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ESTABLISHMENT OF SOFTWARE TO PROCESS
GLOBAL POSITIONING SATELLITE DATA
OBTAINED FROM TI 4100 GPS RECEIVERS

by

Marlene Mozgala

December 1986

Thesis Advisor: M. Kumar

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Software designed to process GPS satellite data was obtained from the U.S. National Oceanic and Atmospheric Administration/National Geodetic Survey (NOAA/NGS). The programs which compute point positions from broadcast ephemeris information (collected using the U.S. government model fo the TI 4100 GPS receiver) have been modified and tested, and are now fully operational at NPS on the IBM-3033 mainframe computer. The two programs to compute relative station positions have also been extensively modified for use on the IBM mainframe at NPS but still require further testing.

NPS now has the capability of computing point positions from data collected on TI 4100 GPS receivers using broadcast ephemeris information.

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Establishment of Software to Process
Global Positioning Satellite Data
Obtained from TI 4100 GPS Receivers

by

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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December 1986

ABSTRACT

The U.S. Naval Postgraduate School (NPS) conducted Seafloor Benchmark experiments in the summers of 1985 and 1986 which utilized the Global Positioning System (GPS) satellite system as the principal source of ship positioning. The data acquired in 1985 had to be processed elsewhere as NPS lacked the software required to process the data.

Software designed to process GPS satellite data was obtained from the U.S. National Oceanic and Atmospheric Administration/National Geodetic Survey (NOAA/NGS). The programs which compute point positions from broadcast ephemeris information (collected using the U.S. Government model of the TI 4100 GPS receiver) have been modified and tested, and are now fully operational at NPS on the IBM-3033 mainframe computer. The two programs to compute relative station positions have also been extensively modified for use on the IBM mainframe at NPS but still require further testing.

NPS now has the capability of computing point positions from data collected on TI 4100 GPS receivers using broadcast ephemeris information.

3

TABLE OF CONTENTS

6

LIST OF TABLES

7

LIST OF FIGURES

8

ACKNOWLEDGEMENTS

I. INTRODUCTION

The Global Positioning System (GPS) was originally developed in the early 1970's as an improvement upon the already-existing U.S. Navy Navigation Satellite (NAVSAT or TRANSIT) System. GPS was to provide a continuous, worldwide, all-weather, real-time navigation system with accuracies in the 10-meter range (Henson et al, 1985). As computer and satellite technology develops and various methods of increasing the accuracy of positions obtained from GPS satellites emerge, other non-military applications for GPS are being realized, including the positioning of offshore platforms, detecting the earth's crustal movements, and geodetic point and relative positioning on land and also on the ocean bottom.

Various agencies are involved in developing mathematical models and refining system software to increase the accuracies of GPS-obtained positions and simultaneously reduce the actual field observation time. These agencies include the U.S. National Oceanic and Atmospheric Administration/National Geodetic Survey (NOAA/NGS), U.S. Defense Mapping Agency (DMA), U.S. Naval Surface Weapons Center (NSWC), U.S. Geological Survey (USGS) and some universities (Ohio State University, etc.).

Students assigned to the U.S. Naval Postgraduate School (NPS) have investigated various uses for and aspects of GPS for precise navigation and geodetic positioning, using both simulated and real data sets received from some of the agencies mentioned above (Newell & Winter, 1981; Rakowsky, 1984; Rahyono, 1985). However, data sets were both acquired and processed by outside sources, for no GPS data acquisition or data processing capabilities existed at NPS.

In May 1985, NPS established an ongoing Seafloor Benchmark Positioning (SBP) experiment using the GPS satellite system as the principle source of ship positioning. Although much data were acquired during Phase I of the SBP experiment (13-24 May), the data sets could not be processed "in-house" as no data reduction software existed on campus.

Recently, the purchase of a GPS receiver by NPS has also been approved. In order to process the data obtained from experiments which utilize the GPS satellite system, computer software must be established at NPS. The establishment of GPS

computer software would not only develop GPS data reduction capabilities at NPS but would also be the foundation upon which future GPS-related research could expand. This thesis involves adapting existing computer programs (as obtained from NOAA/NGS) for operation on the IBM mainframe computer to give NPS such data processing capabilities.

II. BACKGROUND

A. GLOBAL POSITIONING SYSTEM

The Navigation Satellite Timing and Ranging Global Positioning System (NAVSTAR GPS) was developed as an extension of the U.S. Navy Satellite Navigation System (NAVSAT or TRANSIT), although its roots go back to the U.S. Air Force (USAF) 621B Project and TIMATION. It is designed to be a real-time, world-wide navigation system, and consists of three segments.(Easton, 1978; Remondi, 1985a)

1. Space Segment

The Space Segment at present consists of a constellation of seven artificial satellites in the research and development phase (Block I) of GPS. The constellation for the second phase (Block II) of GPS, which is expected to be fully operational in the early 1990's, will consist of eighteen satellites evenly distributed into six equally-spaced orbital planes circling 20,000 km above the earth. The Block II orbits are designed with a $55°$ inclination to the equator.

To date, eleven Block I satellites have been launched, ten of which are in orbit. Seven of these ten satellites are still functioning and providing six to eight hours of satellite observation per day. (Stein, 1986)

Each satellite in the GPS constellation transmits its own ephemeris and identification information on two L-band frequencies, L1 and L2. The L1 signal, with a frequency of 1575.42 MHz, is modulated with two types of code: a precision (P) code and a coarse acquisition (C/A) code. The L2 carrier signal, which has a frequency of 1227.6 MHz, is modulated with only the P-code. Future satellites will have the option of modulating with either P- or C/A-codes (Remondi, 1985a). The L1 and L2 signals are also modulated by a 50-bit per second (bps) message which is the GPS navigation message. This message carries satellite vehicle (SV) identification, clock behavior data, SVs' broadcast ephemeris, GPS time, transmitter status information and C/A to P-code handover information (VanDierendonck et al, 1980).

The P- and C/A-codes are pseudo-random noise (PRN) codes: P-code transmits the L1 and L2 frequencies at a rate of 10.23 megabits per second (Mbps) and repeats the code every 37 weeks; the C/A-code is repeated each millisecond at a rate

1/10th that of the P-code, or 1.023 Mbps. The PRN codes allow the receiver to track and uniquely identify each SV (Texas Instruments, 1983). The 50-bps message, together with the P- and C/A-codes, are utilized for determining ranges via transit time between satellite and receiver, and also for synchronizing code receivers to GPS time (Remondi, 1985b).

GPS users utilize the broadcast ephemeris (BE) of the satellites to determine real-time positions as the precise ephemeris (PE) is not available during satellite signal acquisition. The BE is based upon the predicted position of each satellite which is extrapolated from the actual orbit and then injected into the SV's computer. A complete position determination (X,Y,Z and t) requires simultaneous observations from four SV's. The 3-D position is based on the World Geodetic System (WGS) 1972. GPS receivers are also designed to transform WGS 72 coordinates to other local/regional datums, if required by the users. (Texas Instruments, 1983)

2. Control Segment

Five USAF ground stations which are responsible for tracking and updating satellite ephemeris and related information comprise the Control Segment of the GPS system. These stations are the Master Control station at Falcon Air Force Base, Colorado Springs, Colorado, and four monitoring stations in Hawaii, Diego Garcia, Ascension Island, and Kwajalein Island. In addition, DMA has three other tracking stations in Great Britain, Australia, and Argentina, and two more stations in Ecuador and Bahrein are under shipment (Smith, 1986; Stein, 1986). The five Control Segment stations observe each satellite position and the observed data are then relayed from the monitoring stations to the Master Control station, where each satellite's orbit and it's errors are computed from the data received. The Master Control station then uploads satellites with new information including ephemeris corrections and other system data (satellite health, clock offset values, etc.) which are then relayed to the User Segment by each satellite (Texas Instruments, 1983).

The Control Segment is also responsible for establishing GPS time. GPS time is referenced to a zero time-point in the Universal Time Coordinated (UTC) time system, and is defined to be 0000 hours on the morning of 6 January 1980 (Navstar GPS Space Segment, 1984).

3. User Segment

The GPS User Segment includes all the devices necessary for the user to acquire, track, and process satellite signals (which are a receiver, an antenna, and

usually a signal processing unit) to acquire satellite data and compute the distances to a satellite. This thesis deals with the Texas Instruments model TI 4100 GPS receiver and the software required to process, analyze, and evaluate its data.

B.   TI 4100 GPS RECEIVER

Texas Instruments has developed two types of GPS receivers capable of acquiring and processing SV signals. The commercial model, the TI 4100 Navigator, is available to all users; the TI 4100 model designed for various U.S. government agencies (NOAA/NGS, DoD/DMA, and USGS) is capable of precise positioning by decoding both C/A- and P-code from each SV. The TI 4100 receiver consists of an antenna/ preamplifier, recorder assembly (which records on cassette tapes all incoming satellite data) and a receiver processor assembly for user input (Texas Instruments, 1983). The receiver hereafter referred to in this thesis is the model developed for government use.

The TI 4100 GPS receiver has a single-channel, is dual-frequency (multiplexed), and can acquire and record SV data every second (Texas Instruments, 1983; Henson et al, 1985). The dual-frequency capability of the receiver, along with the multiplexing feature, allows both L1 and L2 frequencies to be acquired for up to four satellites. Multiplexing is a technique whereby each satellite can be rapidly interrogated through the receiver's single channel so that interrogating the L1 and L2 frequencies of the four satellites can be accomplished within milliseconds; the effect is the same as simultaneously acquiring all satellite data. By interrogating the satellites through one channel, interchannel biases which can contaminate the data are eliminated (Texas Instruments, 1983). The receiver is also able to process range data which has been affected by a doppler shift due to the relative velocity existing between each SV and receiver. The true range from receiver to SV can be determined once the user and SV clock time biases have been estimated by the user navigation process. A three-dimensional position (X,Y,Z and t) is attainable using information from four SV's; two-dimensional positions are possible with three SV's if the receiver's antenna height above the reference ellipsoid is known. Positional accuracies determined from data acquired by the TI 4100 receiver are, besides other technical considerations, dependent upon the number of SV's used for the position determination. Table 1 shows the achievable accuracies of position determinations based on observing two to four satellites from both stationary and mobile receiver sites (Texas Instruments, 1983).

14

Four main types of data record formats from the TI 4100 receiver are available to the user: the User State Solution Record, SV Navigation Record, Relative Navigation Record, and Receiver-Ranging Measurements Record. The details of these data types follow (Texas Instruments, 1983).

1. User State Solution Record

The User State Solution Record contains the navigation state information in the GPS geocentric earth fixed coordinate system. It includes the clock bias and clock bias rate, satellite positions (X,Y,Z) and satellite velocities (X',Y',Z'), and thus provides the navigation solution determined by the receiver from SV positions.

2. SV Navigation Record

The SV Navigation Record contains the information necessary for the precise positioning required to obtain geodetic accuracies. The data block description for this

record contains satellite almanac and ephemeral data. Each 30-bit navigation message word sent from a satellite is stored once in the Navigation Message Record.

3. Relative Navigation Record

The Relative Navigation Record contains position and velocity information in the datum of the user's choice along with waypoint navigation data (i.e., cross track errors, range and bearing to waypoint, etc.). It is the record most frequently used by mariners for ship navigation.

4. Receiver-Ranging Measurements Record

The Receiver-Ranging Measurements Record contains the SV range and time data measured by the TI 4100 receiver, including carrier phase, carrier velocity, and fundamental time frame (FTF) information. The receiver acquires data from up to four SV's on both L1 and L2 frequencies and propagates the data to the same 20-msec fundamental time frame segment. Three of the variables in the data block description (Z-count, X1, and P phase) for each L1 and L2 are used to form the pseudorange measurment. These variables represent the SV signal transmission time as received by the TI 4100 at the specified FTF.

Preceding each record is a record header which identifies the record that immediately follows it and time tags it. The time tagging includes the GPS week number and GPS time. GPS time is maintained as seconds into the week from Saturday midnight, and set once the navigation process begins processing measurements. The record header is helpful during the postprocessing of data measurements as the word count provides a way to skip from record header to record header and can be used to check the completeness of the data (i.e., if the number of words collected doesn't match the number of words expected, an error has occurred during satellite data transmission).

C. OBSERVED GPS VARIABLES

1. Pseudorange data

One of the observed variables in the GPS signal is the distance (or the range) measured from a satellite to a receiver. This range can be determined by multiplying the transit time of the radio signal between the satellite and receiver by the speed of light. Range determination in this manner is possible only if the receiver clock is accurate and precisely synchronized with the satellite clock. However, any transit time measurement includes clock errors; therefore, the range measurement, which includes clock errors, is known as the pseudorange.

16

Pseudorange measurements are also affected by propogation delays caused by the earth's atmosphere. Ionospheric delay is approximately inversely proportional to the square of its frequency and can thus be measured by any GPS receiver which has two-frequency capability; the correction for tropospheric effects is modeled as a function of each satellite's elevation above the antenna horizon. (Texas Instruments, 1983)

2. Carrier Phase Data

The carrier phase is the signal that remains after the modulation (L1 or L2 carrier) has been removed. The phase of the satellite signal can be depicted as that part of a sinusoid (or a wave) passing a point at a particular time (i.e., $90°$ of a sine curve $= 0.25$ wavelengths or 0.25 cycles). As any satellite moves toward or away from the receiver, the wavelength (and frequency) of the signal transmitted by the satellite will change due to the Doppler effect. Although the wavelenth/frequency of the signal changes, the pattern of the signal remains the same; the same idea holds for carrier phase. Therefore, the phase measured at a receiver at a particular time is the same as the phase which was transmitted by the satellite at transmission time. (Remondi, 1985b)

The carrier phase observation is an instantaneous measurement of the total carrier phase including whole cycles and fractions of cycles. The effects of relativity, time tagging errors, and ionospheric and tropospheric refraction must also be accounted for in reducing carrier phase data (Remondi, 1984). A stable receiver clock is necessary to count the number of cycles reaching the receiver during a particular time interval. In TI 4100 receivers, the phase of the incoming signal is measured with respect to the phase of the GPS carrier signal generated by the receiver clock.

a. Cycle Slips

Using carrier phase measurement for positioning depends on the continuous tracking of a satellite signal by a receiver. A break in the data stream from a satellite (i.e., a sudden gain or loss of a whole number of cycles) is considered a loss of signal lock or a "cycle slip" (Bock et al, 1985). A cycle slip can be compared to a lane jump in a medium-range positioning system such as ARGO where the fractional value of a lane is known but the whole lane count has been interrupted. If satellite tracking by a receiver is broken, the integer number of cycles will be incorrect after tracking is again resumed on the same satellite. Sources of cycle slips include obstructions, power failure, power switching, low signal strength, intense ionospheric

activity and receiver hardware problems (Remondi, 1984). Postprocessing techniques based on differencing phase values have been developed to identify the location of cycle slips occurring in a data set and to automatically correct for the improper number of cycles added/dropped due to a loss of signal lock (Goad, 1985; Remondi, 1985a).

b. *Differencing Techniques*

The single, double, and triple differencing algorithms, which depend on simultaneous measurements of one or more satellites by two receivers, help in identifying cycle slips, removing errors which are common to a pair of satellites or receivers, and improving the accuracy of each position determination (Bossler et al, 1980; Texas Instruments, 1983). These differencing techniques (Figure 2.1) are discussed below (Remondi, 1984).

(1) *Single Differences.*

The single difference observable is obtained by subtracting the phase signals received from the same satellite at the same epoch, t_k, at two different receivers (for $j = 1,2$) and can be represented by the following equation:

$$SDO(k,j,i) = OBS(k,2,i) - OBS(k,1,i) \tag{2.1}$$

where $OBS(k,j,i)$ is the raw, unprocessed fractional phase plus the count made at epoch t_k by receiver j for satellite i. This differencing causes the satellite clock error term to drop out as it is the only common term in both observations.

(2) *Double Differences.*

The double difference method involves differencing two single difference results (Equation 2.1) from two receivers simultaneously observing (at epoch t_k) two satellites ($i = 1,2$).

$$DDO(k,j,i) = SDO(k,j,2) - SDO(k,j,1) \tag{2.2}$$

The two receivers' clock terms, still present in each single difference observation, drop out in the double difference solution and therefore allows examination of the integer number of cycle counts, N, for each satellite-receiver pair, where N is considered as the "integer bias" to the observed phase measurement. The values of these biases are very close to integers for data obtained from short (< 30 km) base lines due to similar atmospheric effects and satellite orbit errors. As the base-line
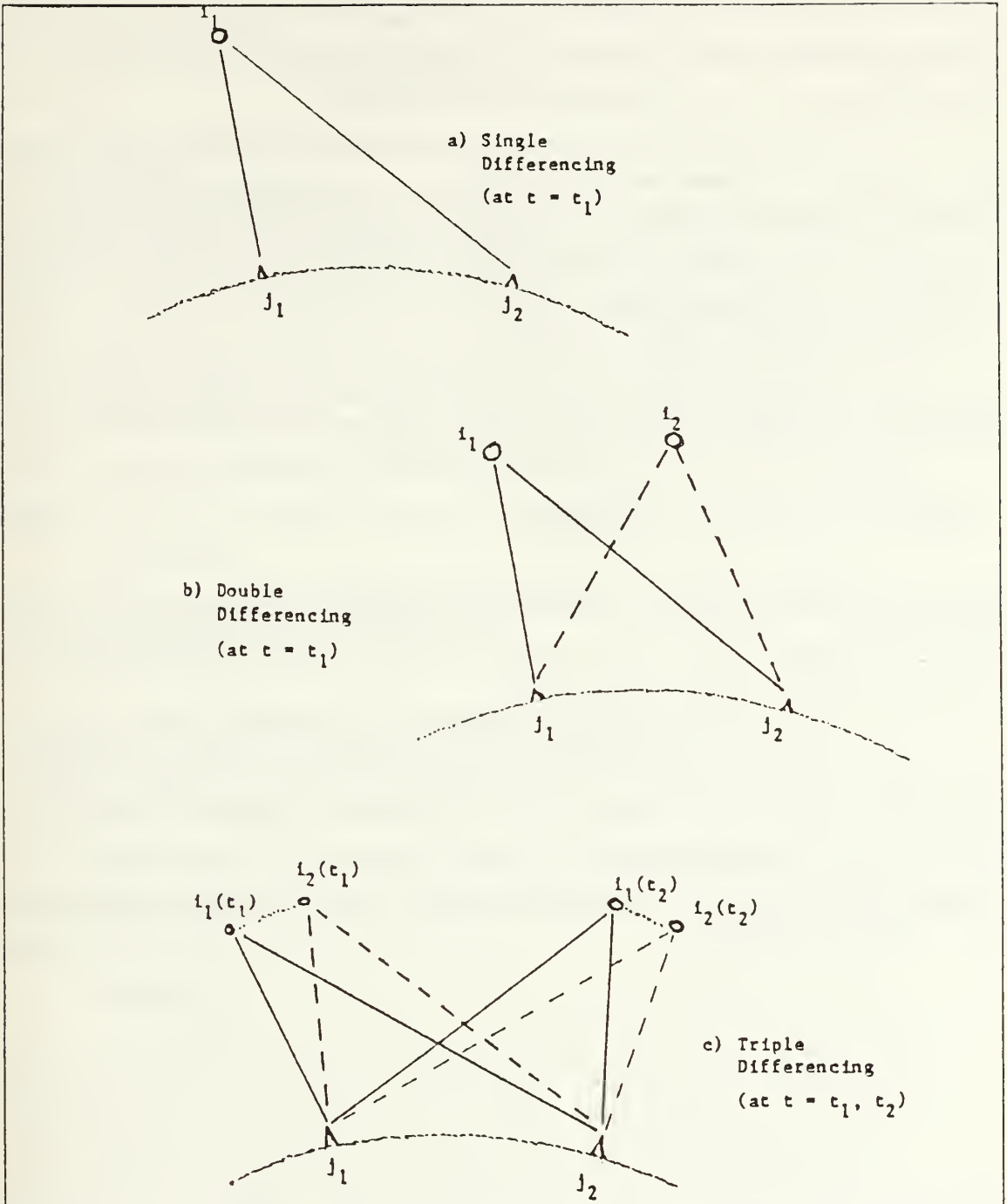
Figure 2.1   Differencing Techniques.

length increases, the possibility of the receivers at each end of the base lines experiencing the same atmospheric effects (i.e., ionospheric and tropospheric effects)

decreases. The same concept applies to the increased errors observed in satellite orbits as base line length increases. Therefore, the biases will become less like integers. (Goad, 1985)

The double difference solution also helps in identifying losses of signal lock (cycle slips) by representing each cycle slip as a step function (Goad, 1985). For example, the initial whole number of cycles plotted against time will generally plot as a straight line. If a cycle slip occurs, the plot will show a jump up (or down) from this initial line to a new integer number of cycles.

(3) *Triple Differences.*

Triple difference involves differencing two double-differenced phase observables at two discrete times, t_k and $t_m (= t_k + \delta t)$:

$$TDO(k,j,i) = DDO(m,j,i) - DDO(k,j,i) \tag{2.3}$$

The integer bias terms common to each double difference observation drop out during triple differencing, leaving eight satellite-to-receiver distance measurements to be computed in future processing (Goad, 1985).

The triple differencing method further helps to identify the location of cycle slips. Using the same idea as was used to depict the step-type attitude of cycle slips in the double difference method, a cycle slip here would appear as a spike on a graph of number of integer cycles against time. The spike could then be used to determine which satellite-to-receiver distance measurement should be edited from the data set (Remondi, 1985b).

III. DATA PROCESSING

A. GENERAL

The purpose of this thesis is to establish at NPS computer software which is capable of processing data obtained from the GPS satellite system. The software adapted for use at NPS was obtained from NOAA/NGS and is capable of processing GPS data obtained from either the Texas Instruments TI 4100 or Macrometer(TM) receivers. The programs are written in Fortran 77 and operate in a batch mode at NOAA/NGS on an HP-9000 and an HP-A900 mini-computer. However, only TI 4100 data were used for adapting and validating the software at NPS. The processing system consists of three stages (Kass and Dulaney, 1986).

1. Preprocessing

The preprocessing stage generally consists of five programs which:
* transfer data from cassette to floppy disk
* check disk for errors
* translate data from binary to hexadecimal notation
* transfer hexadecimal data to standard nine-track tape
* create a position file for each receiver site.

The TI 4100 data used in this thesis were preprocessed by NOAA/NGS with the five programs mentioned above. There are, however, other programs and options used at NOAA/NGS to preprocess GPS data.

2. Processing

The processing stage consists of four highly-interactive programs which can utilize either the precise or broadcast ephemeris to compute single point or relative receiver positions from pseudorange or phase data, respectively. Two programs are used to compute the satellite receiver positions for each data type (pseudorange or phase data): one program reformats the input data; the second program performs the actual position computations. The processing stage first identifies the location of a receiver which collects the maximum number of observations as base station and the SV which provides the maximum amount of data as base satellite and then utilizes these identifications in obtaining a least squares solution from a survey involving more than two receivers (Goad, 1985; Kass and Dulaney, 1986).

21

The two programs which process pseudorange data were successfully adapted at NPS. The phase data programs were extensively modified but still require further validation to be fully operational at NPS.

3. Postprocessing

The postprocessing stage includes a program which performs a complete error analysis of the network of surveyed stations and yields network statistics and a file containing the adjusted station positions.

B.   DESCRIPTION OF THE PREPROCESSING STAGE

The preprocessing stage transfers and reformats the satellite data written on TI 4100 field cassettes into a format suitable for entry into the computer programs comprising the processing stage. The preprocessing stage has been included for clarity of understanding and to supplement the information contained in the processing stage of the pseudorange data covered under this thesis.

Five computer programs (section III.A.1.) comprise the preprocessing stage of TI 4100 field data. The first program, MEMTEC, starts and controls the cassette reader and transfers the image of the satellite data (from the cassette) to a binary file on an IBM-PC floppy disk (Ferguson, 1986). MEMTEC is designed to operate on the Memtec Corporation cassette reader (Model 5450XL) at NOAA/NGS.

A data tape is placed in a cassette reader and loaded. During the execution of MEMTEC, one of the necessary entries is the file name under which a particular data set is to be stored. MEMTEC will internally check the output file name against file name standards established by NOAA/NGS and will display errors if the name is not properly formatted. MEMTEC then displays information from a particular data file for verification of the information by the user. The information to be verified includes the station name, day of data acquisition, etc. MEMTEC continuously displays the number of records written onto the floppy disk, the number of bytes used by the data file, and the number of bytes remaining for entry of other data files. If data are not properly stored on the field cassettes (when originally written in the field) or the tape unit is unable to move the cassette in normal fashion while reading, an error message/light will be displayed. Bad data records can be noted by the program operator, and the preprocessing may be continued by skipping over the bad data records. (Ferguson and Goldrick, 1986)

The second program, QUALCHECK, accesses the binary-coded floppy disk file created by MEMTEC, checks if the tape is readable and verifies sections (i.e., important information needed for processing) of its contents. For QUALCHECK there is a distinct difference between TI 4100 data sets and data files. A data set contains all the data obtained for one TI 4100 receiver site during a particular satellite observing session. A data file contains all or part of a particular data set. (Ferguson and Goldrick, 1986)

QUALCHECK systematically checks each data file within a data set to ensure that all data from a field cassette has been correctly transferred onto the IBM-PC floppy disk. If there are errors within any data files, a new floppy disk can be formatted which contains only those files which have successfully passed through QUALCHECK.

The timing information (precise starting and stopping times of observations, recording intervals, data gaps, etc.) for each data set is also verified in QUALCHECK (Kass and Dulaney, 1986). If there is incorrect timing information within a data file, the time gap information will be displayed on the CRT and can be manually recorded if desired.

After the data file has successfully passed through MEMTEC and QUALCHECK, a third program, TIDUMP, is used to translate the TI 4100 binary data files located on the IBM-PC floppy disks into hexadecimal representation. The translation occurs during the actual transfer of the file to a mainframe computer or other computer system, using either a direct connect or a modem (Ferguson, 1986). The data file is stored on a hard disk in the HP-9000; to transfer the file onto a standard nine-track tape, the fourth program, TAPEOUT, is executed.

The binary coded file which is input into QUALCHECK is also used in program CR8PF, which creates a position file (p-file) for each receiver site. CR8PF uses the position information obtained in the binary data file to develop the p-file. The station position within the p-file (originated by the field operator) is a rough estimate of the receiver's location, usually to within the nearest minute of latitude and longitude (Kass, 1986).

The results of the preprocessing stage are a reformatted ASCII hexadecimal data file for each receiver station, precise timing information and position files for each station in the survey. Appendices A and B are examples of a preprocessed data file and position file used to test the programs at NPS. The position file is identical to that used within the processing stage and the initial receiver (or station) position (Appendix

B) is updated in two of the four data processing programs. The preprocessed file shows the format of three blocks of code acquired during a satellite observation period. The blocks of code contain satellite data which are written on a TI 4100 cassette during acquisition of satellite signals. Appendices C through E give brief descriptions and definitions to each block of code in Appendix A.

C.   BACKGROUND TO PROCESSING STAGE

1. Naming Data Files

Before describing the processing programs, the naming system of programs and files at NPS will be introduced. The programs were renamed once they were adapted at NPS. The names of the NOAA/NGS programs, PHASEDATA, PSEUDOT, STDPHASE, and PHASER were changed to NPHAS1, NPHAS2, NPHAS3, and NPHAS4, respectively. The NPS names reflect the sequential operation of the programs (i.e., NPHAS1 is executed prior to NPHAS2, etc., as the output of NPHAS1 becomes the input to NPHAS2, etc.). See Figure 3.1 for a flowchart of the processing stage.

Once the data from each receiver site have been transferred to floppy disk, checked and translated in the preprocessing stage (section III.B), the data files are ready to be taken through the four computer programs comprising the processing stage. All the programs within the processing stage are very interactive and require the user's continued responses to prompts generated by the programs.

2. Epoch Determination

The processing stage (as per the present algorithm) is capable of processing a maximum of 121 observations (epochs) per receiver during an observation period. For example, if a satellite receiver acquires one observation every 30 seconds during a 2-hour observation period, the receiver would gather satellite data for 241 epochs (7200-second observing period/30 seconds = 240 epochs + 1 epoch = 241 epochs). The number of epochs acquired is then twice that allowed by the program. For this observational scenario, in order to utilize data obtained over the entire observation window and meet the program restriction of 121 observations, every other epoch (60-second interval) would have to be chosen. (Kass and Dulaney, 1986)

24
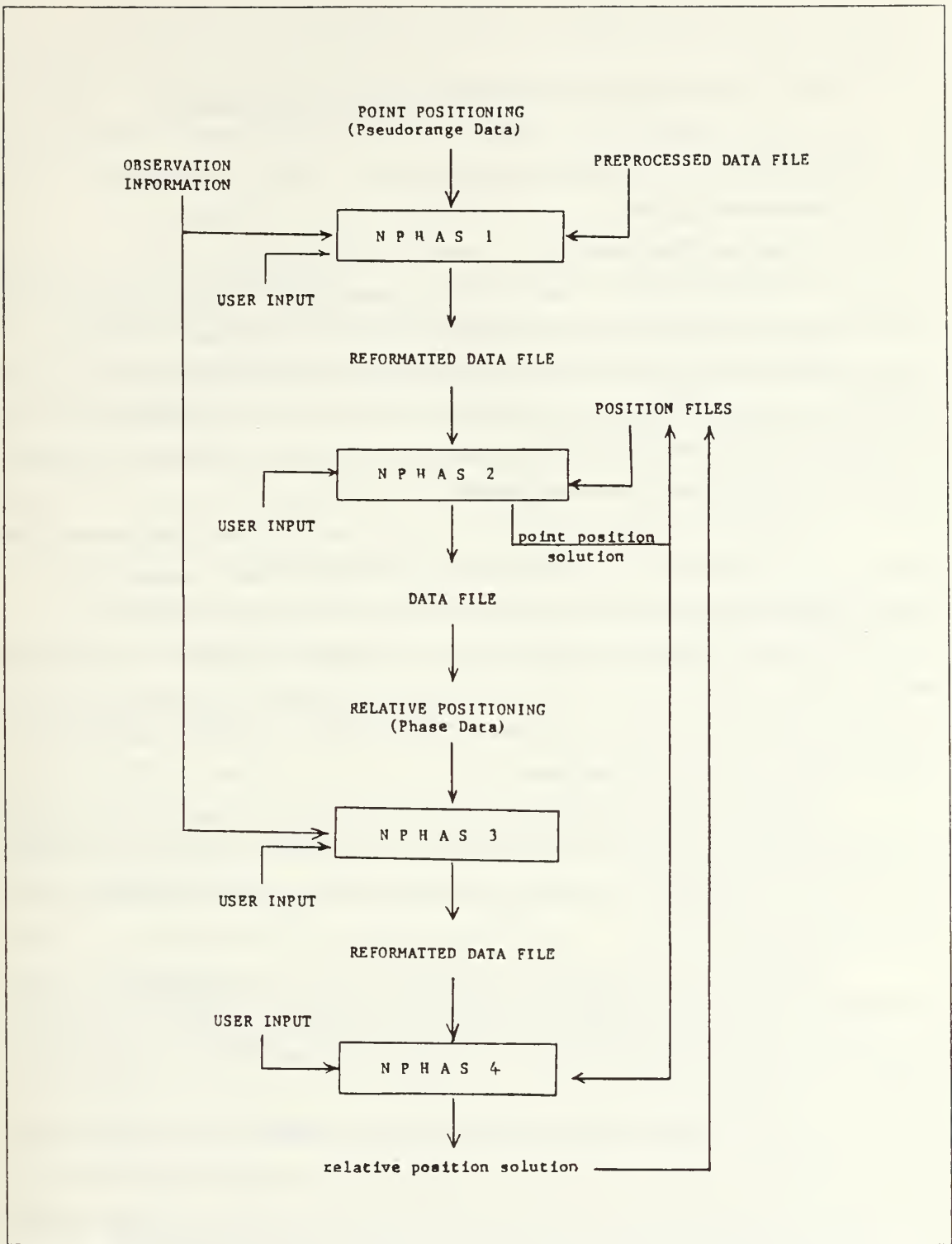
Figure 3.1   Flowchart of Processing Stage.

IV. DESCRIPTION OF PROCESSING STAGE

A. PROCESSING PSEUDORANGE DATA

1. Reformatting of Data

a. *Program Description*

Program NPHAS1, adapted from program PHASEDATA of NOAA/NGS, is the first program within the processing stage. NPHAS1 reformats the data file created in the preprocessing stage so it will be properly formatted for use in the second processing program, NPHAS2. The only files needed to execute NPHAS1 are the data files from TIDUMP (section III.B) and the initial observation information obtained from the logbook during preprocessing stage.

NPHAS1 "asks" the user for the starting year (last two digits), month, day, hour, minute, and second of the first observation. The information entered, in the format yy/mm/dd/hh/mm/ss.ss, is converted to Day of the Year, in seconds, using subroutine JUL. The ending time of the observation period is treated similarly. Error messages will be displayed on the CRT screen should the year of the start/stop dates be improperly entered by the user. The proper format for the year can be reentered as the program will loop back to this prompt.

The date is next referenced to the Saturday midnight immediately preceding the observation day by using the starting year and day of year in subroutine FINSUN. The time interval selected to determine the number of epochs to be processed is also a user input (section III.C.2).

Input/output (I/O) units are then declared (I/O units are described within the program listing). The program accesses the preprocessed data file, reformats the code within each block of satellite data, and writes it to a new file (the output of NPHAS1). Subroutines BLK1, BLK6, and BLK9 are used to access the coded data within Blocks #1, 6, and 9, respectively, within the preprocessed data file (Appendix A). Although NPHAS1 accesses four blocks of code, it only uses code from Blocks #1, 6, and 9 for data processing. The subroutine BLK8 and the code from Block 8, although still called in the program, will soon be deleted by NOAA/NGS (Kass, 1986). Other subroutines for Blocks #2,3,7,10,11,13, and 51, are in the program for possible future use.

NPHAS1 uses a series of IF statements to detect which block of code is being read. As each block is read, the program branches to the subroutine pertaining to that particular block, reads the block information and reformats each entry via format statements. Appendix H contains an example of a reformatted data file, including descriptions of the file's entries.

Subroutine BLK1 reformats the Block 1 variables and retrieves the station site name, etc., from original input information. Subroutine BLK6 contains the precise GPS time of each epoch, pseudoranges, and phase code. The subroutine reformats the Block 6 variables and converts some measurement units of its passed variables to other units (e.g., milliseconds to seconds) so the units of these variables agree with the units set in the programs. Subroutine BLK9 reformats the broadcast navigation message, computes the ionospheric correction coefficients and sets satellite orbit parameters. Appendix F contains brief descriptions of NPHAS1 subroutines and a flowchart of the subroutines within NPHAS1.

b. Program Modifications Made at NPS

To make program NPHAS1 (or the NOAA/NGS program PHASEDATA) compatible with the IBM-3033 mainframe computer at NPS, it was necessary to:

* raise all alpha-characters to upper-case;

* reduce lengths of variable names to less than seven characters;

* reference DO loops to corresponding numbered CONTINUE statements;

* change octal "O" designators in Functions NSBITS and ISBITS to
  integer "I" as the IBM will not support octal code;

* comment out OPEN statements. Opening I/O units was
  accomplished using file definition (FILEDEF) statements within an
  EXEC file.

* modify subroutine DI6TR8 with separate program code to allow bit
  functions on I*2 variables.

Program NPHAS1, and the other three processing programs, were run through two IBM compilers to check for programming and formatting errors. The two compilers used were VS Fortran (FORTVS) and Fortran 77 (WF77). Each error

detected by the compilers was corrected and the program was recompiled. The warning messages displayed by the compilers were then examined and those needing attention were reconciled; for example, the variables within one of the COMMON statements were rearranged so they would be in the same order as the variables used in other COMMON statements within NPHAS1.

c. Program Output

The output of NPHAS1 is an ASCII data file containing the reformatted data (receiver input information, receiver tracking data, and satellite navigation message). The file created by NPHAS1, and all processing programs, were named using the $NP\alpha\beta$ OUTPUT format, where α is the number of the program from which the file was created, and β represents four letters in the name of the station over which the satellite receiver was set (i.e., NP1ATHY OUTPUT is the output file from program NPHAS1 for station ATHY). Appendix G is an example of the contents of an output file from NPHAS1, including a description of each line of code.

2. Point Positioning from Pseudoranges

a. Program Description

Program NPHAS2, adapted from NOAA/NGS program PSEUDOT, uses the pseudoranges acquired from coded phase data (Block 6, Appendix D) to compute the point position of each receiver within the survey network and also gives the the corrected time tag at every epoch (Kass and Dulaney, 1986). The new surveyed position is also injected into the position (p-) file as a position update for the approximate position estimated (by the operator) in program CR8PF during preprocessing. The corrected time tag of every epoch is computed by taking the difference between the receiver and GPS times.

NPHAS2 utilizes either the precise or broadcast ephemeris for data processing. The broadcast ephemeris (BE) branch within the program was adapted and validated at NPS, although both broadcast and precise ephemeris branches within NPHAS2 have been traced in Appendix I. In order to use the precise ephemeris (PE) information, separate library files must be created and properly formatted to hold the PE information and make it available to the programs. The capability to use PE is still not functional at NPS.

The position obtained from NPHAS2 is determined utilizing the entire pseudorange data set for a receiver by computing residuals (observed minus computed ranges) for each pseudorange measurement and then performing a least squares

28

adjustment on all the residuals for a data set; the corrections to the original estimated station position are iterated until the solution converges (Goad, 1986).

The time correction determined for each epoch by differencing the receiver and satellite GPS times is applied to synchronize the receiver clock with the GPS time as available through the satellite clock.

NPHAS2 utilizes the output file from NPHAS1 (i.e., NP1β OUTPUT) and the p-files for each receiver station to be processed. If the precise ephemeris for satellites is to be used, the PE orbit files would also be necessary. I/O units are then declared. To use the initial station position input as latitude, longitude, and height (φ, λ, H), a conversion to X,Y,Z using the following equations (Escobal, 1965) is accomplished in the program:

$$X = G_1(\cos\varphi)$$
$$Y = X(\sin\lambda)$$
$$Z = G_2(\sin\varphi)$$

where: φ = geodetic latitude

λ = east longitude

$G_1 = (a/w) + H$

$G_2 = [a(1-f)^2]/w + H$

H = ellipsoidal height

a = semi-major axis of ellipsoid

f = flattening of ellipsoid

$w = [1-(2f - f^2)\sin^2\varphi]^{1/2} + H$

The program then prompts the user for any satellite bias parameters which are to be applied during the processing of station data. This prompting is useful if the user has a priori knowledge of satellite biases.

Further, the program also displays the following menu for user options:

1 iterate

2 precise/broadcast ephemeris

3 additional print file

4 change iteration parameters

5 another station

6 update p-file

7 ignore satellites

8 prepare phase file (uses precise orbit)

9 sequential estimator

99 stop

Appendix I contains brief descriptions of each subroutine within NPHAS2 and a flowchart of the subroutines when the broadcast ephemeris is used. A brief explanation of each option, followed by the technique used (when running this program), is available in Appendix J. Appendix K contains typical prompts/responses (program user inputs) and descriptions of the prompts used to process data via NPHAS2.

b. *Program Modifications Made at NPS*

To adapt PSEUDOT for operation at NPS (as program NPHAS2) modifications were required to:

* raise all alpha-characters to upper-case;

* reduce lengths of variable names to less than seven characters;

* reference DO loops to corresponding numbered CONTINUE statements;

* reduce three-digit I/O unit numbers to two-digit values;

* comment out OPEN statements. Opening I/O units was accomplished using file definition (FILEDEF) statements within an EXEC file;

* change the dimensions of two arrays, IREC(4) and FREC(4), within subroutines RANGER and SEC to a simple integer and a scalar, respectively;

* add the variable XIDOT(8) to the COMMON/BORBIT declaration within subroutine SEC for this COMMON statement to agree in form with the other COMMON/BORBIT statements;

* comment out one line within subroutine RANGER as it was never used;

* remove variable IERR from subroutine BCXYZ as it was never used.

c. *Program Output*

The outputs from NPHAS2 are a new data file, NP2β OUTPUT (which contains no Block 8 data), and an updated p-file which reflects the new position determined via NPHAS2 execution. The format of an NP2β OUTPUT file, with description of each item, is described in Appendix L.

B. PROCESSING PHASE DATA

1. Reformatting of Data

a. *General*

The third program within the processing stage, NPHAS3, reformats the pseudorange and phase measurements generated in NPHAS2 for entry into program NPHAS4 (NOAA/NGS program PHASER). The program reformats satellite phase data acquired from either TI 4100 or Macrometer GPS receivers for relative station position determinations, although only the TI 4100 processing branch of the program was investigated in this thesis. Version III of this program, which is the version adapted at NPS, stores the L1 frequencies as full wavelengths for TI 4100 data (L1 = 1.0) and as half-wavelengths (L1 = 0.5) for Macrometer data (program documentation).

b. *Program Description*

NPHAS3 uses the output file from NPHAS2, NP2β OUTPUT, and reformats the data within the file. The program begins by establishing the I/O units to be used for data processing (listing of units is within program listing). The user is prompted for use of either TI 4100 or Macrometer data to be input into NPHAS3. Once the choice is made for processing TI 4100 data, NPHAS3 branches to subroutine TISCAN, reads the data files within NP2β OUTPUT and reformats the NP2β data into the format required for use by the last of the processing programs, NPHAS4. Appendix M contains a brief description of the subroutines and a flowchart of the subroutines within NPHAS3. The only input required for NPHAS3 is the output file from NPHAS2 and the precise timing information from the preprocessing stage (i.e., the time manually entered into program NPHAS1, to the same precision). The starting and stopping times are the first times in common between two or more GPS receivers, with the chosen interval to cover the same observation period within the 121 epochs as described in section III.C.2. Appendix N shows the typical prompts/responses used during the execution of NPHAS3.

c. Program Modifications Made at NPS

As with the other processing programs, the I/O unit numbers were changed from three digits to two digits and variable names over six characters in length were shortened to six or less characters (both changes are documented within the program). Unreferenced DO statements were referenced to appropriate line numbers. OPEN statements within the program code were commented out, and the same function was accomplished using FILEDEF's for opening particular I/O units. The FILEDEF's are part of the NPHAS3 EXEC file created at NPS along with the command to execute NPHAS3 ("LOAD NPHAS3 (START"). All alpha-characters were changed to upper-case from lower-case.

Other modifications included changing the designation of variable RECS within subroutine TISCAN from R*8 to I*4 as the variable is used as an integer (and was originally declared in the NOAA/NGS version to be a real number).

d. Program Output

The output of NPHAS3, NP3β OUTPUT, is a reformatted NP2β OUTPUT file which becomes the input file for program NPHAS4. It contains two sections, broadcast ephemeris and phase data information originally obtained from the preprocessed data file. Appendix O shows a portion of an output file from NPHAS3 including value definitions.

2. Relative Positioning from Phase Data

a. Program Description

Program NPHAS4 (NOAA/NGS version named PHASER) determines the relative positions of two stations from satellite phase data. It also gives the user the opportunity to visually check for cycle slips from a listing generated by NPHAS4, flag particular satellites/receivers/epochs at which cycle slips occur, and correct the cycle slips.

NPHAS4 is a highly interactive, menu-driven program which utilizes the single, double, and triple differencing techniques described in subsection II.C.2.b of this thesis to determine the solution from phase data simultaneously acquired by two satellite receivers.

b. Program Modifications Made at NPS

As with the other programs in the processing stage, alpha-characters were set to upper-case, variable lengths were changed so that all variables were six or fewer letters in length, COMMON statement variables were realigned so each COMMON

block had variables in the same order within each subroutine, DO statements were referenced to numbered CONTINUE statements, and three-digit I/O unit numbers were reduced to two-digit values. Further modifications are given in Appendix P. Program NPHAS4 is not yet fully operational at NPS and requires further testing.

c. *Program Output*

The output of NPHAS4 are the positions obtained from each base- line solution, from which the p-files can be updated.

V. RESULTS AND VALIDATION

Test data for this thesis were received from NOAA/NGS in May 1986. The test data consisted of two data files from a base-line survey conducted in Maryland in May 1985. The two TI 4100 receivers were set over two first-order horizontal control stations, ATHY and ORM1, which are part of the national network as maintained by NGS.

The two data files, preprocessed by NOAA/NGS, were on one standard 9-track tape when received at NPS. The tape also included the two p-files, the output files, and the user responses (program inputs) necessary to test and validate the four processing programs using the two data sets.

After the four processing programs had successfully passed through two IBM mainframe compilers (FORTVS and WF77), the data sets from stations ATHY and ORM1 were accessed and the processing programs were sequentially executed. To allow for faster data processing, two additional files containing information necessary for the operation of each processing program were created. One file, NPαβ INPUT, contained the responses to program prompts made by the user which would have otherwise been manually input during program execution. The second file, NPαβ EXEC, contained the FILEDEF's described in Chapter 3 and also the command to execute a particular processing program.

A.   POINT POSITIONING

Testing the adapted programs, NPHAS1 and NPHAS2, involved sequentially executing both programs with the corresponding data sets from stations ATHY and ORM1. NPHAS1 and NPHAS2 have been adapted to process data from only one station at a time. Therefore, the files from ORM1 were first used in the execution of NPHAS1 and NPHAS2 followed by executing these programs again using ATHY data. Actual execution of each program was accomplished by entering "nphas1" or "nphas2" on the computer keyboard. Either entry accessed the appropriate EXEC file (NPHAS1 EXEC or NPHAS2 EXEC) and began the data processing. Appendices G and K contain the INPUT files, EXEC files, and the actual CRT screen presentations of the executions of NPHAS1 and NPHAS2.

To check the validity of each program's results, the same user responses were used at NPS as NOAA/NGS used to process the base-line data. The results of the point positioning determinations for stations ATHY and ORM1 are shown in Table 2.

TABLE 2
RESULTS OF NPHAS2

	NPS RESULTS	*NOAA/NGS RESULTS*
Station: ATHY		
# Measurements Used in Computation	364	364
RMS of Residuals (m)	2.702906	2.702905
Latitude (N)	39°06'11".03522	39°06'11".03522
Longitude (E)	282°42'37".83623	282°42'37".83623
Height (m)	104.139	104.139
Station: ORM1		
# Measurements Used in Computation	401	401
RMS of Residuals (m)	2.640996	2.640998
Latitude (N)	39°08'11".36042	39°08'11".36042
Longitude (E)	282°48'04".60445	282°48'04".60446
Height (m)	124.908	124.907

B. RELATIVE POSITIONING

The output from program NPHAS3 is a reformatted data file which contains satellite broadcast ephemeris information, carrier phase data for both L1 and L2 frequencies, and date/time information (i.e., year, day of year, time of observation in seconds, etc.).

To determine if the output file obtained at NPS agreed with its corresponding file from NOAA/NGS, the IBM mainframe system "Compare" command was used. This command compares, bit by bit, the n-th line of one file with the n-th line of another file; any discrepancies are exhibited on the CRT screen. The "Compare" command was used to validate the NPHAS3 results for stations ATHY and ORM1. Each line within the output file for station ATHY agreed, bit by bit, with that from NOAA/NGS. All data from station ORM1 agreed with the NOAA/NGS results for that file with the exception of the time in seconds (variable DYSEC) and the input year (variable IYR)

within the broadcast ephemeris information. These variables are written to I/O unit #11 (IUNIT3). Although no error messages were generated during the execution of NPHAS3 with data from station ORM1, the problem may exist within one of the scratch files used as an intermediate step in data processing. Temporary code was added to observe what values for IYR and DYSEC were being written. Further investigation of these two variables will be necessary to rectify this problem. As the program properly processes one data file (ATHY) and not the other (ORM1), actual program code is suspect.

Modifications have been made to NPHAS4 so that the program accepts initial program information input (number/names of stations to be processed, etc.). The program halts when the user chooses the first processing option (triple differencing technique described in paragraph II.C.2.b.3) within the program's main menu. The problem was traced at NPS to subroutine TRPLE, which computes the triple difference solution. Temporary WRITE statements inserted in various portions of TRPLE traced the problem to the computation of one of two variables IPAR and ITOT. Further investigation is necessary to correct this, and possibly, other problems.

VI. SUMMARY

The GPS PHASER software package, which processes GPS data (both pseudorange and phase data) using either broadcast or precise ephemeris satellite information, was obtained from NOAA/NGS. The specific programs which compute point positions using pseudorange and broadcast ephemeris information have been successfully adapted to the NPS mainframe computer and are fully operational. Test data run on the adapted point position programs, which are station positions in the WGS 72 coordinate system, give results which agree with those obtained from NOAA/NGS.

Extensive modifications have also been made on the programs within the software package which calculate relative station positions (NPHAS3 and NPHAS4). Further, three of the five computer programs comprising the preprocessing stage of the NOAA/NGS GPS data reduction system have also been obtained, catalogued, and documented at NPS. These preprocessing and relative positioning softwares require further effort to make them operational at NPS.

VII. RECOMMENDATIONS

The processing programs from NOAA/NGS adapted under this thesis at NPS are the beginning of a software library which will reduce broadcast ephemeris GPS data acquired from stationary TI 4100 receiver stations. The following recommendations are offered to make the data processing fully operational and useful at NPS. The preprocessing programs should be adapted on the IBM mainframe to eliminate the necessity of sending the field cassettes to NOAA/NGS; this would not only allow for a faster data reformatting capability but also allow NPS to be self-reliant in preprocessing satellite data. Modifying and testing programs NPHAS3 and NPHAS4 should continue so they are fully operational at NPS. Program NPHAS4 should be examined to determine those options which may be most suitable for data processing by NPS and adapt only those options. Programs NPHAS1, NPHAS2 and NPHAS3 should be modified to process data from more than one receiver site per program execution (although the programs prompt the user for more receiver site information, the corresponding input/output units have not been formatted to accept data from more than one station per execution). The NOAA/NGS postprocessing program should be obtained and adapted in order to adjust an entire survey network surveyed with TI 4100 GPS receivers.

APPENDIX A
EXAMPLE OF PREPROCESSED DATA FILE

```
*** BLOCK NUMBER  1
  220    1       2642 55016 1.471    UT 4  5      3
    184560      191160      198960         0          0
            0          0          0          0          0
            0          0          0          0          0
            0          0          0          0          0
            0          0          0          0          0
    4    4    4    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0
    6    8    9   11   12   13    9   11    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0
    6    0    0    5    6    8    9   11    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0
86400   30   300 39.10000000282.80000000  0.15400000  991   23   60
*** BLOCK NUMBER  6
     115434          0   9094531    6    0    0    0
   10   58   58   58   87   43   43   43   84    0    0    0
   10 4853    158 18836 24396 -4771 18839 32388 -4771 18834-12368 -4771
   10 4853 3743 18828 30791 11630 18828 30791 11630 18828 30791 11630
   -3 4964 8386    0    0    0    0    0    0    0    0    0
    0-26859 -5340    0    0    0    0    0    0    0    0    0
    0   17   17   17    0  128  128  128   43
*** BLOCK NUMBER  9
```

39

```
    1      6  8954  4059  3790  8655  4452-16353  1013  2995  5420 30456
     126 10274  3742 32483   203 27916    63 -6144 15375-23785
    8954  4059  3789-23957   252  8488   883 17638   875  9296
  15511    104 14065 17940   860 -6078   864  4639  2925  5479
    8954  4059  3789-15589     5-25385  5225-16542 16383-29831
    9097-22199  2656  5344  6314 22733 16366 29733   253 31239
```

Descriptions of the inputs into this file may be obtained in
Appendices C through E.

APPENDIX B

EXAMPLE OF POSITION (P-) FILE

1) UPDATED IN   PSEUDOT AT THU MAR 20 14:42:30 1986

2) WGS-72   WGS-72   WGS-72   WGS-72   WGS-72

3) ANT HT(M) = 1.4710(mark to preamp) + 0.218(phase ctr. to preamp ref.pt)

4) S

5) STATION 2

6) STATION NAME   ATHY

7) LATITUDE   39 6 11.03522

8) E-LONGITUDE 282 42 37.83623

9) W-LONGITUDE   77 17 22.16377

10) ELLIP HT(M)   104.1389

11) ANTENNA HT(M)   1.6880

12) GEOID HT(M)   -32.39

13) DATA FILES

14) PHASE DATA FILE   T1275A.F.ATHY

15) ORBIT FILE   /orbits/BE8432

Description of P-File Contents:

1) Information as to source of position in the file (this particular
file was updated within the second program of the processing stage).

2) Coordinate system upon which the p-file position is based.

3) Self-explanatory.

4) Flag within file to signal the end of the p-file header information.

5-12) Self-explanatory.

13-15) Ignore; files used at NOAA/NGS for their processing system.

15) Name of file, in the NOAA/NGS naming system, for the broadcast
orbit files. Can be ignored.

APPENDIX C

DESCRIPTION OF GESAR BLOCK 1 DATA

GESAR/ASDAP BLOCK 1 - INPUT DATA(*)

WORD #	TYPE	DATA NAME	DESCRIPTION
1	I*4	IVERS	SOFTWARE VERSN
2	I*4	IDAIDF	DOPPLER AIDING FLAG (1 = AIDING USED, 0 = NOT)
3-4	I*4	IDAIDV	DOPPLER AIDING VALUE (HZ)
5-12	CHAR*2	RSITE(8)	RECEIVER SITE
13-16	CHAR*2	RSNUM(4)	RECEIVER SERIAL NUMBER
17	CHAR*2	USID	USER ID
18	I*4	INSCEN	NUMBER OF SCENARIOS
19-68	I*4	ISTT(25)	START TIME FOR EACH SCENARIO (GPS SEC)
69-93	I*4	ISATPS(25)	# SAT. TO TRACK PER SCENARIO
94-193	I*4	ISATN(100)	SAT. NOS. TO TRACK
194	I*4	IFSATN	SAT. NO. TO FIRST TRACK
195	I*4	INUMSN	# OF SAT. NOS. AVAILABLE
196-216	I*4	ISNAV(21)	SAT. NOS. AVAILABLE FOR TRACKING
217-218	I*4	ICALIN	CALIBRATION INTERVAL (SEC)
219	I*4	IPRINT	PROCESS INTERVAL FOR DATA PTS (SEC)
220	I*4	IRDINT	RECORD INTERVAL FOR DATA POINTS (SEC)
221-226	CHAR*2	LAT(6)	INITIAL RECEIVER LATITUDE (F12.8)
227-232	CHAR*2	LONG(6)	INITIAL RECEIVER LONGITUDE (F12.8)
233-238	CHAR*2	HT(6)	INITIAL RECEIVER HT (F12.8)
239	I*4	IPRES	PRESSURE (MBAR)
240	I*4	ITEMP	TEMPERATURE (C)
241	I*4	IHUM	HUMIDITY (%)
	R*8	RLAT	LATITUDE (DEGREES)

42

R*8	RLONG	LONGITUDE (DEGREES)
R*8	RHT	HEIGHT (KM)
CHAR*12	TEMP	AGGRAGATE VALUE OF HT,LAT,LONG

Block 1 is the input data provided by the user. This block is written
near the beginning of the first cassette used in data collection. This
block is also written each time the user changes the collection rate,
solution rate or a scenario entry. The pressure, temperature, and
humidity values recorded in Block 1 are the initial values entered during
the input session. These values are used in the calculations of the
solution and will remain constant throughout the data collection
session (Darnell, 1986).

(*) Descriptions of Blocks 1,6 and 9 (Appendices C through E) are
obtained from subroutines BLK1, BLK6 and BLK9 within NPS computer
program NPHAS1.

APPENDIX D

DESCRIPTION OF GESAR BLOCK 6 DATA

GESAR/ASDAP BLOCK 6 - RECEIVER TRACKING DATA

WORD NO.	TYPE	DATA NAME	DESCRIPTION
1-2	I*4	IPFTFV	PSEUDORANGE FTF OF VALIDITY (20 MSEC)
3-4	I*4	IFBIOF	FTF BIAS OFFSET (LSB = 2-16*625 USEC)
5-6	I*4	IUETPR	USER EPOCH TIME OF PSEUDORANGE (20 MSEC)
7-10	I*4	ISVID(4)	SV PRN ID OF EACH DATA INDEX
11-14	I*4	ITRKRM(4)	TRACKER MODE
15-22	I*4	ICPNDR(8)	L1,L2 CARRIER POWER-TO-NOISE DENSITY RATIO (LSB = 0.5 DB-HZ)
23-34	I*4	IL1PR(12)	L1 PSEUDORANGE (LSB = 2-16 P-CHIPS)
35-46	I*4	IL2PR(12)	L2 PSEUDORANGE (LSB = 2-16 P-CHIPS)
47-58	I*4	IL1DPH(12)	L1 CARRIER DOPPLER PHASE AT CODE FTF (LSB = 2-16 CYCLES)
59-70	I*4	IL2DPH(12)	L2 CARRIER DOPPLER PHASE AT CODE FTF (LSB = 2-16 CYCLES)
71-78	I*4	IQVEC(8)	QUALITY VECTOR FOR L1, L2
79	I*4	IITEMP	SET INTERNAL TEMP (DEG C)

COMMON BLOCK BUF6 (OUTPUT)

	TYPE	DATA NAME	DESCRIPTION
	R*8	RPFTFV	PSEUDORANGE FTF OF VALIDITY (SEC)
	R*8	RFBIOF	FTF BIAS OFFSET (SEC)
	R*8	RUETPR	USER EPOCH TIME OF PSEUDORANGE (SEC)
	R*8	RPNDR1(4)	L1 CARRIER POWER/NOISE DENSITY RATIO
	R*8	RPNDR2(4)	L2 CARRIER POWER/NOISE DENSITY RATIO RATIO (DB-HZ)
	R*8	RL1PR(4)	L1 PSEUDORANGE (P-CHIPS)
	R*8	RL2PR(4)	L2 PSEUDORANGE (P-CHIPS)
	R*8	RL1DPH(4)	L1 CARRIER DOPPLER PHASE AT CODE FTF (CYCLES)

R*8	RL2DPH(4)	L2 CARRIER DOPPLER PHASE AT CODE FTF
I*4	I4	CONVERTS 2 I*2 TO I*4
I*2	I2(2)	CONVERTS 2 I*2 TO I*4
		(CYCLES)

Before the time bias adjustment is made, this block is recorded at a six-second rate. Afterwards, block 6 is recorded as often as the user requests, unless this value is changed via the {RET INP} key. If changed, the updated value will be used. One Block 6 is recorded before the almanac data (Darnell, 1986).

APPENDIX E
DESCRIPTION OF GESAR BLOCK 9 DATA

GESAR/ASDAP BLOCK 9 - NAV MESSAGE EPHEMERIS

WORD NO.	TYPE	DATA NAME	DESCRIPTION
1	I*4	ITRKID	TRACKER ID
2	I*4	ITRSID	TRACKER SATELLITE PRN ID
3-22	I*2	ITSPG1(20)	TRACKER SUBFRAME PAGE 1
23-42	I*2	ITSPG2(20)	TRACKER SUBFRAME PAGE 2
43-62	I*2	ITSPG3(20)	TRACKER SUBFRAME PAGE 3

Block 9 is recorded every time a tracker acquires a satellite and
when the ephemeris message is changed on a "download" of the SV
(downloads usually occur at the beginning of each hour) (Darnell,
1986).

Details of Block 9 contents are located in Appendix H.

APPENDIX F

SUBROUTINE DESCRIPTION & FLOWCHART FOR NPHAS1

Subroutine Name	Description
ACOMP	Complements the number of bits within each word for a total of 32 bits.
BLK1	Reads and formats inital input data (Block 1).
BLK2	Reads and formats the navigation almanac (Block 2) of the satellite message.
BLK3	Reads and formats the receiver solution (X,Y,Z of receiver position, solution FTF time and user epoch time(both in 20msec) within Block 3 of message; also converts 20msec to sec and coordinates to meters (LSB of coordinates is 2^{-16} meters).
BLK6	Reads and formats the receiver tracking data within the Block 6 satellite message (pseudorange data).
BLK7	Reads and formats the receiver tracking data within the Block 7 satellite message (code phase data).
BLK8	Reads and formats the receiver tracking data within the Block 8 satellite message.
BLK9	Reads and formats the broadcast ephemeris message within the Block 9 satellite message. Ionospheric correction coefficients, α_k and β_k, and satellite orbit parameters are also obtained.
BLK10	Reads and formats the input weather data from Block 10 of the satellite message.
BLK11	Reads and formats the error messages sent by each satellite within the Block 11 code.

BLK13	Reads and formats the header/trailer data at the beginning and end of each data set and cassette.
BLK51	Reads and formats the synchronization data (FTF of synchronization, GPS week, UE time of synchronization, etc.).
CNVRT	Converts time (LSB = 20msec) to GPS days, hours, minutes, and seconds.
FINDTM	Finds the JD and seconds of day from the user supplied JD of Sunday of GPS week of observation (JDSUN) and the user epoch time of pseudorange (RUETPR).
FINSUN	Computes the beginning of week (Sunday) given an arbitrary year and day of year.
Function DI6TR8	Takes 3 I*2 variables (passed as I*4) and returns the R*8 value of the 48 bits.
Function IBITVL	Tests bit in a particular place has value of 0 or 1.
Function ISBITS	Shifts bits to the left or right to make room for another 32-bit word within a line of code.
Function NSBITS	Finds which word to begin with and the bit number in the starting word.
JUL	Calculates the Julian Day, given the year, month and day.
MJYDAY	Given the modified Julian date, this subroutine returns year and days from beginning of year (i.e., 76 1.5 = Jan 2 12 hours 1976).
SETBIT	Changes bit pattern in each word from 0 to 1 (i.e., value of word tells if its in 1st, 2nd, etc. 32-bit section).

Flowchart of Subroutines Within NPHAS1 (as Constructed at NPS):

MAIN PROGRAM
   JUL
   JUL
   JUL
   JUL
   FINSUN
      JUL
      JUL
      MJYDAY
   BLK1
   BLK6
   FINDTM
   BLK9
      SETBIT
      SETBIT
      SETBIT
   BLK8

Notes: Sources of subroutine descriptions from program
listing or telephone communications with NOAA/NGS.

APPENDIX G

INPUT LISTING & DESCRIPTION FOR NPHAS1

NP1ORM1 Input Listing (*)	*Description*
NP1ORM1 INPUT	1) input file name
NP1ORM1 OUTPUT	2) output file name
85 5 7 5 33 29.0799999999999999	3) time of first observation
85 5 7 7 16 29.0799999999999999	4) time of last observation
60.0	5) time interval (sec)
N	6) print results to the screen?
N	7) enter another station

Description of Input File:

1,2 Self-explanatory.

3   The first time which is common to all stations during satellite
data acquisition.

4   The last time during an observation period which is common to
all stations.

5   This value is the interval chosen to obtain 121 epochs over the
range of the observation period (described in Chapter 3.C). Sixty
seconds gave the proper spread between epochs.

6   Measurements are normally not printed to the screen unless there
is reason to believe data, etc is questionable.

7   Prompts for another station. The I/O units at NPS have not
been set up to process more than one station during the execution
of this program; normally, "yes" would be input to process a number of
stations in a batch mode.

CRT SCREEN RESULTS OF NPHAS1 OPERATION FOR STATION ORM1(*)

Screen Results	(*Comments are in parentheses*)
nphas1	(Command to execute NPHAS1)
FILEDEF 01 DISK NPHAS1 INPUT	(File definitions to open I/O units)
FILEDEF 33 DISK ORM1 DATA	
FILEDEF 12 DISK NP1ORM1 OUTPUT	
LOAD NPHAS1 (START	

     (Note: Above five lines are contents of NPHAS1 EXEC file)

EXECUTION BEGINS...

PHASEDATA 03/13/86   (Version of NOAA/NGS PHASEDATA program)

ENTER INPUT FILE NAME

NP1ORM1 INPUT

ENTER OUTPUT FILE NAME

NP1ORM1 OUTPUT

ENTER YEAR, MONTH, DAY, HR, MIN & SEC OF 1ST OBSERVATION

NOTE: PRECISE TIMING IS ESSENTIAL

(E.G.   YY, MM, DD, HH, MM, SS.SS)

          85   5   7   5   33   29.0799999999999999

ENTER YEAR, MONTH, DAY, HR, MIN & SEC OF STOP TIME

(E.G.   YY, MM, DD, HH, MM, SS.SS)

          85   5   7   7   16   29.0799999999999999

ENTER INTERVAL (SEC)

   60.0000000000000000

PRINT TO THE SCREEN? Y/N

N

ENTER ANOTHER STATION (Y/N)?

N

(*) Input Listing and Screen Results for station ATHY are identical
to that of ORM1 with the exception of the name of the input/output
files, which would be NP1ATHY INPUT and NP1ATHY OUTPUT, respectively.

PORTION OF NPHAS1 OUTPUT FILE

1) C STATION INFORMATION: 55016 1.471   UT 4
2) C INITIAL ESTIMATES: LAT = 39.10000000 LONG = 282.80000000 HT =   154.0000 (M)
3) 8   0.00000   0.00000   0.00000   0.00000
4) 8   0.00000   0.00000   0.00000   0.00000
5) 9 1 6 -0.1202062704D-03 -0.1091393642D-10 0.0000000000D + 00 0.1872000000D + 06
6)   6 6144.00000000   -123.875000000   0.126183828022E-08 0.467641146239
7)   -0.650435686111E-05 0.362983625382E-02 0.641308724880E-05 5153.68763733
8)   187200.0   0.4097819E-07 332.0000   -0.3725290E-08-0.2307239E-09
9)   1.11809471942   2.83035296573   2.04658555515   -0.641741016804E-08
10) 1 1285 127 0.200090800000000D + 05 77.074.0 0.237783232474D + 08 0.237783281626D + 08
11) 2 0.1174887657D-01   7 0.00000000D + 00 0.755366097868D + 08-0.996784614395D + 08
12) 1 1385 127 0.200090800000000D + 05 82.079.0 0.224571663344D + 08 0.224571720428D + 08
13) 2 0.1174887657D-01   7 0.00000000D + 00 0.726657563761D + 08-0.858671224578D + 08
14) 1 985 127 0.200090800000000D + 05 79.080.0 0.215010011841D + 08 0.215010053812D + 08
15) 2 0.1174887657D-01   7 0.00000000D + 00 0.440674103595D + 08-0.415194967887D + 08
16) 1 1185 127 0.200090800000000D + 05 83.077.0 0.209147162535D + 08 0.209147210252D + 08
17) 2 0.1174887657D-01   7 0.00000000D + 00 0.326130483440D + 08-0.361480531176D + 08

Description of Output:

Lines 1-2 Block 1 satellite data

Line 1 = RSITE (receiver site number), RSNUM (receiver serial number)

Line 2 = receiver latitude, longitude and height

Lines 3-4 Block 8 satellite data. Block 8 is called but not used
    (will be commented out by NOAA/NGS in future program versions).

Lines 5-9 Block 9 satellite data (ephemeris data) (*)

Line 5: 9 = FLAG (record mode type)

        1 = ICHAN (satellite channel number/tracking identifier)

        6 = IPRN (tracking satellite PRN identifier)

        -0.120... = A (clock correction coefficient for timing polynomial)

        -0.109... = A (clock correction coefficient for timing polynomial)

        0.000... = A (clock correction coefficient for timing polynomial)

        0.187... = TOC (reference time)

Line 6: 6 = SV# (space vehicle number)

      614... = AODE (age of data (ephemeris))

      -123... = CRS (amplitude of the sine harmonic correction term to the orbit radius)

        0.126... = DELTAN (mean motion difference from computed value)

        0.467... = EM0 (mean anomaly at reference time)

Line 7:-0.650... = CUC (amplitude of the cosine harmonic correction term to the satellite angle of inclination)

        0.362... = E (first eccentricity of satellite)

        0.641... = CUS (amplitude of sine harmonic correction term to the argument of latitude)

        515... = ROOTA (square root of semi-major axis of satellite orbit)

Line 8: 1872... = TOE (ephemeris reference time)

        0.409... = CIC (amplitude of the cosine harmonic correction term to the satellite angle of inclination)

        332... = CRC (amplitude of the cosine harmonic correction term to the orbit radius)

        -0.372... = CIS (amplitude of the sine harmonic correction term to the satellite angle of inclination)

        -0.230... = XIDOT (secular change to the satellite angle of inclination)

Line 9: 1.118... = XI0 (satellite inclination angle at reference time)

        2.830... = OMEGA0 (satellite right ascension at reference time)

        2.046... = PER0 (the argument of perigee)

        -0.641... = OMEGAD (the rate of right ascension)

Lines 10-17 Block 6 satellite data (**)

Line 10: 1 = MT (record mode type)

        12 = SV# (space vehicle number)

        85 = YR (last two digits of the year)

        127 = JD (day of year)

        0.200... = DAYSEC (no. of seconds in the day at the time of observation)

        77.0 = RPNDR1 (L1 carrier power-to-noise density ratio)

74.0 = RPNDR2 (L2 carrier power-to-noise density ratio)

0.2377... = RL1PR (L1 pseudorange (p-chips))

0.2377... = RL2PR (L2 pseudorange (p-chips))

Line 11: 2 = MT (record mode type)

0.117... = RFBIOF (FTF bias offset (seconds))

7 = ITRKRM (tracker mode)

0.000... = DZERO (formatting spacer)

0.755... = RL1DPH (L1 carrier doppler phase (cycles))

-0.996... = RL2DPH (L2 carrier doppler phase (cycles))

(*) The satellite ephemeris variables within block 9 were obtained from the NPHAS2 program listing (subroutine READDT). Information can also be obtained in Table 20-II, "Navstar GPS Space Segment/Navigation User Interfaces, Interface Control Document, ICD-GPS-200", Rockwell International Corp., Downey, CA, 1984.

(**) Lines 12-17 contain similar information (as in lines 10-11 for SV#12) for SV# 13, 9 and 11, respectively.

APPENDIX I

SUBROUTINE DESCRIPTION & FLOWCHART FOR NPHAS2

Subroutine Name	*Description*
ANVRS	Computes double precision inverse of a normal matrix.
BCXYZ	Computes either position or position and velocity via Kepler's equation.
BLOCK DATA CNSTS	Assigns values to 23 "constants of nature" found in two COMMON statements, FUND and ASTRO. Descriptions of each constant and the source of the values are found within the program documentation.
BLOCK DATA TLATE	Declares the semi-major axes and flattening terms for both NAD 27 and WGS 72 (A27,F27,A72,F72) and the translation parameters between the two datums.
CLEAR	Clears an integer (I*4) array.
DCLEAR	Clears a double precision (R*8) array.
DMS	Converts decimal degrees to degrees, minutes, sec.
DOT	PE data only. Computes the dot product between two vectors.
ECFUNO	PE data only. NOAA/NGS subroutine; not documented within NPS version of NPHAS2 (dummy code added until PE data are used).
EPHEM	Changes flag from broadcast to precise ephemeris via small menu.
FIXER	Examines phase data from precise ephemeris and also eliminates large cycle slips.

FLAGST	Flags bad satellites.
FUNCTION DECDG	Converts decimal degrees to degrees/minutes/seconds.
FUNCTION GHA	Computes Greenwich Hour Angle.
FUNCTION IFNSAT	Ignores a satellite.
FUNCTION REDYES	A logical function which will allow user to re-enter a Y/N value if original value is incorrect.
GEOMR	Computes the broadcast ephemeris or can attach to NOAA/NGS library for precise ephemeris data.
INTEGER FUNCTION INONBL	Returns the last nonblank position within parameter. CHARG, or "1" if there are no nonblank characters.
ITRPRM	Allows user to change parameters via menu.
JUL	Calculates the Julian Day, given yr, mon, and day.
KALMAN	Kalman filtering subroutine.
LTIME	PE data only. NOAA/NGS subroutine; not documented within NPS version of NPHAS2 (dummy code added until PE data is used).
PASSER	PE data only. Passes through data three times to find cycle slips; on third pass, corrects them.
PERREL	Transforms rectangular earth-fixed satellite coordinates to inertial coordinates and computes the periodic relativity effect in the range values.
PRED	Predicts a satellite orbit via Kalman filter.
PRTPO	Prints positional information.
RANGER	Reads data, iterates to convergence, updates the X,Y,Z,t values, processes data epoch by epoch accounts for satellite biases and fills the normal matrix (ANVRS).

RDPPI	Reads the position (p-) file.
READ01	Reads only broadcast ephemeris information; bypasses pseudoranges and phases.
READDT	Reads all broadcast, pseudorange, and phase code information. Also accounts for ionospheric correction (average between L1 and L2 values). Ignores Block 8 data.
REDDAT	For PE only. Reads data from Block 8 satellite data.
RIT9	Writes out broadcast ephemeris data from Block 9 satellite data.
RITDAT	Writes the output file of NPHAS2.
SEQ	Uses 25% of the data to compute a "quick and dirty" position from one iteration.
SEQBAY	For PE data only.
SETDE	Sets all values in an array to one value.
SVPVPE	PE data only. NOAA/NGS subroutine; not documented within NPS version of NPHAS2 (dummy code added to NPHAS2 until PE data are used).
TOECF	Computes earth-centered fixed coordinates from inertial coordinates.
TOGND	Computes coordinates of antenna, reduces antenna ht to ground, and computes X,Y,Z values of mark on ground.
TOIN	Computes inertial coordinates from ECF values.
TOPO	For PE data only.
TOPOT	For PE data only.
TRANF	Converts geodetic latitude, east longitude, height

	to X,Y,Z values. Uses first-order Taylor Series to solve for geodetic latitude and height.
TROPRF	Computes tropospheric refraction correction via modified Hopfield Troposheric Refraction routine.
VECAD	PE data only. Returns vector C to the result of additions and subtractions; also gives unit vector of C and the magnitude of C.
VMPV9	PE data only. Ninth-order (eighth-degree) polynomial is fit to the NOAA/NGS orbital ephemeris table. On the initial call, the system of linear equations is solved; all other times this code is skipped. Velocities are found by differentiating polynomial.
WRPPF	Prints position (geodetic latitude, east longitude, ellipsoidal height) in p-file.
WRPPT	Replaces the old latitude, longitude, and height in the p-file with new values.
INTEGER FUNCTION INONBL	Returns the last nonblank position within parameter. CHARG, or "1" if there are no nonblank characters.

Flowchart of Subroutines within NPHAS2 (as constructed at NPS)

MAIN PROGRAM
    JUL
    RDPPI
    TRANF
    TRANF
    DMS
    PRTPO
        DMS
        DMS
        DMS

Main program now utilizes options within menu for data processing

1) iterate:

LTIME

WRPPF

    DMS

    DMS

    DMS

RANGER

    DCLEAR

    READ01

    DCLEAR

    READDT

      JUL

    DCLEAR

    DCLEAR

    RIT9

    DCLEAR

    GEOMR (User chooses BE or PE option)

(BE Option)	(PE Option)
BCXYZ	TOPOT
TOIN	ECFUNO
TOECF	SVPVPE
PERREL	VECAD
TROPRF	DOT
	TOIN
	TOECF
	PERREL
	TROPRF

(Program proceeds as follows after either BE or PE is used)

ANVRS

TOGND

    TRANF

    TRANF

PRTPO

DMS

DMS

DMS

PRTPO

DMS

DMS

DMS

2) precise/broadcast ephemeris:

EHPEM(BCAST)

3) additional print file:

PRTPO

DMS

DMS

DMS

4) change iteration parameters:

ITRPRM

5) another station:

(no subroutines called)

6) update p-file:

WRPPT

LTIME

DMS

DMS

DMS

7) ignore satellites:

FLAGST

8) prepare phase file (uses precise orbit):

FIXER

CLEAR

REDDAT

JUL

REDDAT
   JUL
PASSER
   TOPO
      ECFUNO
      SVPVPE
      TOIN
      TOECF
      VECAD
      DOT
   TOPOT
      ECFUNO
      SVPVPE
      VECAD
      DOT
   TROPRF
   PRED (called 4 times)
   CLEAR (called 9 times)
PASSER
PASSER
RITDAT
   JUL

9) sequential estimator:
  SEQ
    DCLEAR
    DCLEAR
    READ01
    READDT
    DCLEAR
    GEOMR
      (same as for menu item #1, GEOMR subroutine)
    SEQBAY
      ANVRS
      ANVRS

KALMAN

TOGND

    TRANF

    TRANF

PRTPO

    DMS

    DMS

    DMS

PRTPO

    DMS

    DMS

    DMS

Note: Source of subroutine descriptions from program listing or telephone communications with NOAA/NGS.

APPENDIX J
DESCRIPTION OF NPHAS2 MENU

Menu Item: *Description*

1 iterate: Will process the pseudorange data and update the position of each station for the chosen number of iterations or until the position values converge. The iteration process using the broadcast ephemeris is accomplished within subroutine RANGER.

2 precise/broadcast ephemeris: Displays a short menu, prompting the user to pick either precise or broadcast ephemeris. Menu is displayed within subroutine EPHEM.

3 additional print file: Option calls subroutine PRTPO which takes the most recent position information and prints it into file.

4 change iteration parameters: Gives the user another method of changing the parameters assigned to the iteration of position information via another small menu.

5 another station: Closes a scratch file and loops back to the beginning of the program where it reads and prints the initial positions of another station from its p-file and continues processing that station's data.

6 update p-file: Writes the geodetic latitude, east longitude, height and program name in which the p-file was updated via subroutine WRPPT.

7 ignore satellites: Gives the user the opportunity to choose which SV numbers will be used for processing. Subroutine FLAGST allows user to "flag" SV numbers which are to be ignored during processing.

8 prepare phase files (uses precise orbit): Uses precise ephemeris data to establish phase files. This option calls subroutine FIXER which is the main subroutine within NPHAS2 that processes PE data.

9 sequential estimator: Processes approximately one quarter of the satellite data for a "quick and dirty" position. Calls subroutine SEQ which gives a result faster than iterating. This option is not normally used by NOAA/NGS as it was a test to see if less data could be analyzed while maintaining accuracies.

99 stop: Ceases program operation.

During the processing of a typical two-station base line using broadcast ephemeris data, the above menu is utilized as follows: the names of the input/output files will be entered by the user, along with the number of satellite bias parameters (if any). The user picks the broadcast ephemeris mode and has the program iterate the data to convergence. The user has the option of choosing either the number of iterations to be performed or iterating to convergence (the value "-20" is used as the negative sign signifies iterating to convergence; the numerical value is a default value used by NOAA/NGS). During the iterative process, the result of each iteration is displayed on the CRT screen. Option 6 (above) is chosen as the newly determined position will replace the old position within the p-file. The program will iterate once more time before replacing the new station position for the old one. The same process continues for subsequent stations to be located. Appendix K shows the typical prompts/responses by NOAA/NGS to process data via NPHAS2.

APPENDIX K

INPUT LISTING AND DESCRIPTION FOR NPHAS2

NP2ORM1 Input(**)	*Description*
MM	1) analyst's initials
ORM1 DATA	2) p-file name
1	3) # of satellite bias parameters
4 0.0	4) SV# and initial value for bias
2	5) menu: precise/broadcast ephemeris
2	6) menu: broadcast selected
1	7) menu: iterate
N	8) print measurements
N	9) create new data file
-20	10) # of iterations
1	11) menu: iterate
N	12) print measurements
Y	13) create new data file
NP2ORM1 OUTPUT	14) new data file name
6	15) menu: update p-file
99	16) menu: stop
Y	17) quit

Description of Input File:

1,2 Self-explanatory

3   A "satellite bias parameter" is a value assigned to a satellite
which is known to be sending bad data (most often the data information
being sent pertains to the satellite's clock). In this case, one
satellite was known to be transmitting bad data.

4   Satellite 4 was known to be bad during the time of data acquisition
and the initial bias value was set to zero.

5   At this point, the menu is displayed to give the user various
options. The data used for testing NPHAS2 was broadcast ephemeris

data; therefore, broadcast was chosen (the program defaults to precise).

6   A smaller menu, giving the choice of broadcast or precise, is
displayed. Again the user picks the broadcast ephemeris.

7   Processing the pseudorange data is the next step NOAA/NGS takes.
NPHAS2 processes the range data via an iterative process; therefore,
the "iteration" option is chosen.

8   This option is not chosen unless the data/results are suspect.

9   A new file isn't created until the iteration process is completed.

10 Normally "-20" is the chosen number of iterations to
be performed for any one data set. The negative value denotes the
iterations will be performed until the calculated positions converge;
the numerical value is a default value.

11 After the positions converge in the iterative process, the computed
station position is ready to be filed as the position obtained from
NPHAS2. To write the new position to a file, the program goes through
one more iteration. This last iteration is the position which will be
written to the new file.

12 Same as number 8.

13 The positions obtained will be put into the new data file.

14 The name of the output file is from the standard file naming
procedure discussed in Chapter 3 of the thesis text.

15 The menu is again displayed. The user now chooses to write the
new station position over the old position within the p-file. The
new p-file position will be used in the processing of satellite phase
data (program NPHAS4).

16 The user has a choice of options within the program.
All processing for one station has been completed and the option to halt
further processing is chosen.

17 The program allows user to verify the response given in number

16 above.

CRT SCREEN DISPLAY OF NPHAS2 WITH STATION ORM1 DATA(**)

Screen Display   (*Comments are in parentheses*)

nphas2   (Command to execute NPHAS2)
FILEDEF * CLEAR
FILEDEF 05 DISK NPHAS2 INPUT   (File definitions used to open
FILEDEF 30 DISK NP2ORM1 OUTPUT I/O units)
FILEDEF 78 DISK NP1ORM1 OUTPUT
FILEDEF 79 DISK FILE6 DATA
FILEDEF 51 DISK FILE6 DATA
    (Note: Above seven lines are contents of NPHAS2 EXEC file)
LOAD NPHAS2 (START
EXECUTION BEGINS...
PSEUDOT 86.02.06   (Version of NOAA/NGS PSEUDOT
                                         program)
EXPERIMENTAL PSEUDO-RANGE PROGRAM   ALL IN WGS 72
ENTER ANALYS NAME
    MM
ENTER PPFILE NAME -- :: TO END
    FILE6 DATA (ORM1)
UPDATED IN PHASER 03/12/86 AT THU MAR 20 14:51:22 1986
UPDATED IN   PSEUDOT AT THU MAR 20 14:45:30 1986
    (Note: Above two lines show history of ORM1 position)
                  (at NOAA/NGS)
  WGS-72   WGS-72   WGS-72   WGS-72   WGS-72

ANT HT(M) = 1.4710(mark to preamp) + 0.218(phase centr. to preamp ref.point)

STATION 1
STATION NAME   orm1
LATITUDE   39 8 11.17064

E-LONGITUDE 282 48 4.71856

W-LONGITUDE   77 11 55.28144

ELLIP HT(M)   121.3769

ANTENNA HT(M)   1.6890

GEOID HT(M)   -32.35

  (Note: Above position obtained from p-file)

DATA FILES

PHASE DATA FILE   T1275A.F.ORM1

ORBIT FILE   /orbits/BE8432

  (Note: Two above files are from the NOAA/NGS)

   (processing system; not applicable at NPS)

    STAT =   orm1

LATITUDE   39.1364363 39 8 11.17064

E-LONGITUDE 282.8013107 282 48 4.71856

W-LONGITUDE 77.1986893 77 11 55.28144

HEIGHT(M)   121.377

ANT HT(M)   1.689

DATA FILE NAME T1275A.F.ORM1

ENTER NUMBER OF SATELLITE BIAS PARAMETERS

  1

ENTER SV NUMBER AND INITIAL VALUE FOR BIAS

  4 0.000000000000000000E + 00

PICK ONE   1 ITERATE

    2 PRECISE/BROADCAST EPHEMERIS

    3 ADDITIONAL PRINT FILE

    4 CHANGE ITERATION PARAMETERS

    5 ANOTHER STATION

    6 UPDATE P-FILE

    7 IGNORE SATELLITES

    8 PREPARE PHASE FILE (USES PRECISE ORBIT)

    9 SEQUENTIAL ESTIMATOR

    99 STOP

   2

PICK ONE   1 PRECISE EPHEMERIS

            2 BROADCAST EPHEMERIS

          99 NO CHANGE:RETURN TO PROCESSING

CURRENT MODE IS PRECISE

YOU ARE NOW USING BROADCAST EPHEMERIS

PICK ONE   1 ITERATE

           2 PRECISE/BROADCAST EPHEMERIS

           3 ADDITIONAL PRINT FILE

           4 CHANGE ITERATION PARAMETERS

           5 ANOTHER STATION

           6 UPDATE P-FILE

           7 IGNORE SATELLITES

           8 PREPARE PHASE FILE (USES PRECISE ORBIT)

           9 SEQUENTIAL ESTIMATOR

          99 STOP

        1

DO YOU WANT MEASUREMENTS PRINTED ?

N

CREATE NEW DATA FILE ?

N

ENTER NUMBER OF ITERATIONS

A NEGATIVE NUMBER MEANS ITERATE TO CONVERGENCE

ABS. VALUE OF THIS NUMBER IS MAX. NO. OF ITER.

      -20

IFY151I VDIOS : 50 RECORDS OF LENGTH 120 FORMATTED ON FILE FT23F001.

    (Note: This message is displayed by the NPS IBM system only;)

      (gives information regarding the number and size of records)

          (within the direct scratch file, I/O unit #23.)

ITERATION NUMBER   1

BIAS : SATELLITE   0.000 : 4

 NUMBER OF MEAS RMS   402   30517.36

    (Note: Program shows number of records used for processing.)

     (RMS = root mean square of residuals; RMS < 5 is very)

(good (Dulaney, 1986).)

STAT= orm1

LATITUDE 39.1364876 39 8 11.35553

E-LONGITUDE 282.8012794 282 48 4.60583

W-LONGITUDE 77.1987206 77 11 55.39417

HEIGHT(M)   124.458

ANT HT(M)   1.689

ITERATION NUMBER   2

BIAS : SATELLITE   0.000 : 4

  NUMBER OF MEAS RMS   402   4.833046

STAT= orm1

LATITUDE 39.1364876 39 8 11.35553

E-LONGITUDE 282.8012794 282 48 4.60583

W-LONGITUDE 77.1987206 77 11 55.39417

HEIGHT(M)   124.461

ANT HT(M)   1.689

ITERATION NUMBER   3

BIAS : SATELLITE   0.000 : 4

  NUMBFR OF MEAS RMS   402   2.752095

STAT= orm1

LATITUDE 39.1364876 39 8 11.35553

E-LONGITUDE 282.8012794 282 48 4.60583

W-LONGITUDE 77.1987206 77 11 55.39417

HEIGHT(M)   124.461

ANT HT(M)   1.689

ITERATION NUMBER   4

   363 85 127 25409.08   9   24799724.5278   -13.5191 *

BIAS : SATELLITE   0.000 : 4

  NUMBER OF MEAS RMS   401   2.671542

STAT= orm1

LATITUDE 39.1364890 39 8 11.36042

E-LONGITUDE 282.8012790 282 48 4.60445

W-LONGITUDE 77.1987210 77 11 55.39555
HEIGHT(M)   124.907
ANT HT(M)   1.689
ITERATION NUMBER   5
   363 85 127 25409.08   9   24799724.5278   -18.0206 *
BIAS : SATELLITE   0.000 : 4
  NUMBER OF MEAS RMS   401   2.658646
              STAT =   orm1
LATITUDE   39.1364890 39 8 11.36042

E-LONGITUDE 282.8012790 282 48 4.60445

W-LONGITUDE 77.1987210 77 11 55.39555
HEIGHT(M)   124.908
ANT HT(M)   1.689
ITERATION NUMBER   6
   363 85 127 25409.08   9   24799724.5278   -18.3327 *
BIAS : SATELLITE   0.000 : 4
  NUMBER OF MEAS RMS   401   2.640996
              STAT =   orm1
LATITUDE   39.1364890 39 8 11.36042

E-LONGITUDE 282.8012790 282 48 4.60445

W-LONGITUDE 77.1987210 77 11 55.39555
HEIGHT(M)   124.908
ANT HT(M)   1.689
ITERATION NUMBER   7
   363 85 127 25409.08   9   24799724.5278   -18.3329 *
BIAS : SATELLITE   0.000 : 4
  NUMBER OF MEAS RMS   401   2.640996
              STAT =   orm1
LATITUDE   39.1364890 39 8 11.36042

E-LONGITUDE 282.8012790 282 48 4.60445

W-LONGITUDE 77.1987210 77 11 55.39555

HEIGHT(M)   124.908

ANT HT(M)   1.689

PICK ONE   1 ITERATE
            2 PRECISE/BROADCAST EPHEMERIS
            3 ADDITIONAL PRINT FILE
            4 CHANGE ITERATION PARAMETERS
            5 ANOTHER STATION
            6 UPDATE P-FILE
            7 IGNORE SATELLITES
            8 PREPARE PHASE FILE (USES PRECISE ORBIT)
            9 SEQUENTIAL ESTIMATOR
            99 STOP
                  1

DO YOU WANT MEASUREMENTS PRINTED ?

N

CREATE NEW DATA FILE ?

Y

ENTER NEW DATA FILE NAME

NP2ORM1 OUTPUT

1 ITERATION ONLY FOR WRITING NEW FILE

ITERATION NUMBER   8

NEW DATA FILE WRITTEN

PICK ONE   1 ITERATE
            2 PRECISE/BROADCAST EPHEMERIS
            3 ADDITIONAL PRINT FILE
            4 CHANGE ITERATION PARAMETERS
            5 ANOTHER STATION
            6 UPDATE P-FILE
            7 IGNORE SATELLITES
            8 PREPARE PHASE FILE (USES PRECISE ORBIT)
            9 SEQUENTIAL ESTIMATOR
            99 STOP
                  6

PICK ONE   1 ITERATE
            2 PRECISE/BROADCAST EPHEMERIS
            3 ADDITIONAL PRINT FILE
            4 CHANGE ITERATION PARAMETERS
            5 ANOTHER STATION
            6 UPDATE P-FILE
            7 IGNORE SATELLITES
            8 PREPARE PHASE FILE (USES PRECISE ORBIT)
            9 SEQUENTIAL ESTIMATOR
            99 STOP
        99

ARE YOU SURE YOU WANT TO QUIT?(Y/N)
Y
END-OF-RUN

* Program will "flag" the satellite which contains bad data; these
data will not be processed.

(**) Input Listing and Screen Results for station ATHY are identical
to that of ORM1 with the exception of the name of the input/output
files, which would be NP2ATHY INPUT and NP2ATHY OUTPUT, respectively.
There were four iterations of ATHY data before the position converged;
final results from the iterations are in Chapter 5.

APPENDIX L

PORTION OF NPHAS2 OUTPUT FILE

1) CC ANALYS MM

2) CC

3) CC NUSED RMS   401   2.64100

4) CC LATITUDE   39 8 11.36042

5) CC E-LONGITUDE 282 48 4.60445

6) CC W-LONGITUDE   77 11 55.39555

7) CC ELLIP HT(M)   124.9075

8)   9 1 6 -0.1202062704D-03 -0.1091393642D-10 0.0000000000D+00 0.1872000000D+06

9)   6 6144.00000000   -123.875000000   0.126183828022E-08 0.467641146239

10)   -0.650435686111E-05 0.362983625382E-02 0.641308724880E-05 5153.68763733

11)   187200.0   0.4097819E-07 332.0000   -0.3725290E-08-0.2307239E-09

12)   1.11809471942   2.83035296573   2.04658555515   -0.641741016804E-08

13)   1 1285 127 0.200090800000000D+05 77.074.0 0.237783232474D+08 0.237783281626D+08

14)   2 .117488765700D-01   7-0.78879837D-04 0.755366097868D+08-0.996784614395D+08

15)   1 1385 127 0.200090800000000D+05 82.079.0 0.224571663344D+08 0.224571720428D+08

16)   2 .117488765700D-01   7-0.78879837D-04 0.726657563761D+08-0.858671224578D+08

17)   1 985 127 0.200090800000000D+05 79.080.0 0.215010011841D+08 0.215010053812D+08

18)   2 .117488765700D-01   7-0.78879837D-04 0.440674103595D+08-0.415194967887D+08

19)   1 1185 127 0.200090800000000D+05 83.077.0 0.209147162535D+08 0.209147210252D+08

20)   2 .117488765700D-01   7-0.78879837D-04 0.326130483440D+08-0.361480531176D+08

Description of Output File:

Lines 1-7: New position data from NPHAS2 computations (within p-file).

Lines 8-20: Same variables as in NPHAS1 OUTPUT file (Appendix H,
            Lines 5-17).

APPENDIX M

SUBROUTINE DESCRIPTION & FLOWCHART FOR NPHAS3

Subroutine Name	Description
CLEAR	Clears I*4 arrays (never called in NPHAS3).
FRDATE	Computes fraction of day for variable MJD.
JUL	Computes the Julian Day given year,month,day
JYDAY	Returns the year, day of year and seconds of day from modified julian date (MJD).
LOAD9	Reads and writes data from satellite Blocks #1 and 9.
MCSCAN	Obtains satellite data from Macrometer receivers, formats data and flags any errors in data records or files.
TISCAN	Same as MCSCAN: uses TI4100 receivers.
YDAYS	Given MJD, YDAYS returns year and days from beginning of year (i.e., 76 1.5 = Jan 2 12 hours 1976).
YDCGR	Computes Gregorian Date (i.e., present day calendar date) from the actual year and day and fractional parts of the actual day from beginning of year.
FUNCTION REDYES	Flags an input Y/N error and gives user opportunity to re-enter the Y/N answer.
INTEGER FUNCTION MONTHS	Computes year, month, and day from year and day.

MAIN PROGRAM

Choice of TI4100 or Macrometer data:

TISCAN	MCSCAN
JUL	FRDATE
JYDAY	JUL
YDAYS	FRDATE
LOAD9	JUL
JUL	JYDAY
JUL	YDAYS
JYDAY	JYDAY
YDAYS	YDAYS
YDCGR	YDCGR
JUL	JUL
FRDATE	FRDATE
JUL	JUL
JUL	JUL
JUL	JUL

Note: Sources of subroutine descriptions from program listing or telephone communications with NOAA/NGS.

APPENDIX N

INPUT LISTING AND DESCRIPTION FOR NPHAS3

NP3ATHY Input(*)	*Description*
NP3ATHY OUTPUT	1) output file name
1	2) menu: TI data
NP2ATHY OUTPUT	3) input file name
	4) use space bar for no further entries
60	5) time interval (sec)
85 5 7 5 33 29.07999999999999999	6) start time (same as for NPHAS1)
85 5 7 7 16 29.07999999999999999	7) end time (same as for NPHAS1)
N	8) another station

Description of Input File:

1   Self-explanatory.

2   Menu is displayed and the user has the choice of processing either
TI4100 or Macrometer data; TI4100 data are chosen.

3   Self-explanatory.

4   No more files to be entered into program; space bar on console
is pressed.

5   Time interval calculated to use maximum amount of data during
the observation period (explanation in Chapter III.C).

6,7 The first/last common start/stop times for the stations to be
processed (same values input into NPHAS1).

8   User is asked if another station is to be processed (at NPS
it is recommended the response be "N" as the I/O units have not been
adapted to erase prior and accept new data.

Screen Display   (*Comments are in parentheses*)

NPHAS3   (Command to execute NPHAS3)
FILEDEF * CLEAR   (File definitions used to open I/O units)
FILEDEF 05 DISK NPHAS3 INPUT
FILEDEF 10 DISK NP2ATHY OUTPUT
FILEDEF 11 DISK NP3ATHY OUTPUT
LOAD NPHAS3 (START
  (Note: Above six lines are contents of NPHAS3 EXEC file)

EXECUTION BEGINS...
STDPHASE 03/24/86   (Version of NOAA/NGS STDPHASE
                                                    program)

GENERATE TI-4100 OR MACROMETRICS GPS RECEIVER PHASE DATA
               IN STANDARDIZED FORMAT
ENTER OUTPUT FILE NAME
FILE - NP3ATHY OUTPUT
ENTER RECEIVER TYPE
    1 - TI-4100
    2 - MACROMETER
              1
REFORMAT TI-4100 DATA
ENTER INPUT FILE NAME (< CR > IF NONE)
FILE - NP2ATHY OUTPUT
NO SITE IDENTIFICATION AND SV NUMBERS ARE PRESENT
NO STATION POSITION IS PRESENT
  INPUT RECS = 863   PHASE DATA = 800
         (Note: Program shows 863 records available,)
              (800 of which contain phase data)
ENTER INPUT FILE NAME (< CR > IF NONE)
FILE -   (No other file to be entered.)
MINIMUM DATA INTERVAL = ********
PHASE DATA EPOCHS =   100

PHASE DATA START DATE - 85 5 7
PHASE DATA START TIME -   5 37 29.0800
PHASE DATA END   DATE - 85 5 7
PHASE DATA END   TIME -   7 16 29.0800
ENTER DESIRED TIME INTERVAL (SEC)
(ZERO ENTRY TERMINATES PROCESSING)
SELECTED INTRVL -   60.00 SEC.
ENTER DESIRED STARTING YEAR, MONTH, DAY, HR, MIN, SEC
SELECTED - 85   5   7   5 33 29.08
ENTER DESIRED END DATE (AS ABOVE)
SELECTED - 85   5   7   7 16 29.08
- END -
 INPUT RECORDS = 402   OUTPUT EPOCHS = 104
          (Note: Program shows 402 records available at)
          (the chosen 60-sec time interval; 104 epochs)
                  (are used for processing.)
ENTER ANOTHER STATION (Y/N)?
NORMAL TERMINATION

(*) Input Listing and Screen Results for station ORM1 would be
identical to that of ATHY with the exception of the I/O file names,
which would be NP3ORM1 INPUT and NP3ORM1 OUTPUT, respectively.

1)   46192   0.234364351851852D + 00 85 127   0.202490800000000D + 05

2) 9 112 0.1267143525D-03 0.6139089237D-11 0.0000000000D + 00 0.1980000000D + 06

3)   12 6144.00000000   -124.906250000   0.141827336846E-08 -2.54513174259

4) -0.632926821709E-05 0.825415668078E-02 0.578351318836E-05 5153.64504814

5)   198000.0   0.1266599E-06 334.5000   0.1136214E-06-0.1521492E-09

6)   1.10595206195   2.84006382180   -1.18065500229   -0.642883921553E-08

7) 0 1 12 8 82.0 0.236607557468800D + 08 84.0 0.236607525966001D + 08

8) 0 1 12 8 82.0 0.846215296823001D + 07 84.0 -0.640237481526001D + 07

9) 0 1 12   -99999.9 1013.0 -99999.9 20.0 -99999.950.00-.155924670D-05

10) 0 2 13 8 84.0 0.223474200325001D + 08 77.0 0.223474155296001D + 08

11) 0 2 13 8 84.0 0.114267965295001D + 08 77.0 -0.140319198741001D + 08

12) 0 2 13   -99999.9 1013.0 -99999.9 20.0 -99999.950.00-.155924670D-05

13) 0 3 9 8 79.0 0.215498185221001D + 08 82.0 0.215498131718001D + 08

14) 0 3 9 8 79.0 0.103644588338001D + 08 82.0 -0.143583578344001D + 08

15) 0 3 9   -99999.9 1013.0 -99999.9 20.0 -99999.950.00-.155924670D-05

16) 0 4 11 8 87.0 0.209241764571001D + 08 81.0 0.209241723580001D + 08

17) 0 4 11 8 87.0 0.106479406425001D + 08 81.0 -0.141312971600001D + 08

18) 0 4 11   -99999.9 1013.0 -99999.9 20.0 -99999.950.00-.155924670D-05

Description of Output:

Line 1: 46192 = modified starting Julian Day (MJD = JD-2500000.5)

   0.234... = fractional part of modified starting Julian Day

   85   = starting year

   127   = Julian Day

   0.202...= day, expressed in seconds

Lines 2-6: Contains same information as shown in NPHAS1 OUTPUT

   (Appendix H, Lines 5-9) but for a different station.

Lines 7-18: Block 6 satellite data (Lines 7-9 = SV #12 Block 6 data)

Line 7: 0 = FINE (spacer)

   1   = CHAN (receiver channel)

12 = SVID (satellite number)

8   = ITRKRM (tracker mode)

82.0 = RPNDR1 (L1 carrier power/noise density ratio)

0.2366... = RL1DPH (L1 carrier doppler phase at code ftf)

84.0 = RPNDR2 (L2 carrier power/noise density ratio)

0.2366... = RL2DPH (L2 carrier doppler phase at code ftf)

Line 8: 0 = FINE (spacer)

1   = CHAN (receiver channel)

12 = SVID (satellite number)

8   = ITRKRM (tracker mode)

82.0 = RPNDR1 (L1 carrier power/noise density ratio)

0.8462... = RL1DPH (L1 carrier doppler phase at code ftf)

84.0 = RPNDR2 (L2 carrier power/noise density ratio)

-0.6402... = RL2DPH (L2 carrier doppler phase at code ftf)

Line 9: 0 = FINE (spacer)

1   = CHAN (receiver channel)

12 = SVID (satellite number)

-99999.9 = SURFHT (surface height) *

1013.0   = PRESS (pressure, mb) *

-99999.9 = SURFHT (surface height) *

20.0   = TEMP (temperature, °C) *

-99999.9 = SURFHT (surface height) *

50.0   = HUMID (humidity, %) *

-.788... = DTTIME (= difference between UTC and time offset)

 * Default values written to this output file from the main program
listing.

Lines 10-18: Contain information (similar to that for SV#12, lines 7-9)
for SV#13, 9 and 11, respectively·

APPENDIX P

MODIFICATIONS TO NPHAS4

1. COMMON/RECBUF statements: Renamed variable CHANGE to LCHANG as there exists a subroutine CHANGE.

2. Declared all LOGICAL variables as LOGICAL*4 variables.

3. Subroutine BAND: Changed W(BANDW) to W(BANDW,1);

changed CLEAR subroutine to DCLEAR.

4. Subroutine BANDSL: Changed array B(IDIMB,1) to B(IDIMB,NRHS);

changed CLEAR subroutine to DCLEAR.

5. Subroutine BORBIT: Changed variable BSAT to MBSAT.

6. Subroutine CLEAR: Changed to DCLEAR to clear all R*8 variables. within an array.

7. Subroutine CLEARI: Added to clear all I*4 variables within an array.

8. Subroutine CLEAR4: Added to clear all R*4 variables within an array.

9. Subroutine FLUSH: Commented out a RETURN statement; declared variable BUFFER as INTEGER*4.

10. Subroutine GEOM0T: changed DIMENSION RECF(3) to RECF(6);

11. Subroutines LTIME,MJLCYD,QSORT: Dummy subroutines added at end of program to keep NPHAS4 running.

12. Subroutine NMATX: Deleted variables WV1 and WV2 from COMMON/DA statement as they were not used.

13. Subroutine RSEARCH: Changed CLEAR subroutine to CLEAR4.

14. Subroutine SVPVPE: Changed DIMENSION RECF(3) to RECF(6).

15. Subroutine TABLE: Declared variable CORE as LOGICAL*4.

16. Subroutine TOPO: Added variable CORE (and declared it LOGICAL*4);

changed DIMENSION RECF(3) to RECF(6).

17. Subroutine TRPLE: Changed CLEAR subroutine to DCLEAR;

changed DCLEAR(ATA,MAXCOM,MAXCOM*2) to
        DCLEAR(ATA,MAXCOM,MAXCOM);
changed DCLEAR(ATY,MAXCOM,2) to
        DCLEAR(ATY,MAXCOM,1);
changed DCLEAR(W,MAXBW,MAXBW*2) to
        DCLEAR(W,MAXBW,MAXBW).

18. Subroutine YYMMDD: Commented out; temporary NPS code added.

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