIEX,.REC,.IXMT,.TASK,.AKILL,.XMT
.EXTD .CPYL,.FRET
.COMM KEY 4  ;LABELLED COMMON AS IN LS
.TXTM 1
.NREL
;DEVICE CONTROL TABLE----------
IDDCT:DCT
DCT:.-.
1B7
ISR42
;-------------------------
;INTERRUPT SERVICE ROUTINE
;RESPONDS TO ONLY ONE INTERRUPT
;FROM 4065 INTFC.  LOADS 5 WORDS IN A
;ROW AS FAST AS DECODER PROVIDES THEM.
;TIMING MATCHES DECODER'S EXACTLY

ISR42: NIOC DVC
STA 2 URTN2
STA 3 URTN3
LDA 0 SYNC
JSR @.TOBUF

LDA 1 CN5

MOR: DIA 0 DVC
JSR @.TOBUF
JSR TMR
INC 1 1 SZR
JMP MOR
JMP OUT

.TOBUF: TOBUF
TOBUF: LDA 2 @.MBP
STA 0 0 2
INC 2 2
STA 2 @.MBP
JMP 0 3

TMR: LDA 2 CN15
INC 2 2 SZR
JMP .-1
JMP 0 3

OUT: LDA 0 @BMESS  ;GET TIME COUNTER
LDA 2 @.MBP
STA 0 0 2  ;STORE TIME WITH MSG
INC 2 2
STA 2 @.MBP

SUB 1 1
LDA 2 URTN2
LDA 3 URTN3

NIOS DVC
.UIEX
;--------------------------


URTN2:.-.
URTN3:.-.

SYNC: 12214
CN5: -5.
CN15: -15.
CN2100:-2100.
CTR:.-.
.MBP: MBP

UG:JSR @.CPYL
STA 2 AC2
STA 3 AC3
SUB 0 0   ;GEN A 0
LDA 2 CN2100
STA 2 CTR
LDA 2 PBUF
STA 0 0 2  ;INIT BUFFER TO ALL 0'S
INC 2 2
ISZ CTR
JMP .-3
LDA 0 DVCN   ;DEFINE 4065 DIGITAL I O BOARD TO SYSTEM
LDA 1 IDDCT
.SYSTM
.IDEF
JMP @.ERT
.SYSTM
.GDAY
JMP @.ERT
MOV 2 3  ;NEXT 7 LINES STORE YR,MO,DAY IN SDF
LDA 2 PBUF
STA 2 MBP
STA 1 0 2
INC 2 2
STA 0 0 2
INC 2 2
STA 2 MBP
.SYSTM
.GTOD
JMP @.ERT
MOV 2 3  ;NEXT 7 LINES STORE HR,MIN,SEC IN SDF
LDA 2 @.MBP
STA 3 0 2
 INC 2 2
STA 1 0 2
INC 2 2
STA 0 0 2
INC 2 2
STA 2 @.MBP
LDA 0 AMESS
SUB 1 1
NIOS DVC
.REC  ;WAIT HERE FOR LAST LOOK ANGLE TO BE SENT
LDA 0 DVCN
.SYSTM
.IRMV
JMP @.ERT
LDA 0 ASDF  ;POINT TO FILE NAME
SUB 1 1  ;DEVICE CHARS
.SYSTM
.APPEND 6
JMP @.ERT
LDA 0 PBUF
MOVZL 0 0  ;BYTE POINTER
LDA 1 C4200  ;BYTE COUNT
.SYSTM
.WRS 6   ;DUMP THE BUFFER
```

```
JMP @.ERT
.SYSTM
.CLOSE 6
JMP @.ERT
LDA 2 AC2
LDA 3 AC3
LDA 0 AMESS
SUBZL 1 1
.XMT
JMP @.ERT
JSR @.FRET

;DATA AREA-------------
AC2:.-.
AC3:.-.
AMESS:.GADD KEY,1  ;POINTS TO 2ND ELEMENT IN LABELLED COMMON,"KEY"
BMESS: .GADD KEY,3   ;POINTS TO TIME COUNTER (SECS) IN T1
ASDF: .+1*2
.TXT "USER:SDF"  ;SATELLITE DATA OUTPUT FILE
C4200: 4200.


DVCN:42
DVC=42
MBP:0   ;MOVABLE BUFFER POINTER
.ERT:ERT
ERT:.SYSTM
.ERTN
PBUF:BUF
BUF:  .BLK 2100.  ;BUFFER FOR 300 MSG*7WDS/MSG
.END UG
R
TYPE TASKCALL
.TITL TASKCALL
.ENT .TASK,.XMT,.XMTW,.REC,.KILL,.OVEX,.TOVLD
.ENT .OVREL,.OVKIL,.QTSK,.PRI,.SUSP,.PEND,.IDST
.ENT .TIDS,.TIDR,.TIDK,.TIDP,.AKILL,.ASUSP
.ENT .ARDY,.APEND,.AUNPD
.EXTN CTASK,XMTT,XMTTW,RECC,KILL,TOVEX,TOVLD,TOVRL,TOVKL
.EXTN TQTSK,TPRI,TPEND,TIDST,STID,RTID,KTID,TIDP
.EXTN TAKIL,TAPEN,TAUNP

.ZREL
.TASK = JSR  @.
CTASK
.XMT = JSR  @.
XMTT
.XMTW = JSR  @.
XMTTW
.REC = JSR  @.
RECC
.KILL = JSR  @.
KILL
.OVEX = JSR  @.
TOVEX
.TOVLD = JSR  @.
TOVLD
.OVREL = JSR  @.
TOVRL
.OVKIL = JSR  @.
TOVKL
.QTSK = JSR  @.
TQTSK
.PRI = JSR  @.
TPRI
.SUSP = JSR  @.
TPEND
.IDST = JSR  @.
TIDST
.TIDS = JSR  @.
STID
.TIDR = JSP  @.
RTID
.TIDK = JSR  @.
KTID
.TIDP = JSR  @.
.AKILL = JSR  @.
TAKIL
.ASUSP = JSR  @.
TAPEN
.ARDY = JSR  @.
TAUNP

;EQUIVALENT RDOS CALLS

.PEND = .SUSP
.APEND = .ASUSP
.AUNPD = .ARDY

.END
R
\
\
.
GTOD
3/23/76   13:4:50
P
```

28-E-4

ORIGINAL PAGE IS
OF POOR QUALITY

```
TYPE TRACKLOAD
RLDR TRACK OT1 TCALC SGP SRV INCT SEMI EXANM PEAK
GARB/L FORT.LB;DELETE/C GARB
R
TYPE TRACK
C         TDB 4DEC75
          COMPILER DOUBLE PRECISION
          DIMENSION TT(6),ID(3)
          CALL FGTIM(I,J,K)
          TT(4)=I
          TT(5)=J
          TT(6)=0
          CALL DATE(ID,IER)
          TT(1)=ID(3)
          TT(2)=ID(1)
          TT(3)=ID(2)
          CALL OT1(TT)
          END
R
TYPE TCALC
C TDB 2/28/75
          COMPILER DOUBLE PRECISION
          SUBROUTINE TCALC(T,TSINCE,THETA,LAMBDA E)
          REAL LAMBDAE
          DIMENSION T(6)
          COMMON /IBLK/DAYSINMO(12)
          EP=2442778.5 ;1 JAN 76
          TWOPI=6.2831853072
          DTHDT=.25068447  ;DTHETA/DT
          EPYR=DFLOAT(76)
          XJD=EP+(T(1)-EPYR)*365. ;ADD 365 DA/YR THRU LAST YR
          N=T(2)-1.
          DO 50 I=1,N  ;DAYS IN MONTH THRU LAST MO
          XJD=XJD+DAYSINMO(I)
50        CONTINUE
          N=T(1)-1.  ;N=LAST YR
          DO 100 I=75,N  ;CHECK FOR LEAP YRS THRU LAST YR
          IF(I/4*4.NE.I)GO TO 100
          XJD=XJD+1.
100       CONTINUE
          N=T(1) ;NOW LOOK AT THIS YR
          IF(N/4*4.NE.N)GO TO 200  ;IS THIS NOT A LEAP YR?
          IF(T(2).LE.2.)GO TO 200  ;ARE WE BEYOND 2/29?
          XJD=XJD+1.  ;YES, ADD A LEAP DAY
200       XJD=XJD+T(3)
C     JULIAN DATE AT INSTANT
          TSINCE=XJD+T(4)/24.+(T(5)+T(6)/60.)/1440.-EP
          DT=T(4)*60. + T(5)+T(6)/60.    ;(HR,MIN,SECS) AS MINS
          TU=(XJD-2415020.0)/36525.
          THETA G0=DMOD((99.6909833+(36000.7689*TU)+.00038702*
     *TU**2),360.)
          THETA G=DMOD((THETA G0+DT*DTHDT),360.)
C     SIDEREAL TIME IN RADIANS
          THETA=(DMOD((THETA G+LAMBDA E),360.))*TWOPI/360.
          RETURN
          END
R
TYPE SEMI
C  TDB 2/28/75
          COMPILER DOUBLE PRECISION
          DOUBLE PRECISION FUNCTION SEMI(EE,XNN,XII)
 COMPUTES THE MEAN (KOZAI) SEMI-MAJOR AXIS OF A SATELLITE
          YY=.3333333333
          XJ2=.00108248
          XMU=11467.25298
          AA=(XMU/XNN**2)**YY
          DD=-1.5*XJ2*((1./AA)**2)/((DSQRT(1.-EE**2))**3)
          DD=DD*(1.-1.5*(DSIN(XII))**2)
          SEMI=AA*(1.+YY*DD-YY*DD**2)
          RETURN
          END
R
TYPE INCT
C  TDB  2/28/75
          COMPILER DOUBLE PRECISION
          SUBROUTINE INCT(T,DT)
          DIMENSION T(6)
          COMMON/IBLK/DAYSINMO(12)
          IF(DT.GE.60.)GO TO 600
          T(6)=T(6)+DT ;INCR SECONDS
          IF(T(6).LT.60.)GO TO 350
          T(6)=T(6)-60. ;RESET SECONDS
600       IF(DT.GE.60.)T(5)=T(5)+DT/60.
          IF(DT.GE.60.)GO TO 700
          T(5)=T(5)+1 ;INCR MINUTES
700       IF(T(5).LT.60.)GO TO 350
          T(5)=T(5)-60.  ;RESET MINUTES
          T(4)=T(4)+1.  ;INCR HOUR
          IF(T(4).LT.24.) GO TO 350
          T(4)=T(4)-24  ;RESET HRS
          I=T(2)  ;PTR TO MO
          T(3)=T(3)+1. ;INCR DAY
          IYR=T(1)
          ILEAP=0
          IF(I.EQ.2.AND.IYR/4*4.EQ.IYR)ILEAP=1
          DAYSINMO(2)=28+ILEAP
          IF(T(3).LE.DAYSINMO(I))GO TO 350
          T(3)=1.  ;RESET DAYS
          DAYSINMO(2)=28.  ;RESET FEB
          T(2)=T(2)+1.  ;INCR MO
          IF(T(2).LE.12.)GO TO 350
          T(2)=1.  ;RESET MO
          T(1)=T(1)+1.  ;INCR YR
350       RETURN
          END
R
TYPE EXANM
C  TDB 2/28/75
          COMPILER DOUBLE PRECISION
          DOUBLE PRECISION FUNCTION EXANM(XMM,ECC)
COMPUTES ECCENTRIC ANOMALY USING KEPLER'S EQUATION
          TWOPI=6.2831853072
          EXANM=DMOD(XMM,TWOPI)
          DO 10 I=1,50
          AA=ECC*DSIN(EXANM)
          DELM=XMM-EXANM+AA
          ZZ=1.-ECC*DCOS(EXANM)
          DELE=DELM/(ZZ+((.5*DELM)/ZZ)*AA)
          IF(DABS(DELE)-1.)30,30,20
20        DELE=DELE/DABS(DELE)
30        EXANM=EXANM+DELE
          IF(DABS(DELE)-.000001)40,10,10
10        CONTINUE
40        CONTINUE
          RETURN
          END
R
GTOD
```

```
TYPE OT1
C         TDB 4DEC75
          COMPILER DOUBLE PRECISION
          SUBROUTINE OT1(T)
          DIMENSION T(6),TS(6)
          REAL I0,IM,N0,NDOT0,M0,NODE0,NODEM,LM,NM,NDOTM,LLONG,
     $L0,NODDT,J2,J3,MU,IS,NODES,LAMBDA E
          EXTERNAL SEMI
          INTEGER YR
          COMMON EPOCH,YR,M0,NODE0,OMEG0,NDOT0,
     $AM,EM,IM,NODEM,OMEGM,LM,NM,NDOTM,E0,N0,I0,L0,A0,
     $ELONG,LLONG,EXLNG,OMEGL,TRUEU,RMAG,RDOT,NODDT,OMGDT,
     $UX,UY,UZ,PX,RY,RZ,RDOTX,RDOTY,RDOTZ
          COMMON/IBLK/DAYSINMO(12)
          DATA DAYSINMO/31.,28.,31.,30.,31.,30.,31.,31.,30.,31.,
     $30.,31./
          CONV=.01745329251 ;DEGREES TO RADS
          ICOUNT=0
          J2=.00108248
          Q=-1.
          JO=1
          AE=1.
          IMANY=0
          X2=0.
          Z=0.
          X=0
          IW=1
          TWOPI=6.2831853072
          CALL APPEND(15,'TLOG',3,IER)
          IF(IER.NE.1)TYPE 'TLER',IER
          CALL OPEN(5,'ELEMENTS',1,IER)
          CALL DFILW('PTAE',IER)
          CALL CFILW('PTAE',2,IER)
          CALL OPEN(4,'PTAE',3,IER)
          IF(IER.NE.1)TYPE 'OE',IER
C INPUT FROM NORAD
          READ(5)EPOCH,NDOT0,I0,NODE0,E0,OMEG0,M0,N0
          OMEG0=OMEG0*CONV
          I0=I0*CONV
          NODE0=NODE0*CONV
          M0=M0*CONV
          N0=N0*TWOPI
          NDOT0=NDOT0*TWOPI
          CALL CLOSE(5,IER)
          IF(IER.NE.1)TYPE "CE",IER
          L0=M0+NODE0+OMEG0
          A0=SEMI(E0,N0,I0)
          TEMP=1.5*N0*J2*(AE/(A0*(1.-E0**2)))**2
          NODDT=-TEMP*DCOS(I0)
          OMGDT=TEMP*(2.-2.5*(DSIN(I0))**2)
          BDT=300.
          SDT=10.
          DT=BDT
          X1=DT
          CALL OPEN(8,"COORD",1,IER)
          IF(IER.NE.1)TYPE "COE",IER
          READ(8)LAMBDA E,G1CSPHI,G2CSPHI,SNPHI,CSPHI,G2SNPHI
          LAMBDA E=LAMBDA E-.99077 ;E.L. CORR TO COINCIDE WITH
C                                     NORAD PREDICTION
          IPASS=1
          WRITE(10,69)
          WRITE(15,69)
69        FORMAT(" SATELLITE RISE TIME    PASS #   PEAK  DURATION")
          DO 25 I=1,6
25        TS(I)=T(I)
20        CALL TCALC(T,TSINCE,THETA,LAMBDA E)
          TSINCE=TSINCE-EPOCH ;NO. OF DAYS SINCE MOST RECENT NORAD
C                                  EPOCH
          CALL SGP(TSINCE)
          CALL SRV(THETA,H,A,G1CSPHI,G2CSPHI,SNPHI,CSPHI,G2SNPHI)
          IF(X2.NE.X1)GO TO 889
          IGO=0
          Z=0
          X=0
          IMANY=IMANY+1
          JO=1
          A=0.0
          STEL=90.00    ;STOW ANGLE
          WRITE(4,339)A,STEL
          IF(IMANY.NE.IPASS)GO TO 990
          CALL CLOSE(4,IER)
          CALL CLOSE(8,IER)
          CALL CLOSE(15,IER)
          CALL CHAIN("INTERP1.SV",IER)
          IF(IER.NE.1)TYPE "LSCE"
          CALL EXIT
CHECK TO SEE IF SATELLITE IS ABOVE THE HORIZON
990       X2=0
889       IF(H.LT.0.)GO TO 250
          IF(Q.GE.0..OR.IFLAG.EQ.1)GO TO 190
          IFLAG=1
          DO 150 I=1,6
150       T(I)=TS(I)
          DT=SDT
          H=Q
          X2=DT
          GO TO 20
190       Q=H
          IOVER=1
          CALL PEAK(IMANY,H,Z,X,ICOUNT,A,DT,IOVER)
          IFLAG=0
          IF(JO.EQ.1)WRITE(15,135)T(4),T(5),T(6)
          IF(JO.EQ.1)WRITE(10,135)T(4),T(5),T(6)
135       FORMAT(1X,2(F3.0"/"),F3.0,Z)
          JO=2
          TSS=TSINCE+EPOCH
          IF(IW.EQ.1)WRITE(4,333)TSS,DT
333       FORMAT(1X,F14.9/1X,F6.1)
          WRITE(4,339)A,H
339       FORMAT(2H A,F6.2,1HE,F6.2,':   ')
          IW=2
290       DO 300 I=1,6
300       TS(I)=T(I)
          CALL INCT(T,DT)
          GO TO 20
250       IF(Q.GT.0.)DT=BDT
          IF(X2.EQ.0)GO TO 887
          IF(Q.GT.0)X2=DT
887       Q=H
          IW=1
          GO TO 290
          END
R
GTOD
3/23/76   16:6:16
R
```

```
TYPE SGP
C SGP BY TDB  -- REV 2 14 75 AT 1430
       COMPILER DOUBLE PRECISION
       SUBROUTINE SGP(TSINCE)
C----THIS ROUTINE COMPUTES SATELLITE POSITION USING A SIMPLIFIED
C    GENERAL PERTURBATIONS METHOD,CLASSICAL MEAN ELEMENTS ARE
C    INPUT;  AND POSITION, VELOCITY, & OSCULATING ELEMENTS ARE
C    RETAINED

       REAL I0,IM,N0,NDOT0,M0,NODE0,NODEM,LM,NM,NDOTM,LLONG,
     $NDOT6,L0,NODDT,J2,J3,MU,IS,NODES
       EXTERNAL EXANM
       INTEGER YR

C      INPUT PARAMETERS
       COMMON EPOCH,YR,M0,NODE0,OMEG0,NDOT0,
     $AM,EM,IM,NODEM,OMEGM,LM,NM,NDOTM,E0,N0,I0,L0,A0,
     $ELONG,LLONG,EXLNG,OMEGL,TRUEU,RMAG,RDOT,NODDT,OMGDT,
     $UX,UY,UZ,PX,PY,RZ,RDOTX,RDOTY,RDOTZ
       J2=.00108248
       J3=-.000002562
       NDOT6=0.
       AE=1.
       MU=1.
       TWOPI=6.2831853072

COMPUTE TIME VARIANT MEAN ELEMENTS AT TSINCE
       TT=TSINCE ;TIME SINCE EPOCH (DAYS)
       DM=N0*TT+NDOT0*TT**2+NDOT6*TT**3 ;CHG IN MEAN ANOMALY
       DOMEG=OMGDT*TT ;D ARG PER
       DNODE=NODDT*TT ;D ASC NODE
       LM=DMOD((L0+DM+DOMEG+DNODE),TWOPI) ;MEAN ORBITAL LNGTUDE
       OMEGM=DMOD((OMEG0+DOMEG),TWOPI) ;A.P.
       NODEM=DMOD((NODE0+DNODE),TWOPI) ;RA OF AN
       IM=I0 ;INCLINATION UNCHNGD
       SINI=DSIN(IM)
       COSI=DCOS(IM)
       NM=N0+2.*NDOT0*TT+3.*NDOT6*TT**2
       AM=A0*(((N0/NM)**.3333333333)**2)
       EM=1.-A0/AM*(1.-E0)
       IF(EM)10,10,20
10     EM=0.00001

COMPUTE AND APPLY LONG PERIODIC TERMS (SUBSRCPTD "L")
20     TEMPL = (J3/J2)*(AE/AM)*SINI/(1.-EM**2)
       AXNL=EM*DCOS(OMEGM)
       AYNL=EM*DSIN(OMEGM)=.5*TEMPL
       ELONG=DSQRT(AXNL**2+AYNL**2)
       OMEGL=DMOD((DATAN2(AYNL,AXNL)),TWOPI); PRESERVE QUAD
C  LONG PERIODIC ON L IS:
       LLONG=DMOD((LM-.25*TEMPL*AXNL*(3.+5.*COSI)/(1.+COSI)),
     $TWOPI)

C  SOLVE KEPLER'S EQUATION AND OTHER TWO-BODY FORMULAE

C  LONG PERIODIC ECC ANOM:
       EXLNG=EXANM(LLONG-OMEGL-NODEM,ELONG)
C TRUE ARG OF LATITUDE:
       TRUEU=2.*DATAN(DSQRT((1.+ELONG)/(1.-ELONG))*(DSIN(.5*
     $EXLNG)/DCOS(.5*EXLNG)))+OMEGL
       RMAG=AM*(1.-ELONG*DCOS(EXLNG)) ;R SUB L
C  TRANSVERSE COMPONENT OF VEL VECTOR
       RVDT=DSQRT(MU*AM*(1.-ELONG**2))*(1./RMAG)
C  RADIAL COMP OF VEL VECTOR
       RMGDT=DSQRT(MU*AM)*ELONG/RMAG*DSIN(EXLNG)

COMPUTE AND APPLY SHORT PERIODIC TERMS

       TEMPS=.25*J2*(AE/(AM*(1.-ELONG**2)))**2 ;PERTURBATION
       SIN2U=DSIN(2.*TRUEU)                     ;CONSTANT
       COS2U=DCOS(2.*TRUEU)
       RMAG=RMAG+TEMPS*SINI**2*COS2U*(AM*(1.-ELONG**2))
       TRUEU=DMOD((TRUEU-.5*TEMPS*(6.-7.*SINI**2)*SIN2U),TWOPI)
       IS=IM+3.*TEMPS*SINI*COSI*COS2U
       NODES=NODEM+3.*TEMPS*COSI*SIN2U

COMPUTE QUANTITIES FOR OUTPUT
       SNODE=DSIN(NODES)
       CNODE=DCOS(NODES)
       SINI=DSIN(IS)
       COSI=DCOS(IS)
       SINU=DSIN(TRUEU)
       COSU=DCOS(TRUEU)
C  UNIT VECTOR POINTING TOWARD SATELLITE:
C    SEE P.104 IN ESCOBAL, "METHODS OF ORBIT DETERMINATION",
C    TO CHECK VALUES
       UX=COSU*CNODE-SINU*SNODE*COSI
       UY=COSU*SNODE+SINU*CNODE*COSI
       UZ=SINU*SINI
C      VX=-SINU*CNODE-COSU*SNODE*COSI
C      VY=-SINU*SNODE+COSU*CNODE*COSI
C      VZ=COSU*SINI
C      WX=SINI*SNODE
C      WY=-SINI*CNODE
C      WZ=COSI
       RX=RMAG*UX
       RY=RMAG*UY
       RZ=RMAG*UZ
C      RDOTX=RMGDT*UX+RVDT*VX
C      RDOTY=RMGDT*UY+RVDT*VY
C      RDOTZ=RMGDT*UZ+RVDT*VZ
C      RDOT=DSQRT(RDOTX**2+RDOTY**2+RDOTZ**2)
       RETURN
       END
P
```

ORIGINAL PAGE IS OF POOR QUALITY

```
TYPE SRV
C       SRV (SLANT RANGE VECTOR) TDB (6/27/75)
C       COMMENTS AFTER LINES IN THIS SUBROUTINE
C       ARE EQUATIONS IN APPENDIX OF ESCOBAL;
        "METHODS OF ORBIT DETERMINATION"
        COMPILER DOUBLE PRECISION
        SUBROUTINE SRV(THETA,H,A,G1CSPHI,G2CSPHI,SNPHI,CSPHI,
     $G2SNPHI)
        REAL I0,IM,N0,NDOT0,M0,NODE0,NODEM,LM,NM,NDOTM,LLONG,
     $L0,NODDT,LX,LY,LZ,LXH,LYH,LZH
        INTEGER YR
        COMMON EPOCH,YR,M0,NODE0,OMEG0,NDOT0,
     $AM,EM,IM,NODEM,OMEGM,LM,NM,NDOTM,E0,N0,I0,L0,A0,
     $ELONG,LLONG,EXLNG,OMEGL,TRUEU,RMAG,RDOT,NODDT,OMGDT,
     $UX,UY,UZ,PX,RY,RZ,RDOTX,PDOTY,RDOTZ
        TWOPI=6.2831853072
        X=(G1CSPHI)*DCOS(THETA)  ;1A.62
        Y=(G1CSPHI)*DSIN(THETA);1A.63
        RHOX=PX+X  ;1A.68
        RHOY=RY+Y  ;1A.69
        RHOZ=RZ+G2SNPHI  ;1A.70
        RHOH=DSQRT(RHOX**2+PHOY**2+RHOZ**2)  ;1A.71
        LX=RHOX/RHOH ;UNIT VECTOR FROM SITE  1A.72 TO SATELLITE
        LY=RHOY/RHOH ;DITTO 1A.73
        LZ=PHOZ RHOH; DITTO  1A.74
        COSTH=DCOS(THETA)
        SINTH=DSIN(THETA)
        LXH=LX*SNPHI*COSTH+LY*SNPHI*SINTH-LZ*CSPHI  ;1A.75
        LYH=-LX*SINTH+LY*COSTH  ;DITTO
        LZH=LX*COSTH*CSPHI+LY*SINTH*CSPHI+LZ*SNPHI  ;DITTO
        COSH=DSQRT(1.-LZH**2)
        H=DATAN(LZH/COSH) ;1A.76 IN MOOD
CORRECTION FOR REFRACTION FOLLOWS ;COURTESY OF RALPH RHSS (GSFC)
        H=H+.0007*DCOS(H)/(DSIN(H)+DSQRT(.04+(DSIN(H))**2))
        H=360.*H/TWOPI ;+ OP - DEGREES FROM HORIZON
        A=DATAN2(LYH,-LXH)  ;1A.77
        A=360.*A TWOPI ;DEGREES CW FROM NORTH
        IF(A.LT.0.)A=A+360.  ;ADJUST COORDINATE SYSTEMS
        RETURN
        END
R
```

```
TYPE PEAK
C  JHB  6/30/75
        COMPILER DOUBLE PRECISION
        SUBROUTINE PEAK(IMANY,H,Z,X,ICOUNT,A,DT,IOVER)
        CALL APPEND(15,"TLOG",3,IER)
        ICOUNT=ICOUNT+1
        IF(H.LT.Z)GO TO 333
        Z=H
        RETURN
333     IF(X.EQ.1)GO TO 1
        IM=IMANY+1
        NUM=ICOUNT-1
        ZNUM=NUM
        XNUM=(ZNUM*2*DT) 60.
        IF(IOVER.EQ.0)GO TO 10
        IF(Z.EQ.0 .OR.X.EQ.0)WRITE(15,222)IM,Z,XNUM
10      IF(Z.EQ.0 .OR.X.EQ.0)WRITE(10,222)IM,Z,XNUM
222     FORMAT(11X,I3,5X,F7.2,2X,F5.0/ )
        X=1
        IF(Z.LT.15.AND.A.LT.0)CALL FCHAN("WAIT20.SV")
1       CONTINUE
        CALL CLOSE(15,IER)
        RETURN
        END
R
STOD
3/23/76   16:20:9
R
```

ORIGINAL PAGE IS OF POOR QUALITY

```
TYPE P3

C  RMC 8 JAN 76
      DIMENSION IDX(14,25),ITEMP1(6),ITEMP2(12)
      COMMON/JBLK/NUM(24),SUM(12),X(8),JBIN(9),LBIN(3)
      COMMON/JBLK/J,K,S,F,JX,IX,NAME(12),CHK
      COMMON/JBLK/COND,DOX,TEMP,PH
      CALL DFILW('DATA',IER)
      CALL CFILW('DATA',2,IER)
      CALL APPEND(5,'DATA',3,IER)
      CALL APPEND(6,'TLOG',3,IER)
      CALL OPEN(7,'INDX',1,IER)
      CALL OPEN(8,'DIRC',1,IER)
      CALL OPEN(9,'LS2DAT',1,IER)
      IF(IER.NE.1)TYPE'OE= ',IER
      WRITE(6,21)
      WRITE(10,21)
21    FORMAT(1X,'PID ',2X,'STATION NAME',9X,'DATE',6X,'EST',/)
      IX=0
      READ(7,16)IDX
16    FORMAT(I4,1X,I1,1X,12A2)
4     IFLG=0
      READ(8,10,END=150)IPD
10    FORMAT(I4)
6     READ(9,18,END=11)ITEMP1,IPID,ITEMP2
18    FORMAT(6A2,I4,12A2)
      IF(IPID.EQ.IPD)WRITE(5,19)ITEMP1,IPID,ITEMP2
      IF(IPID.EQ.IPD)IFLG=IFLG+1
19    FORMAT(1X,6A2,I4,12A2)
      GO TO 6
11    REWIND 9
      IF(IFLG.EQ.0)GO TO 39
      CALL CLOSE(5,IER)
      CALL OPEN(5,'DATA',1,IER)
      DO 15 IW=1,IFLG
      READ(5,20,END=145)IY,IMO,IDD,IHH,MM,ISS,IEPR,IPID,NUM
20    FORMAT(I1,5I2,A1,I4,24I1)
      IF(IERR.EQ.17696)GO TO 15
      CALL WTII(IY,IMO,IDD,IHH,MM,ISS)
      DO 30 I=1,25
      IF(IDX(1,I).EQ.IPID)GO TO 40
30    CONTINUE
40    IND=IDX(2,I)
      DO 45 J=3,12
      K=J-2
45    NAME(K)=IDX(J,I)
      WRITE(6,48)IPID,NAME,IMO,IDD,IY,IHH,MM
      WRITE(10,48)IPID,NAME,IMO,IDD,IY,IHH,MM
48    FORMAT(1X,I4,1X,12A2,1X,I2,'/',I2,'/',I2,1X,I2,':',I2,Z)
      CHK=0.
      GO TO(61,62,63,64,65,66,67,68,69)IND
61    WRITE(6,51)
      WRITE(10,51)
51    FORMAT(3X,'TEST SET')
      GO TO 15
62    CALL ERTDA
C     IF(CHK.EQ.1.)GO TO 125
      WRITE(6,54)S
      WRITE(10,54)S
54    FORMAT(3X,'STG=',F6.2)
      GO TO 15
63    CALL ERTDA
C     IF(CHK.EQ.1)GO TO 125
      WRITE(6,55)S
      WRITE(10,55)S
55    FORMAT(3X,'PRC=',F6.2)
      GO TO 15
64    COND=0
      DOX=0

      TEMP=0
      PH=0
      CALL WTQLY
      IF(CHK.EQ.1.)GO TO 125
      WRITE(6,56)COND,DOX,TEMP,PH
      WRITE(10,56)COND,DOX,TEMP,PH
56    FORMAT(3X,'CD=',F6.1,2X,'DO=',F6.3,/,
     ?43X,'WT=',F6.2,2X,'PH=',F6.3)
      GO TO 15
65    CALL SNOP(NUM,IND,DEPTH)
C     IF(CHK.EQ.1)GO TO 125
      WRITE(10,57)DEPTH
      WRITE(6,57)DEPTH
57    FORMAT(3X,'WES=',F7.3)
      GO TO 15
66    WRITE(6,58)
      WRITE(10,58)
58    FORMAT(3X,'CRREL')
      GO TO 15
67    CALL ERTDA
      CALL SNOP(NUM,IND,DEPTH)
C     IF(CHK.EQ.1)GO TO 125
      WRITE(6,59)S,DEPTH
      WRITE(10,59)S,DEPTH
59    FORMAT(3X,'STG=',F6.2,2X,'WES=',F7.3)
      GO TO 15
68    CALL ERTDA
      COND=0
      DOX=0
      TEMP=0
      PH=0
      CALL WTQLY
C     IF(CHK.EQ.1)GO TO 125
      WRITE(6,60)S,COND,DOX,TEMP,PH
      WRITE(10,60)S,COND,DOX,TEMP,PH
60    FORMAT(3X,'STG=',F6.2,/,43X,'CD=',F6.1,2X,'DO=',F6.3,
     ?/,43X,'WT=',F6.2,2X,'PH=',F6.3)
      GO TO 15
69    WRITE(6,52)
      WRITE(10,52)
52    FORMAT(3X,'DEMO. SET')
      GO TO 15
125   WRITE(6,130)
      WRITE(10,130)
130   FORMAT(6X,'INVALID')
15    CONTINUE
39    DO 152 IQ=1,25
      IF(IDX(1,IQ).EQ.IPD)GO TO 154
152   CONTINUE
      GOTO 4
154   DO 156 JQ=3,12
      KQ=JQ-2
156   NAME(KQ)=IDX(JQ,IQ)
      IF(IFLG.EQ.0)WRITE(6,160)IPD,NAME
      IF(IFLG.EQ.0)WRITE(10,160)IPD,NAME
160   FORMAT(1X,I4,1X,12A2,4X,'NO REPORT')
```

38-E-10

```
145     REWIND 5
        GO TO 4
150     CONTINUE
        CALL CLOSE(5,IER)
        CALL DFILW('DATA',IER)
        CALL CFILW('DATA',2,IER)
        CALL CLOSE(6,IER)
        CALL CLOSE(7,IER)
        CALL CLOSE(8,IER)
        CALL CLOSE(9,IER)
        WRITE(10,200)
200     FORMAT(//////)
        CALL CHAIN('TRACK.SV',IER)
        IF(IER.NE.1)TYPE'CE= ',IER
        STOP
        END
R
TYPE ERTDA
        SUBROUTINE ERTDA
        COMMON/JBLK/NUM(24),LBIN(3),JBIN(9),X(8),SUM(12)
        COMMON/JBLK/J,K,S,F,JX,IX,NAME(12),CHK
        COMMON/JBLK/COND,DOX.TEMP,PH
        JJ=3
        S=0
        F=1.
        J1=1
30      J2=J1+2
        K=-3
        T=0.005
        DO 10 I=J1,J2
        IF(NUM(I).GT.7) GO TO 40
        K=K+3
        CALL DCBRY(LBIN.NUM(I),JJ)
        DO 10 L=1,3
        J=L+K
10      JBIN(J)=LBIN(L)
        K1=2
        DO 20 I=2,9
        IF(I-6)31,32,31
32      F=10.*F
        T=0.005
        K1=6
31      IF(JBIN(I))20,25,20
25      T1=F*2.**(I-K1)
        T=T+T1
        IF(F*10.-T)40,26,26
26      S=S+T1
20      CONTINUE
        J1=4
        F=.01
        IF(J2-4)30,40,40
        RETURN
40      CHK=1.
        RETURN
        END
R
TYPE BINA1
C D C  1/1/75
        SUBROUTINE BINA1
        COMMON/JBLK/NUM(24),SUM(12),X(8),JBIN(9),LBIN(3)
        COMMON/JBLK/J,K,S,F,JX,IX,NAME(12),CHK
        COMMON/JBLK/COND,DOX,TEMP,PH
        K=-3
        DO 10 I=1,3
        IX=3*JX-(3-I)+6
        IF(NUM(IX)-7)45,45,55
45      K=K+3
        CALL DCBRY(LBIN,NUM(IX),3)
        DO 10 L=1,3
        J=L+K
        JBIN(J)=LBIN(L)
10      CONTINUE
55      RETURN
        END
R
TYPE BINE1
        SUBROUTINE BINE1
        COMMON/JBLK/NUM(24),SUM(12),X(8),JBIN(9),LBIN(3)
        COMMON/JBLK/J.K,S,F,JX,IX,NAME(12),CHK
        COMMON/JBLK/COND,DOX,TEMP,PH
        DO 45 I=2,9
        M=I-1
        IF(JBIN(I))40,10,40
10      IF(I-6)20,30,30
20      X(M)=2**(5-I)
        GO TO 45
30      X(M)=2**(9-I)
        GO TO 45
40      X(M)=0
45      CONTINUE
        M=0
        DO 80 N=1.2
        M=2*JX-(2-N)
        SUM(M)=0
        DO 60 L=1,4
        LX=4*N-(4-L)
        SUM(M)=SUM(M)+X(LX)
        X(LX)=0
60      CONTINUE
        IF(SUM(M)-10)80,70.70
70      K=2
80      CONTINUE
        RETURN
        END
R
TYPE DCBRY
C   D C 1/1/75
        SUBROUTINE DCBRY(LBIN.NUM,JJ)
        DIMENSION LBIN(4)
        DO 10 I=1,JJ
10      LBIN(I)=0
        IF(NUM)5,5,35
35      DO 30 KK=1,NUM
        DO 15 I=1.JJ
        J=JJ-I+1
        IF(LBIN(J))20,20,15
15      CONTINUE
20      DO 25 I=J,JJ
25      LBIN(I)=0
        LBIN(J)=1
30      CONTINUE
5       RETURN
        END
R
```

```
TYPE UTQLY
        SUBROUTINE UTQLY
        COMMON/JBLK/NUM(24),SUM(12),X(8),JBIN(9),LBIN(3)
        COMMON/JBLK/J,K,S,F,JX,IX,NAME(12),CHK
        COMMON/JBLK/COND,DOX,TEMP,PH
        DO 25 JX=1,6
        CALL BINA1
        CALL BINB1
25      CONTINUE
        IF(K-6)10,30,30
30      COND=0
        DOX=0
        PH=0
        TEMP=0
        COND=1.5*(100*SUM(4)+10*SUM(1)+SUM(2))
        DOX=0.02*(100*SUM(11)+10*SUM(12)+SUM(3))
        PH=0.014*(100*SUM(5)+10*SUM(6)+SUM(7))
        TEMP=0.04*(100*SUM(8)+10*SUM(9)+SUM(10))
        RETURN
10      CHK=1.
        RETURN
        END
R
TYPE UTII
C  RMC 13 JAN 76
C CONVERTS ZULU TIME TO EASTERN STANDARD TIME (EST)
        SUBROUTINE UTII(IY,IMO,IDD,IHH,MM,ISS)
        INTEGER DAYSINMO
        COMMON/IBLK/DAYSINMO(12)
        DATA DAYSINMO/31,29,31,30,31,30,31,31,30,31,30,31/
        IHH=IHH-5
        IF(ISS.GE.30)MM=MM+1
        IF(MM.GE.60)IHH=IHH+1
        IF(MM.GE.60)MM=MM-60
        IF(IHH.LT.0)IDD=IDD-1
        IF(IHH.LT.0)IHH=IHH+24
        IF(IDD.LT.1)IMO=IMO-1
        IF(IMO.LT.1)IMO=IMO+12
        IF(IDD.LT.1)IDD=DAYSINMO(IMO)
        IY=IY+70
        RETURN
        END
R
TYPE SNOP
        SUBROUTINE SNOP(NUM,I,DEPTH)
        DIMENSION NUM(24)
        CRCT=6.98
        IF(I.EQ.5)CRCT=3.92
        D6=64*NUM(16)+8*NUM(17)+NUM(18)
        D7=64*NUM(19)+8*NUM(20)+NUM(21)
        DEPTH=(D7/D6)*55.36-CRCT
        RETURN
        END
R
\
\
\
\
\
\
\
\
\
\
```

```
TYPE LSTGE
C   SUBROUTINE TO CALCULATE DISCHARGES AND VALIDITY FROM
C   VALUES OF STAGE AND STATION NUMBER

        SUBROUTINE LSTGE(ISN,STAGE,Q,NAME,DA,J)
        DIMENSION DISCH(44),NAME(10)
        COMMON/KBLK/LS1(16)
        DATA LS1/7147,7101,7220,7071,7272,7356,7201,7233,
     $6063,7106,7304,7345,7254,7335,7206,6504/

        DO 85 N=1,16
        IF(LS1(N).EQ.ISN)GO TO 8
85      CONTINUE
        GO TO 285
8       NN=N-1
        CALL FSEEK(13,NN)

C   T=INITIAL STAGE IN TABLE;  Q=STAGE INCREMENT IN 2ND LINE

        READ(13,3)NAME,DA,T,Q,DISCH
3       FORMAT(6X,10A2,24X,F6.0,12X,F6.0,6X/(3X,9F8.0))
C   J=0 FOR VALID OR    J=1 FOR NON VALID STAGE
        J=0
        IF(Q)50,50,21 ;FOR DUMMY FILE, INCRMNT (Q) WILL BE 0
21      IF(STAGE-T)51,22,22
51      Q=-.005
        GO TO 285
22      DO 60 N=1,43
        S=STAGE -T-N*Q
        R=(S+Q)/Q
        Z=DISCH(N)
        P=DISCH(N+1)-Z
        IF(P)24,60,65
65      IF(S)70,70,60
C     INTERPOLATE ON RATING TABLE
70      IF(Z)52,52,700
52      IF(R)51,152,152
152     Q=P*(P**1.5)
        GO TO 50
700     Q=Z+P*P+.005
        GO TO 50
60      CONTINUE
C     EXTRAPOLATE ON RATING TABLE
24      Q=Z+P*(Z-DISCH(N-1))+.005
285     J=1
50      RETURN
        END
P
```

```
TYPE QD3
C  TDB 10 MARCH 76
C   PROGRAM TO CONVERT LANDSAT MSGS TO NASA-LIKE
C  FORMAT.  THIS PROVIDES INPUT TO "P" OR "P3"
C  PROGRAM ACCEPTS MSGS FROM ALL DCP'S AND SCREENS OUT
C  THOSE WHICH ARE NOT NED'S
       DIMENSION IA(6),IB(12)

       CALL APPEND(15,"TLOG",3,IER)
       IF(IER.NE.1)TYPE "QLER",IER
       CALL OPEN(5,"USER:SDF",1,IER)
       CALL DFILW("LS2DAT",IER)
       CALL CFILW("LS2DAT",2,IER)
       CALL OPEN(6,"LS2DAT",3,IER)
       CALL APPEND (7,"STORAGE",3,IER)

       IF(IER.NE.1)TYPE "OPENERR"
       WRITE(10,10)
       WRITE(15,10)
10     FORMAT(//)
       ICOUNT=0
       ICT=0
       IYR=6
       READ BINARY (5)IMONTH,IDAY,IHR,IMIN,ISEC  ;GET STARTING TIME
       ISEC=ISEC+60*IMIN
1      READ BINARY(5)IA,ISC   ;GET DATA AND SECONDS COUNTER
       ISC=ISC+ISEC-ICT*3600
       IF(ISC.LT.3600)GO TO 4
       ICT=ICT+1
       ISC=ISC-ICT*3600
       IHR=IHR+1
       IF(IHR.GE.24)IHR=IHR-24
4      IMIN=(ISC/60)
       ISC=ISC-60*IMIN
       IF(IMIN.LT.60)GO TO 5
       IMIN=0
       IHR=IHR+1
       IF(IHR.LT.24)GO TO 5
       IDAY=IDAY+1
       IHR=0
5      CONTINUE
       IF(IA(1).EQ.0)GO TO 100
       ICOUNT=ICOUNT+1

       DO 20 I=3,6
       ID=IA(I).AND.377K
       IC=ISHFT(IA(I),-8)
       IC=IC.AND.377K
       J=I*2-1
       IB(J)=IC
       J=J+1
       IB(J)=ID
20     CONTINUE

       ICHK=IA(2).AND.20000K
       IA(2)=IA(2).AND.7777K  ;STRIP EVERTHING BUT THE DCP #

       IF(IA(2).EQ.6063K.OR.IA(2).EQ.6504K)GO TO 25
       IF(IA(2).LT.7000K)GO TO 1
       IF(IA(2).EQ.7627K)GO TO 1
       IF(IA(2).EQ.7514K)GO TO 1
       IF(IA(2).EQ.7346K)GO TO 1

25     IER=8224  ;ASSUME NO ERROR, OUTPUT A BLANK
       IF(ICHK.GT.1)IER=17696  ;IF ERR IS FLAGGED OUTPUT AN "E"
       WRITE(6,35)IYR,IMONTH,IDAY,IHR,IMIN,ISC,IER,IA(2),(IB(K),K=
5,12)
       WRITE(10,35)IYR,IMONTH,IDAY,IHR,IMIN,ISC,IER,IA(2),(IB(K),K
=5,12)
       WRITE(15,35)IYR,IMONTH,IDAY,IHR,IMIN,ISC,IER,IA(2),(IB(K),K
=5,12)
       WRITE(7,35)IYR,IMONTH,IDAY,IHR,IMIN,ISC,IER,IA(2),(IB(K),K=
5,12)
       CONTINUE
35     FORMAT(1X,I1,5I2,A1,O14,8O13)
       GO TO 1

100    CALL CLOSE(5,IER)
       CALL CLOSE(6,IER)
       WRITE(10,120)ICOUNT
       WRITE(15,120)ICOUNT
120    FORMAT(" TOTAL NUMBER OF MESSAGES = ",I3)
       WRITE(10,110)
       WRITE(15,110)
110    FORMAT(/ //)
       CALL CHAIN("P3.SV",IER)
       IF(IER.NE.1)TYPE "QDER",IER
       CALL EXIT
       END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
TYPE LS2DIS
1 46 ST JOHN R,NINEMILEBR                              1290.              0.
2 46       0.3      43      84     147     243      375     546     766    1060
3 46      1420    1810    2240    2720    3290     3950    4700    5540    6420
4 46      7380    8410    9520   10700   11900    13000   14200   15400   16600
5 46     17800   19200   20600   22100   23600    25200   26700   28300   29300
6 46     31600   33200   35000   35600   36200    36800   37400   38000   38600
1 47 ST JOHN R. DICKEY                                 2700.             3.5
2 47       0.5     160     560    1140    2020     3120    4450    6050    7800
3 47      9800   11800   13800   16100   18600    21000   23600   26400   29700
4 47     32900   36200   39400   42700   46600    50100   54200   58700   63200
5 47     67700   72200   76700   81200   85700    90200   94700   99200       0
6 47         0       0       0       0       0        0       0       0       0
1 48 ST JOHN R, FORT KENT                              5630.             0.5
2 48       1.0     450    1280    2280    3600     5310    7494   10100   13000
3 48     16000   19700   23700   28000   33000    38000   44000   50000   56500
4 48     63500   71000   79000   87000   95000   140000  113000  123000  133000
5 48
6 48
1 49 PENOBSCOT, W.ENFIELD                              6670.              1.
2 49       0.5    1860    2660    3590    4630     5750    6960    8270    9700
3 49     11200   12900   14600   16600   18600    20700   23000   25500   28000
4 49     30700   33500   36500   39500   42500    45500   49000   52500   56200
5 49     60000   63900   67800   71800   75900    80000   84000   88200   92500
6 49     97000  101500  106200  111000  116000   121000  126000  131000  136500
1 50 CARABASSET R, N.ANSON                              354.              2.
2 50       0.5       0      50     128     270      490     795    1160    1550
3 50      2030    2590    3230    3880    4530     5270    6070    6870    7670
4 50      8520    9400   10300   11200   12200    13100   14100   15000   16000
5 50     17000   18100   19200   20300   21400    22600   23700   24800   26000
6 50     27200   28500   29800   31000   32300
1 51 SACO R, CORNISH                                   1298.              1.      7
2 51       0.5     215     351     531     761     1060    1440    1930    2550
3 51      3240    4040    4950    5950    7000     8130    9360   10600   11700
4 51     12900   14100   15400   16600   17900    19200   20500   21800   23200
5 51     24500   25800   27200   28600   29900    31200   32600   34000   35300
6 51     36700   38100   39500   40900   42400    43800   45300   46800   48300
1 32 PLYMOUTH             3 2 3 1                  622.0     0.0  11.0  -1.0  12.6
02 32       .5              50     193     430      980    1780    2340    2790
3 32      3250    3750    4290    4360    5430     6160    6900    7710    8580
4 32      9480   10410   11360 12350.0 13350.0  14350.0 15370.0 16420.0 17470.0
5 32   18570.0 19670.0 20770.0 21900.0 23050.0  24200.0 25400.0 26500.0 27850.0
6 32   29100.0 30350.0 31650.0 32960.0 34310.0  35710.0   37110   38510   39910
1  9 GOFFS FALLS          4 2 3 7                 3092.0     0.0   12.   1.0   14.
2  9       1.0   115.0   454.0  1110.0  2330.0   4780.0  8200.0 12500.0 17240.0
3  9   22040.0 26840.0 31640.0 36440.0 41240.0  46040.0 50840.0 55640.0 60440.0
4  9   65240.0 70040.0 74800.0 79400.0 84000.0  83800:0 93600.0 98400.0103200.0
5  9  108000.0113000.0118000.0123000.0128000.0133000.0138000.0143000.0148000.0
6  9  153000.0     0.0     0.0     0.0     0.0      0.0     0.0     0.0     0.0
1 52 IPSWICH R, IPSWICH                                 124.             2.0
2 52       0.2       0    0.76    3.39    17.5       32      52      82     122
3 52       174     240     325     430     550      685     825     950    1055
4 52      1150    1240    1340    1440    1540     1640    1740    1845    1955
5 52      2065    2175    2290    2410    2530     2670    2810       0       0
6 52         0       0       0       0       0        0       0       0       0
1 53 N.NASHUA R,FITCHBURG                               63.6
2 53       0.2      17      31      52      80      120     175     242     323
3 53       416     530     650     770     890     1010    1130    1260    1400
4 53      1540    1680    1820    1980    2140        0       0       0       0
5 53         0       0       0       0       0        0       0       0       0
6 53         0       0       0       0       0        0       0       0       0
1 55 BRANCH R, FORESTDALE                               91.2            1.60
2 55       0.4       6      26      65     122      200     299     421     560
3 55       720     880    1040    1215    1395     1580    1780    1985    2205
```

```
4 55       2425      2650      2890         0         0         0         0         0         0
5 55          0         0         0         0         0         0         0         0         0
6 55          0         0         0         0         0         0         0         0         0
1 56 PAWTUXET R, CRANSTON                                  200.                3.2
2 56        0.2        19        47        89       140       207       287       368       450
3 56        530       605       675       740       800       860       925       995      1065
4 56       1135      1205      1275      1345      1415      1485      1555      1625      1695
5 56       1765      1835      1910      1990      2070      2150      2230      2310      2390
6 56       2470      2550      2630      2715      2305      2895      2985      3075      3165
1 19 HARTFORD              4 1 9 1                       10480    0.0  16.0    0.0   22.0
2 19        1.0       0.0    2000.0    4000.0    7000.0   10000.0   12000.0   16000.0   20000.0
3 19    23000.0   28000.0   32000.0   37000.0   42000.0   47000.0   54000.0   60000.0   66000.0
4 19    71000.0   80000.0   88000.0   96000.0105000.0114000.0124000.0134000.0143000.0
5 19  153000.0162000.0172000.0182000.0192000.0203000.0214000.0226000.0237000.0
6 19  250000.0267000.0295000.0       0.0       0.0       0.0       0.0       0.0       0.0
1 45 CONN. R, MIDDLETOWN                                  10882.
2 45
3 45
4 45
5 45
6 45
1 57 MANCHESTER, CONN.                                    1.
2 57          0         0         0         0         0         0         0         0         0
3 57          0         0         0         0         0         0         0         0         0
4 57          0         0         0         0         0         0         0         0         0
5 57          0         0         0         0         0         0         0         0         0
6 57          0         0         0         0         0         0         0         0         0
1 58 ST. FRANCIS R., N.B.                                 1.
2 58          0         0         0         0         0         0         0         0         0
3 58          0         0         0         0         0         0         0         0         0
4 58          0         0         0         0         0         0         0         0         0
5 58          0         0         0         0         0         0         0         0         0
6 58          0         0         0         0         0         0         0         0         0
R
```

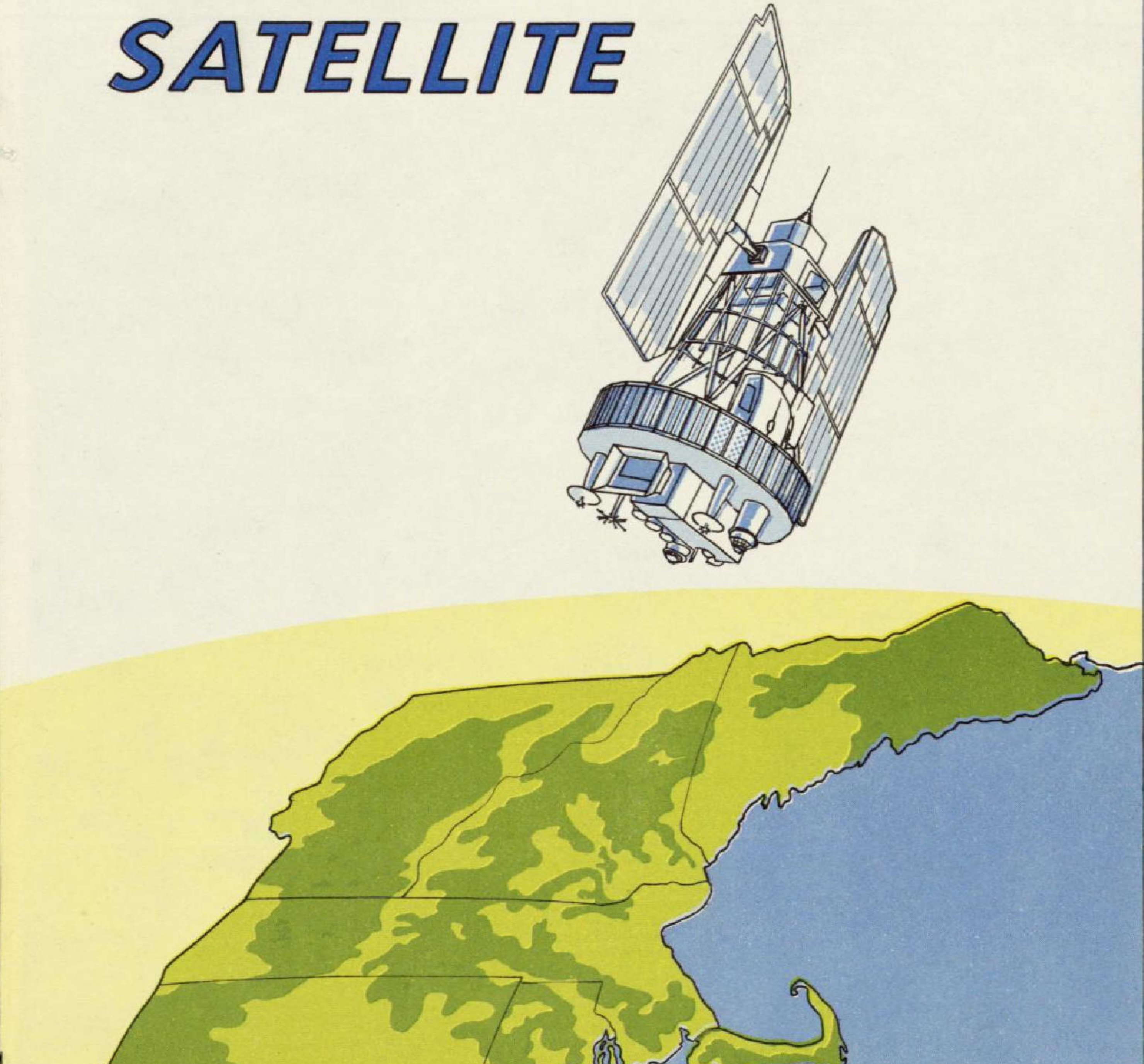
```
TSS
C  TDB 4 DEC 75    PROGRAM TO CONVERT DECIMAL AZIMUTH AND
C      ELEVATION ANGLES TO BCD SUITABLE FOR INPUT TO
C      INTERFACE
C     TO 1845 DIGITAL COMPARATOR
         COMPILER DOUBLE PRECISION
         DIMENSION X1(2),X2(2),IBCDH(2),IBCDL(2)
         COMMON IBLK/BCDHIGH(10),BCDLOW(8),ISTOW(5)
         DATA BCDHIGH/200.,100.,80.,40.,20.,10.,8.,4.,2.,1./
C     BCD TABLE
         DATA BCDLOW/.8,.4,.2,.1,.08,.04,.02,.01/

C    STOW ANGLES AND FILE ENDER
         DATA ISTOW/0,0,200K,211K,-1/

         CALL OPEN(5,"PTAE",1,IER)
         CALL OPEN(6,"BCDAZEL",3,IER)
         CALL OPEN(7,"NANGLES",3,IER)
         IF(IER.NE.1)TYPE "OE",IER
         M1=-1
         D1=1

         READ(5,6,END=500)TSINCE  ;READ 1ST REC ON FILE
         READ (5,7)DT,X2
6        FORMAT(F14.9)
7        FORMAT(F5.1/2(1X,F6.2))
         IFIN=DT
         WRITE(6,11)TSINCE,D1
         ICT=1
         IFLG=0
11       FORMAT(F14.9,F6.1)
         GO TO 109

15       IFLG=0
         IF(ABS(X2(1)-X1(1)).GT.300)IFLG=1
         IF(IFLG.EQ.1)X2(1)=X2(1)-360.
         X1INC=(X2(1)-X1(1))/DT
         X2INC=(X2(2)-X1(2))/DT

         DO 105 INC=1,IFIN
         DO 100 I=1,2    ;AZ ,EL
         X=X1(I)
         IHIGH=0
         ILOW=0
         DO 30 J=1,10
         IF(BCDHIGH(J).LE.X)GO TO 20   ;CHECK BCD TABLE
         GO TO 30   ;SMALLER THAN VALUE IN TABLE

20       X=X-BCDHIGH(J)   ;>=VALUE IN TABLE
         II=J+2-(J-1)*2
C PREVIOUS LINE IS MAPPING FROM DO LOOP INDEX TO BIT POS
         CALL ISET(IHIGH,II)   ;BIT ORDER ON P.9-11 OF FORT IV
30       CONTINUE

         DO 50 J=1,8
         IF(BCDLOW(J).LE.X)GO TO 40
         GO TO 50
40       X=X-BCDLOW(J)
         II=J+6-(J-1)*2   ;BIT MAPPING
         CALL ISET(ILOW,II)
50       CONTINUE
         IBCDH(I)=IHIGH
         IBCDL(I)=ILOW
100      CONTINUE
         WRITE BINARY(6)IBCDL(1),IBCDH(1),IBCDL(2),IBCDH(2)
         ICT=ICT+1
         X1(1)=X1(1)+X1INC
         IF(X1(1).GE.0)GO TO 201
         X1(1)=X1(1)+360.
201      X1(2)=X1(2)+X2INC
         IF(X1(1).GT.360.)X1(1)=X1(1)-360.   ;PROB NOT NEEDED,B
UT..

105      CONTINUE
109      IF(IFLG.EQ.1)X2(1)=X2(1)+360.
         X1(1)=X2(1)
         X1(2)=X2(2)
         READ(5,110)X2
110      FORMAT(2(1X,F6.2))
         IF(X2(1).EQ.0.AND.X2(2).EQ.90)GO TO 120
         GO TO 15
120      WRITE BINARY (6)ISTOW
         WRITE(7,700)ICT
700      FORMAT(1X,I6)
500      CALL CLOSE(5,IER)
         CALL CLOSE(6,IER)
         CALL CLOSE(7,IER)
         CALL CHAIN("LS1.SV",IER)
         IF(IER.NE.1)TYPE"INTERP1ERR",IER
         STOP
         END
*
```

APPENDIX F - LITERATURE CITED AND RELATED DOCUMENTS

1. Escobal, P.R.* "Methods of Orbit Determination". New York: John Wiley and Sons, 1965
2. "How to Use the NOVA Computers". Data General Corporation Southboro, Massachusetts
3. "Real Time Disc Operating System", Revision 3 or higher. Data General Corporation, Southboro, Massachusetts
4. "Fortran IV", Data General Corporation, Southboro, Massachusetts

*Referred to in text.

LANDSAT
SATELLITE



Flood Control in NEW ENGLAND

DEPARTMENT OF THE ARMY • NEW ENGLAND DIVISION • CORPS OF ENGINEERS • WALTHAM, MA.

THE LANDSAT SATELLITE
and
FLOOD CONTROL IN NEW ENGLAND

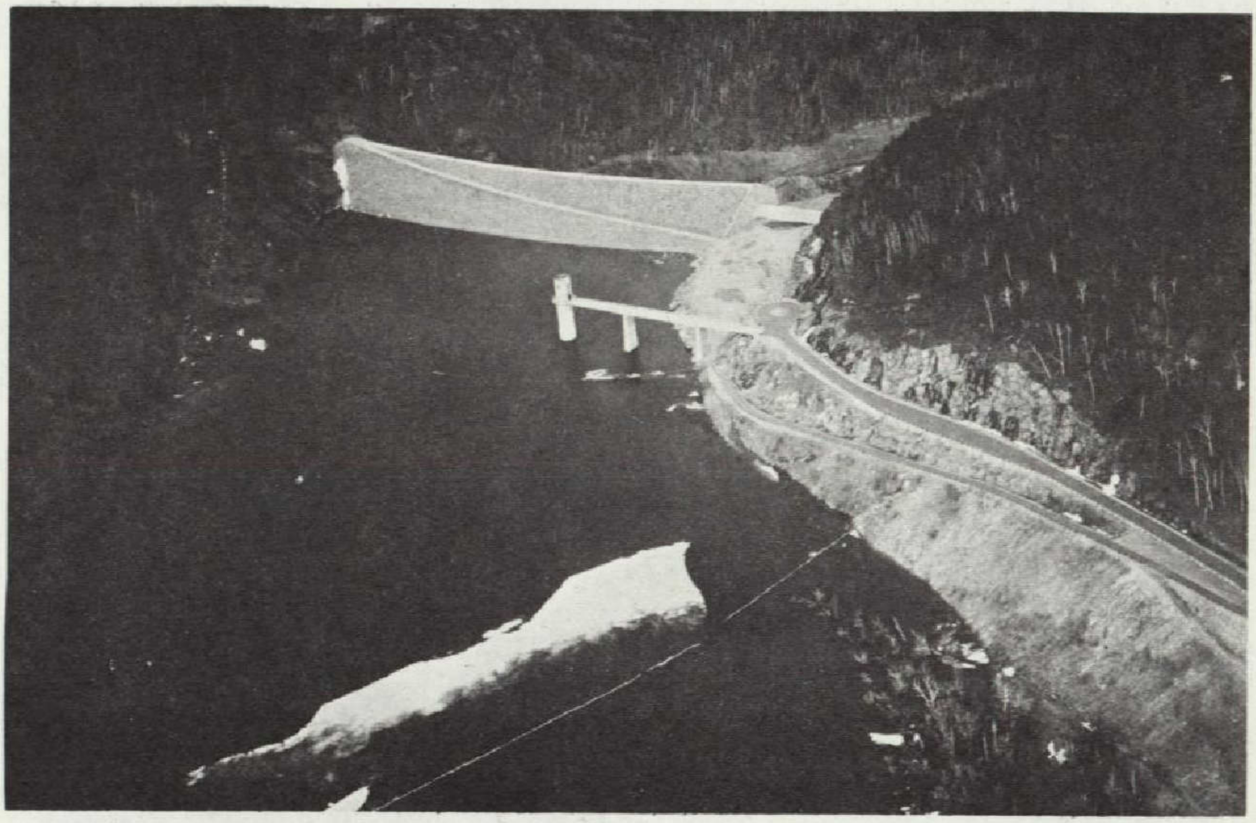
JUNE 1976

HISTORY AND BACKGROUND

Since the Industrial Revolution in the 1800's, the rivers of New England have been developed to supply water for power and transportation. As new means of transportation became more economical both railroad and highway systems were built along the banks of the rivers to service the expanding needs of the industrial, commercial and urban centers. Structures, such as buildings, roads, bridges and dams have restricted floodways to such an extent that considerable property and environmental damages have occurred during moderate and major floods. Notable floods of November 1927, March 1936, September 1938 and August 1955 have demonstrated the need for flood control to prevent these natural catastrophes.

AUGUST 1955 FLOOD DAMAGE AT WINSTED, CONNECTICUT

At the direction of Congress, the U.S. Army Corps of Engineers developed a comprehensive plan of protection for each river basin after a careful analysis of all water resources. Protective works generally consist of a combination of channel improvements, dikes and / or floodwalls at major damage centers augmented by upstream flood control reservoirs. Many of these reservoirs contain additional storage reserved for other uses such as water supply, conservation and recreation. The Corps has built 35 flood control reservoirs, 37 local protection projects and 4 hurricane barriers in New England at a total investment of over $350 million.



BALL MOUNTAIN DAM AND RESERVOIR JAMAICA, VERMONT

To achieve optimum operating benefits from this comprehensive protection system, the New England Division requires hydrologic data such as river, reservoir and tidal levels, wind velocity and direction, barometric pressure and precipitation.

In the past this data was collected from field observation and relayed via telephone or voice radio. It took several hours to compile and assess the data in this manner. With the need for timely and reliable information increasing, the Corps began development of new methods of data collection.

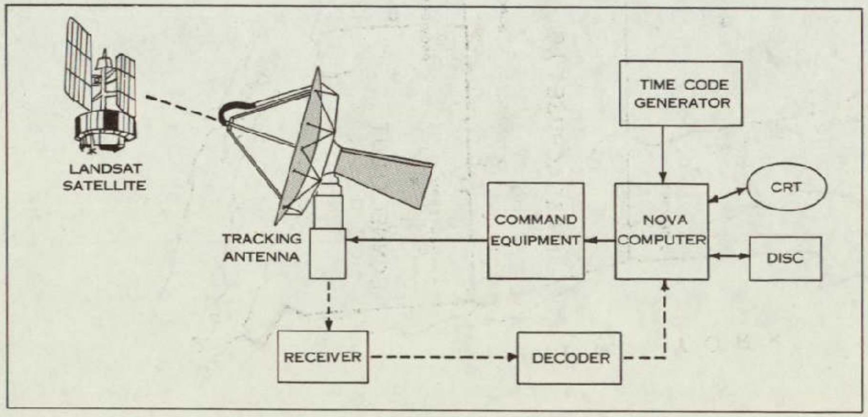
28-F-4

LANDSAT

Since July 1972, LANDSAT has been relaying river stage, precipitation and water quality data from DCP's via the Goddard Space Flight Center to the U.S. Army Corps of Engineers, New England Division, in near real time. This is the first resources satellite designed to obtain data from the planet Earth exclusively for planning, design, operations and research of land and water resources.

THE NED GROUND RECEIVE STATION

Since any operational satellite configuration should include ground receiving stations at all major user locales, NED, with NASA support has constructed and is now operating an inexpensive semiautomatic and easily maintained ground receive station as a follow-up to its original study. The Division is now able to receive hydrometeorological data from data collection platforms in the field directly at its headquarters in Waltham, Massachusetts with no time delays. The software to drive the antenna system has been developed with the intention that the antenna operate in an unattended mode automatically over nights and during weekends and holidays, with a computer controlling all processes. A diagram of the overall facility is shown.

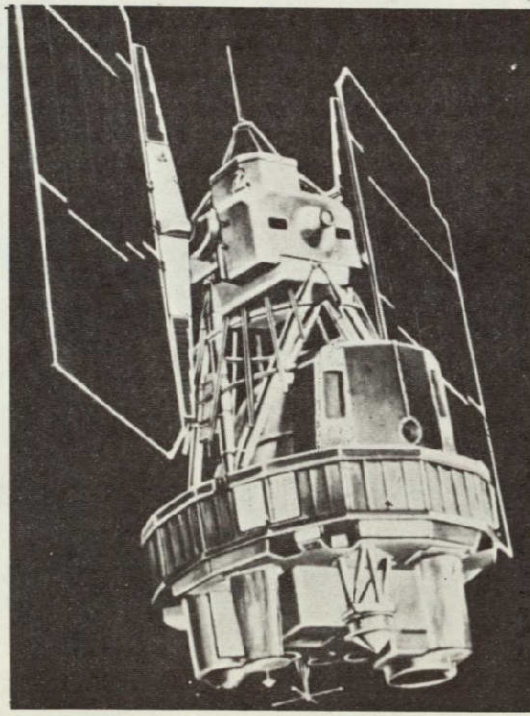


NED GROUND RECEIVING STATION DIAGRAM

28-F-8

In 1970, the Automatic Hydrologic Radio Reporting Network was placed in operation. This ground-based radio relay system consists of 41 remote reporting stations, and a central control at Division Headquarters in Waltham, Massachusetts. This network, under computer programmed control, collects and analyzes, in real time mode, information which is essential for flood regulation. The remote reporting stations are strategically located in five major river basins and at key coastal points, with each contributing to a detailed, comprehensive hydrologic picture.

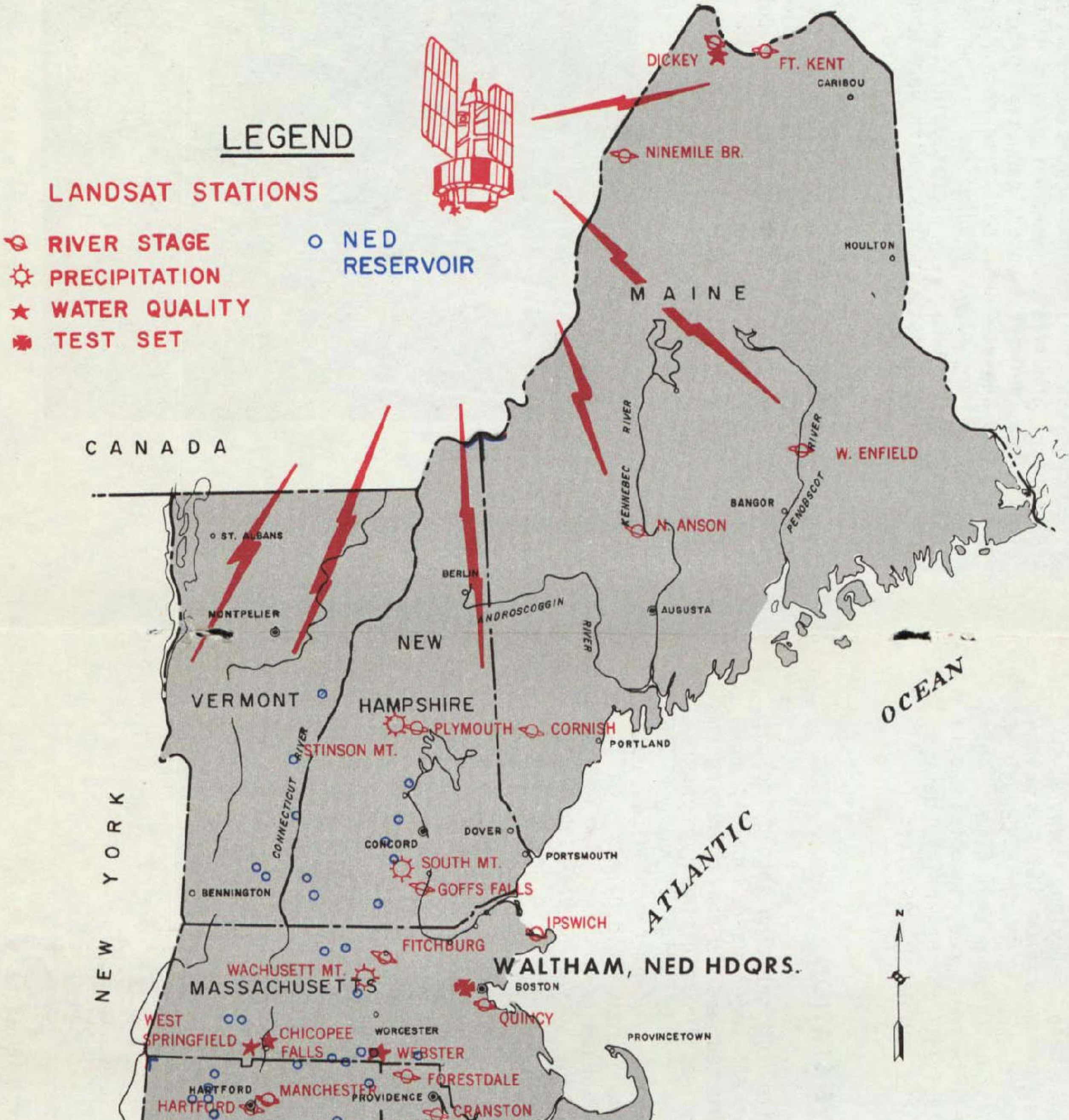
In June 1972, NASA entered into a contract with the Corps for an experiment to study the feasibility of using the Earth Resources Technology Satellite (ERTS or LANDSAT) for collecting environmental data from Data Collection Platforms (DCP's) which are installed at 27 locations throughout New England. Many are situated at existing U.S. Geological Survey gaging stations.



LANDSAT SATELLITE

28-F-5

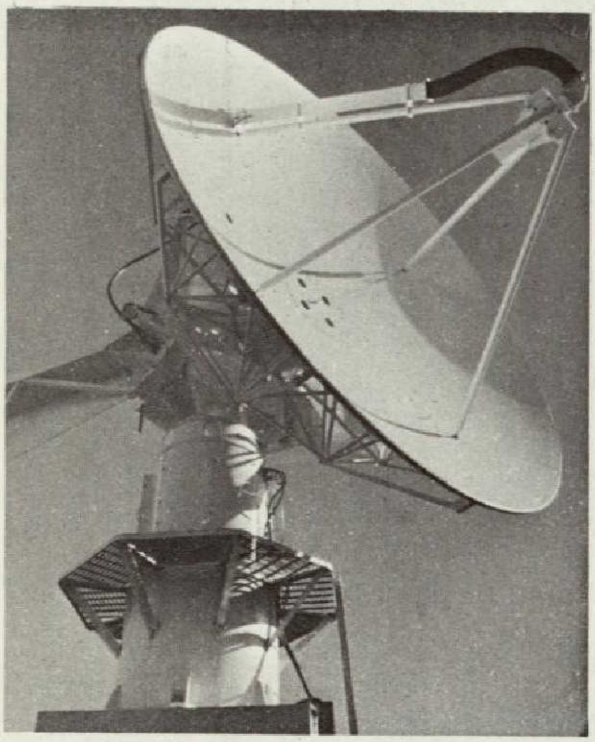
LANDSAT—2 DATA REPORTING STATIONS



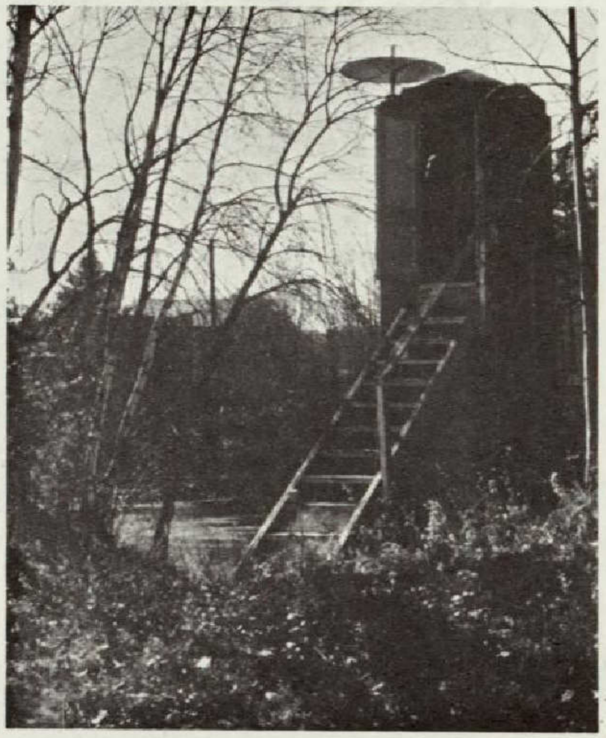
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

A major objective of the program has been to compare the cost, reliability, and operational effectiveness of the LANDSAT Data Collection System with the existing NED radio network.

Data collection platforms tested by the Corps have performed successfully in all seasons including the winter months and also during significant flood events, transmitting near real time operationally useful data for our flood fighting missions.



TRACKING ANTENNA
AT NED WALTHAM, MA.

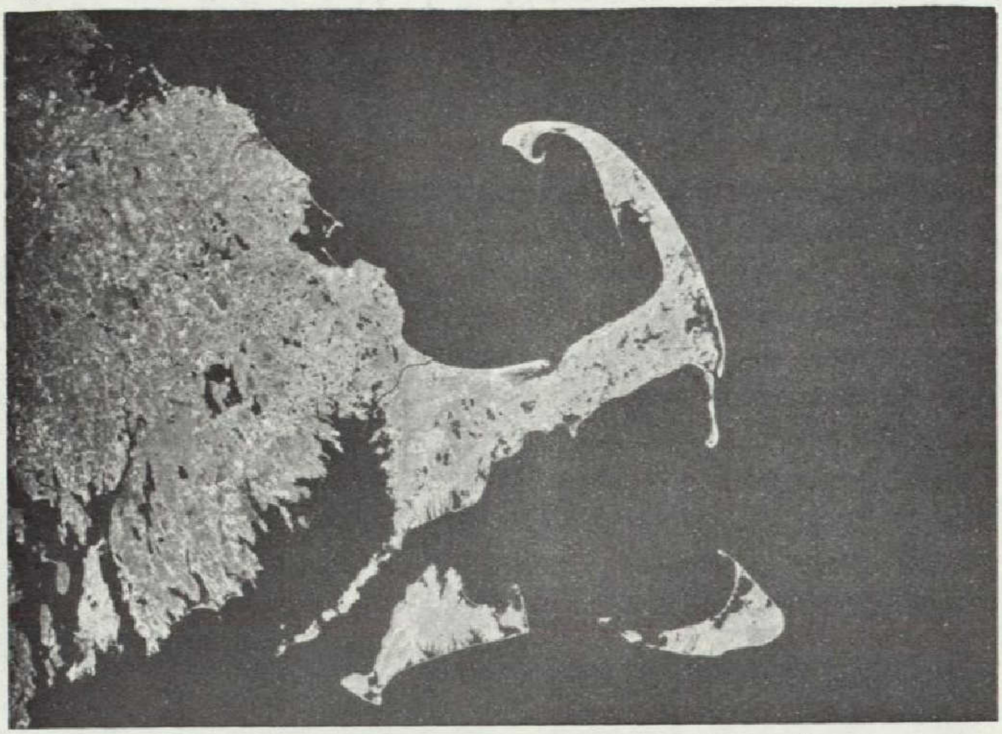


DATA COLLECTION PLATFORM
SACO RIVER CORNISH, MAINE

The satellite proved invaluable in April and early May of 1973 and 1974, monitoring flooding in Maine Rivers. LANDSAT relayed data from five remote river points in that state to aid the New England Division in the coordination of the flood emergencies.

The successful testing of the LANDSAT Data Collection System at the New England Division should encourage serious consideration of the institution of an operational satellite data relay system on a Corps-wide basis. System analysis is being performed to refine cost data and to articulate the data collection needs of Corps users.

The New England Division is also studying imagery regularly collected by LANDSAT to determine the usefulness in planning, designing, and managing water resource systems. It is well established that such imagery is suited to measuring areal extent of ice, snow, and open water, and for estimating moisture regimes. Our studies involve computer analysis of scenes and will explore indirect methods of calculating other hydrologic parameters as well.



IMAGERY PHOTO TAKEN FROM LANDSAT

FLOOD CONTROL OPERATIONS

Data received at the New England Division's Reservoir Control Center from either the Automatic Hydrologic Radio Reporting Network or the LANDSAT Data Collection System is compiled by computer. This is augmented by information from other sources such as the National Weather Service Meteorologic and River Forecast Offices and the U.S. Geological Survey. Experienced engineers and hydrologists at the Reservoir Control Center analyze the data for timely operation of dams and hurricane barriers, and then issue instructions to operating field personnel.

Flood control reservoirs, local protection projects and hurricane barriers built by the Corps in New England have been responsible for prevention of about $300 million in flood and storm damage.

Lieutenant General
William C. Gribble, Jr.
Chief of Engineers

Colonel
John H. Mason
Division Engineer

KEY OFFICIALS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

COLONEL JOHN H. MASON
New England Division Engineer

COLONEL RALPH T. GARVER
Deputy Division Engineer

JOHN WM. LESLIE
Chief, Engineering Division

VYTO L. ANDRELIUNAS
Chief, Operations Division

SAUL COOPER
Chief, Water Control Branch

U.S. ARMY · CORPS OF ENGINEERS · 1975 ·
BICENTENNIAL · 1775
200th