OPERATION OF THE LANDSAT

AUTOMATIC TRACKING SYSTEM

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

MAY 1976
Operation of LANDSAT

Automatic Tracking System

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by

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March 1976

Original Contains Color Illustrations
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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 troubleshooting is in Sections II - VII and the Appendices. All figures referred to in the text are in Appendix B.
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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.
I: 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 TELETYPING 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
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 DP0). ("0" IS A ZERO: "J" 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 TELETYPEx 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 accurately 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:

At this time, NBS signal is coming in by telephone. Return is pressed at exactly 13:10:30.

Continue listening to NBS and compare teletype pulses to telephone signal.
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.XXXXXXXXXX (DAYS)

2. NDOTØ** — First derivative of mean motion + or — XXXXXXXXXXX (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; "0" is the 15th character of the alphabet.
3. \( \theta \) — Inclination. \( XX.XXXX \) (DEGREES)

4. NODE\( \theta \) — Right Ascension of the Ascending Node, \( XX.XXXX \) (DEGREES)

5. E\( \theta \) — 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. OMEG\( \theta \) — Argument of Perigee. \( XXX.XXX \) (DEGREES)

7. M\( \theta \) — Mean Anomaly. \( XXX.XXX \) (DEGREES)

8. N\( \theta \) — Mean Motion. \( XX.XXXXXXX \) (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
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 inputting 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 (NORAD) in
Colorado. Twice a week, NORADCS 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. Sideral time is a relationship between the constellation ARIES (\( \gamma \)) 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 \( \Theta \). This angle is called the local sidereal time. Knowing the east longitude (\( \lambda_e \)) of an observer's station and, \( \Theta_g \) (Greenwich Sidereal time) \( \Theta \) can be easily determined. This is given by \( \Theta = \Theta_g - \lambda_e \), where \( 0 < \Theta \leq 2\pi \) (Escobal, p. 20, Eq. 1.26).

*See Appendix F for literature cited.
TOOLD I7 TOUT 7 PRAM FRAM ENTER TRACK CURRENT TIME (UTC) PASS TIME IN ARRAY "TT CALL LATE OR PEAD LE NS (ELENS'UESCRiPTION CALCULATE ORBIT INITI-AL ESCriPTION STAMTIPARAMETERS READ "RD SUBTRACTPU SET IPASS=I YES E(PASS NO.)] SEIW=I YES WRITE NO ? B NO N=TC HEADINGS YES BACK UP IMANYIMNY.I CURRENT TIME IN BELWIDEROF=SEALVE NOYSSlEEIFPEA< ELVTO PTA" IL IW E ELEVATION=2E TESTORETIME CALCULATE TRAL CALCULATE WRT AZ =2E S 20ST NOC -- EL WRoT r NORA DCWPO TESTORETIME CACULPATE AST SAVED I-L UJ>E: YE NO Y I TIME mNp YES SAVE T INREEN BY 0 SGP a SRV CETORN EORT -- B WCK NN AE ELEVATION oJ SWTH O= 90j 466x105 D E I E F&DT N T W IS USED TO ASSURE THAT TSS GET WRITTEN IN PTAE ONLY ONCE.

* IW IS USED TO ASSURE THAT TSS & DT GET WRITTEN IN PTAE ONLY ONCE.

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 $TP". 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 INTERPI is executed right after TRACK to interpolate ten angle pairs for every one pair in PTAE. Furthermore, INTERPI 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 INTERPI (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 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**, \( \theta \) – Sidereal time (measured in radians) – the angle between a line from the center of the earth to the first point of the constellation ARIES \( (\lambda) \), and the plane of observer's meridian.

\[ \theta \]

**Center of earth**

**Observer's meridian**

**NED, Waltham**

See Escobal, p. 20

\( \Theta \) is used by SRV in determining Azimuth (A) and elevation (H).
EXPLANATION OF TICALC 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).

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 0 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, 0 seconds; Number of hours, minutes, seconds expressed in minutes: DT = 615 minutes.

XJD = 2442648.5

DTHDT = .25068447

TU = (XJD-2415020)/36525 = .7564271047227926

THETA GØ = 99.6909833 + (36000.7689) (TU) + (.00038708) (TU)²

= 331.6485916015490

THETA G = THETAGØ + (DT) (DTHDT) = 125.819546515490°

THETA = (THETA G + LAMBDÆ) (2π/360) = .9530184529430946 radians
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, \( \Omega \), 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 \( \Omega \) 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 (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 LSI

After TRACK has predicted the satellite's path across the sky and prepared a file of pointing angles, it chains automatically to the program LSI 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, LSI 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 INTERPI 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.
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
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.
FIGURE 2. LANDSAT ANTENNA AND PEDESTAL. DCP ANTENNA IS SHOWN TO THE RIGHT.
FIGURE 3

COLD START

STOD $\pm \frac{1}{4}^\circ$

TRACK
PREDICTS
NEXT
PASS

ENTER

ENTER

P
OUTPUTS
DATA

STORAGE

HARD COPY

ENTER

LS
TRACKS
SATELLITE
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-O F050851 0819 DEC 75
NEDED-W/ATTN COOPER

FIGURE 5 FORMAT OF ORBITAL ELEMENTS PROVIDED BY NORAD C.
Figure 6

Dialogue between operator and computer during execution of ELW.

Note: "\" stands for return.
SUBJECT: CORPS OF ENGINEERS, U.S. ARMY

DATE: 27 Sept 49

FIGURE B. BIT MAPPING BETWEEN NOVA SOFTWARE AND 1848 DIGITAL COMPARATOR INTERFACE CONTROLLING 1848 DIGITAL COMPARATOR.

START
PULSE

START
PULSE

COMPUTED BY ______________________
CHECKED BY ______________________
DATE 7 MARCH 76

ORIGINAL PAGE IS OF POOR QUALITY

BIT

1 = AZ
2 = ELEV
3 = PROG
4 = STDBY

NOVA DATA WORDS
LOW ORDER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

10: 00: 40: 80: 100: 120: 150: 110: 130: 140: 123415

1 = AZ
2 = ELEV
3 = PROG
4 = STDBY

TO 1848 DIGITAL COMPARATOR

THIS MAPPING IS DONE BY SOFTWARE AND INTERFACES BUILT BY ROBERT SNYDER.
<table>
<thead>
<tr>
<th>DCP</th>
<th>STATION NAME</th>
<th>PARA-METER(S)</th>
<th>LAT</th>
<th>LONG</th>
</tr>
</thead>
<tbody>
<tr>
<td>7147</td>
<td>ST. JOHN RIVER AT MINEMILE BRIDGE, ME.</td>
<td>UES</td>
<td>46</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WES</td>
<td>46</td>
<td>42</td>
</tr>
<tr>
<td>7191</td>
<td>ST. JOHN RIVER AT Dickey, ME.</td>
<td>UG</td>
<td>47</td>
<td>06</td>
</tr>
<tr>
<td>7355</td>
<td>MICHAUD FARM AT ALLAGASH FALLS, ME.</td>
<td>UES</td>
<td>46</td>
<td>57</td>
</tr>
<tr>
<td>7273</td>
<td>ST. JOHN RIVER AT FORT KENT, ME.</td>
<td>RS</td>
<td>47</td>
<td>15</td>
</tr>
<tr>
<td>7287</td>
<td>PENOBSCOT RIVER AT WEST ENFIELD, ME.</td>
<td>RS</td>
<td>45</td>
<td>14</td>
</tr>
<tr>
<td>7282</td>
<td>CARABASSET RIVER NEAR NORTH ANSON, ME.</td>
<td>RS</td>
<td>44</td>
<td>52</td>
</tr>
<tr>
<td>7355</td>
<td>SACO RIVER AT CUMBERLAND, ME.</td>
<td>UG</td>
<td>43</td>
<td>48</td>
</tr>
<tr>
<td>7271</td>
<td>STINSON MOUNTAIN, N.H.</td>
<td>P</td>
<td>43</td>
<td>59</td>
</tr>
<tr>
<td>7237</td>
<td>SOUTH MOUNTAIN, N.H.</td>
<td>P</td>
<td>42</td>
<td>58</td>
</tr>
<tr>
<td>7281</td>
<td>PENCEVASSAT RIVER AT TOTTLE, N.H.</td>
<td>RS</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td>7233</td>
<td>MERRIMACK RIVER NEAR GOFFS FALLS, N.H.</td>
<td>RS</td>
<td>42</td>
<td>56</td>
</tr>
<tr>
<td>7214</td>
<td>STRUGS RIVER NEAR CUMBERLAND, N.H.</td>
<td>T</td>
<td>VARIABLE</td>
<td></td>
</tr>
<tr>
<td>7246</td>
<td>UACHUSETT MOUNTAIN, MA.</td>
<td>P</td>
<td>42</td>
<td>29</td>
</tr>
<tr>
<td>7263</td>
<td>IPSWICH RIVER NEAR IPSWICH, MA.</td>
<td>RS</td>
<td>42</td>
<td>39</td>
</tr>
<tr>
<td>7125</td>
<td>NORTH NASHUA RIVER AT TOTTLE, MA.</td>
<td>RS</td>
<td>42</td>
<td>34</td>
</tr>
<tr>
<td>7192</td>
<td>CHICHEP RIVER AT CHICHEP FALLS, MA.</td>
<td>UG</td>
<td>43</td>
<td>09</td>
</tr>
<tr>
<td>7201</td>
<td>WESTFIELD RIVER AT WEST SPRINGFIELD, MA.</td>
<td>UG</td>
<td>43</td>
<td>05</td>
</tr>
<tr>
<td>7207</td>
<td>FRENCH RIVER AT WEBSTER, MA.</td>
<td>UG</td>
<td>42</td>
<td>53</td>
</tr>
<tr>
<td>7212</td>
<td>BRANCH RIVER AT FORESTDALE, R.I.</td>
<td>RS</td>
<td>41</td>
<td>59</td>
</tr>
<tr>
<td>7246</td>
<td>PAUTERX RIVER AT CRANSTON, R.I.</td>
<td>RS</td>
<td>41</td>
<td>56</td>
</tr>
<tr>
<td>7254</td>
<td>CONNECTICUT RIVER AT HARTFORD, CT.</td>
<td>RS</td>
<td>41</td>
<td>45</td>
</tr>
<tr>
<td>7242</td>
<td>CONNECTICUT RIVER NEAR MIDDLETON, CT.</td>
<td>RS</td>
<td>42</td>
<td>43</td>
</tr>
<tr>
<td>7206</td>
<td>PORTER BROOK NEAR MANCHESTER, CT.</td>
<td>RS</td>
<td>41</td>
<td>45</td>
</tr>
<tr>
<td>7224,6216</td>
<td>PORTER BROOK NEAR MANCHESTER, CT.</td>
<td>T</td>
<td>VARIABLE</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

- P - PRECIPITATION
- UES - WATER EQUIVALENT OF SNOWPACK
- UG - RIVER STAGE
- RL - RESERVOIR LEVEL
- UQ - WATER QUALITY
- RS - RESERVOIR STAGE
- GST - GROUND SURFACE TEMPERATURE
- GT - GROUND TEMPERATURE
- AT - AIR TEMPERATURE
- WIND PASSAGE
- CONDUCTIVITY
- PH AND DISSOLVED OXYGEN

**SPARES:**

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

**ORIGINALLY PAGE IS OF POOR QUALITY**
JULIAN DATE OF SATELLITE RISE TIME, MEASURED FROM BEGINNING OF CALENDAR YEAR.

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

PAIRS OF AZIMUTH AND ELEVATION ANGLES

ORIGINAL PAGE IS OF POOR QUALITY

PAIR OF STOW ANGLES; SENDS ANTENNA TO STOW POSITION

PEAK ELEVATION FOR THIS PASS

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY
PAGE 1

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

COMPUTATION

COMPUTED BY ___________________ CHECKED BY ___________________ DATE 5 MARCH 76

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY
Original Page Is Of Poor Quality
APPENDIX D - GLOSSARY

ADR - Analog 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, "DP0" and "USER". Most system programs are in DP0, 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 central 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.
TYPE LSILOAD
RLDR S/K 16/C LSI T1 T2 T3 T5 UG ANG GARB/L TASK CALL FMT.LB FORT.LB DELETE/C GARB
R
TYPE LSI
1 CALLED BY INTERPR OR EXEC'D BY ITSELF
2 WAITS FOR SATELLITE RISE TIME - MIN.
3 ORIENTS ANTEenna, TRACKS SATELLITE, LOGS DATA
4 ACCEPTS CORRECTIONS, DUMPS DATA AT END OF.
5 PASS, STOWS ANTEenna IN UPRIGHT POSITION
6 TURNS ON AND OFF CIRCUITRY IN COMMAND
7 EQUIPMENT, CHAINS TO CDB
8
C
9
10
TYPE LSI
1 CALLED BY INTERPR OR EXEC'D BY ITSELF
2 WAITS FOR SATELLITE RISE TIME - MIN.
3 ORIENTS ANTEenna, TRACKS SATELLITE, LOGS DATA
4 ACCEPTS CORRECTIONS, DUMPS DATA AT END OF.
5 PASS, STOWS ANTEenna IN UPRIGHT POSITION
6 TURNS ON AND OFF CIRCUITRY IN COMMAND
7 EQUIPMENT, CHAINS TO CDB
8
C
9
10
READ(7,51)IT1(2) ; NO. TIMES TO EXECUTE

C
9
10
NOTE THAT IT1(2) IS THE LOC THAT IS MODIFIED BY TS

C
9
10
FORMAT(16)
11 TIME+(TSINC-ZMIN)-INT(TSINC-ZMIN)+84.
12 IT1(5);(TIME-FLOAT(IT1(4)))+3600. ; SECOND WITHIN HOUR
13 IT1(7)+DT
14
C
9
10
CALL TASK(DUM,T1,T1,IER,-1)
11 IF(IER.NE.1) TYPE "F01", IER
12 IMIN+IT1(5)+60
13 ISEC=INT(15)-IMIN+60+1
14 WRITE(10,10)IT1(4),IMIN,ISEC
15 WRITE(15,60)IT1(4),IMIN,ISEC
16 FORMAT(11,36) ; NEXT PASS AT "12," "13," "14"
17 IT2+1 ; ORIENT ANTEenna ONCE
18 TIME+(TSINC-ZMIN)-INT(TSINC-ZMIN)+84.
19 IT2(4)=INT(TIME)
20 IT2(5);(TIME-FLOAT(IT2(4)))+3600.
21 IT2(7)+8
22 IT2(11)+200
23 CALL TASK(DUM,T2,T2,IER,-1)
24 IF(IER.NE.1) TYPE "F02", IER
25 IT3(2)+330
26 IT3(4)+IT1(4)
27 IT3(5)+IT1(5)
28 IT3(6)+9
29 IT3(7)+300
30 CALL TASK(DUM,T3,T3,IER,-1)
31 IF(IER.NE.1) TYPE "F03", IER
32 IT4(3)+1
33 IT4(4)+IT1(4)
34 IT4(5)+IT1(5)
35 IT4(6)+10
36 IT4(8)+10
37 IT4(9)+8
38 IT5(1)+500
39 CALL TASK(DUM,T5,T5,IER,-1)
40 IF(IER.NE.1) TYPE "F04", IER
41 IONE=0
42 CALL REC(KEV1,IONE)
43 CALL FDELY(120) ; WAIT FOR ANT TO PCH STW POS.
44 CALL ANT(II,II,II,II,II) ; TURN OFF CIRCUITRY
45 CALL CLOSE(5,IER)
46 CALL CLOSE(7,IER)
47 CALL CLOSE(12,IER)
48 WRITE(10,10)
49 WRITE(15,70)
50 FNMNT(1)
51 CALL 1 ; See README FOR MORE INFO
52 IF(CURDTE .LE. (TSINC-ZMIN)) GOTO 50 ; TASK SCHEDULING
53 CONTINUE
54 CALL CHAIN(TRA CIK,IER)
55 IF(IER.NE.1) TYPE "LSIRD",IER
56 CALL EXIT
57
C
9
10
TASKER T1 SENDS ANGLES, T2 ORIENTS, T3 GATHERS DATA
11 T5 ACCEPTS CORRECTIONS

C
TYPE 71

C TDB 9 DEC 75

TASK T1
COMMON KEY1,KEY2,KEY3,KEY4
COMMON KBLK,TIT1(11)
DIMENSION J(4)
I=0
KEY4-KEY3+1
IF KEY3.GE.0 GO TO 10
KEY3-KEY4_1
IT1(2)=IT1(2)+1
GO TO 25
READ BINARY(5):I(1)
IF I(1).EQ.-1 GO TO 30
READ BINARY(5):I(I),J(2),4,NO, GET 3 MORE /5
CALL ANTI1(I(2),I(3),I(4),J(10)) ;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
CALL KILL
CALL KILL
COMMON KB/L/I(11)
CALL KILL
F10100 J(4)=1
CALL APPEND(I,1,TLOG,2,IER)
READ BINARY(12)J ;GET FIRST ANGLE PAIR
FROM 'STAPTANGLE'
IPOINT=1
GO TO 100 ;GO SEND PAIR
CALL FDELY(30) ;WAIT FOR ANTIENNA TO GET THERE
DO 20 I=1,21 ;SEND ANTENNA CCW TWICE
READ BINARY(12)J
IPOINT=2
GO TO 100
10 CALL FDELY(21)
20 CONTINUE
GO TO 21
100 CALL ANTI(J(1),J(2),J(3),J(4),I10)
WRITE(15,120)
WRITE(10,120)
120 FORMAT(17,2)
GO TO (10,15,25,35),IPOINT
DO 30 I=1,9 ;SEND ANTIENNA CW ONCE
READ BINARY(12)J
IPOINT=3
GO TO 100
30 CALL FDELY(21)
CONTINUE
GO TO 21
30 READ BINARY(5):J ;FIRST LOOK ANGLE,
IPOINT=4
GO TO 100

35 WRITE(10,130)
WRITE(15,130)
130 FORMAT(11*)
CALL KILL
CALL CLOSE(15,IER)
END

R

TYPE 73

TASK T3
CALL US
CALL KILL
END

R

TYPE ANT
.TITL ANT
.EXTD CPYL,FRET
.IREL
I=-157 ;LO AZ
J=+1 ;HI AZ
K=+1 ;LO EL
L=+1 ;HI EL
M=-15 ;PROG/STDBY SWITCH
N=0
.ANT:JSR .CPYL
.STA 3 PTH
LDA 0 RM 3
MOU 0 0 .SRR ;TURN OFF PEDESTAL?
.JMP OFF
LDA 0 ATS ;NO, SEND ANGLES
STA 0 TTB
LDA 2 CH4
MOR LDA 0 BI 3
LDA 1 TTB
COM 0 0
WHD 1 0
COM 0 0
IS2 TTB

OFF: LDA 0 RC0
DCAS 0 DUC
JMP BK

.DATAS AREA--------------------------
.DUC=42
BTC=+1
8E1:135777 081+085
B4:133777 081+084
B3:127777 081+083
B2:117777 081+082
B0:188+182

RTH=..
CN4=-4
TTH=...
TYPE WG
.TITL WG
.ENT WG
.EXTN .UIEX,.REC,.IXMT,.TASK,.AKILL,.IXMT
.EXTN .CPVL,.FRET
.COMM KEY 4 ;LABELLED COMMON AS IN L5
.TXTM 1
.NRKL
.DEVICE CONTROL TABLE--------
.IDDICT:DCT
.5TA 3
.STD:.-.
.107
.SUB 00 -GEN LOA 2 Chia&6
.ISP42-- -- -
.gINTERRUPT
;RESPOND 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 DUC
STA 2 URTM2
STA 3 URTM3
LDA 0 SYSTM
JSR "TOBUF
LDA 1 CN5

MOR: DIA 0 DUC
JSR "TOBUF
JSR "MP
INC 1 1 SZR
JMP MOR
JMP OUT

"TOBUF: TOBUF
TOBUF: LDA 2 "MEP
STA 0 0 2
INC 2 2
STA 2 "MEP
JMP 0 3

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

OUT: LDA 0 " MPs ;GET TIME COUNTER
.LDA 2 "MEP
STA 0 0 2 ;STORE TIME WITH MSG
INC 2 2
STA 2 "MEP

SUB 1 1
LDA 2 URTM2
LDA 3 URTM3
NIOS DUC
;UIEX

URTM2: --
URTM3: --
JMP *ERT.
`SYSTM.
CLOSE 6.
JMP *ERT.
LDA 2 AC2.
LDA 3 AC3.
LDA 0 AMES5.
SUBL 1 1.
XMT.
JMP *ERT.
JSR *FRET.

;DATA AREA---------
AC21:...
AMES5:ADD KEY, 1: POINTS TO 2ND ELEMENT IN LABELLED COMMON, "KEY" ; TAPEN.
AMES6:ADD KEY, 2: POINTS TO TIME COUNTER (SECS) IN TL.
AMES7:ADD KEY, 3: POINTS TO TIME COUNTER (SECS) IN TL.
AMES8:ADD KEY, 4: POINTS TO TIME COUNTER (SECS) IN TL.
AMES9:ADD KEY, 5: POINTS TO TIME COUNTER (SECS) IN TL.
AMESA:ADD KEY, 6: POINTS TO TIME COUNTER (SECS) IN TL.
AMESB:ADD KEY, 7: POINTS TO TIME COUNTER (SECS) IN TL.
AMSC:ADD KEY, 8: POINTS TO TIME COUNTER (SECS) IN TL.
AMESD:ADD KEY, 9: POINTS TO TIME COUNTER (SECS) IN TL.

;EQUIVALENT ROOS CALLS

PEND + SUSP.
APEND = RSUSP.
APEND = RSUSP.
APEND = ARDY.

4200: 4200.

DVC:42.
DVC-42.
MBP:0.
MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.

;MOUBLE BUFFER POINTER.
TYPE TRACKLOAD
CALL TRACK OTI TDCALL SGF SRV INCNT SEMI EXAM SEMI
GARB/G, FORT.LB/DELETE/C GARB

R
TYPE TRACK
C TDB 4DEC75
COMPILED DOUBLE PRECISION
DIMENSION TT(6),ID(3)
CALL POTIM(I,J,K)
TT(4)=I
TTE(3)=I
TTE(6)=0
CALL DATE(ID,IER)
TT(1)=ID(3)
TT(2)=ID(1)
TT(3)=ID(2)
CALL OTI(I)
END

R
TYPE TRACAL
C TDB 2/28/75
COMPILED DOUBLE PRECISION
SUBROUTINE TDCALL(T,TSINC,THETA,LAMDAE)
REAL LAMDAE
DIMENSION T(6)
COMMON /IBLK/DAVs
INVO (1)

R
TYPE INCT
C TDB 2/28/75
COMPILED DOUBLE PRECISION
SUBROUTINE INCT(T,DT)
T(6)=T(6)+DT
R
TYPE EXAM
C TDB 2/28/75
COMPILED DOUBLE PRECISION
FUNCTION EXAM(XMM,ECC)
COMPUTES ECCENTRIC ANOMALY USING KEPLER'S EQUATION
END

R
TYPE SEMI
C TDB 2/28/75
COMPILED DOUBLE PRECISION
DOUBLE PRECISION FUNCTION SEMI(XM,XI)
COMPUTES THE MEAN (X02@) SEMI-MAJOR AXIS OF A SATELLITE
END

R
GTOD
TYPE O1I
C
TDB 4DEC 75
COM PI LER DOUBLE PRECISION
SUBROUTINE O1110(T)
DIMENSION T(0), TS(0)
 INTEGER I, J, K, L, M, N, T0
 REAL NOD0, NODE0, NODE0, NOD0, NOD0, NOD0, NOD0, NOD0, NOD0,
 $10, NOD0, J, J, M, N, ORDER, ORDER, ORDER, ORDER, NOD0, ORDER,
 EXTERNAL SEMI
 INTEGER I, J, K, L, M, N, T0
 COMMON EPOCH, YR, M, NODE0, ORDER, ORDER, ORDER,
 $ M, J, M, M, N, M, N, M, N, M, N, M, N, M, N,
TYPE SGP
C SGP BY TDB -- REV 2 14 75 AT 1430
COMPILED 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 IO, IN, NO, NDOTO, NO, NODE, NODEL, LM, NNDOT, LLONG,
$NDOTL, L0, NDDOT, JE, J3, MU, I5, NODES
EXTERNAL EXANM
INTEGER YR
COMPUTE TIME VARIATION MEAN ELEMENTS AT TSINCE
JT=TSINCE; TIME SINCE EPOCH (DAYS)
EM=30I+4TDEH DMEG+DMGTIT; D ARG PER
NODE+NDOTTIT; D HSC NODE
LM=NDROD (L0+DIN+DMEG+NODE) ; TOUPI ; MEAN ORBITAL LAGITUDE
OMEG=DNOE) (L0+DIN+DMEG+NODE) ; TOUPI ; LNP.
NODE+DNOE (NO+DNOE, TOUPI) ; RA OF AN
IN=NO; INCLINATION UNCHANGED
SI=DSII; IN
COS1=DCOS(SMN
NO=NO+2.100T4T+3.*NDOT+IT+2
MTMDTI (100/IN; 3333333333681)
EN=1-90+AM (1-E0)
IF (EN) 10, 10, 20
10 EN=-0.000001

COMPUTE AND APPLY LONG PERIODIC TERMS (SUBRACPTS L)
20 TEMPL=1.13 JI2 (10. AM) DSIN (1. EMFI);
NAV=EMDOS (OMEG)
AUH=EMIDOS (OMEG); S TEMPL
ELONG=DSORT (AXNH+AXNH+AVNH#2)
OMEG=DSORT (DATAE+AXNH+AXNH; TOUPI); PRESERVE QUAD
C LONG PERIODIC ON L IS
LONGL=DSORT (LM=2STEMPL+AXNH(3.5 COSI/1.5 COSI)),
*TUUPI)
C 'SOLVE KEPLER'S EQUATION AND OTHER TWO-BODY FORMULAE
C LONG PERIODIC ECL ANOM;
EXNLG=EXANM(LONG+OMEG-NOEDEL+LONG)
C TRUE ARG OF LATITUDE;
TRUE=2*DATAE(DSORT)(1.14LONG) (1.14LONG)*DSIIH.5
*EXNLG/DCOS(.5*EXNLG) ) OME
RMAG=2*DSORT (1.14LONG) (EXNLG)) ; R SUB L
C TRANSVERSE COMPONENT OF VEL VECTOR
RUDT=DPSORT) MUNAMH (1.14LONG) (1. RMAG)
C RADIAL COMP OF VEL VECTOR
RMDT=DPSORT) MUNAMH (1.14LONG/ RMAG)
SUBROUTINE PEAK

IMPLICIT DOUBLE PRECISION (A-H,O-Z)

INTEGER ICOUNT, IER, I
REAL HZ, DT, IOVER

EXTERNAL TDB

DATA TDB, 627/75

DOUBLE PRECISION HZ, DT, IOVER, ICOUNT

SUBROUTINE PEAK(HZ, DT, IOVER)

CALL TDB(HZ, ICOUNT)

END
REWIND 5
GO TO 4
CONTINUE
CALL CLOSE(5,IER)
CALL DFILU('DATA',ZER,IER)
CALL CFILU('DATA.2',IER)
CALL CLOSE(6,IER)
CALL CLOSE(7,IER)
CALL CLOSE(8,IER)
CALL CLOSE(9,IER)
WRITE(6,200)
FORMAT(/////)
CALL CHAIN('TPACK.SU',IER)
IF (IER.NE.1) TYPE 'CE.
STOP
END

SUBROUTINE ERTDA
COMMON JBLC/NUM(24),LDIV(3),JEIN(9),X(3),SUM(12)
COMMON JBLC/JO.K.S,F,JX,IV,NAM(12),CHK
COMMON JBLC/COND,DOK,TEMP,PH
END

SUBROUTINE BIER
COMMON JBLC/NUM(24),LDIV(3),JEIN(9),X(3),SUM(12)
COMMON JBLC/JO.K.S,F,JX,IV,NAM(12),CHK
COMMON JBLC/COND,DOK,TEMP,PH
END

SUBROUTINE DCSRY
DIMENSION LEIN.JJ
DO 10 I=1,3
LEIN(I)=0
10 IF (NUM(N).LT.30) GO TO 30
DO 30 KK=1,NAM
30 CONTINUE
END

SUBROUTINE BINAI
COMMON JBLC/NUM(24),SUM(12),X(3),JEIN(9),LEIN(3)
COMMON JBLC/JO.K.S,F,JX,IV,NAM(12),CHK
COMMON JBLC/COND,DOK,TEMP,PH
END
TYPE UTOLY

SUBROUTINE UTOLY
COMMON JBLK/NUM(24), SUM(12), X(8), JBIN(9), LSIN(3)
COMMON JBLK/J.K.S.F.JX,IX,NAME(12), CHK
COMMON JBLK/COND, DOX, TEMP, PH
DO 25 JX=1,5
CALL BINAI
CALL BINBI
25 CONTINUE
IF(K.EQ.6) DO 30, 30, 30
30 PH=0
PH=0.026711*SUM(11)+10*SUM(12)+SUM(3)
DOX=0.01141*SUM(5)+10*SUM(6)+SUM(7)
TEMP=0.047(100+SUM(8)+10*SUM(9)+SUM(10))
RETURN
END

TYPE UT11I

C RMC 13 JAN 76
C CONVERTS ZULU TIME TO EASTERN STANDARD TIME (EST)

SUBROUTINE UT11I
COMMON JBLK/DAYSINMO(12)
DATA DAYSINMO/31,29,31,30,31,30,31,30,31,30,31,31/
IH=1,JH=1
CONTINUE
GO TO 26
IF(IH.EQ.3) GO TO 85
IF(JH.GT.6) RETURN
CONTINUE
GO TO 26
DO 60 N=1,43
READ(13,3)HAI, T,
60 FORMAT(1A, 4,5E,12:4F,6P,12:4F)
IF(HAI.GT.1) RETURN
CONTINUE
IF(HAI.GT.1) RETURN
CONTINUE
IF(HAI.GT.6) RETURN
CONTINUE
CONTINUE
RETURN
END

TYPE SNOH

C SUBROUTINE TO CALCULATE DISCHARGES AND VALIDITY FROM STAGE AND STATION NUMBER

SUBROUTINE SNOH(ISH,STAGE,0,NAME,DA,J)
COMMON JBLK/LS1(16)
DATA LS1/7147,7101,7200,7271,7356,7201,7233,
5693,7106,7204,7254,7335,7286,8504/
DO 85 N=1,16
IF(LS1(N).EQ.IGN) GO TO 8
85 CONTINUE
GO TO 285
8 NH=N-1
CALL FSEEK(13,NH)
CONTINUE
GO TO 285
285 IF(ISH.LT.0) RETURN
END

TYPE LSTGE

C SUBROUTINE TO CALCULATE DISCHARGES AND VALIDITY FROM STAGE AND STATION NUMBER

SUBROUTINE LSTGE(ISH,STAGE,0,NAME,DA,J)
DIMENSION DISCH(44), NAME(10)
CONTON/KBLV./LS1( S)
DATA LS1,7147,7101,7200,7271,7356,7201,7233,
5693,7106,7204,7254,7335,7286,8504/
DO 85 N=1,16
IF(LS1(N).EQ.IGN) GO TO 8
85 CONTINUE
GO TO 285
8 NH=N-1
CALL FSEEK(13,NH)
CONTINUE
GO TO 285
285 IF(ISH.LT.0) RETURN
END
CALL APPEND(15,'FILE',I,IER)
IF(IER.NE.1)TYPE 'ERROR',IER
CONTINUE
CALL READ(6,10)
FORMAT(10)
ICOUNT=0
ICT=0
IRE=6
READ BINARY (E)IMONTH,IGDAY,IIHR,IMIN,ISC,ICHR(2),IB(K),K
IF(ICHK.GT.1)IER=12696 ;IF ERR IS FLAGGED OUTPUT AN 'E'
WRITE(6,13)IPR,IMONTH,IGDAY,IIHR,IMIN,ISC,IER,IA(2),IB(K)
WRITE(10,35)IPR,IMONTH,IGDAY,IIHR,IMIN,ISC,IER,IA(2),IB(K)
WRITE(15,35)IPR,IMONTH,IGDAY,IIHR,IMIN,ISC,IER,IA(2),IB(K)
WRITE(7,35)IPR,IMONTH,IGDAY,IIHR,IMIN,ISC,IER,IA(2),IB(K)
CONTINUE
35 FORMAT(10) ICOUNT=ICOUNT+2
100 CONTINUE
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**Notes:**
- Values in the table represent measurements or data points.
- The table includes a variety of columns, each with specific units or categories.
- The table is structured to clearly display related data entries.
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**Note:** The table above represents data for different districts, with columns for current values, prior values, and changes. The data includes numerical values and some text descriptions.
PROGRAM TO CONVERT DECIMAL AZIMUTH AND ELEVATION ANGLES TO BCD SUITABLE FOR INPUT TO INTERFACE TO LS45 DIGITAL COMPARATOR

DIMENSION XI(2),X2(2),IBCDH(2),IBCDL(2)
COMMON IBLK/BCDHHIGH,BCDLOW/IBCDL(),ISTOW(5)
DATA BCDHIGH/200.,100.,80.,60.,40.,20.,10.,8.,4.,2.,1./

C FCD TABLE
DATA BCDLOW/.3.,.4.,.2.,.1.,.9.,.8.,.7.,.6.,.5.,.4.,.3./

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

CALL OPEN(5,'PTAE',I,IER)
CALL OPEN(6,'BCDAZEL',3,IER)
CALL OPEN(7,'HANGLES',3,IER)
IF(IER.NE.1)TYPE 'OE',IER
M1=1
D1=1
READ(5,6,END=500)TSINC READ 1ST REC ON FILE
6 FORMAT(F14.9)
WRITE(6,11)TSINC,D1 ICT=1
11 FORMAT(F14.9,F6.1)
GO TO 100
100 IFLG=0
IF(ABS(X2(1)-X1(1)).GT.300.)IFLG=1
IF(IFLG.EQ.1)X2(1)=X2(1)+360.
XINC=(X2(1)-X1(1))/DT
XINC=(X2(2)-X1(2))/DT
DO 105 INC=1,IFIN
105 INC=I+1,IFIN
DO 100 I=1,2,AE,EL
X=X(I)
IHIGH=0
ILOW=0
DO 20 J=1,10
IF(EDGHIGH(J).LE.X)GO TO 20;CHECK BCD TABLE
GO TO 30;SMALLER VALUE IN TABLE

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

30 DO 60 J=1,2
60 DO 50 J=1,2
IF(BCDLOW(J).LE.X)GO TO 40
GO TO 50
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.
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.
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.

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.
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.

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.
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.

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.
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