REGISTERED

SATELLITE WHALE TAG ANALYSIS PACKAGE

USER DOCUMENTATION

IBM-PC Version

Written by

"Richard L. Merrick
Bruce R. Mate
Oregon State University
Marine Science Center
Newport, OR

Funded by

US Department of the Interior
Minerals Management Service
Alaska OCS Region
Anchorage, Alaska

Contract # 14-12-0001-29042

December, 1985

Table of Contents

ACKNOWLEDGEMENTS

We thank the Minerals Management Service for their support of this project and particularly Jerry Imm, Cleve Cowles, and Jerome Montague in the Alaska Regional Office of MMS for their genuine interest and advice. We also thank Dave Beaty, Stan Tomcowitz, and Boyd Hanson at Telonics for their electronic wizardry and numerous discussions; Charles Hoisington (NASA) for special satellite monitoring and location algorithms; the USF&WS for their collaboration on manatee tracking; Robin Brown (ODF&W), Jim Harvey (OSU) and Jon Temte (OSU) for their patient help in the testing and deployment of the satellite tag; and the many volunteers who made up our field crews to collect data for evaluating the potential of satellite monitored radio tags.

INTRODUCTION

A. Background

In 1979, the Bureau of Land Management through the Naval Arctic Research Laboratory provided funds to Oregon State University (OSU) to develop and test a radio tag for large whales. This "umbrella" tag was successfully attached to three gray whales, Eschrichtius robustus, in San Ignacio Lagoon, Baja California, Mexico during February-April, 1979 (Mate, et al, 1983). One animal was relocated 5 times by-radio after" leaving Mexico as it travel led over 94 days from San Ignacio, to Unimak Pass, at the base of the Aleutian Islands. This same animal was observed 27 months after tagging with the tag still attached. Eighteen more gray whales were tagged in 1980 with BLM and Office of Naval Research (ONR) funds. These successes initiated a feasibility assessment of tracking whales by satellite using the ARGOS satellite system (Mate and Harvey, 1982).

ARGOS is the only satellite system available to civilians to calculate. locations of platform transmitter terminals (PTT's). The ARGOS system is administered by Service ARGOS (SA), a branch of the French Centre National D'Estudes Spatiales (CNES) in cooperation with the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautic and Space Administration (NASA). ARGOS receivers are on board polar orbiting, sun-synchronous NOAA weather satellites (currently NOAA 6, 8 and 9). The system receives encoded data from special PTT's (e.g., a transmitter on a whale), and when certain criteria are met, determines the PTT's location by analysis of doppler shift. The satellites pass over different geographic areas in each successive orbit. They are above the horizon for up to 15 minutes, depending upon the satellite's relative elevation and the distance between the satellite and the PTT, during which they may receive a PTT signal. Each satellite is in view of any location on earthseveral times each day, with more frequent coverage of northern latitudes.

Surfacing data collected from gray whales in 1980 and data from the literature on humpback (Megaptera novaeangliae) and bowhead (Balaena mysticetus) whales were used to determine the probability that each would surface often enough to be located by ARGOS (Mate and Harvey, 1982). These analyses predicted that location determination by satellite was feasible.

OSU was authorized by the Minerals Management Service (MMS) and ONR to proceed with the development and testing of a prototype Satellite Whale Tag (SWT), and to demonstrate the system by applying 3 SWT's to gray or humpback whales. A collaborative effort in PTT design, construction, and implementation by the National Center for Atmospheric Research (NCAR), OSU and Telonics, Inc. (Mesa, AZ) resulted in the successful deployment of a SWT on a humpback whale off the northeast coast of Newfoundland in July, 1983 (Mate, et al, 1983). Subsequently, a depth measurement system was incorporated which allowed dive profiles of a gray whale tagged in San Ignacio Lagoon, Baja California to be monitored (Mate, et al., in press).

Data from the PTT's are available from Service ARGOS (SA) as monthly printouts and computer tapes. They can also be retrieved from SA with a computer terminal within six hours of the transmission or directly from the satellite within minutes of a transmission when using a local user terminal

(LUT). These latter forms of retrieval al low current monitoring of an animal's movements and behavior; however, they also require the use of computer hardware and software. Software was not available for this processing, so OSU was authorized to design, code and test the necessary programs. This led to the development of the Satellite Whale Tag Package (SWTPAK) software presented in this document. Initially, this consisted of a single program (written for a TRS-80, Model III) for reformatting data retrieved from SA. This was later supplemented with programs for presentation of the data and calculation of location fixes. In the most recent version, the software has been modified to run on an IBM-PC, and includes seven programs. In effect, SWTPAK provides a bridge between the PTT's transmission and the available commercial software; however, it also provides certain capabilities which are tailored to this specific application - location fixes, two-dimensional plots of dive profiles, and three-dimensional plots of a series of dives. It is capable of using data from either SA or an LUT, and is designed to interface with off-the-shelf communication, database and graphics software. During the development of this software, data from a U.S. Fish and Wildlife Service funded experiment was retrieved and analyzed with the package in order to monitor the movements of satellite tagged manatees over a 114 day period.

B. Overview of the Satellite Whale Tag Package (SWTPAK)

The Satellite Whale Tag Analysis Package (SWTPAK) is a collection of seven programs designed to:

1. Edit, print and reformat data received from tag transmissions communicated from the NOAA-n satellites via the Service-Argos data dissemination center at Toulouse, France or from a local user terminal (LUT).
2. Prepare graphical displays of dive data.
3. Calculate the location of the animal at the time of transmission, if the location is not included in the transmitted record.

Figure 1 illustrates the overall design of the package. The seven programs include:

1. CONTROL - Package menu
2. DISPOSE - Dispose file analysis.
3. LINEPLOT - 2D plot of time vs depth for a single dive.
4. DIVEPLOT - 3D plot of a group of dives. Requires a plotting package and a printer capable of printing graphics, such as an Epson FX80.
5. HISTGRAM - Histogram and related statistics of the time or depth frequency for a group of dives.
6. LOCFIX1 - Location fixes without reference station.
7. LOCFIX2 - Location fixes with reference station.

All programs are written in Microsoft Basic , implemented under PC-DOS Version 2.0, using a IBM PC (tin) with 256K of RAM, and 2 single sided disk drives, or one disk and a fixed disk. A color monitor or a monochrome monitor with a graphics adapter is optional for the graphics software. Full implementation of the package requires communications software, such as PC-TALK (tin), database management software, such as PC-File (tin) or dBASE III (tin), and graphics software, such as the Golden Software (tin) package.

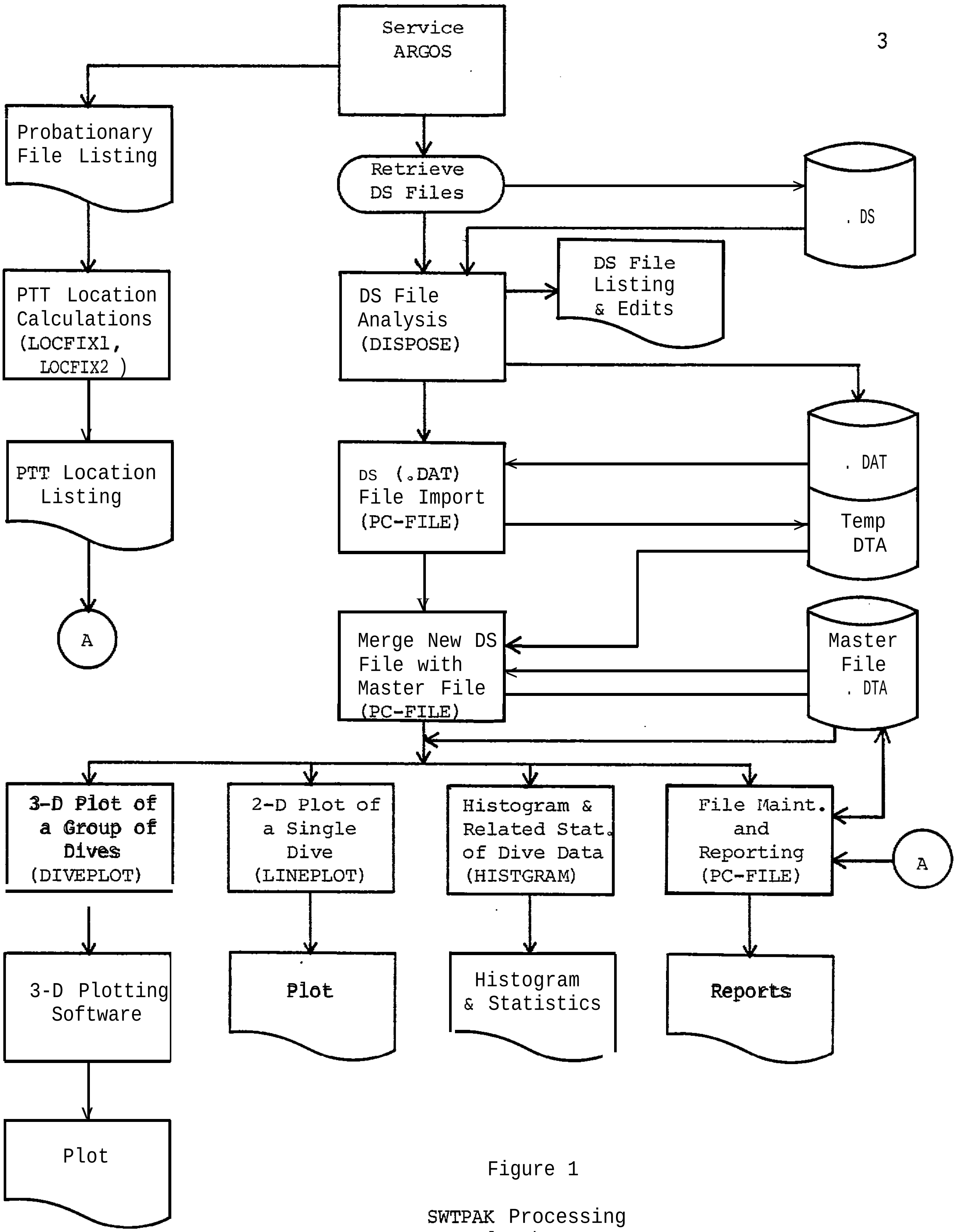

Figure 1

SWTPAK Processing Flowchart

The first step in using SWTPAK is to retrieve data from Service Argos (SA), and to store it on a data diskette. This requires use of a communications program such as PC-TALK (tin) or Smartcom II (tin), a modem, and a long distance telephone connection to SA via TYMNET and TRANSPAC. Once connected to SA you can retrieve two types of data on the tag or platform (PTT) - summary data on the most recent "good" transmission from the PTT (Adjour or Telex data), or detailed data for al 1 good transmissions received in the last 12 hours (Dispose data). Normally, the latter will be more useful because of its level of detail, and this version of SWTPAK is designed to only allow retrieval of the Dispose data. Figure 2 provides an example of a typical session with SA.

All programs use Dispose data or a reformatted version of the data as prepared by the program DISPOSE. These files are referred to by the generic name DSOUT. Detailed procedures for data retrieval are presented in Section II, and formats of the various data files are presented in Appendix A.

Data for each tag or PTT should be maintained as a separate file in the database. Thus when Dispose files are retrieved from SA, it should be by PTT, with this data stored under separate filenames.

Once the data has been retrieved, you can begin to use SWTPAK. Table 1 presents some of the characteristics of the programs, and Figure 1 presents their sequence of use.

You can invoke the package from the operating system by invoking the program CONTROL. The package is then presented in a "menu" mode, and you will be queried as to which program to run. After normal termination of a SWTPAK program, control will return back to this menu. Thus you do not need to know or remember the program's names. However, the programs can be run independent of the operating system, by entering BASIC and invoking the desired program by name.

In either case, your first step after retrieving the data is to print and/or write the data in the Dispose format. The program will first ask the name of the input file. It will then read the file, eliminate unnecessary text, edit the data, and print it out in a labelled format. DISPOSE will also write out a file. You will also be directed by the program to enter this file into the permanent database. Appendix A shows the format of the output file (DSOUT) created by DISPOSE. The printer listings generated by these programs will show a listing of errors found in the file. You should check these and if necessary, correct errors using text editor or database software.

Once the DISPOSE file has been reformatted and added to the permanent DSOUT file for the PTT, it is available for graphical display. Three programs are available:

1. LINEPLOT - 2D plot of a single dive
2. DIVEPLOT - 3D plot of a group of dives
3. HISTGRAM - histogram and statistics for a group of dives' durations or depths

Each program is run in a similar fashion. You will first be prompted for the input file name. Then you will be asked for the criteria by which to select records for further analysis (e.g., PTT#, date of data, time, location). LINEPLOT and HISTGRAM will then generate displays on the screen. If desired,

```
please type your terminal identifier
-2540-010-
please log in: CNESERVICE

password: :208031010283
itt/remote network: call connected" via itt:

*** ARGOS SYSTEM READY PLEASE LOGIN
LOGIN.0040.PIERRE


LOGIN AT 065/1836

*
*WELCOME TO THE ARGOS PROCESSING CENTER.
*FUNCTIONING OF THE CENTER IS NOMINAL
*ORBITAL ELEMENTS
●SAT! 064/2223Z 22%'.4-25.5 102.0
*SAT2 0.54/10522 122.2-25.3 101. 1

ARGOS READY
*STAT


•
     **STATUS LABEL USER 0040 **

**N.EX**FILES **SIZE**REC.TIME**STAT**

**0263**DS6602**0004**065/0630** AVA**

**0263**DS6D01**0002**065/1321** AVA**

**0263**DS6C01**0003**065/1241** AVA**

PUBLIC FILE LAST UPDATE : 065/1825

ARGOS READY
*prv.0263. ds6602


*
  263  11   847 4 12848 85  65   0 28 57 3  -1 2        0 401650345       001
  263       3     29.317 276.885  27.882  269.944       0 401650203       002
  263 12848  0 23 57  1  203         1:8       000         000          003
  263 12848 0  24 57  1  203         143       000         000          004
  263 12S48  o 25 57 1   203         148       000         000          005
  263 12848  o  26 57 1  203         154       000         000          006
  263 12848  0 27 57 1   203         161       000         000          007
  263 12B48  0 28 57  1  203         186       000         000          008
  263 12848  0 30 57 1   202         185       000         000          009
  263 12848  0 32 57 . 2 203         200       000         000          00A
  263 12848  0 33 57 1   203         198       000         000          00B

ARGOS READY
*COM.0263.DICK.00847


*
EXP 0263

00847 29. 276N 83.104W OR 35.938N 112.624W 065/0920Z-
  ( 1) 1 99          246       0 0 9        000


ARGOS READY
*LOGOUT


LOGOUT AT 065/18?.9
```

Figure 2

Sample Service. ARGOS Session

you can also generate an output file (LPLOT) from LINEPLOT, which can be used by commercial graphics software to prepare a presentation quality displayon the printer. DIVEPLOT will create an X,Y,Z coordinate file (DPLOT), which can be used as input data by graphics software on a PC with a dot matrix printer, which has graphics capability (e.g., an Epson FX80).

The last programs in the package, LOCFIX1 and LOCFIX2, are used to calculate the PTT's location. The LOCFIX1 routines operate solely on data about the animal's PTT (i.e., 3 or more sets of transmission data and an approximate location). LOCFIX2 provides more precise fixes, but, requires satellite epoch data and reference station (e.g., the Goldstone tracking station) data, as well as data on the animal. Both programs require at least 3 messages from the same satellite pass. Unlike other programs in the package, all data is entered from the keyboard. Output includes an error index, transmission bias, and the PTT's latitude and longitude. The latter should be added to the PTT's data record. Appendix D includes a description of the algorithms included in these programs.

The syntax used to describe keyboard entry for the programs is as follows. Text included within brackets indicates the exact form of user entries, and should be entered as shown. Commands are shown in upper case (e.g. , [RUN]), while requests for filename, program name, and data, are shown in lower case (e.g., [RUN "progname"]) . The term "type" is used to indicate where data or a command should be typed in, while "press" means to simply press down on the indicated key. Thus "type [END] and, press [enter]", means to type in the letters "E", "N", "D" and press down on the enter or return key. Virtually all entries ill require the user to press [enter] after keying in the appropriate response. System responses (e.g., "*** ARGOS SYSTEM READY PLEASE LOGIN") are shown within quotes, as are program names when run from BASIC.

Table 1
SWTPAK Program Characteristics

Program Name	Input Files	output Files	Other Output	SelectIon Criteria Dte Rge	Dte/ Time	Loc	Dte/ Loc	PTT #
CONTROL	keybd	CNTRL	none	-	-	-	-	-
DISPOSE	DISPOSE or LUT	DSOUT	DL,E	-	-	-	-	-
LINEPLOT	DSOUT	LPLOT	plot	Y	Y	Y	Y	Y
DIVEPLOT	DSOUT	DPLOT	none	Y	N	Y	Y	Y
HISTGRAM	DSOUT	none	plot, stats	Y	N	Y	Y	Y
LOCFIX1	keybd	none	location	Y	Y	Y	Y	Y
LOCFIX2	keybd	none	location	Y	Y	Y	Y	Y

DL=data list; E=edit results; N=no, Y=yes
Dte Rge=date range; Dte/time=date and time; Loc=location (longitude and latitude); Dte/Loc=date and location

USE OF INDIVIDUAL PROGRAMS

A. Data Retrieval from Service-Argos

Procedures for accessing SA using the communications package PC-TALK (tin), an acoustic modem, an IBM PC-XT (tin) with 1 floppy disk drive and a hard disk, and TYMNET/TRANSPAC follow. Procedures for using an autodial modem and automatic signon are described in Appendix B.

1. Item 1 in the SWTPAK menu will direct processing to the appropriate communications software. Invoke the menu (via CONTROL), and press [1] for communications. If, for example you are using PC-TALK(tm) then it will be invoked, and you will be presented with its menu. You are now ready to begin communications.

2. Initialize the communications software. Make sure that the communications parameters are set at 300 baud, 7 data bits, 1 stop bit and even parity. Correct settings as necessary.

3. Turn on the modem and set switches. For example, with a CAT Novation the left switch should be set at "O" (Originate) and the right switch should be set at "F" (full duplex).

4. Dial the local access number for TYMNET (e.g., from Newport, OR the number would be 1-226-0627). Place the receiver in the modem cradle (mouthpiece at end of modem with switches) when you hear the carrier tone from TYMNET.

5. TYMNET will first ask you to "Please type your terminal Identifier". Press [A].

6. TYMNET will next ask "Please log in:". Type [CNESERVICE] and press [enter]. Note that you may get a double C when you type in the first C. This means you have not set PC-TALK to full duplex. Just backspace once and continue typing the log in. You can change the PC-TALK settings to full duplex later.

7. Now TYMNET will ask for your password. Type [ARGOS.01;] and pause. TYMNET will return a second ";". You can then continue typing the password [208031010283] and finish by pressing [enter].

8. If all has gone well to this point, and SA is not busy or down TYMNET will reply "nti transpac: call connected via itt". If they are busy or down, the call will not be connected. In this case you should hang up and try again later.

9. If you made contact, you can now signon to SA. They will ask "*** ARGOS SYSTEM READY PLEASE LOGIN". Type [LOGIN,0040,PIERRE] and press [enter].

10. SA will reply with "LOGIN AT ddd/hhmm". You are now ready to retrieve files. SA is very slow, so be patient.

11. If you want the data transmissions to be printed press [Ctrl][PrtSc]; otherwise, they will simply be shown on the screen.

12. To see if you have any DISPOSE files, type [STAT] and press [enter]. This will list the names of the files available. If you want to look at your ADJOUR or TELEX files type [COM,expr,DICK,ALL] [enter].

13. If there are files and you want to save them, you should press [Alt][R] for Receive Files. Now you will be prompted for a drive and file name. This will be a temporary file, and should be stored on the A drive. Make sure you have a formatted disk there. Specify the name as [A:filename.DS], and press [enter]. Filenames should be specified as F###mdd#, where F### is the PTT# (e.g., F839 for PTT 839), and mdd# is the month/day/daily sequence (e.g., F062 would be the second dataset recovered from SA on February 6).

14. Now type [PRV,expr,DSxxxx] and press [enter]. DSxxxx is the name of

the specific files you want to retrieve. If you want all files, type [PRV,expr,DS] and press [enter]. If you have more than one experiment, then all the files accessible to you can be retrieved with [PRV,,DS]. In any event, the files will be transmitted to you and stored on the A disk, until you press [Alt][R] for end transmission. Note that once a DS or TX file has been transmitted, it is wiped from the SA system. Be careful, you only have one chance to get it.

15. If you are saving data by PTT, and you have more than one PTT, then you should save each to a separate temporary file.

16. Continue retrieving files. When finished, you will need to sign off SA. Type [LOGOUT] and press [enter]. SA will then reply “LOGOUT AT ddd/hhmm”.

17. You can now leave PC-TALK (tin). Press [Alt][X] to exit to the SWTPAK Menu.

B. Invoking SWTPAK and its programs

You can invoke SWTPAK either from the SWTPAK Menu or in a program mode.

1. Menu mode

a. After you boot the system, type [CONTROL] and press [enter]. This will invoke a batch file, which calls the BASIC program CONTROL.

b. You will now be presented with the SWTPAK menu. Select the desired program or function from the list presented and press the appropriate number. If you selected either the LINEPLOT or HISTGRAM routines, then you will also be asked if you have a color monitor or a monochrome monitor with extended graphics capability. The purpose of this is to route you to the software with the proper graphics routines for your monitor. If you have a monochrome monitor without full graphics capabilities, type [N] and press [enter]; otherwise, type [Y] and press [enter].

c. The necessary program(s) will now be invoked, and you will be prompted as necessary for input options, file names and so on. See the program descriptions on the following pages for explanations of how to run each program.

d. Once the program is complete you will be returned to the SWTPAK menu. You can now select another program, or return to the operating sys tern.

2. Program mode

a. First enter the BASIC interpreter.

b. Once in BASIC you can invoke the desired program by typing [RUN "progname"] [enter]. To invoke DISPOSE, you would type [RUN "DISPOSE"].

c. Note that the program will return you to the operating system at the successful completion of a run. To avoid this, press [Ctrl][Break] at the end of the run to return to BASIC. You can invoke another program by following these same procedures with the new filename or you can return to the operating system by typing [SYSTEM] [enter].

i. Printed output includes a list of the data, and errors found. The program will print (after all records have been read) a count of errors found by field number (see record format for field number), and a count of records read and written.

j. After the file has been processed you will be asked if you want to process another file. If not type [END] and press [enter]; otherwise, you should type the new filename and press [enter] to repeat the process.

k. You should now add the file to the permanent database. If you use the PC-File (tin) software, this would require 2 steps, both of which can be run through the SWTPAK menu. First invoke file maintenance (item 3 on the menu). This will pass you to PC-File. The name and location of the new DSOUT file to be created should be specified at the first prompts. Go to the PC-File utilities next (press [F8]). Then run the "import" program (press [6]). You will be prompted for the location (drive A) and name of the input file, the location (drive A) and name of the output file, and the type of formatting to use (select option 2 - text format). The program will then read the input file, and reformat it to the proper form for PC-File. You will now be returned to the main menu. This would be a good time to correct any errors in the data, and this can be done by running the "modify" program (press [F2]). If the file is clean, you can now run the "merge" program to add this file to the larger permanent database. Press [F8] for the utilities, and then press [7] for "merge". Again you will be prompted for the location (drive A) and name of the input file, and the location (drive C) and name of the file to be added to. The program will then merge the two files together. Be careful to add the new file to the permanent file, and not the other way around.

3. Input/Output
   a. Input
      (1) Files - Dispose (.DS) files from SA.
         PTTDATA.DAT - valid PTT#'s
         PTTDIVE.DAT - valid dive profile PTT#'s
      (2) Keyboard - Run specifications
   b. Output
      (1) Files - DSOUT (see Appendix A for format)
      (2) Printed - Data lists and edits.

C. DISPOSE - Processing Dispose file data

1. Purpose - DISPOSE reads the Dispose file format data retrieved from SA (the file named with the .DS suffix), edits it, prints a formatted report, and writes out the DSOUT file with a .DAT suffix. This output file includes one record per transmission, incorporates all of the input data, and where appropriate (e.g., dive depths), reformats or recalculates values. These modifications include:

a. Conversion of julian dates to calendar dates (e.g., January 1 = julian day 001).

b. Calculation of temperature, number of surfacings, dive duration, and dive depths from their original encrypted formats.

2. Operation

a. Invoke DISPOSE from the SWTPAK menu by typing [2] and pressing [enter].

b. The program will then list the names of all files on the data diskette in drive A, which is the drive the input .DS file should be located on.

c. You will then be asked to enter the name of the file to be processed. Type the name and press [enter]. Do not add an extension to the filename, as the program automatically adds a .DS suffix to input and .DAT suffix to output file names.

d. You will next be prompted for the year in which the data was collected. This is required in order to convert the julian dates found in the DS files.

e. The program will then read a ancillary file (PTTFILE.DAT) from drive C, which includes the numbers for all known active PTT#'s. You will then be asked if your PTT# is in the file. If not, you can add it at this time. Following this you will be asked if the PTT is from a dive profiling unit. If it is you will then be shown a second list of PTT#'s (from file PTTDIVE. DAT, also on drive C), and asked if your PTT# is in it. If not, you can update the file at this time.

f. Finally, you will be asked if you are retrieving data from SA or an LUT. Press [S] or [L] to branch to the proper format.

g. The program will now search the file for all records with active PTT numbers. When a record is found, the data will be read and converted, edited, and the results printed. The record will then be written out to drive A. Subsequent records will be read, and the processing repeated until all records in the file have been read.

h. The edits performed include:

(1) Range check on temperature (between -2 and +30 degrees Celsius).

(2) Range check on dive time (between O and 10 minutes).

(3) Range check on surfacings (between O and 9).

(4) Range check on depths (between O and 350 m).

(5) Comparison of the dive duration transmitted from the tag with the dive duration that can be calculated from the number of dive increments times 15 seconds.

(6) Check for possible bit synchrony error. This is presumed if a series of fields are in error.

listing(s) for the file(s) you are analyzing.

g. Finally, you will be prompted as to where you want the data displayed - screen or printer. You can have either or both, and you can specify at this time whether you want to print all the plots. If you will only print some of the plots, then type [N] and press [enter] when prompted. You will have the opportunity later to specify which you want to print.

h. The program will now read the file and select the dives which meet your selection criteria. Each will be plotted on the screen if this was requested. The program will pause to allow you to view it. If you desire an immediate print of the plots then press [shift][PrtSc], and the contents of the screen will be printed. You should then press any text key when you are ready to go on.

i. If you did not previously request printer plots, you will now be prompted. If you again enter no, then the next dive will be processed. Otherwise, you will prepare an LPLOT file for printing by the graphics software. There are two advantages to this type of printer plot. First, you will be able to prepare a better looking plot this way than if you simply dumped the plot from the screen. You can add titles, and change dimensions. The resolution is better too. Secondly, you can plot up to five dives together on the same axis. You can also preview the plot before printing. Try this method, you will probably like it better than the screen dump, although it takes longer. If you opt for this route then you will now be prompted for a filename. Enter just the name of the file, and not the drive or extension. These will be added on automatically. The filename will be printed out for future reference.

j. The next dive will now be processed, and the process repeated until the file has been completely processed. The selection criteria and counters will then be printed.

k. You will then be asked if you wish to process another file. If not, type [N] and press [enter] and you will be returned to the SWTPAK menu. If you type [y] you will begin the process anew.

1. If you wish to plot the LPLOT files you can immediately proceed to plotting by following the prompts which appear after LINEPLOT finishes. You will automatically be passed first to GRAFIT (for preparation of the final format of the plot), to PC (for optimization of the plotfile), and finally to PLOT (for printing). I suggest you read the program documentation available for GRAFIT before making a run. However, at the simplest a run would go as follows. Press [1] to specify input. Then select the dataset code. If you just read in one, you would use file A. For two you would use A, and then B for the next, and so on. Then press [D] to indicate you are reading in a data file, followed by [N] to indicate it is numeric - numeric. Finally, you should type in the filename. If it is on the hard disk, just type the filename, If you are using a floppy drive, then add the drive (e.g., A:PLOT1). Repeat this process for each file to be read. Each file is designated by a separate letter (A-E). Now return to the initial screen by typing [Q] for quit. To view the plot simply press [V]. Add your titles, change scales, and so on until you are satisfied with the plot. Then you should press [P]. You will again be prompted for a filename. Enter this and the file will be written but not plotted. You will now be passed to PC and PLOT. At each you simply specify the filename. At the end of PLOT, the plot will print out (rather slowly).

m. You can press [Ctrl][C] before you enter the graphics software,

D. LINEPLOT - 2D plot of dive depth versus dive time

1. Purpose - LINEPLOT reads a DSOUT file created by the program DISPOSE or a file in the permanent database and creates a plot of dive depth versus time for user selected PTT transmissions. Dives may be selected by PTT#, specific time and date, date range, or location (longitude/latitude range). The program will display each dive in the file which meets the selection criteria, with each dive generating a separate display. The plot also lists the available descriptive information for the dive. Output can be displayed on the screen or on the printer.

This version of the package is implemented to interface with the Golden Software (tin) graphics to produce a high quality line plot on the printer. Thus LINEPLOT will produce an output file (LPLOT) which is passed to the program GRAFIT for previewing, and the addition of titles and legends. This program then produces an output file (filename.PLT) for use by programs PC and PLOT, which produce the actual printer plot. A batch file is used so that the user need not return to the SWTPAK menu. Rather, the user simply replies to prompts for filenames. Documentation for GRAFIT, PC and PLOT are provided in the Golden Software (tin) manual.

2. Operation

a. Invoke LINEPLOT from the SWTPAK menu by typing [4] and pressing [enter].

b. The program will then ask for the input file name. Type the name and press [enter]. The filename here should include the drive and extension. The extension for all files in the DISPOSE output files is .DAT and for the permanent database is .DTA. The drive for the A drive is simply "A:"; however, if the file is on the hard disk, as the files in the permanent database are, the drive should be specified as "C:/SWTPAK/".

c. You will then be prompted for the PTT# of the dives to be plotted. Type the number and press [enter]. A check of the input file will be made to ensure that the file contains records for the PTT. If none are found, you will be notified as such and asked if you wish to try another file.

d. If the file is correct, you will be asked to specify your selection criteria. First, you will be prompted for the basic criteria:

(1) Zulu (GMT) time and date of dive (Code 1) - this is for selection of a specific dive. Note that all times and dates are the Zulu times of data acquisition, and not the date of the last location fix. Both are shown in the record.

(2) Zulu date range of dives (Code 2) - use this to select a group of dives.

(3) Longitude and latitude range of dives (Code 3) - use this to select a group of dives.

(4) Terminate run (Code 9) - use this to escape from the program.

Decide which of these selection criteria you will use, type the desired code number, and press [enter].

f. If you selected codes 1-3, you will next be prompted to enter the specific selection criteria. For example, if you specified code 1, you will next be prompted for the time (in hours and minutes) and date (as MM/DD/YY) of the dive. It will help you to have in hand the and you will return to the system. You can then plot the files later by directly invoking the graphics software.

3. Input/Output
   a. Input
      (1) Files - DSOUT file from the program DISPOSE or from the permanent database.
      (2) Keyboard - Selection criteria
   b. Output
      (1) Files - LPLOT, and intermediate .PLT and .OPT for the graphics software
      (2) Printed - Dive plot with associated data on screen or printer.

E. DIVEPLOT - 3D plot of a group of dives

1. Purpose - DIVEPLOT reads a series of DSOUT files as prepared by DISPOSE and generates a file (DPLOT) of dive frequencies by one of the following criteria:

a. Time vs depth
b. Latitude vs longitude
c. Latitude vs time
d. Longitude vs time
e. Latitude vs depth
f. Longitude vs depth.

The DPLOT file will include the number of dives (O-999) for each combination of the X (e.g., time) and Y (e.g. ,depth) criteria. The format for the DPLOT file is shown in Appendix A, and conforms to the format 'required by the QGRID program in the Golden Software (tin) graphics package. After running DIVEPLOT it is necessary to run QGRID, then SURF, PC, and PLOT, all part of the Golden Software (tin) package.

2. Operation

a. Invoke DIVEPLOT from the SWTPAK menu by typing [6] and pressing [enter].

b. The program will the ask you for the name of the input file. Type the name and press [enter].

c. The program will then ask for the PTT# of the dives to be plotted. Type the number and press [enter]. The file will then be checked to ensure the file contains that PTT#.

d. You will then be asked to specify the selection criteria for the dives to be included in the plotfile. First you will be asked for the general criteria:

(1) Zulu (GMT) date range (Code 1)
(2) Longitude and latitude range (Code 2)
(3) Date and location (Code 3)
(4) Terminate run (Code 9)

Type the desired code and press [enter].

f. You will then be prompted for the detailed criteria. If you specified, for example, Zulu date range you will then be prompted for the begin and end date. Remember to use Zulu dates and times, and to use the dates and times of data acquisition (as shown in the record) and not of location fix.

g. You will now be prompted to specify the type of plot:

(1) Time vs maximum depth (Code 1)
(2) Latitude vs longitude (Code 2)
(3) Latitude vs time (Code 3)
(4) Longitude vs time (Code 4)
(5) Latitude vs depth (Code 5)
(6) Longitude vs depth (Code 6)
(7) Terminate run (Code 9)

Type the appropriate code and press [enter].

h. You will next be prompted for latitude and/or longitude ranges, if you specified plots 2-6 and have not previously specified location criteria. Type in the locations as prompted.

i. Time, depth, and location scales will now be determined:

(1) Time - 24, 1 hour intervals.
(2) Depth - 30, 5 meter intervals. Depths over 295

meters will be grouped together.

(3) Latitude/longitude - range/30 increments.

j. The dive records will then be read and those which meet the criteria will be selected. These will have their X and Y indices determined, and the appropriate X/Y combination incremented by 1.

k. The input file will be closed after all records have been read, and you will be asked if you desire to add another input file to the plot. If you specify another at this point, then the process will begin anew at step j above. In other words, the program will assume that the data in this new file is to be grouped with that of the previous file, so no new selection criteria is relevant. You may repeat this as many times as you wish, each time adding more counts to the plot.

1. You will be prompted for an output file name when all the files have been read. Type the name and press [enter]. The DPLOT file will then be created. The selection criteria and counters will also be printed.

m. You will now be prompted to either end the run or to create another plotfile. If you elect to end the run you will be passed to the Golden Software (tin) programs; otherwise, you will be prompted for a new file name and the process will begin anew.

n. You now need to prepare the data for plotting. You can do this immediately or wait until later. If you wish to wait, press [Ctrl][C] when asked. Otherwise you will be presented with the QGRID menu. Type your input file name at the prompt. In most cases you can go right to program operation; however, QGRID allows you to change and subset your data before formatting. In some cases you may want to do this, so read the QGRID documentation for an explanation. Once you have invoked the program, it will take a while to run (about a half hour), so be patient. Go get a cup of coffee. The programs purpose is simply to generate an output file, so once it is done, you will need to go onto to the actual plotting routine.

p. You will now be presented with the menu for SURF. Enter the file name when prompted, make any changes, and begin execution. If you have a color monitor or a monochrome monitor with a color graphics adapter, the program will first present the plot on the screen, so you can make any changes (e.g., rotating the plot) before you go to the printer. Once done, create your output file, dnd go on to PC and PLOT.

q. As with LINEPLOT, you can also run the Golden Software (tin) directly.

3. Input/Output

a. Input

(1) Files - DSOUT files from the database or the program DISPOSE

(2) Keyboard - selection criteria

b. Output

(1) Files - DPLOT file, and intermediate files, .GRD, .PLT, and .OPT for the graphics package.

(2) Printer - selection criteria and counters, and plots.

F. HISTGRAM - Histogram of dive times or maximum depths

1. Purpose - HISTGRAM reads DSOUT files and based on user supplied criteria generates a frequency histogram and related statistics for dive times or maximum dive depths. The statistics include the number of observations, coefficient of variation, variance, standard deviation, mean and standard error. These are generated only if the number of observations is greater than 4. Dive records may be selected by Zulu (GMT) date range, location, or both. Output is usually directed to the screen; however, the screen display can be printed by pressing [shift][prt sc] together.

2. Operation

a. Invoke HISTGRAM at the SWTPAK menu by typing [5] and pressing [enter].

b. You will then be asked to specify the name of the first input file. Type the name and press [enter].

c. You will next be asked for the PTT number. Type the specific PTT number (e.g., [839]) or [ALL] if all PTT's are desired, and then press [enter]. A check of the file will be made to ensure the file does include the PTT.

d. You will then be asked for the selection criteria. First, you will be asked for the general record selection criteria:

(1) Zulu (GMT) date range (Code 1)
(2) Longitude and latitude range (Code 2)
(3) Both date and location (Code 3)
(4) All records (Code 4)
(5) Terminate run (Code 9)

Type your selection and press [enter].

e. You will then be prompted for the details of this selection. For example, if you specified the Zulu date range, you will be asked to specify the beginning and ending dates. Type your criteria and press [enter] after each prompt. Remember that times and dates are Zulu dates and times of data acquisition.

f. The program will then ask you for the type of histogram:

(1) Dive times (Code 1)
(2) Maximum dive depths (Code 2)
(3) Number of surfacings (Code 3)
(4) Ambient temperature (Code 4)
(5) Terminate run (Code 9)

Type your selection and press [enter].

g. Finally, you will be prompted for the histogram design criteria:

(1) Number of bars (1-15)
(2) Upper limit of data (9999 maximum)
(3) Lower limit of data (O minimum)

Type your choice after each prompt and press [enter].

h. The program will then read the file, select out records which meet the criteria, and begin to build the histogram and calculate the statistics. The histogram will then appear on the screen, expanding as each new record is read.

i. Once all records in the file have been read, the program will pause and ask if another file is to be read. This provides the opportunity to print the screen, if you desire to. Press [shft][PrtSc] to print the plot. If you desire to add another file, type [Y] and you will be asked for the next file's name. You can continue this until all files have been read. The selection criteria and counters will be printed whenever you end the run by typing [N] in response to the additional files prompt.

j. You will next be prompted to create another plot. If yes, then type [Y] and press [enter], and the process will begin anew; otherwise, type [N], press [enter] and you will be returned to the SWTPAK menu.

3. Input/Output

a. Input

(1) Files - DSOUT files from the database or from the program DISPOSE

(2) Keyboard - selection criteria

b. output

(1) Files - none

(2) Printed - Histogram plotted on screen, and optionally, on the printer. Also selection criteria and counters printed on printer.

G. LOCFIX1 - Location fixes without reference station data

1. Purpose - LOCFIX1 uses an initial location estimate of a PTT (latitude, longitude, and altitude), and data from satellite transmissions to determine the location of a PTT. Unlike LOCFIX2 this program does not use transmissions from a ground station at a known location (e.g., Goldstone tracking station) as a reference for updating the satellite's location. Thus these fixes are not as accurate as those provided by LOCFIX2; however, since this program requires less data, it is easier to run. Three or more transmissions (TMS) from a single satellite pass are required. Location fixes are calculated based on the doppler shift between TMS (see Appendix D for a description of the algorithms). Output includes a listing of the input data, the PTT's location, a measure of the quality of the fix (error index) and transmitter bias.

2. Operation

a. Invoke LOCFIX1 from the SWTPAK menu by typing [7] and pressing [enter].

b. You will then be asked for the PTT# of the animal. Type the number and press [enter].

c. You will next be asked for an estimate of the PTT's latitude (degrees), longitude (degrees), and altitude (meters). Type each in sequence, separating each by a comma (e.g., 60,-170,0), and then press [enter]. Use as close an estimate as possible, as this will help the model close faster. Elevation will usually be zero. Longitudes in the western hemisphere and latitudes in the southern hemisphere should be preceded by a minus sign (e.g., 170W = -170).

d. You will now be asked for the satellite's TMS data - time of transmission (seconds), frequency (Hz), and the satellite's location (X,Y,Z coordinates). All of this data should be taken from the probationary file records for the TMS. Type the data, again separating each by commas, and press [enter]. You will then be asked if you wish to enter another record. Remember that you need at least 3 TMS from a pass in order to calculate a fix. If you enter [N] before you have entered 3 or more TMS, you will get an error message and will have to start again. Guidelines for entering the data are:

(1) Only enter TMS from the same satellite pass.
(2) Enter TMS in time sequence; that is, enter the earliest record first, and the latest, last.
(3) Enter all the TMS you have.

Once you have at least 3 TMS entered you can end the prompts for additional TMS by typing [N] at the prompt and pressing [enter].

e. The input data will be printed, and the program will begin its calculations. This is an iterative process and may take some time, so be patient. The program will end when one of the following conditions is met:

(1) There is no improvement in the fix
(2) The error index is less than .1
(3) The model has iterated 10 times

The results will then be printed, and will include the number of iterations, error index, transmission bias, PTT latitude and longitude, and residual error terms. You should examine the error terms. Fixes with error terms greater than .1 are suspect.

f. You will now be asked if you wish to calculate another fix. If yes, type [Y] and the program will begin again; otherwise, type [N] and you will be returned to the SWTPAK menu.

g. After you are finished calculating fixes you should enter the location fixes and their dates and times into the appropriate dive records using data base software. This is provided with PC-File (tin) in this version of the package, and can be invoked from option 3 of the SWTPAK menu.

3. Input/Output
   a. Input
      (1) Files - none
      (2) Keyboard - all data including initial estimate of PTT location, and satellite data (TMS time, frequency, satellite location)
   b. Output
      (1) Files - none
      (2) Printed - location estimates, error terms, and transmitter bias.

H. LOCFIX2 - Location fixes with reference station

1. Purpose - LOCFIX2 uses an initial spacecraft epoch vector (year, day, time, angle of inclination, ascending node and period), and the location and transmissions from a ground station at a known location (a reference station) to calculate the satellite's location at the time of transmission. This location together with an initial location estimate of the animal's PTT (latitude, longitude, and altitude), and data from its satellite transmissions are used to determine the location of the animal. Three or more transmissions (TMS) from a single satellite pass are required for each data set. Location fixes are calculated based on the doppler shift between TMS (see Appendix D for a description of the algorithms). Output includes a listing of the input data, the PTT's location, a measure of the quality of the fix (error index) and transmitter bias.

2. Operation

a. Invoke LOCFIX2 from the SWTPAK menu by typing [8] and pressing [enter].

b. You will then be prompted to enter an initial estimate of the satellite's epoch vector from the pass on which the animal's TMS were received:

(1) Year (last two digits)
(2) Julian date
(3) Epoch vector
  (a) time (seconds)
  (b) Inclination angle (degrees)
  (c) Ascending node angle (degrees)
(4) Spacecraft period (seconds)

These data are available from orbital prediction software (e.g., PATHFINDER III (tin)), which would need to be run separately from SWTPAK in order to obtain these data. Type these data when requested in a sequential fashion, separating each by a comma, and press [enter].

c. You will now be prompted to enter data from the reference station. First you will be prompted for its PTT#. Type the number and press [enter].

d. You will then be prompted for the reference station's location - latitude (degrees), longitude (degrees), and altitude (meters). Latitudes in the southern hemisphere and longitudes in the western hemisphere should be preceded by a minus sign (e.g. 170W = -170). Enter each sequentially, separating each by a comma, and then press [enter].

e. Now you will be prompted to enter the satellite TMS data's time of transmission (seconds), frequency (Hz), and the satellite's location (X,Y,Z coordinates). All of this data should be taken from the probationary file records for the reference station TMS. Type the data, again separating each by commas, and press [enter]. You will then be asked if you wish to enter another record. Remember that you need at. least 3 TMS from a pass in order to calculate a fix. If you enter N before you have entered 3 or more TMS, you will get an error message and will have to start again. Guidelines for entering the data are:

(1) Only enter TMS from the same satellite pass.
(2) Enter TMS in time sequence; that is, enter the earliest record first, and the latest, last.
(3) Enter all the TMS you have.

Once you have at least 3 TMS entered you can end the prompts for additional TMS by typing [N] at the prompt and pressing [enter].

f. The program will then list the input data, and will calculate the corrected spacecraft vector. This is done through doppler shift calculations. This may take a while so be patient.

g. The results will be printed when the calculations are completed, and will include:

(1) Number of iterations
(2) Error index
(3) Transmitter bias
(4) Ascending node
(5) Node time
(6) Error residuals

The error term should be .1 or less or the results are suspect.

h. At this point the program will begin to process the animal's location data. First it will ask for the PTT# of the animal. Type the number and press [enter].

i. The program will ask for an estimate of the PTT's latitude (degrees) , longitude (degrees), and altitude (meters). Type each sequentially, separating each by a comma (e.g., 60,-170,0), and then press [enter]. Use as close an estimate as possible, as this will help the model close faster. Elevation will usually be zero.

j. You will now be asked for the animal±s satellite TMS data - time of transmission (seconds), and frequency (Hz). All of this data should be taken from the probationary file records for the TMS. Type the data, again separating each by commas, and press [enter], You will then be asked if you wish to enter another record. Remember that you need at least 3 TMS from a pass in order to calculate a fix. If you enter [N] before you have entered 3 or more TMS, you will get an error message and will have to start again.

k. The input data will now be printed, and the program will begin its calculations. This is an iterative process and may take some time, so be patient. The program will end when one of the following conditions is met:

(1) There is no improvement in the fix
(2) The error index is less than .1
(3) The model has iterated 10 times

The results will then be printed, and will include the number of iterations, error index, transmission bias, PTT latitude and longitude, and residual error terms. You should examine the error terms. Fixes with error terms greater than .1 are suspect.

1. You will now be asked if you wish to calculate another fix. If yes, type [Y] and the program will begin again; otherwise, type [N] and you will be returned to the SWTPAK menu.

g. After you are finished calculating fixes you should enter the location fixes and their dates, and times into the appropriate dive records using data base management software. This is provided using PC-File (tin) in this version of the package, and can be invoked from the SWTPAK menu with option 3.

3. Input/Output

a. Input

(1) Files - none
(2) Keyboard - all data including initial estimate of PTT location, and satellite data (TMS time,

frequency, satellite location) for both the reference station and the animal.

b. Output

(1) Files - none

(2) Printed - epoch vector data, location estimates, error terms, and transmitter bias.

LITERATURE CITED

Harvey, J. T. and B. R. Mate. 1984. Dive characteristics and movements of radio-tagged gray whales in San Ignacio Lagoon, Baja California Sur, Mexico. In, The Gray Whale)M.L. Jones, S. Swartz, and S. Leatherwood, eds.). Academic Press, New York. pp. 577-589.

Mate, B.R. 1982. Feasibility of tracking whales using the ARGOS satellite sys tern. Final report prepared for U.S. Dept. Int., Alaska Environmental Studies Program. Oregon State University, Newport, OR. 31pp.

_____, D. Beaty, C. Hoisington, R. Kutz, and M.L. Mate. 1983. Progress report - May 1983 to September 1983. Satellite monitoring of humpback whale diving behavior and movements. Prepared for Alaska Outer Continental Shelf Program Office, Minerals Management Service. Oregon State University, Newport, OR. 30 pp.

_____, _____, and M. L. Mate. In press. Tracking the movements of a humpback whale by satellite. J. Wildl. Manage.

_____, _____, and S. Tomcowitz. In press. Monitoring the dive depths of gray whales by satellite. J. Wildl. Manage.

_____, and J. T. Harvey. 1984. Ocean movements of radio-tagged gray whales. In, The Gray Whale (M.L. Jones, S. Swartz, and S. Leatherwood, eds.). Academic Press, New York. pp. 561-575.

_____, and L. Hobbs. 1983. A new attachment device for radio-tagging 'large whales. J. Wildl. Manage. 47(3):868-872.

APPENDICES

A. File Formats

1. DISPOSE

DISPOSE RECORD TYPE 1

Field #	Positions from	to	#	field description
1	1	5	5	Experiment number (263)
2	6	7	2	blank
3	8	9	2	# of records
4	10	10	1	blank
5	11	15	5	PTT#
6	16	16	1	blank
7	17	18	2	# of sensors
8	19	19	1	blank
9	20	24	5	Zulu julian day of location fix
10	25	25	1	blank
11	26	27	2	Zulu year suffix of location fix
12	28	28	1	blank
13	29	31	3	Zulu day of location fix
14	32	32	1	blank
15	33	34	2	Zulu hour of location fix
16	35	35	1	blank
17	36	37	2	Zulu minute of location fix
18	38	38	1	blank
19	39	40	2	Zulu second of location fix
20	41	41	1	blank
21	42	42	1	location calculation code
22	43	43	1	blank
23	44	46	3	PTT type
24	47	47	1	blank
25	48	48	1	satellite number
26	49	52	4	blank
27	53	58	6	initial altitude
28	59	59	1	blank
29	60	68	9	initial frequency (Hz)
30	69	77	9	blank
31	78	80	3	line number

DISPOSE RECORD TYPE 2

Field #	Positions from	to	#	field description
1	1	5	5	experiment number
2	6	9	5	blank
3	10	11	2	location quality index
4	12	14	3	blank
5	15	22	8	latitude (F8.3)
6	23	23	1	blank
7	24	31	8	longitude (F8.3)
8	32	32	1	blank
9	33	40	8	latitude component of vel. vector or alternate latitude (F8.3)
10	41	41	1	blank
11	42	49	8	longitude component of vel. vector or alternate longitude (F8.3)
12	50	51	2	blank
13	52	57	6	computed altitude of PTT
14	58	58	1	blank
15	59	67	9	transmission frequency (Hz)
16	68	76	9	blank
17	77	80	3	line number

DISPOSE RECORD TYPE 3

Field #	Positions from	to	#	field description
1	1	5	5	experiment number
2	6	6	1	blank
3	7	11	5	Zulu julian day of data transmission
4	12	12	1	blank
5	13	14	2	Zulu hour of data transmission
6	15	15	1	blank
7	16	17	2	Zulu minute of data transmission
8	18	18	1	blank
9	19	20	2	Zulu second of data transmission
10	21	21	1	blank
11	22	23	2	number of messages received
12	24	25	2	blank
13	26	35	10	data word #1
14	36	36	1	blank
15	37	37	1	quality index
16	38	38	1	blank
17	39	48	10	data word #2
18	49	49	1	blank
19	50	50	1	quality index
20	51	51	1	blank
21	52	61	10	data word #3
22	62	62	1	blank
23	63	63	1	quality index
24	64	64	1	blank
25	65	74	10	data word #4
26	75	75	1	blank
27	76	76	1	quality index
28	77	77	1	blank
29	78	80	3	line number

DISPOSE RECORD TYPES 4 TO 10

#	from	to	#	field description
1	1	5	5	experiment number
2	6	25	20	blank
3	26	35	10	data word 5/9/13/17/21/25/29
4	36	36	1	blank
5	37	37	1	quality index
6	38	38	1	blank
7	39	48	10	data word 6/10/14/18/22/26/30
8	49	49	1	blank
9	50	50	1	quality index
10	51	51	1	blank
11	52	61	10	data word 7/11/15/19/23/27/31
12	62	62	1	blank
13	63	63	1	quality index
14	64	64	1	blank
15	65	74	10	data word 8/12/16/20/24/28/32
16	75	75	1	blank
17	76	76	1	quality index
18	77	77	1	blank
19	78	80	3	line number

2. LUT

LUT RECORD TYPE 1

Field #	Positions from	to	#	field description
1	1	5	5	PTT number
2	6	6	1	blank
3	7	9	3	Zulu julian day of fix
4	10	10	1	blank
5	11	18	8	Zulu time of fix
6	19	19	1	blank
7	20	27	8	latitude with suffix (N or S)
8	28	28	1	blank
9	29	36	8	longitude with suffix (E or W)
10	37	37	1	blank
11	38	39	2	number of hits during pass
12	40	40	1	blank
13	41	42	2	number of hits used in location calculation
14	43	43	1	blank
15	44	46	3	number of parity errors in hits used in location calculation
16	47	47	1	blank
17	48	50	3	maximum number of successive hits without parity errors
18	51	51	1	blank
19	52	53	2	ratio of good hits per all hits
20	54	54	1	blank
21	55	56	2	residual index
22	57	57	1	blank
23	58	59	2	reference platform vector index
24	60	60	1	blank
25	61	62	2	satellite number
26	63	63	1	blank
27	64	74	11	PTT frequency at inflection point (11.1)
28	75	75	1	blank
29	76	76	1	number of records in this transmission
30	78	80	4	blank

LUT RECORD TYPES 2-5

Field #	Positions from	to	#	field description
1	1	5	5	PTT number
2	6	6	1	blank
3	7	9	3	Zulu julian day of data
4	10	10	1	blank
5	11	18	8	Zulu time of data
6	19	19	1	blank
7	20	21	2	number of parity errors
8	22	22	1	blank
9	23	33	11	frequency of hit (11.1) Hz
10	34	34	1	blank
11	35	38	4	signal strength in dBm
12	39	39	1	blank
13	40	42	3	data word 1/9/17/25
14	43	43	1	blank
15	44	46	3	data word 2/10/18/26
16	47	47	1	blank
17	48	50	3	data word 3/11/19/27
18	51	51	1	blank
19	52	54	3	data word 4/12/20/28
20	55	55	1	blank
21	56	58	3	data word 5/13/21/29
22	59	59	1	blank
23	60	62	3	data word 6/14/22/30
24	63	63	1	blank
25	64	66	3	data word 7/15/23/31
26	67	67	1	blank
27	68	70	3	data word 8/16/24/32
28	71	80	10	blank

3. DSOUT

DSOUT RECORD

Field #	Positions from	to	#	field description
1	1	4	4	PTT number
2	2	9	8	Zulu date of fix
3	10	17	8	Zulu time of fix with AM or PM suffix
4	21	21	1	satellite number
5	22	29	8	latitude with suffix (N/S)
6	30	37	8	longitude with suffix (E/W)
7	38	45	8	latitude component of vel. vector or alternate latitude
8	46	53	8	longitude component of vel. vector or alternate longitude
9	54	59	6	altitude of PTT
10	60	67	8	Zulu date of data
11	69	75	8	Zulu time of data
12	76	79	4	temperature in degrees celsius
13	80	81	2	number of surfacings
14	82	85	4	dive duration in seconds
15	86	91	6	atmospheric pressure in psi
16	92	97	6	maximum dive depth in meters
17	98	103	6	first dive depth in meters
.	.	.	.	.
.	.	.	.	.
.			.	.
42	248 "	253 "	6	twenty-sixth dive depth in meters

4. LPLOT

LPLOT RECORD

Field #	Positions from	to	#	field description
1	1	4	4	time from beginning of dive in minutes - 26 values from .25 to 6.50
2		5	1	comma
3	8^5	12	7	dive depth in meters with minus sign

Note: file always has 26 records, one per dive increment

5. DPLOT

DPLOT RECORD

Field #	Positions from	to	#	field description
1	1	2	2	X coordinate (maximum is 30)
2	3	3	1	comma
3	4	5	2	Y coordinate (maximum is 30)
4	6	6	1	comma
5	7	10	3	number of dives for the X,Y pair

Note: one record per X,Y combination

6. PTTFILE - This file contains one record per valid PTT number, with the number in columns 1-5. Every PTT that is to be processed should be included here.

7. PTTDIVE - This file contains one record per valid dive profiling PTT, with the number in columns 1-5. This file is a subset of PTTFILE, and is used by the program DISPOSE to determine how data words 3 and 4 are to be handled.

8. CNTRL.BAT - This is a batch file generated by CONTROL which tells the operating system which program to process next. Its format is simply the name of the appropriate batch file (e.g., MDISP.BAT) in columns 1-12.

B. Procedures for accessing SA using an autodial modem and automatic signon

The following discusses the technique for accessing SA using a Hayes 1200b Smartmodem (tin) and Smartcom II (tin), a communications package.

1. Smartcom II (tin) uses an autodial function, so you can access SA by pressing three keys. First press [1] to Begin Communication. You will then be asked whether you wish to Originate communications, so press [0]. Finally, you will be prompted for the Communication set. Press [P], and the software will dial TYMNET, and pass on the appropriate passwords.Note that you will have needed to set up the communications directory and auto logon previously.

2. You can now proceed as discussed in Section II.A. to determine the file status.

3. If there are files and you want to save them, you should press [4] for Receive Files. You will be asked which communications protocol to use, press [2] for Stop-Start. Next you will be prompted for a file name. This will be a temporary file, and should be stored on the A drive. Make sure you have a formatted disk there. Specify the name as [A:filename.DS], and press [enter]. Filenames should be specified as F###mdd#, where F### is the PTT# (e.g., F839 for PTT 839), and mdd# is the month/day/daily sequence (e.g., F062 would be the second dataset recovered from SA on February 6). You will now be returned to the screen.

4. After you have completely received the file, press [Fl] to close it.

5. To hang up the phone, return to the main menu by pressing [F1]. Then press [O][H], and the phone connection will be broken. To return to the SWTPAK menu, press [O][E].

C. Sample program outputs

```
******************************************************************************
                  Satellite Whale Tag Analysis Package
                           IBM-PC Version
                            PACKAGE MENU
******************************************************************************

        YOUR OPTIONS FOR THIS PACKAGE ARE:

                1. Communications with Service-Argos
                2. Reformat and import Service-Argos dispose file data
                3. File maintenance and reporting
                4. Two dimensional plot of a single dive
                5. Histogram of transmitted data
                6. Three dimensional plot of a group of dives
                7. Location fix without reference platform data
                8. Location fix with a known reference platform
                9. Return to operating system

        ENTER # OF THE PROGRAM TO RUN (TYPE 9 IF NONE)
```

Figure 3

SWTPAK Menu from program - CONTROL

```
DATE OF THIS RUN WAS : 03-05 985

 NPUT FILE WAS : A:TESTFILE.DS          OUTPUT FILE WAS : A:TESTFILE.DAT

******************************************************************************

ID:  838  SAT #:1               9 SURFACINGS        DIVE TIME:  788 SECS
LOCATION: 12/30/83  1:20:15PM 44.62N 120.044E OR .6128 6.956E
DATA     : 12/30/83  2:45:45PM                      TEMP: -9.691258  'C
ATM PRS :           MAX DEP :
DEP # 1 :           DEP # 2 :           DEP # 3 :           DEP # 4 :
DEP # 5 :           DEP # 6 :           DEP # 7 :           DEP # 8 :
DEP # 9 :           DEP # 10 :          DEP # 11 :          DEP # 12 :
DEP # 13 :          DEP # 14 :          DEP # 15 :          DEP # 16 :
DEP # 17 :          DEP # 18 :          DEP # 19 :          DEP # 20 :
DEP # 21 :          DEP # 22 :          DEP # 23 :          DEP # 24 :
DEP # 25 :          DEP # 26 :

ERROR: TEMP OUT OF RANGE: LESS THEN -2.0 'C OR GREATER THAN 30.0 'C   TEMP =
-9.691258
WARNING: DIVE TIME OUT OF RANGE: LESS THAN 0 SEC OR GREATER THAN 600 SEC
    TIME =  788

******************************************************************************

ID:  838  SAT #:1               9 SURFACINGS        DIVE TIME:  793 SECS
LOCATION: 12/30/83  1:20:15PM 44.62N 120.044E OR .6128 6.956E
DATA     : 12/30/83  2:47:45PM                      TEMP: -9.678882  'C
ATM PRS :           MAX DEP :
DEP # 1 :           DEP # 2 :           DEP # 3 :           DEP # 4 :
DEP # 5 :           DEP # 6 :           DEP # 7 :           DEP # 8 :
DEP # 9 :           DEP # 10 :          DEP # 11 :          DEP # 12 :
DEP # 13 :          DEP # 14 :          DEP # 15 :          DEP # 16 :
DEP # 17 :          DEP # 18 :          DEP # 19 :          DEP # 20 :
DEP # 21 :          DEP # 22 :          DEP # 23 :          DEP # 24 :
DEP # 25 :          DEP # 26 :

ERROR: TEMP OUT OF RANGE: LESS THEN -2.0 'C OR GREATER THAN 30.0 'C   TEMP =
-9.678882
WARNING: DIVE TIME OUT OF RANGE: LESS THAN 0 SEC OR GREATER THAN 600 SEC
    TIME =  793

******************************************************************************

ID:  839  SAT #:1               3 SURFACINGS        DIVE TIME:  485 SECS
LOCATION: 12/30/83  1:20:20PM 44.62N 120.044E OR .6125 6.056E
DATA     : 12/30/83  2:05:10PM                      TEMP: 17.93493  C
ATM PRS : 0         MAX DEP : 134.0129
DEP # 1 : 0         DEP # 2 : 0         DEP # 3 : 0         DEP # 4 : 0
DEP # 5 : 0         DEP # 6 : 0         DEP # 7 : 0         DEP # 8 : 11.6533
DEP # 9 : 31.07546 DEP # 10 : 46.61319 DEP # 11 : 64.09314 DEP # 12 : 81.57309
DEP # 13 : 99.05302DEP # 14 : 124.3018 DEP # 15 : 134.0129 DEP # 16 : 118.4752
DEP # 17 : 99.05302DEP # 18 : 81.57308 DEP # 19 : 67.97757 DEP # 20 : 48.55541
DEP # 21 : 34.95989DEP # 22 : 3.884433 DEP # 23 : 0        DEP # 24 : 0
DEP # 25 : 0        DEP # 26 : 0

WARNING: DIVE TIME AND NUMBER OF DIVE INCREMENTS DO NOT COMPARE WELL
DIVE TIME =  485           DIVE INCREMENT'S TIME =  225

******************************************************************************

ID:  838  SAT #:1               3 SURFACINGS        DIVE TIME:  278 SECS
LOCATION: 12/27/83  5:43:11AM 42.77N 119.044E OR .5555 5.555E
DATA     : 12/27/83  5:43:11AM                      TEMP:  53.66646
```

Figure 4

DISPOSE data listing

```
ATM PRS :           MAX DEP :
DEP # 1 :           DEP # 2 :            DEP # 3 :            DEP # 4 :
DEP # 5 :           DEP # 6 :            DEP # 7 :            DEP # 8 :
DEP # 9 :           DEP # 10 :           DEP # 11 :           DEP # 12 :
DEP # 13 :          DEP # 14 :           DEP # 15 :           DEP # 16 :
DEP # 17 :          DEP # 18 :           DEP # 19 :           DEP # 20 :
DEP # 21 :          DEP # 22 :           DEP # 23 :           DEP # 24 :
DEP # 25 :          DEP # 26 :

ERROR: TEMP OUT OF RANGE: LESS THEN -2.0 'C OR GREATER THAN 30.0 'C   TEMP =
 53.66646

*******************************************************************************

ID:  839  SAT #:1              9 SURFACINGS         DIVE TIME:  330 SECS
LOCATION: 12/27/83  5:43:22AM 44.675N 119.045E OR .678 6.5E
DATA     : 12/27/83 11:05:43AM                      TEMP:  18.24801  'C
ATM PRS : 0         MAX DEP : 192.2794
DEP # 1 : 1.942216 DEP # 2 : 1.942216  DEP # 3 : 19.42216  DEP # 4 : 29.13325
DEP # 5 : 38.84433 DEP # 6 : 48.55541  DEP # 7 : 48.55541  DEP # 8 : 50.49763
DEP # 9 : 69.91979 DEP # 10 : 104.8797 DEP # 11 : 122.3596 DEP # 12 : 139.8396
DEP # 13 : 157.3195DEP # 14 : 182.5683 DEP # 15 : 192.2794 DEP # 16 : 176.7417
DEP # 17 : 157.3195DEP # 18 : 139.8396 DEP # 19 : 126.2441 DEP # 20 : 106.8219
DEP # 21 : 93.22638DEP # 22 : 62.15092 DEP # 23 : 0        DEP # 24 : 0
DEP # 25 : 0       DEP # 26 : 0
```

Figure 4(cont)

DISPOSE data listing

```
READ    4   # 1   RECORDS
READ    4   # 2   RECORDS
READ    5   # 3   RECORDS
READ    2   # 4   RECORDS
READ    2   # 5   RECORDS
READ    2   # 6   RECORDS
READ    2   # 7   RECORDS
READ    2   # 8   RECORDS
READ    2   # 9   RECORDS
READ    2   # 10   RECORDS
READ    27   TOTAL RECORDS

FOUND   3   POSSIBLE ERRORS IN DATA FIELD #   1
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   2
FOUND   3   POSSIBLE ERRORS IN DATA FIELD #   3
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   4
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   5
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   6
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   7
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   8
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   9
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   10
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   11
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   12
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   13
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   14
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   15
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   16
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   17
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   18
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   19
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   20
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   21
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   22
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   23
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   24
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   25
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   26
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   27
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   28
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   29
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   30
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   31
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   32
FOUND   0   POSSIBLE ERRORS IN DATA FIELD #   33
FOUND   6   POSSIBLE ERRORS IN ALL FIELDS

WROTE   5   OUTPUT RECORDS
```

Figure 5

DISPOSE count lists

```
SELECTION CRITERIA FOR THIS RUN WERE :

FILENAME = A:TESTOUT.DAT
PTT# = 839
TIME OF DIVE = 0
BEGINNING DATE = 120183
ENDING DATE = 123183
EASTMOST LONGITUDE CONSIDERED = 0
WESTMOST LONGITUDE CONSIDERED = 0
SOUTHMOST LATITUDE CONSIDERED = 0
NORTHMOST LATITUDE CONSIDERED = 0

COUNTERS FOR THIS RUN WERE

RECORDS READ = 4
RECORDS MEETING CRITERIA = 2
RECORDS REJECTED = 2
```

```
  Z        PTT= 839  TIME=  205    DATE= 12/30/83
(m)
  00*0*0*0*0*****+*********+*********+*****0*0*0*0*0*0 MAX DEP = 382.9
   *                                   0             *
   *                                                 * DIV DUR =  485
   *         0                       0               *
   *           0                   0                 * NUM SRF =  3
191*                             0                   *
   *             0                                   * LONG =  120.044
   *               0           0                     *
   *                 0       0                       * LAT =   44.620
   *                   0                             *
382+*******+*******+*****0*0*****+*********+*********+
   0     1       2       3       4       5       6
                    DIVE DURATION (min)

When finished viewing, press any text key
```

Figure 6

LINEPLOT selection criteria,
counts and dive profile.

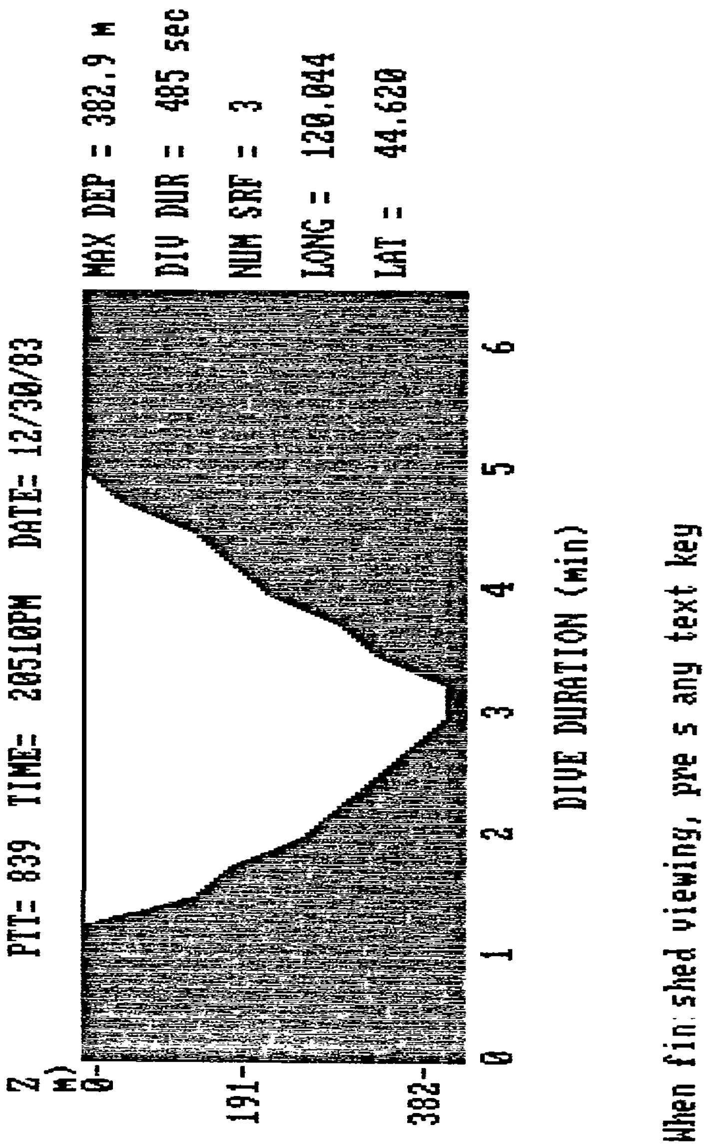

Figure 7

LINEPLOT dive profile
in
full graphics mode

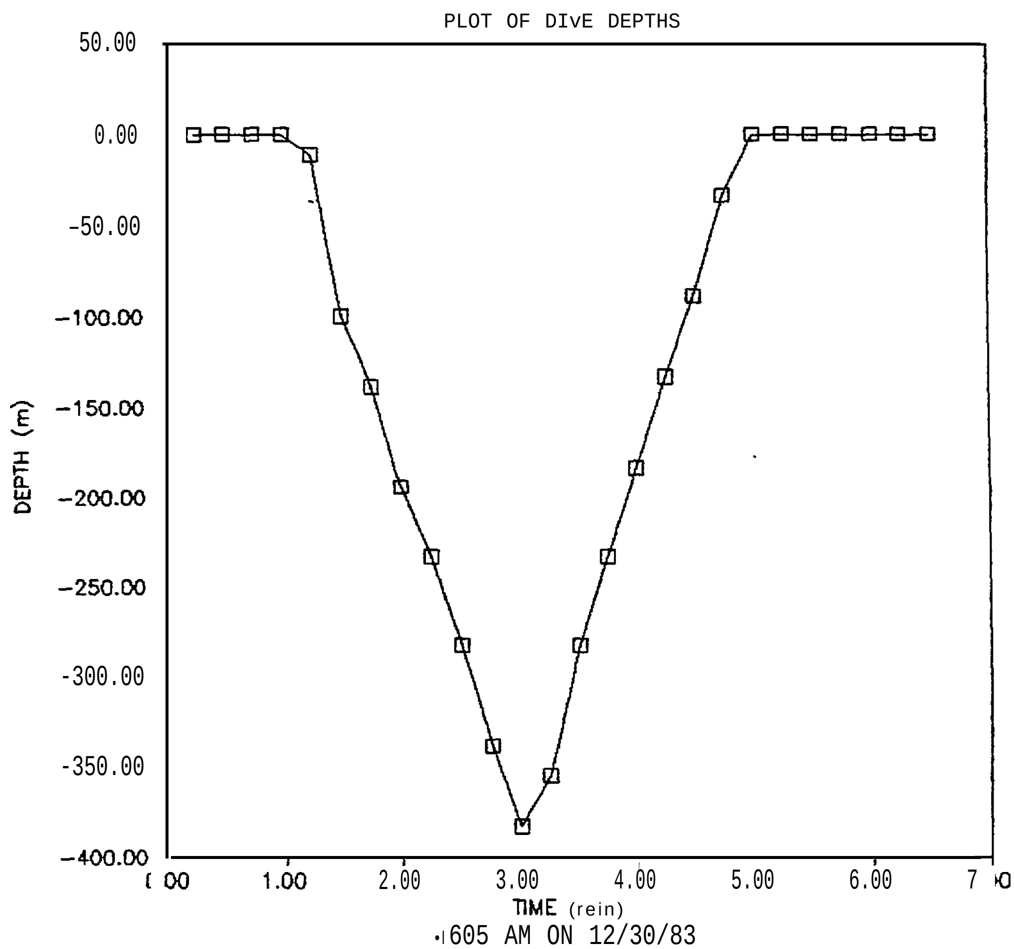

Figure 8

LINEPLOT dive profile
using
Golden Graphics (tin) software

```
SELECTION CRITERIA FOR THIS RUN WERE :

FILENAME =OUTPUT/DAT
PTT# =ALL
TIME OF DIVE = O
BEGINNING DATE =12/31/84
ENDINE DATE =01/01/84
EASTMOST LONGITUDE CONSIDERED = O
WESTMOST LONGITUDE CONSIDERED = 1S1
SOUTHMOST LATITUDE CONSIDERED = O
NORTHMOST LATITUDE CONSIDERED = 91

COUNTERS FOR THIS RUN WERE

RECORDS READ = 1
RECORDS MEETING CRITERIA = O
RECORDS REJECTED = 1
RECORDS WRITTEN = 49
```

Figure 9

DIVEPLOT selection criteria
and counts

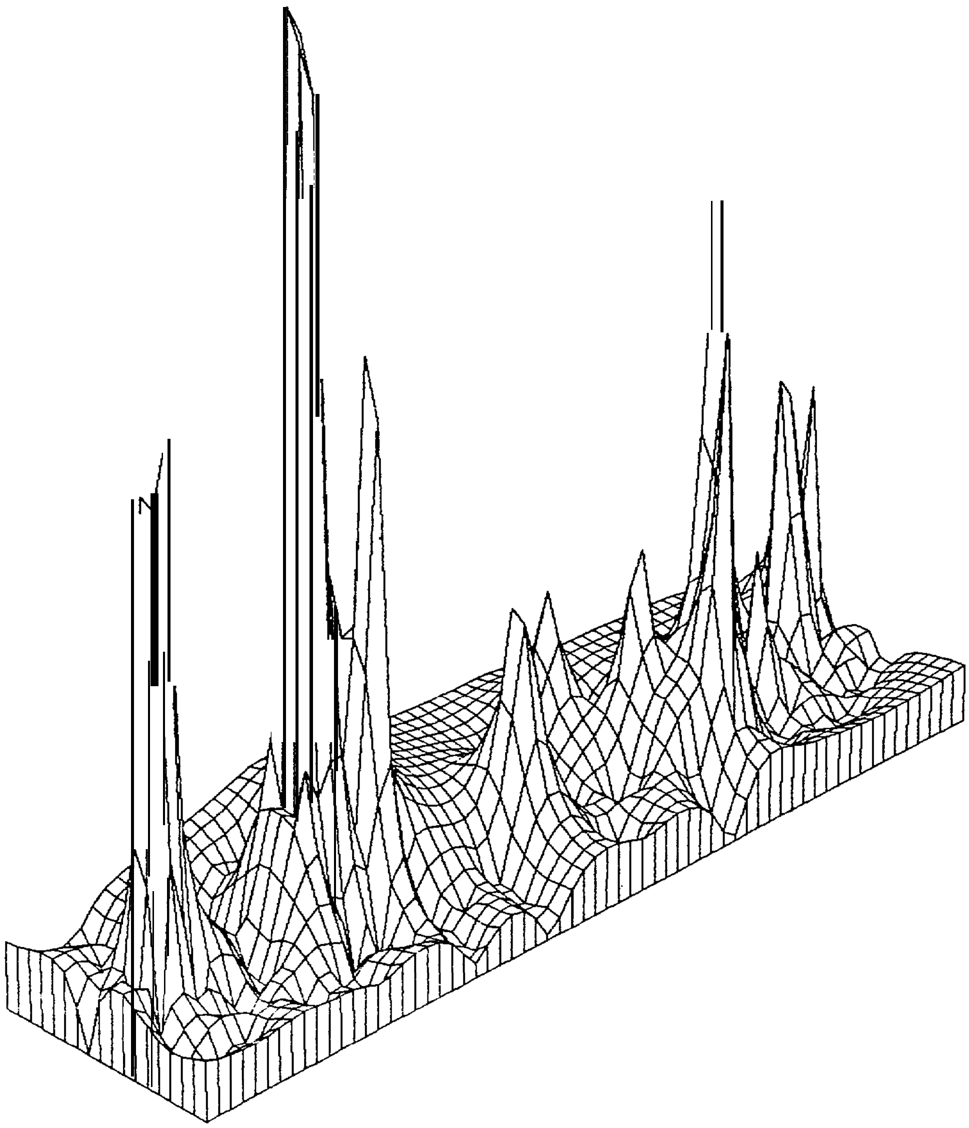

Figure 10

DIVEPLOT 3-D plot
using
Golden Graphics (tin) software

```
SELECTION CRITERIA FOR THIS RUN WERE :

LAST FILENAME = a:f847m031.dat
PTT# = ALL
BEGINNING DATE =
ENDING DATE =
EASTMOST LONGITUDE CONSIDERED = 0
WESTMOST LONGITUDE CONSIDERED = 180
SOUTHMOST LATITUDE CONSIDERED = 0
NORTHMOST LATITUDE CONSIDERED = 90

HISTOGRAM PREPARED FOR SURFACINGS

NUMBER OF INTERVALS = 15
MAXIMUM DATA VALUE ALLOWED = 60
MINIMUM DATA VALUE ALLOWED = 0

COUNTERS FOR THIS RUN WERE

RECORDS READ = 24
RECORDS MEETING CRITERIA = 24
RECORDS NOT MEETING INITIAL SELECTION CRITERIA = 0
GOOD RECORDS EXCLUDED FROM HISTOGRAM = 0



      ----------------------   -------------------------------------
 60  :
 56  :
 52  :
 48  :
 44  :
 40  :
 36  :
 32  :
 28  :
 24  :
 20  :
 16  :
 12  :* 1
 8   :***** 5
 4   :****************** 18
 0   +++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

SAMPLE =  24                COEFF. VAR. =  155.2094        MEAN =  3.041667
VARIANCE =  10.04167        STD DEV =  3.168859          STD ERR =  .6468407

                            PLOT OF SURFACINGS

Do you wish to add another file to this (Y/N)?
```

Figure 11

HISTGRAM selection criteria
counts and histogram

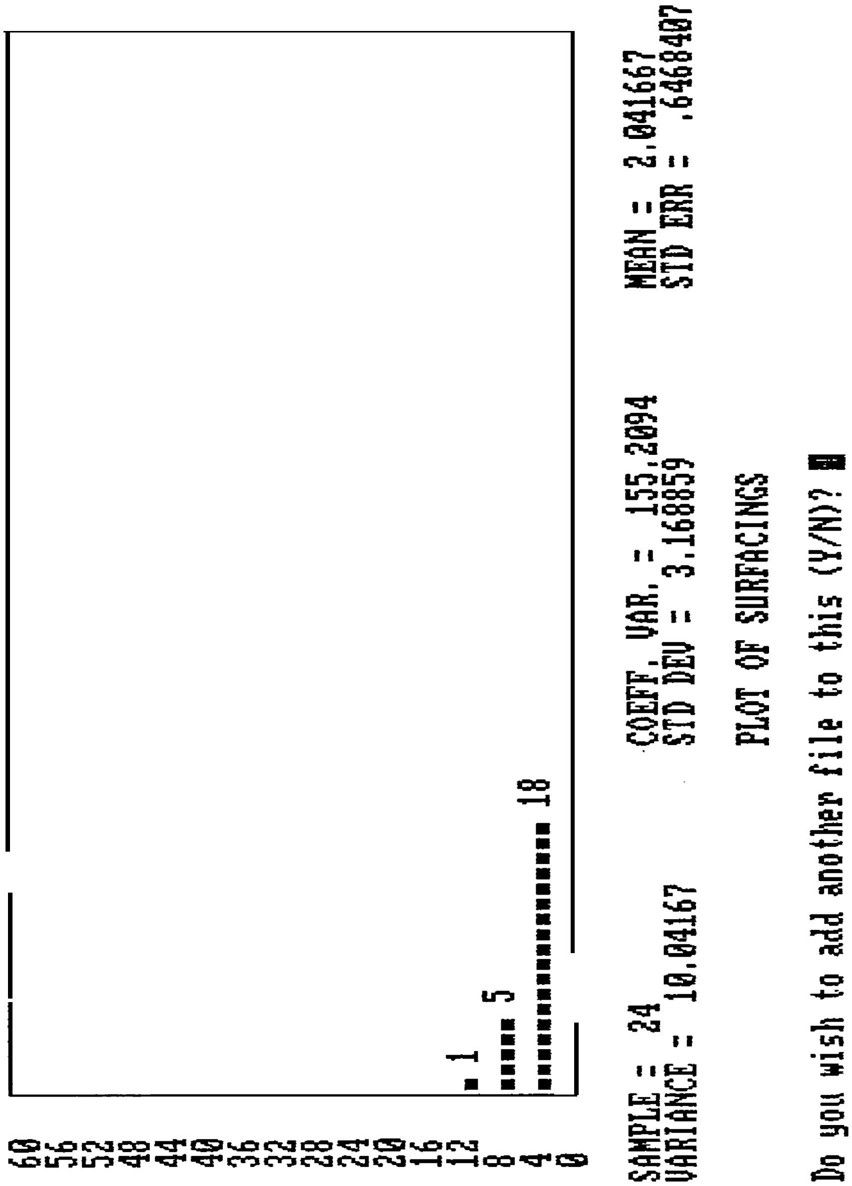

Figure 12

HISTGRAM output in
full graphics mode

```
                 FTT DATA  ENTERED  BY USER

               ****************************
               ID      LAT      LONG      ELEV
               ****************************

               26      39       -77        100

***********************************************************************
 TIME               FREQ           X COORD          Y COORD          Z COORD
***********************************************************************

63282.865      401654143.3      4371.952        -4310.321        3791.647
63322.133      401653637.1      4210.988        -4250.934        4032.615
63361.381      401653045.3      4043.624        -4183.729        4266.858

***********************************************************************
                              RESULTS
***********************************************************************

          NUMBER OF ITERATIONS        3
          ERROR INDEX                 5.16225E-03
          TRANSMITTER  BIAS          -1336.916587553531
          FTT LATITUDE                38.94339285874507
          FTT LONGITUDE              -76.86326598593672

***********************************************************************
                             RESIDUALS
***********************************************************************

        SATELLITE HIT # 1  RESIDUAL = 4.748361996462336D-03
        SATELLITE HIT # 2  RESIDUAL = 1.979826517526817D-03
        SATELLITE HIT # 3  RESIDUAL =-4.268453712938936D-04
```

Figure 13

LOCFIX1 data list

```
                    ORBITAL DATA ENTERED BY USER

***********************************************************************
    EPOCH   EPOCH     EPOCH          INC       ASC
     YR      DAY       TIME          ANGLE     NODE       PERIOD
***********************************************************************
     83       88      70647          98.981    -69.038     6118.8
***********************************************************************


                 REFER. PTT DATA ENTERED BY USER

                  ***** ************************
                  ID      LAT      LONG     ELEV
                  ***** ************************
                  6       37.95   -75.46     13
***** ***** ***** ***** ***** *********************************************
                     TIME               FREQ
***** ***** ***** ***** ***** *********************************************
                  71090.:52        41>1657829.7
                  71120.359        401 657417.1
                  71210.322        401654826.3
                  71240.33         40165 3234.2
***** ***** ***** ***** ***** *********************************************
                            RESULTS
***** ***** ***** ***** ***** *********************************************
             NUMBER OF ITERAT IONS        4
             ERROR INDEX                  . 108C)06
             TRANSMITTER  BIAS           -19.6531 195718 0004
             ASC NODE                    -69. 01532140575476
             NODE TIME                    7<)646. 93273157369
***** ***** ***** ***** ***** *********************************************
                           RESIDUALS
***** ***** ***** ***** ***** *********************************************
           SATELLITE HIT # 1   RESIDUAL = .05713 0129275719B1
           SATELLITE HIT # 2   RESIDUAL =-.07941378497525875
           SATELLITE HIT # 3   RESIDUAL = .03843160044834804
           SATELLITE HIT # 4   RESIDUAL =-.02485954664643941
***********************************************************************
```

Figure 14

LOCFIX2 data list

```
                ANIMAL PTT DATA  ENTERED  BY  USER

                  ****************************
                  ID      LAT      LONE      ELEV
                  ***** **********************
                  26      38. 99   -7.5. 8     100
***** ***** ***** ***** ***** ********************************************
                     TIME                FREQ
***** ***** ***** ***** ***** ********************************************
                   71172.585        401655585. 2
                   71211.809        401654431
                   71251.052        401652619. S
                   71290. 296       401650059.8
***** ***** ***** ***** ***** ********************************************
                                RESULTS
***** ***** ***** ***** *****  ********************************************
              NUMBER  OF  ITERATIONS
              ERROR  INDEX                . 63(:]319
              TRANSMITTER  BIAS         -1 350. 432476087669
              PTT  LATITUDE              39.00158609677875
              PTT  LONGITUDE            -76. 84649235711789 "
**************************************************************************
                               RESIDUALS
**************************************************************************
           SATELLITE  HIT  # 1   RESIDUAL  = .226037720878594
           SATELLITE  HIT  # 2   RESIDUAL =-.4729176388791529
           SATELLITE  HIT  # 3   RESIDUAL  = . 334173320009 5405
           SATELLITE  HIT  # 4   RESIDUAL =-. 104335007175905
**************************************************************************
```

Figure 14 (cent)

LOCFIX2 data list

D. LOCFIX algorithms

The following paper, presented by Charles Hoisington at the 1984 ARGOS user's conference. discusses the algorithms employed in LOCFIX1 and LOCFIX2 to determine PTT locations.

Some Methods of Computing Platform Transmitter Terminal Location Estimates

C. Hoisington, Science Systems and Applications Inc.
Eugene Gilbert, Goddard Space Flight Center

Sponsored by
NASA Goddard Spaceflight Center User Terminal and Location Systems Branch
Greenbelt, Md.

In a recent experiment, a Humpback Whale was tagged with a platform transmitter terminal in an effort to track the animal's movements thru System ARGOS. However, a transmitter deployment failure and the whale's diving behavior precluded the computation of position estimates using standard ARGOS procedures and an alternate method was devised.

This experience suggests that there may be other instances where circumstances inherent in the experiment yield message data unsuitable for the standard ARGOS reduction. In particular, the message data may be too sparse, span an insufficient period, or include variable-length messages. In these cases, if the user is willing to accept the increased location uncertainties, System ARGOS can still provide much valuable location information.

The algorithm used to locate the whale is described in part 1 and has special merit where a transmitter location program currently exists; it determines the classical keplerian spacecraft orbital elements from the ARGOS spacecraft position vectors included with the Probationary File messages. A minimum of three distinct messages are required. Once the spacecraft orbit is determined, the whale is located using standard least squares regression techniques.

A general procedure for computing platform locations from initial position estimates and available spacecraft orbital elements is described in part 2. The procedure includes a method for adjusting the orbital parameters using a well surveyed platform.

Part 3 outlines a second method for computing positions from the Probationary File suitable for implementationon a personal computer. A minimum ofthree messages is required.

The general procedure is simplified for use on a personal computer in part 4. This algorithm computes location estimates from the doppler frequencies and an initial spacecraft epoch vector. Three messages are required from a reference station.

A general discussion including some design and operational cautions is included in part 5.

1. A procedure for computing positions entirely from the ARGOS Probationary File is now outlined. While the ARGOS position reductions are more accurate, this scheme has merit where the data do not meet the more stringent ARGOS requirements. This algorithm has been included as an enhancement to a FORTRAN Station Location Program currently installed on a Data General Nova 3 Computer in the User Terminal Systems Branch of the Goddard Space Flight Center.

The"algorithm determines the classical keplerian elements from the ARGOS spacecraft position vectors included with the Probationary File messages. A minimum of three distinct messages are required. Once the spacecraft orbit is determined, the transmitter is located using standard least squares regression techniques.

The derived keplerian elements are globally poor but are adequate locally in the region of message acquisition when a second order spherical harmonic gravity model is used.

The procedure is described in ref. 1,2 and is not difficult; three non-colinear spacecraft position vectors are selected from a pass and transformed to an inertial coordinate system. The cross product of two position vectors establishes a vector normal to the orbital plane. This vector defines the orbital plane orientation in inertial space; that is, the inclination angle and the ascending node angle. Further, the position vector dot and cross products may be used to compute the sines and cosines of the angles between the true anomalies. From an equation of the ellipse, the true anomalies, orbital eccentricity, and semi-major axis, are expressed as functions. of these sine and cosine terms.

Let R_i, $i=1,2,3$ be three distinct time-ordered spacecraft position vectors in earth fixed geocentric coordinates each with components r_x, r_y, r_z. The Z-axis points northward and the X-axis is in the direction of the Prime Meridian with the X and Y axes in the equatorial plane. Each position vector may be transformed to an inertial reference frame by

$$
\begin{aligned}
R'_x &= R_x\cos(q) - R_y\sin(q) \\
R'_y &= R_x\sin(q) + R_y\cos(q) \\
R'_z &= R_z
\end{aligned}
\qquad (1.1)
$$

where q is the instantaneous Greenwich Hour Angle, R' is a position vector in the inertial coordinate system and the X-axis is in the direction of the Vernal Equinox (Aries).

The choice of the Greenwich hour angle is arbitrary; any transform carrying the three vectors into an inertial coordinate system is sufficient.

The sines and cosines of the differences in true anomalies f_1, f_2, f_3 corresponding to each position vector are

$$\sin(f_3 - f_i) = |R'_i \times R'_3| \;/\; |R'_i|\,|R'_3| \qquad (1.2)$$

$$\cos(f_3 - f_i) = |R'_i \bullet R'_3| \;/\; |R'_i|\,|R'_3| \qquad i=1,2\ . \qquad (1.3)$$

For brevity let

$$S_{3j} = \sin(f_3 - f_j)$$
$$C_{3j} = \cos(f_3 - f_j) \qquad j=1,2\ .$$

From an equation of the ellipse

$$R'_i = \frac{a(1-e_s^2)}{1+e_s\cos(f_i)}\ , \quad i=1,2,3 \qquad (1.4)$$

where a is the orbital semi-major axis and e_s is the eccentricity.

It may be shown that

$$f_3 = \tan^{-1}\left[\frac{r_1(r_2-r_3)C_{31} + r_2(r_3-r_1)C_{32} + r_3(r_1-r_2)}{r_1(r_2-r_3)S_{31} + r_2(r_3-r_1)S_{32}}\right] \qquad (1.5)$$

with r_i, $i=1,2,3$ the components of R_i'. Note that f_3 may assume two values. The correct value gives a positive eccentricity in equation 1.7 below. Computing the remaining anomalies from the correct f_3:

$$f_1 = f_3 - \cos^{-1}(C_{31}) \qquad (1.6)$$
$$f_2 = f_3 - \cos^{-1}(C_{32})$$

and the orbital eccentricity,

$$e_s = \frac{r_i - r_j}{r_j\cos(f_j) - r_i\cos(f_i)} \qquad (1.7)$$

the orbital semi-major axis,

$$a = \frac{r_i\left(1+e_s\cos(f_i)\right)}{1-e_s^2} \qquad i,j = 1,2,3 \quad i \# j \qquad (1.8)$$

the eccentric anomaly for R_2',

$$E_2 = 2\tan^{-1}\left[\sqrt{\frac{1-e_s}{1+e_s}}\tan\left(\frac{f_2}{2}\right)\right] \qquad (1.9)$$

the mean anomaly for R_2',

$$M = E_2 - e_s \sin E_2 \qquad (1.10)$$

The remaining elements are obtained from the cross product of two position vectors. Let V_1, V_2, V_3, be the components of $R_1 \times R_3$. Then from geometric considerations the angle of inclination is

$$i = \pi/2 \pm \sin^{-1}\left[\frac{V_3}{\left(V_1^2 + V_2^2 + V_3^2\right)^{1/2}}\right] \qquad (1.11)$$

where the algebraic sign of the second term is that of $-V_3$.

Also, the ascending node angle is

$$\Omega = \tan^{-1}(V_2/V_1) \pm \pi/2 \qquad (1.12)$$

where the algebraic sign is that of V_1V_2.

From spherical trigonometry the argument of perigee is

$$w = \pm\cos^{-1}\left[\frac{r_x \cos\Omega + r_y \sin\Omega}{r'_2}\right] - f_2 \qquad (1.13)$$

the algebraic sign being that of r_z

and r_x, r_y, r_z, are the components of R'_2 .

The method was tested using Probationary File data from a well-surveyed DCS station (0026) located at the Goddard Space Flight Center in Green belt, Md. Messages from NOAA-7 passes were parsed in groups of three to simulate a minimal number of transmissions.

2. A procedure for solving the more general problem of computing platform transmitter locations from-the spacecraft keplerian elements' and the doppler frequencies from three or more messages is now briefly examined. The method is well known and is implemented in a FORTRAN station location program at the Goddard Space Flight Center. The interested reader can find further details in ref. 3,7.

The platform transmitter location estimates are computed by using a least squares, iterative procedure to determine the latitude and longitude minimizing the differences between calculated and observed message doppler frequencies .

Beginning with the initial estimates, each iterative step adds a correction to the latitude and longitudeto reduce the calculated and observed doppler differences. Practical considerations dictate the inclusion of a third parameter, the bias term. The bias removes the apparent doppler frequency resulting from transmitter carrier deviations about the nominal 401.65 Mhz.

The computed range rate $\dot{\rho}_c$ is a function of the geodetic latitude 0, longitude, λ and a bias term b:

$$\dot{\rho}_c = \dot{\rho}_c(\emptyset,\lambda) + b \qquad (2.1)$$

and the best location estimates are the $\emptyset$, λ, b minimizing the error function, E :

$$E = \sum_{i=1}^{N} (\dot{\rho}_{oi} - \dot{\rho}_{ci})^2 \qquad N \geq 3 \qquad (2.2)$$

Where $\dot{\rho}_o$ = -d/1.3395933 cycles/meter is the observed range rate computed from the doppler frequency, d, and N is the number of messages. The error E is reduced at each iterative step, k, by adding to the current parameters, $P_K = (\emptyset_k, \lambda_k, b_k)$, a correction vector C_K to produce a new set of estimates

$$P_{K+1} = P_K + C_K \qquad (2.3)$$

The correction vector, C, is computed at each step by the well known Gauss-Newton equation

$$C = -(A^TA)^{-1}A^TZ \tag{2.4}$$

where

$$A^TA = \begin{bmatrix} \sum \frac{\partial \dot{\rho}_{ci}}{\partial \phi}\frac{\partial \dot{\rho}_{ci}}{\partial \phi} & \sum \frac{\partial \dot{\rho}_{ci}}{\partial \phi}\frac{\partial \dot{\rho}_{c}}{\partial \lambda} & \sum \frac{\partial \dot{\rho}_{i}}{\partial \phi} \\ & \sum \frac{\partial \dot{\rho}_{ci}}{\partial \lambda}\frac{\partial \dot{\rho}_{ci}}{\partial \lambda} & \sum \frac{\partial \dot{\rho}_{i}}{\partial \lambda} \\ & & \sum 1 \end{bmatrix}$$

and

$$A^TZ = \begin{bmatrix} \sum \frac{\partial \dot{\rho}_{ci}}{\partial \phi}(\dot{\rho}_{oi} - \dot{\rho}_{ci}) \\ \sum \frac{\partial \dot{\rho}_{ci}}{\partial \lambda}(\dot{\rho}_{oi} - \dot{\rho}_{ci}) \\ \sum (\dot{\rho}_{oi} - \dot{\rho}_{ci}) \end{bmatrix}$$

with the summation over $i=1$ to N, the number of messages.

The iterative procedure is terminated when some step reduces the error by less than some arbitrary amount, say 5% and further "error reduction yields no significant improvement in the location estimates.

When the keplerian elements are not well known, the location estimates may be considerably improved by reversing the problem of locating a transmitter from the known spacecraft position and first adjusting the keplerian elements to minimize the observed and calculated doppler frequency differences from a well surveyed platform. A first order correction may be had by adjusting only the epoch time, t_o, and the ascending node angle, Ω. The problem is equivalent to minimizing

$$\varepsilon = \sum_{i=1}^{N} (\dot{\rho}_{oi} - \dot{\rho}_{ci})^2, \quad \text{where} \quad \dot{\rho}_c = \dot{\rho}_c(\Omega, t_o) + b \tag{2.5}$$

For computational purposes, the partial derivative $\partial\dot{\rho}/\partial t$ is computed numerically and $\partial\dot{\rho}/\partial\Omega$ is taken to be $-\partial\dot{\rho}/\partial\phi$. The partial $\partial\dot{\rho}/\partial\Omega$ replaces $\partial\dot{\rho}/\partial\phi$ and $\partial\dot{\rho}/\partial t$ replaces $\partial\dot{\rho}/\partial\lambda$ in eq. 2.4 and the correction vector updates the epoch time and ascending node.

In either case, the robustness of the least squares regression algorithm may be significantly improved by the inclusion of a binary search of the correction vector when a succeeding iteration fails to decrease the error function, E. If E_{K+1} is greater than E_K, then the parameters are restored to P_K, and with $C_K = C_K/2$, P_K is recomputed. Each succeeding binary step further halves the search vector. The standard search is resumed when the binary search fails to further reduce the error function. 55

When solving for Ω and t_o, the procedure is especially vulnerable to time errors. This difficulty may be sidestepped by letting

$$A^TA = \begin{bmatrix} \sum \frac{\partial\dot\varrho_{ci}}{\partial t}\frac{\partial\dot\varrho_{ci}}{\partial t} & \sum \frac{\partial\dot\varrho_{ci}}{\partial t} \\ & \sum 1 \end{bmatrix} \qquad A\sum = \begin{bmatrix} \sum \frac{\partial\dot\varrho_{ci}}{\partial t}(\dot\varrho_{oi} - \dot\varrho_{ci}) \\ \sum (\dot\varrho_{oi} - \dot\varrho_{ci}) \end{bmatrix}.$$

for the first several iterations. The simpler system rapidly converges, and with a better estimate of t_o and b, the complete system including, is easily solved. As a further enhancement, b is constrained to -2500hz b +2500hz.

The partial derivatives are computed in geocentric earth fixed rectangular coordinates with the Z-axis pointing north, the X-axis pointing thru the Greenwich Meridian and Y-axis completing the dextral system. Letting x_s, y_s, z_s, be the spacecraft position and x_p, y_p, z_p be the platform transmitter terminal position, then the range ϱ, must be

$$\varrho = \left[(x_s - x_p)^2 + (y_s - y_p)^2 + (z_s - z_p)^2\right]^{1/2} \text{ and} \tag{2.6}$$

$$\dot\varrho = \left[\dot x_s(x_s - x_p) + \dot y_s(y_s - y_p) + \dot z_s(z_s - z_p)\right]/\varrho. \tag{2.7}$$

so that

$$\partial\dot\varrho/\partial x_p = \left[-\dot x_s + \dot\varrho(x_s - x_p)\right]/\varrho \tag{2.8}$$

$$\partial\dot\varrho/\partial y_p = \left[-\dot y_s + \dot\varrho(y_s - y_p)\right]/\varrho$$

$$\partial\dot\varrho/\partial z_p = \left[-\dot z_s + \dot\varrho(z_s - z_p)\right]/\varrho,$$

and the required partials are

$$\frac{\partial\dot\varrho}{\partial\phi} = \frac{\partial\dot\varrho}{\partial x_p}\frac{\partial x_p}{\partial\phi} + \frac{\partial\dot\varrho}{\partial y_p}\frac{\partial y_p}{\partial\phi} + \frac{\partial\dot\varrho}{\partial z_p}\frac{\partial z_p}{\partial\phi} \tag{2.9}$$

$$\frac{\partial\dot\varrho}{\partial\lambda} = \frac{\partial\dot\varrho}{\partial x_p}\frac{\partial x_p}{\partial\lambda} + \frac{\partial\dot\varrho}{\partial y_p}\frac{\partial y_p}{\partial\lambda} + \frac{\partial\dot\varrho}{\partial z_p}\frac{\partial z_p}{\partial\lambda},$$

where $\partial z_p/\lambda$ is zero.

The platform coordinates x_p , y_p , z_p , are derived from the geodetic coordinates assuming a spheroid. earth where r_e is the earth equatorial radius, e_r is the spheroid eccentricity, r_v is the radius in the prime vertical and h is the platform height above the reference spheroid:

$$r_v = r_e / (1-e_r^2 \sin \phi)^{1/2} \qquad (2.10)$$
$$x_p = (r_v + h) \cos \phi \cos \lambda$$
$$y_p = (r_v + h) \cos \phi \sin \lambda$$
$$z_p = [r_v (1-e_r^2) + h] \sin \phi$$

and differentiating:

$$\partial x_p / \partial \phi = -r_v \sin \phi \cos \lambda \qquad (2.11)$$
$$\partial y_p / \partial \phi = -r_v \sin \phi \cos \lambda$$
$$\partial z_p / \partial \phi = +r_v (1-e_r^2) \cos \phi$$
$$\partial x_p / \partial \lambda = - y ,$$
$$\partial y_p / \partial \lambda = +x_p$$
$$\partial z_p / \partial \lambda = 0$$

In what follows, the spacecraft position x_s, y_s, z_s and velocity $\dot{x}_s$, $\dot{y}_s$, $\dot{z}_s$ at a message time t, are first computed in keplerian elements and the transformed to a geocentric inertial rectangular coordinate system where the axes are defined as before excepting the X-axis is in the direction of Aries. A subsequent rotation transforms the coordinates to the earth fixed system.

Retaining only the most significant first order secular terms and the second spherical harmonic, the keplerian angular velocities may be approximated as

$$\dot{\eta} = C_o + [C_1 / (4C_2^{3/2} a^2)] (1-3 \cos i), \qquad (2.12)$$
$$\dot{w} = [C_1 / (4C_2^2 a^2)] (1-5 \cos i)$$
$$\dot{\Omega} = [C_1 / (2C_2^2 a^2)] \cos i$$

where η is the mean anomaly, w is the argument of perigee, Ω is the ascending node angle, i is the angle of inclination, a is the orbital semi-major axis, and for brevity, $C_o = (GM/a^3)^{1/2}$, $C_1 = 3C_o J_2 r_e^2$, $C_2 = 1-e^2$, G is the universal gravitational constant, M is the earth mass, and J_2 is the second spherical harmonic term. GM is approximately 0.3986032E+15 m/see and J_2 is 1082.63E-6. The spacecraft keplerian angles at a time t are

$$\eta = \eta_o + \dot{n} (t - t_o) \qquad (2.13)$$
$$\Omega = \Omega_o + \dot{\Omega} (t - t_o)$$
$$w = w_o + \dot{w} (t - t_o)$$

The keplerian position and velocity elements in inertial coordinates may be shown to be (ref 1): 57

$$x' = a\, l_1 \cos E + b\, l_2 \sin E - a\, e_s\, l_1$$
$$y' = a\, m_1 \cos E + b\, m_2 \sin E - a\, e_s\, m_1 \qquad (2.14)$$
$$z' = a\, n_1 \cos E + b\, n_2 \sin E - a\, e_s\, n_1$$

$$\dot{x}' = \eta a/r\, (b\, l_2 \cos E - a\, l_1 \sin E)$$
$$\dot{y}' = \eta a/r\, (b\, m_2 \cos E - a\, m_1 \sin E) \qquad (2.15)$$
$$\dot{z}' = \eta a/r\, (b\, n_2 \cos E - a\, n_1 \sin E)$$

where

$$l_1 = \cos \Omega \cos w - \sin \Omega \sin w \cos i$$
$$m_1 = \sin \Omega \cos w + \cos \Omega \sin w \cos i$$
$$n_1 = \sin w \sin i$$

$$l_2 = -\cos \Omega \sin w - \sin \Omega \cos w \cos i$$
$$m_2 = -\sin \Omega \sin w + \cos \Omega \cos w \cos i$$
$$n_2 = \cos w \sin i,$$

and a is the semi-major axis, b is the semi-minor axis, r is the instantaneous radius and E is the eccentric anomaly.

The inertial position and velocity vectors are transformed thru the Greenwich Hour Angle q, to the earth fixed coordinates as

$$x = x' \cos q + y' \sin q$$
$$y = -x' \sin q + y' \cos q \qquad (2.16)$$
$$z = z'$$

$$\dot{x} = \dot{x}' \cos q + \dot{y}' \sin q + y\, \dot{q}$$
$$\dot{y} = -\dot{x}' \sin q + \dot{y}' \cos q - x\, \dot{q} \qquad (2.17)$$
$$\dot{z} = \dot{z}'$$

The rate $\dot{q}$, is taken to be the earth's rotation rate θ_2, and q is computed as

$$q = 1.746647027 + \theta_1 D + \theta_2 t - 7.671432057\text{E-5} \sin (0.2114043493 - \theta_3 D) - 0.566228671\text{E-5} \sin (3.4934931630 + \theta_4 D) \qquad (2.18)$$

where θ_1 = 0.1720729100E-1 Rev/Day (the GHA rate)
θ_2 = 0.7292115000E-4 Rad/Sec (the earth rotation rate)
θ_3 = 0.9242186639 E-3 Rad/Day (the earth nutation rate)
θ_4 = 0. 3443558258 E-1 Rad/Day (the earth orbital revel ution component)

and D is the number of elapsed days since 01 Jan 1950.

3. An algorithm suitable for implementation on a personal computer is now described for computing positions from the Probationary File. This procedure has been implemented in BASIC on an HP 87XM personal computer at the Goddard Space Flight Center. The method requires a minimum of 3 messages and combines key elements of parts 1 and 2.

Substituting $\alpha = \dot{\theta}_2(t_N - t_1)$ for the Greenwich Hour Angle, q, in eq. 1.1, the last message position vector, R_N is transformed to R'_N in the earth fixed coordinates at t_1, the time of the first message.

Letting $R'_1 = R_1$, the position vectors R'_1, R'_2, determine the orbital plane in a geocentric inertial system identical to the earth fixed system at t_1.

The orbital inclination, i, and the ascending node, Ω, are determined as in eqs. 1.11, 1.12.

As the orbital eccentricity approaches zero, the argument of perigee, w, and the mean anomaly, m, become undefined. However, the spacecraft angular position in its keplerian orbit is w+m. This justifies approximating the orbit as a circle by defining the orbital eccentricity, e_s, and the true anomaly, f, as zero so that the eccentric anomaly (eq.1.9) is zero and w (eq. 1.13) is the spacecraft angular displacement from the ascending node. With a,r equal to b, eqs. 2.15 become

$$\dot{x} = \dot{\eta} r l_1, \quad \dot{y} = \dot{\eta} r m_2, \quad \dot{z} = \dot{\eta} r n_2, \tag{3.1}$$

where $\dot{\eta}$ is computed as

$$\dot{\eta} = \sin^{-1}\left[\frac{R_1 \times R_N}{|R_1|\,|R_N|}\right] / (t_N - t_1) \tag{3.2}$$

The angular displacement, w_1 at the time of the first message is computed from 1.13. Subsequently, the displacement w_i for each message, i, is computed as

$$w_i = w_1 + \dot{\eta}\,(t_i - t_1)\ . \tag{3.3}$$

The velocity components are transformed to the 'earth fixed coordinate system defined above using eq. 2.17, again substituting α for q.

An initial latitude, longitude and height estimate are transformed into the rectangular coordinate system by equations 2.10 and the partials are computed as in equations 2.11.

For each message, the range and range rate partials $\partial\dot{\rho}/\partial\phi$, $\partial\dot{\rho}/\partial\lambda$, are computed and these are summed over the message set to form the A^TA and A^TZ matrices. The correction vector, $C = -(A^TA)^{-1}A^TZ$ is computed thru a series of elementary row transforms.

4. A simplified general procedure for computing location estimates from the doppler shift has been written in BASIC for the HP 87XM and is presented here. The program uses a surveyed reference station to correct the spacecraft epoch vector expressed as nodal elements.

The spacecraft nodal period, T, the orbital inclination, i, and the ascending node angle, Ω, are the nodal elements defining a circular orbit. The epoch time t , is the instant of the spacecraft south-to-north equator crossing.

From the nodal elements, the semi-major axis, a, the angular velocity, n, and position w, are computed as 59

$$a = \left[GM/(4 \pi T^2)\right]^{1/3} \quad (4.1)$$

$$\dot{\eta} = 2 \pi / T \quad (4.2)$$

$$w = \mathring{\eta} \ (t - t_o) \ . \quad (4.3)$$

The spacecraft geocentric inertial cartesian coordinate velocity components are computed using eqs. 3.1, 3.3 as before, and, taking e and f to be zero as in part 3, eqs. 2.14 may be approximated as

$$\dot{x} = a l_1 , \quad \dot{y} = a m_1 , \quad \dot{z} = a n_1 \quad (4.4)$$

The position and velocity components are transformed to earth fixed coordinates by eqs. 2.16, 2.17, where the periodic terms are neglected in the computation of the Greenwich Hour Angle, q.

The epoch time t_o, and the ascending node angle, Ω, are iteratively-adjusted to minimize the error function, E, in eq. 2.5, where $\partial\dot{\rho}/\partial\Omega = -\partial\dot{\rho}/\partial\lambda$ as before, but $\partial\dot{\rho}/\partial t$ is computed analytically as

$$\frac{\partial\dot{\rho}}{\partial t} = \frac{\partial\dot{\rho}}{\partial\phi}\frac{\partial\phi}{\partial z}\frac{\partial z}{\partial t} \quad (4.5)$$

with $\partial z/\partial t$ taken to be $\dot{z}$, and $\partial\phi/\partial z = 1/(\rho_e \cos \phi)$.

The adjusted orbital elements are then used in the minimization of eq. 2.2 to obtain the transmitter position estimates.

5. The most difficult aspect of location estimation is the determination of the spacecraft state vector at an arbitrary time. The position estimate accuracy is largely determined by the quality of the initial epoch vector and the sophistication of the orbital model employed. The automated execution of more complex models requires more machine resources and this may conflict with size, weight and cost constraints. One procedural compromise sidesteps this issue by correcting the epoch vector using a surveyed reference station as in part 2 after acquiring each spacecraft pass, then the model need only be sufficient to again acquire the spacecraft on the next available pass. Stations using the model (eqs. 2.12) in part 2 have operated more than two weeks in this mode. When the spacecraft acquisition time is significantly different then the epoch time, a more sophisticated model is required. The authors have used an abbreviated Brouwer-Lydanne model without adjusting the orbit to compute locations two days from epoch with an error less than 7 km. The interested reader may wish to-further explore models described in ref. 4,6. .

Other errors are inherent in certain unfavorable pass geometries. From considerations of symmetry, the locus of possible transmitter locations giving a specific doppler frequency is a cone defined by $\dot{\rho}_o = \dot{\rho}_s \cos B$ where $\dot{\rho}_o$ is the observed range rate and $\dot{\rho}_s$ is the spacecraft linear velocity and B is the angle between the spacecraft velocity and $\dot{\rho}$. The cones from multiple messages intersect to form a ring and the intersections of the ring with the earth-reference spheroid are the two possible transmitter locations.

As the spacecraft orbital plane approaches the transmitter zenith, the ring 60
becomes more nearly tangential to the reference spheroid and the intersections become less distinct. Consequently, location estimates become especially vulnerable to spacecraft altitude and transmitter height errors. Further, the iterative search vector may converge to the alternate or "mirror" intersection, particularly if the initial estimates are far from the computed position.

The techniques presented require a minimum of three messages to compute position estimates because the system is solved for three parameters, latitude, longitude and doppler bias. However, aminimal ly determined system (3 messages) lacks certain desirable statistical measures of accuracy. The reliability of the position estimates increases with the number of messsages.

A practical implementation of the described location estimation procedures should include a scheme for detecting invalid messages and removing them from further consideration. Messages not exhibiting monotonically increasing transmission times and monotonically decreasing doppler frequencies should be discarded. Further, doppler frequencies greater than 62.6 Khz. or less than 39 Khz should be deleted.

The majority of users will find the standard System Argos services the most accurate and convenient method for obtaining transmitter location estimates. However, the demonstrated feasibli tyof implementing location software-on personal computers may be of interest to those users with a real-time position estimation requirement. Historically, commercial vendors have addressed this market with dedicated microprocessor-controll ed receiving stations, but the high development costs and limited market have made these systems prohibitively expensive for some users. An inexpensive receiving station providing real-time transmitter location and data reduction services using a personal computer now seems attainable. The interested reader can find downlink telemetry format message extraction details in ref. 8.

Other position location methods are under investigation. Present location methods are viewed as a basis for future development as the ARGOS user community requirements expand.

The authors thank Charles Vermilion for his support and encouragement in the presentation of this paper, L. Henry (Andy) Anderson for our many informative discussions concerning orbital mechanics, Dr. L. E. Hoisington for his thorough review of the text, and Dr. Bruce Mate whose enthusiastic interest prompted our initial examination of alternative position location methods.

References

1. Roy, A. E.,''Orbital Motion", 2nd edition, Adam Hilger Ltd., 1982

2. Briggs, R. E. and Slowey, J. W., 1959 Smithsonian Institution, Astrophysical Observatory Research in Space Science Report No. 27

3. Schmid, Jr., Paul E., Lynn, J. J. ,"Satellite Doppler-Data Processing Using a Microcomputer", IEEE Transactions on Geoscience Electronics, Vol. GE-16, no. 4, October, 1978

4. "Mathematical Theoryof the Goddard Trajectory Determination System", Goddard Space Flight Center, Greenbelt, Md., April, 1978

5. Yionoulis, S. M., Eisner A., "Search and Rescue Satellite (SARSAT) Error Analysis of the 406 MHz System", The Johns Hopkins University Applied Physics Laboratory, Laural, Md.

6. "Project Spacetrack", Report No. 3, Models for Propagation of NORAD Elements", Aerospace Defense Command, United States Air Force

7. "TIROS Spacecraft Data Collection System Station Location Program", author's unpublished notes.

8. "Extraction of Data Collection System Telemetry from TIROS Spacecraft Data", author's unpublished notes.

Appendix I

Herein is a list of some possible sources of TIROS spacecraft orbital elements.

Source: Nasa Prediction Bulletin

Contact: Adam Johnson
Goddard Space Flight Center
Code 513.2
Greenbelt, Md. 20771

A written letter specifing the spacecraft identification and requesting the user's inclusion in the mailing list is required. A kit describing the bulletin is available. The TIROS spacecraft identifications are below:

	International ID	NORAD Object
NOAA-7	198159A	12553
NOAA-8	198322A	13923

Source: NOAA/NESDIS

Contact: Dr. Robert Popham
NOAA/NESDIS
FOB4 Rm. 3308 Mailstop D
Washington, D.C. 20233

Users should request their entry on the mailing list in a letter.

Source: American Radio Relay League

Contact: American Radio Relay League
225 Main Street
Newington, CT. 06111

The American Radio Relay League broadcasts satellite equator crossing times and longitudes daily.

Source: National Weather Service

contact: Communications Division W/OTS32
National Weather Service
8060 13th Street, Room 1330
Silver Spring, Maryland 20910
Attn: Terri Faulkner

The National Weather Service (NWS) provides access to the Global Telecommunications Network (GTS). However, private individuals are encouraged to obtain access thru commercial services or subscribing institutions rather than directly from NWS.