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LithoSEIS User Manual

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LithoSEIS

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User Manual

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What is LithoSEIS

LithoSEIS is a software package developed at the Geological Survey of Canada for field operation of the Portable Recording Seismographs (PRS1 & PRS4). The software package is particularly useful for the users of the PRS seismographs. It operates on IBM-PC computers under DOS and can be obtained at no cost from the Geological Survey of Canada at the following address.

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Contents

1 How To Use This Manual.

This manual is a narrative account of how to perform an experiment using LithoSEIS hardware and software. When you have mastered the ideas and concepts presented herein you will be well on the way to being able to conduct an experiment. What you will not get from this manual is a key by key account of which buttons to press when. The principal reason for this is that there is no single "correct" way of achieving any particular outcome with LithoSEIS, rather you should approach it in much the same way you would a text editor that offers you a set of tools to be applied to a problem. The choice of precisely how you use these tools is your own.

In common with many text editors, LithoSEIS contains many features that some users will never need, and therefore it may seem complicated at first. However persevere and you will find that for most applications you are never more than a few keystrokes away from success.

If you wish further information on how to use LithoSEIS, there are many sources of information. The first one is the LithoSEIS On-Line help which is directed towards giving information on the effect of pressing particular keys at a particular menu level. This information is bound together as the LithoSEIS On-Line help manual, and is also available anywhere in LithoSEIS by pressing the universal help key, the F1.

A second source of information is the LithoSEIS work-book which provides important hints about many of the critical aspects of the software.

However, you will gain most by actually experimenting with the package. As you do so you will learn from the information line associated with each menu choice, together with the success and error messages issued by LithoSEIS itself.

Some terms in this manual are considered LithoSEIS technical terms and presented in sans serif type, for example WINDOW. These terms will either be in the glossary of LithoSEIS technical terms which may be found in Appendix C, or represent a menu item or function key to be selected by the user. Where necessary the path to sub-menus will be given in full, for instance PREPARE:SITES implies selecting the PREPARE menu followed by the choice of the SITES item.

We begin by a short introduction in section 2 followed by LithoSEIS ideas in section 3 and a description of the overall system in section 4.

In section 5 of this manual you get to know about the overall planning of a LithoSEIS experiment. More precisely, we teach you how to PREPARE for your field program.

In section 6, we explain the actual field procedure and teach you how to collect data with LithoSEIS.

In section 7 we examine the REFRACTION mode analysis where you get to know what to do with refraction data.

We then present the SEISMICITY mode ANALYZE package in section 8 and show you how to locate earthquake hypocenters.

Section 9 of this manual offers general maintenance hints and is related to the MAINTAIN part of the LithoSEIS package.

The hardware and software installations are described in appendix A and B and the

glossary of items is presented in appendix C.

2 Introduction

The Portable Refraction Seismograph (PRS1) was originally designed and tested by the Instrumentation Laboratory of the Geophysics Division of the Geological Survey of Canada in 1985 and the first 12 prototype PRS1 units were successfully tested in 1986 in the Canadian Arctic and around the Great Lakes. Under a technology transfer agreement from the Survey, EDA Instruments of Toronto (now Scintrex Limited) manufactured 170 PRS1 units for the Canadian LITHOPROBE project.

The PRS1 is a single channel recorder with a fixed sample rate of 120 samples per second. It is configured with 1 MB of random access memory and is adequate for a typical refraction deployment with a total recording capacity of 72 minutes which can be divided into up to 128 time windows.

A four channel version of the PRS1 instrument (called the PRS4) is commercially available from Scintrex Limited and can record three component seismic data and one time channel both in timed mode for refraction studies and in triggered mode for seismicity monitoring.

The PRS instrument must be programmed by an external computer before deployment. Similarly, when the instrument is retrieved, all data stored in memory must be recovered from the seismograph and stored on external devices. In principle this can be achieved with relatively simple communication software but in practice due to the sheer volume of data to be collected from hundreds of seismographs, more sophisticated field processing facilities using database management systems are required.

LithoSEIS was originally designed to allow easy execution of large refraction experiments using the PRS1 instruments. The new release of LithoSEIS presents features specifically designed to handle both refraction and seismicity monitoring experiments using the PRS4 instruments.

In LithoSEIS, those tasks that require scientific input such as the planning of an experiment and the choice of recording parameters are first separated from the more mundane tasks of getting data in and out of a seismograph. The former tasks are designated as FHQ functions whilst the latter are designated as FSU functions. The FSU functions are managed by AT class IBM-PC computers running MS-DOS Version 3.3x or higher while the FHQ tasks are normally managed by 386 based PC's with 100 MB hard disks.

3 LithoSEIS ideas

Most LithoSEIS users will have had some experience with portable seismographs and will have participated in a typical experiment involving 18 hours a day of physical labor collecting data followed by months of work in the laboratory to produce a final product ready for scientific scrutiny. Compare such a method of operation with that of a professional reflection seismic crew who send from the field organized tapes of the data, together with sufficient information for the geophysicist to begin work, even though orders of magnitude more data are involved. LithoSEIS offers the facilities to allow a refraction crew to operate with the efficiency of a reflection crew.

It may seem to the uninitiated that such a goal is a luxury, but in our experience, it is a necessity. After our first experiment involving the **Lunch Boxes** it took 3 months to play back and organize on a mainframe a couple of hundred traces. We now collect tens of thousands of traces each season. To do so has taken a complete rethinking of both field operations and software.

We will continue this section with an overview of the entire package since many of you are probably wondering what LithoSEIS is. We will divide the description into four parts. Section 2.1 contains a brief overview of the overall organization of a LithoSEIS experiment, section 2.2 contains a description of the functions of a Field Service Unit (FSU), the field computer that programs the PRS's and reads data from them. Section 2.3 presents a summary of the functions of the Field Headquarters Unit (FHQ) which plans, controls, and manages data for the entire experiment, and finally section 2.4 introduces some important LithoSEIS terms.

3.1 LithoSEIS Operational Considerations.

The goals of a LithoSEIS survey are to maximize the recording capability of a set of PRS instruments using the minimum possible resources and to return from a field operation with the data processed and ready for interpretation. To achieve these goals under complicated conditions, each survey is broken down into a number of elements or operations.

1. After a scientific target is identified an initial site inspection should normally follow to determine the position of the FSU and FHQ camps for optimum coverage.

2. Before the main crew arrives in the field, recording sites should be identified and their coordinates determined.

3. The LithoSEIS hardware are inspected in the laboratory and shipped to the field.

4. In the field, the FHQ hardware and software installation are carried out first. A maximum of 25 PRS's are allocated to each FSU camp, the FSU camps are installed and a calibration test undertaken.

5. A master plan is finalized at the FHQ. The master plan defines databases that contain allocations for each camp, shot times, window tables and other relevant

information. This plan is then exported to all FSU camps. At the end of this step, all camps hold identical operational parameters and FSU operators can check these parameters and report to the FHQ.

6. All FSU camps now DOWNLOAD the operation plan into the PRS's and deploy them for recording. An in-field MONITOR program permits dynamic checking and control of the instruments during the recording cycle. At the end of recording, the PRS's are retrieved and their data uploaded into the FSU's. At this time, a copy of the recorded data is stored on the hard disk and a **Level One Backup** is stored on floppy diskettes. Seismic traces can be viewed for quality control before all data are ARCHIVEd for dispatch to the FHQ. Two different types of data volumes are created at each FSU. All the recorded wave-form data are stored on mass storage volumes (normally cartridge units) which constitute the ARCHIVE VOLUME's. All the support information which is kept in databases is stored on floppy diskettes which constitute the SAVE FSU Volumes. The ARCHIVE VOLUME's and SAVE FSU VOLUME's issued by FSU camps are essential to the running of LithoSEIS. They can be retrieved at the FHQ camp or at any FSU camp and provide an organized vehicle for merging of the recorded data. The ARCHIVE VOLUME's and SAVE FSU VOLUME's thus serve two important purposes: they hold a complete copy of recorded wave-form data and field support data for archiving purposes, and they are used as a vehicle for transporting data between the FSU's and the FHQ.

7. To ensure that further data processing is performed efficiently it is necessary that final support information, such as the geographic coordinates of shot and receiver sites is entered into LithoSEIS *whilst in the field.*

8. While the experiment is still in progress, the FHQ camp receives and merges the ARCHIVE VOLUME and SAVE FSU VOLUME's from FSU's to create and update the master CATALOG. The master CATALOG contains all the header information for the entire survey. It is then possible to retrieve certain groupings of recorded data and process them. This processing includes the production of SEGY files or tapes in REFRACTION mode and event identification and location in SEISMICITY mode. At this point, the normal recording cycle is complete and the data can be analyzed. At the end of the experiment, all of the recorded data are available at the FHQ camp. All the support information is also available and latest updates of site geography and time corrections are registered in the LithoSEIS databases. An UPDATE function provides an automated process to correct the master CATALOG.

During the experiment one person known as the Data Processing Supervisor, should have the sole task of ensuring the integrity and completeness of the data. He is the LithoSEIS equivalent of the observer on a seismic reflection crew, and is second in command after the scientific authority. In large experiments he will need an assistant FHQ operator.

3.2 FSU operations

A flow diagram for the functions of an FSU is shown in Figure 1. The primary purpose of the FSU is to program the Portable Refraction Seismographs (PRS's) and recover data from them. A single FSU is usually able to handle up to 20 seismographs depending on the amount of disk space it has available and the amount of memory used in the seismographs. If you look at Figure 1 you will note that these programming and data reading steps (which are called DOWNLOADand UPLOAD in LithoSEIS jargon) are just a small part of the overall FSU operations. What does the rest of it do ?

The power of LithoSEIS comes from its relational databases, these store every conceivable piece of information relevant to the experiment other than the data values themselves. This database information includes such items as site coordinates, recording window times, clock drift curves and so on.

In Figure 1 the databases are shown on the left hand side as rectangles, they may have been filled up in various ways. Normally in a large experiment much of the initial planning, and therefore database entry, will have taken place at a central headquarters, and then imported to the individual FSU's. Often this is the first operation undertaken at the FSU.

In the perfectly planned experiment these databases will never need modifying, however in practice, last minute changes in plans and errors in the original entries will mean that an FSU will need to edit the databases.

You will notice in Figure 1 that four main databases are shown. The simplest to describe and maintain is the sites database which contains geographic and other information about sites occupied by shots and receivers.

The shots database contains information such as the times of shots and various recording parameters associated with each shot. LithoSEIS calculates its recording windows from these data.

The plan database contains details of the overall experiment plan such as the dates that seismographs are to put in the field, trigger parameters etc.

Finally the recordings database contains information such as the time the instruments were programmed, where they were put, and seismograph clock corrections. Most of these are calculated automatically by LithoSEIS, but occasionally must be corrected by the FSU operator.

Some of the entries in these databases are essential for LithoSEIS to be able to program the seismographs, however much of the information in the databases has another equally important function. It is the aim of LithoSEIS to provide the user with a complete and accurate header for every trace recorded during the experiment. This header is based on an extension of the SEGY industry standard seismic trace header and is calculated automatically when data that are read from the PRS's are saved. The information for this header is calculated from information in the LithoSEIS databases. Thus it is highly desirable to have these databases as complete and accurate as humanly possible before the data are saved onto a permanent medium. If this is not done then the headers have to be updated later on at the FHQ.

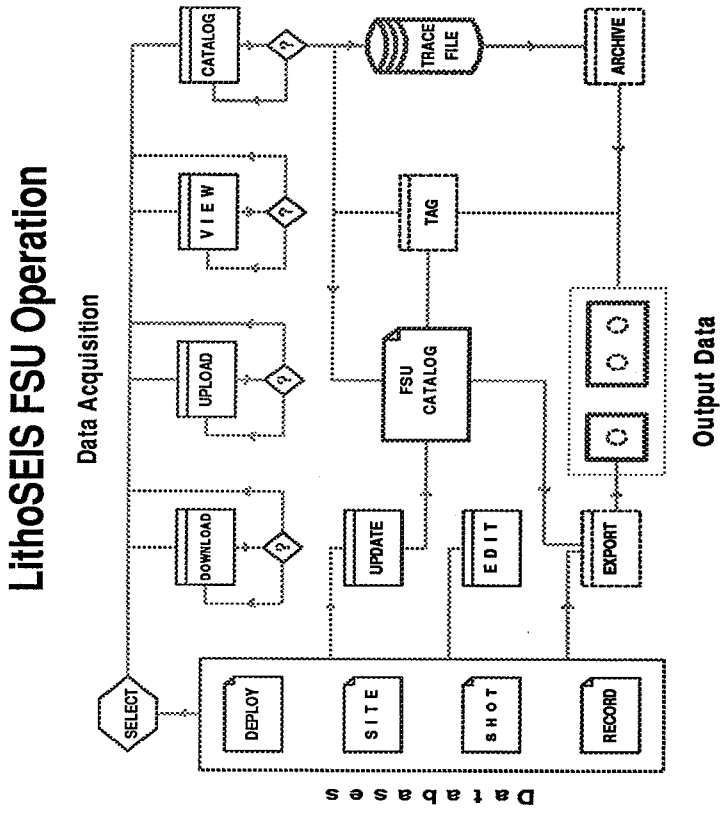


Figure 1: LithoSEIS FSU Operation

LithoSEIS treats the FSU operator as if he doesn't have a functioning brain and spoon feeds him through most of his duties. The reason for this is that most of us begin to make mistakes at midnight halfway through a trying experiment and LithoSEIS does its level best to avoid mistakes. There are a few items, however, where the FSU operator must pay attention.

The most important of these is that he must enter into LithoSEIS the site at which each PRS was deployed. This process of assigning sites to PRS's is known as MATCHing, it takes place just before the UPLOAD process when the data are recovered from the PRS's.

Another important function of the FSU operator is to periodically rate against U.T. any master clocks that are being used by LithoSEIS to rate PRS clocks.

After data have been read from the PRS, a recording window or seismic event is known as a TRACE. The FSU operator must perform several operations on TRACEs or groups of TRACEs.

As each PRS is uploaded, a backup copy of the data is made on floppy disks; this is

called a Level One Backup. Under normal circumstances this backup copy (the Level One Backup) is never used again, rather a more formal copy of the data and associated header information is put to a permanent ARCHIVE VOLUME. The FSU operator must decide which traces are to be stored permanently on LithoSEIS archive volumes and which can be deleted immediately.

This brings us neatly to the concept of UPLOADED, CURRENT, and ARCHIVED-TRACEs. When a PRS or group of PRS's are first uploaded at the FSU the resultant traces are known as uploaded TRACEs. The FSU operator must then move the traces he wishes to keep in LithoSEIS from the UPLOAD database to the CURRENT database. As he does so the SEGY header for that trace will be stored in a permanent catalog of such headers. Not surprisingly this operation is known as cataloging. Those traces that he does not move to the CURRENT database can be deleted. Once important traces have been moved to the CURRENT database they may be moved *en masse* onto archive volumes for permanent storage along with the appropriate header information taken from the CATALOG, whereupon they are deleted from the FSU disk and become known as ARCHIVEd traces. The FSU operator is responsible for keeping track of the status of every TRACE uploaded at his or her FSU.

ARCHIVE VOLUMEs, which are usually datacassette cartridges but can be floppies, are the principle product of the FSU. They contain all the information the FSU knew about each trace at the time the trace was put on the cartridge. Thus the data on them can be processed on any other computer without the need to go back to the individual databases on the FSU.

The FSU operator can at any time save copies of the important databases to floppy disk. This has two functions, firstly these disks can be used as backups in the event of computer failures, and secondly they can be taken to the field headquarters unit to be merged into the databases, in this way the FHQ databases are kept in step with those at the individual FSU's.

3.3 FHQ operations.

The field headquarters is the nerve center of LithoSEIS operations and so should have someone of responsibility and experience in charge of it. He or she will not only have the task of operating the FHQ computer, but will also have to advise the Scientific Authority on who should be doing what during the course of an experiment to ensure data integrity.

The processing capabilities of the FHQ in REFRACTION mode are shown in Figure 2. They may be summarized as follows.

- LithoSEIS Planning. The initial experiment plan should be entered into the FHQ in as much detail and as accurately as possible. It may then be exported to the individual FSU's at the appropriate time. When the logistics of an experiment are being planned the Scientific Authority and Data Processing supervisor should ensure that adequate lines of communication are set up between the FHQ and FSU's.

- Database Completion. The Data Processing Supervisor must ensure that by the final stages of an experiment the databases are complete and accurate. As a rule all manual entries in the databases should have been checked by a third party. As part of the completion of the databases the FHQ may have to merge in partial databases completed by the FSU's.

- Catalog Merging and Updating. The FHQ receives archive volumes from the FSU's containing traces and catalog entries. The FHQ must merge these into a single master CATALOG. Once this is done it can be updated to reflect any changes to the databases since the data were first cataloged.

- SEGY File and Tape Production and Processing. The FHQ has the responsibility of producing the final outputs of an experiment in the form of SEGY files and tapes. These are assemblages of traces grouped in ways to facilitate analysis in the laboratory with an accurate header at the start of each trace. This header is obtained from the catalog just before the SEGY files are made. Therefore final SEGY files should only be created when the catalog is correct. SEGY files may be processed with the VISTA time series processing package.

- Report Production. At suitable stages in the experiment full reports of the progress of the experiment can be produced.

In SEISMICITY mode, the SEGY stage is replaced by first arrival picking and event location. See the SEISMICITY ANALYZE section for more details.

3.4 Important ideas.

This section introduces many of the ideas which should be understood prior to running a LithoSEIS experiment. Once you have mastered them you should be ready to play with the package on the computer.

3.4.1 The four main phases of LithoSEIS.

LithoSEIS operations are divided into four main phases: PREPARE, EXECUTE, ANALYZE and MAINTAIN. The first two of these deal with the pre-experiment planning and the collection of data respectively, thus they are essential steps. The latter two deal with the processing of the data after they have been recovered from the PRS's and the housekeeping associated with running the computers. They are not essential, and often in the middle of a busy experiment it is very tempting to ignore them completely. Try not to do this, these are the steps which turn the chaos of a raw dataset into an organized entity suitable for processing.

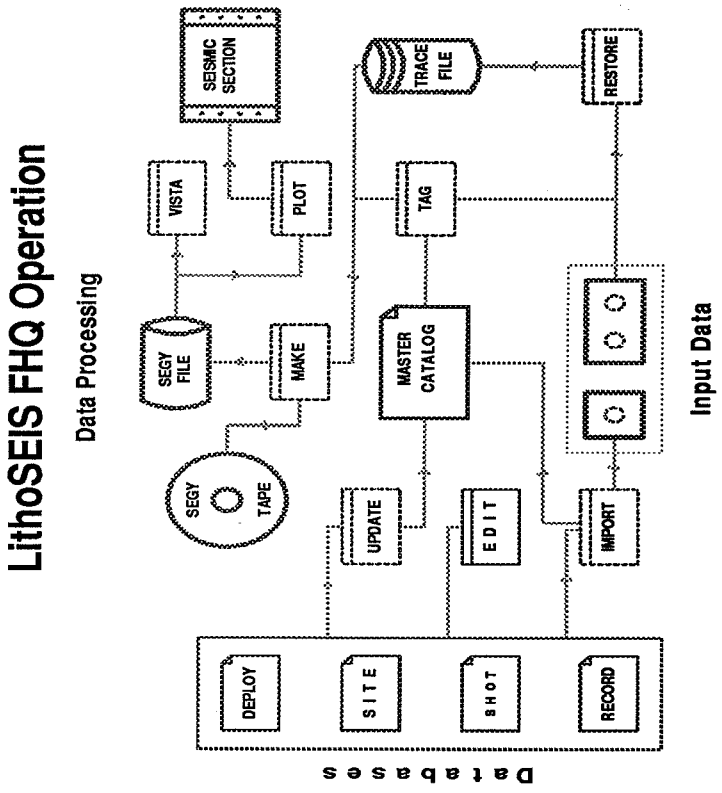


Figure 2: LithoSEIS FHQ Operation

3.4.2 FSU's and FHQ's.

There is a logical distinction between computers that are used mainly for the EXECUTE phase of LithoSEIS (and therefore must talk to the PRS's) and those that are used mainly for the other three phases which do not require communication with the PRS's. The primary functions of a Field Service Unit (FSU) are the programming of PRS's and the recovery of data, in general you need lots of them. The primary functions of a Field Headquarters Unit (FHQ) are the planning of the experiment and the merging of data from several FSU's.

3.4.3 DOWNLOADING and UPLOADING.

The PRS1 and PRS4 instruments are controlled by a microprocessor and like all microprocessors they must be programmed. The program for the PRS is read from the FSU during the DOWNLOAD process. The reverse operation of reading data from the PRS into the FSU is called UPLOADing.

3.4.4 WINDOWS AND DEPLOYMENTS

The program DOWNLOADed into a PRS instructs the recorder to turn on and off at various times. Each such on/off cycle is called a WINDOW and the set of WINDOWs constituting a single programming is called a DEPLOYMENT. LithoSEIS draws extensively on the DEPLOYMENT concept, indeed you will notice that many items that you input into LithoSEIS apply only to the currently active DEPLOYMENT. It may be helpful to discuss the reasons for the special emphasis placed on DEPLOYMENTs. In a typical refraction experiment the unit of work, which seismologists have traditionally called a deployment, involves the recording of several shots by a number of PRS's. Each of these recorders must switch on and off at precisely the same times and therefore all must be given the same program at DOWNLOAD time. In LithoSEIS this concept of a deployment has been extended to mean strictly a single program. There are some important consequences of this rule. For instance, supposing that you wish to simultaneously deploy two sets of instruments one of which is to record a number of WINDOWs starting on even minutes and the other of which is to begin on odd minutes. To program this you must create two LithoSEIS DEPLOYMENTs, one for each set.

3.4.5 The CATALOG.

The CATALOG is the processing heart of LithoSEIS that makes possible all the LithoSEIS steps following recovery of data. Quite simply it is a database containing an entry for each seismic trace that the LithoSEIS operator considers worthy of keeping for posterity. It contains all the information LithoSEIS knows about each trace apart from the data themselves and constitutes a complete record of an experiment. Amongst the many functions which rely on a proper catalog are; a) the archiving of data, b) the restoration of data, c) the merging of data, d) the updating of header information, e) the sorting of data, f) the splitting of data and g) the production of experiment reports. The maintenance of the CATALOG is one of the most important functions of the LithoSEIS FHQ operator.

4 The Keyboard, Menus, Screens and Tagging.

LithoSEIS has been carefully written to provide you the user with a consistent "look and feel" that will allow you to use prior experience to guess the effects of your actions with a reasonable degree of certainty. The purpose of this section is to introduce you to some of the aspects of LithoSEIS which apply throughout the package. Much of the feel of the package has been influenced by software packages such as dBASE and Lotus 1-2-3 so users familiar with this sort of software should have no trouble assimilating this information.

4.1 The Keyboard.

Several global (HOT) keys are available to the LithoSEIS user. These keys are always active during the running of LithoSEIS, performing the functions described below.

4.1.1 Help

F1 is the On-Line Help key. Each level in the LithoSEIS menu structure has at least one Help screen, providing relevant information to the user for the current process.

4.1.2 Exit

F10 is the EXIT key. Most of the data entry screens use this key for a clean exit. When you press this key, changes you have made to the entries will be stored and the current process terminated.

4.1.3 Local Abort

ESC is the local abort key. It aborts the current level and returns control to one level above. If it is used in a data entry screen, any editing performed for that screen may be lost. The ESC key can be used for navigation as well. A novice user may use this key to explore all levels of LithoSEIS without registering any changes at all. After using the ESC key it is wise to return to the aborted screen to check exactly what was stored.

4.1.4 Global Aborts Alt-C, Ctrl-C, Ctrl-Break

These keys are active in various parts of LithoSEIS. They should only be used in emergency situations. These keys normally provide some system clean up like closing the open files and so on. The re-boot key (Ctrl-Alt-Del) must be avoided unless the system is completely hung.

4.1.5 Cursor Control Keys

The cursor keys control the movement of the cursor (that little blinking thing) and the highlighting of menu choices and are active during all data entry screen operations.

Up-Arrow (Ctrl-E) Moves the cursor up one line or field.
Down-Arrow (Ctrl-X) Moves the cursor down one line or field.
Left-Arrow (Ctrl-S) Moves the cursor one space to the left.
Right-Arrow (Ctrl-D) Moves the cursor one space to the right.
Home (Ctrl-A) Moves the cursor to the start of a field.
End (Ctrl-F) Moves the cursor to the end of a field.

4.1.6 Page Up and Down.

PgUp (Ctrl-R) Moves back to the previous data page.
PgDn (Ctrl-C) Moves to the next data entry page.
These keys are used to page up and down in the current module. When in data entry screens, this will have the effect of moving to the next or previous entry in the database.

4.1.7 Do it/Change Mode.

The F2 key is often used to execute a particular function once an input data screen is complete. In other places F2 toggles between ADD and EDIT mode.

4.1.8 Next Page in multipage screen.

When in a data entry screen that has to be split over several pages, the F3 key will bring up the next page.

4.1.9 List - Print

The F9 key is used in many places to produce a listing on the screen or printer of LithoSEIS information.

4.1.10 LithoSEIS notepad.

The key combination ALT-N will bring up a notepad for any notes you wish to keep.

4.1.11 LithoSEIS 'Show Hot Keys' ALT-F1

The key combination ALT-F1 will display a one line note about other hot keys available. They include ALT-O for PREPARE:DEFAULTS:OPERATION menu and ALT-H for PREPARE:DEFAULTS:COMMUNICATION menu.

4.2 The Menus

The selection of items from menus is the way you give instructions to LithoSEIS, indeed it is the only way to do so. You will notice that there are two types of menus, they are known as command menus and OPTIONS menus.

4.2.1 Command Menus.

Command menus consist of a number of commands arranged in a vertical or horizontal list; choosing a command causes that command to be executed.

You can make your choice in one of two ways. Firstly, you can use the arrow keys to cause the desired command to be highlighted then press RETURN to execute the command, or secondly, you can press the first letter of a command and it will be executed regardless of which command is highlighted. The choice of which method you use is up to you, however using the arrow keys has the advantage that an INFO-LINE is displayed for each command as it is highlighted. The INFO-LINE gives you one line of help information on each command, you can find it on the second line of the screen above the main menu. Please get into the habit of reading this line, since of necessity the menu items themselves are brief and their purpose is not always obvious.

Many menu choices simply bring up another menu. When the menu boxes overlap (or tile on each other), the active menu can easily be identified as the one in front of the others. In addition, the current cursor position is emphasized in a color or shade different from any other box on the screen.

4.2.2 OPTIONS menus.

OPTIONS menus are slightly different. They are usually presented fairly well down the menu tree and consist of a list of function keys and their effects. You choose a particular option by pressing the desired function key. In some cases there is not enough room in the OPTIONS menu to list all the options, in which case the purpose of one of the function keys will be to bring up more options. There is no INFO-LINE for OPTIONS items.

4.3 Data Entry Screens.

Just as menu choices are the only way you tell LithoSEIS what you want to do, Data Entry Screens (or screens for short) are the way you input information into LithoSEIS. Screens are presented to you in many places, usually as the result of two or more menu selections, contain a number of boxes for you to fill in, they are presented on the screen in different colors or shades than the rest of the screen.

Almost all the screens have an OPTIONS menu associated with them, these options will invoke commands which are designed to help you fill in the screen. You must work through a screen filling up each box with the information that you want to input. The box you are currently working on will be clearly distinguishable from the others by its color or shade. LithoSEIS knows what kind of information must be input into each box and will not let you do anything silly, for instance attempting to input alphabetic information into a box designed for the input of a time will fail. Similarly an attempt to input numeric information which is outside sensible bounds will produce an error message. You finish inputting to a box by pressing a RETURN whereupon the information in that box will be stored and the cursor will move to the next box on the screen. You

may move from box to box by repeated use of the RETURN key or by using the up and down arrow keys.

Some boxes that appear on the screen cannot be edited. LithoSEIS, being rather clever, will have a good reason for this, something that you did earlier in the experiment has meant that it makes no sense to change these items and you are stuck with the information you have now.

As you type information into boxes, the normal editing keys are available to help correct typing information. Pay special attention to boxes designed for the input of alphanumeric information since the justification within the box is significant. Also they sometimes can accept more information than there is space for within the box, in which case pressing the left and right arrow keys will pan through the text. **Case is not important to LithoSEIS text strings since all characters are converted to upper case before storage**

Some screens require so much information from the user, that they have had to be split up into several pages - your current page number and the total number of pages in the screen is displayed just above the screen. One or more of the OPTIONS keys will change pages for you.

When all information on a screen is correct press F10 to tell LithoSEIS to store the information and proceed. Selecting PgDn or PgUp will cause LithoSEIS to store information and bring up the next item in a database. Pressing ESC will abort the screen if you have got in a mess. Some screens are considered by LithoSEIS to be of such importance that after you change them you will be asked whether you really meant what you said. Replying no to this question will give you an opportunity to undo your mistakes.

Many of the screens contain a number of boxes to be filled in with information you may not yet have. LithoSEIS doesn't care if you leave unimportant information blank. If you attempt to leave a screen (by going off the bottom, pressing PgDn or PgUp to move to the next item, or pressing F10) with critical information blank, LithoSEIS will inform you of the problem. Similarly if you attempt to leave a screen whilst it contains information which LithoSEIS knows cannot be correct, you will be forced to correct the offending information.

Inevitably you will get stuck in a screen not knowing what to do. Usually this will be because a) you don't know what you are supposed to be doing or even whether you should be in this menu or not, or b) you are being asked for a piece of information which you have forgotten. Problem a) is solved by reading this manual and/or pressing F1 to get the on-line help. Problem b) is a little more interesting; if you are in a screen and trying to input an item that requires knowledge of something you have input previously but forgotten, then usually one of the options keys will bring up that information. For example, supposing you are in a screen that requires you to input into a box, for some reason, the name of one of the LithoSEIS sites, you can obtain a list of LithoSEIS sites by pressing the appropriate function key. Indeed you can go beyond this by using the cursor to point to the required SITE and pressing RETURN whereupon the box in question will be filled with that SITE name. This mode of operation has two advantages: it reduces

the amount the user has to write down and remember, and, more importantly it leaves no possibility of typing errors.

4.4 TAGGING

Tagging is an extremely simple but elegant idea that is central to many phases of LithoSEIS operation, it works as follows. LithoSEIS modules that can operate on many seismograms at once, require that a selection be made as to precisely which are to be used. This selection process is called "TAGGING" and once selected a TRACE is known as a TAGGED TRACE. In general LithoSEIS operations you perform, whether it be plotting, deleting, archiving or whatever will apply only to tagged traces.

Several different mechanisms for tagging are provided in LithoSEIS; the most frequently used are the TAG screen which allows you to cumulatively tag and untag ranges of traces, and GLIMPSE which allow you to individually TAG displayed traces by pressing the space-bar. Associated with the TAG screen is an OPTIONS menu which allows you to do useful things such as find tagged seismograms etc. The user is strongly advised to become thoroughly familiar with the tagging operation and all of the associated OPTIONS.

4.5 Error Handling

Certain LithoSEIS errors cause the system to crash issuing an error number. Error and warning messages in LithoSEIS are usually fairly self explanatory, however, these errors are documented in the LithoSEIS Error Utility and relevant methods of error recovery are provided for them. Each has a unique number associated with it. You can obtain further information on the meaning of and remedies for the various errors by exiting LithoSEIS and typing **error nnn** at the DOS level, where nnn is the number of an error message.

4.6 Miscellaneous

We conclude this discussion of the general features of LithoSEIS with a description of some of the other pieces of information presented to you on the computer screen.

4.6.1 The Statistics Box.

The STATS BOX appears near the top right hand corner of your computer screen. The contents of the box vary according to your position in LithoSEIS, since it contains information considered to be useful to the current processing stage. If the Catalogue Stats flag is set to 'N' (in PREPARE:DEFAULTS:OPERATION), then a smaller STATS BOX will appear in the CATALOG's tag screen. To get the regular STATS BOX, simply press the F9 key. You will find items such as the amount of disk space available, the name of the current DEPLOYMENT, the number of traces tagged and so on. Keep one eye on the STATS BOX at all times.

4.6.2 The System Line.

The first line on the computer screen is called the SYSTEM-LINE, it is reserved for weird and wonderful messages from the system and compilers. Programming bugs announce themselves on the SYSTEM-LINE, as do responses to really brutal treatment by the user such as the pressing of control-C. It has very little relevance to the everyday operation of LithoSEIS.

4.6.3 The Information Line.

The INFO-LINE tells you more about the currently highlighted menu item. You will save yourself hours of head-scratching and manual browsing if you read it (though our experience is that few people ever do !).

4.6.4 The Message Line.

The bottom line of the computer screen is called the MESSAGE LINE and is used by LithoSEIS to report warnings to the user that he may be about to do something wrong, or errors messages, reporting to the user that he actually did something wrong. In cases of major disaster, a whole series of messages have to be sent to the user, in which case LithoSEIS will hold each message on the screen for a length of time before moving on to the next one. The user can step through the messages more quickly by pressing RETURN after each message. Note that in general no audible beeps are issued by LithoSEIS errors.

4.6.5 The Prompt Line.

Immediately above the MESSAGE LINE is the PROMPT-LINE where the user is requested to input small amounts of information such as a confirmation yes or no. If LithoSEIS doesn't appear to be doing anything, check if it isn't waiting for input on the MESSAGE LINE. Pressing RETURN completes input of the PROMPT-LINE.

5 Preparing LithoSEIS for an experiment.

And so to business ! Our first job is to plan the experiment. This is a job for the Scientific Authority or Data Processing Supervisor, it is done once only, beginning as soon you get out into the field, if possible. Normally it will be done on the FHQ and then exported to the participating FSU's.

Here is a brief outline of what the work described in this section is supposed to accomplish.

a) Enter some sites in the SITE database.

b) Set up some of the DEFAULTS to let LithoSEIS know some generalities about your hardware and the experiment.

c) Plan a single LithoSEIS DEPLOYMENT, in which recording WINDOWs corresponding to the times of a number of shots and their backups will be created.

Assuming your computer is set up for LithoSEIS simply switch it on and type **lithosei.** After a short while a screen announcing LithoSEIS and giving you the software version number should appear. Make a note of the version number and determine if you are reading the right manual. If all appears OK then press any key to continue. Magically the LithoSEIS main-menu and your first STATS BOX will appear. You might want to read the screen and play with the highlighting for a while using the cursor control keys. As with nearly all LithoSEIS menus the main menu is ordered such that if you go through its items in order you will be doing roughly the right thing. So lets choose the first item PREPARE. A submenu will appear with three items and EXIT. Of the three items that actually do something, DEFAULTS sets up some default parameters to assist in further operation, SITES lets you input shot and receiver site information into LithoSEIS, and PLAN plans the recording schedule.

5.1 DEFAULTS

By now you should feel comfortable with the LithoSEIS menu and screens as exemplified in the SITES planning option. We now take a look at the DEFAULTS command. Unfortunately, this set of menus departs somewhat from the standard LithoSEIS "feel" because we have to place severe restrictions on the answers you may enter. Select this command and choose each of the menu items in turn. As you go through each screen you will be presented with various hardware and software options. Highlight the one most suited to your equipment, finishing with a RETURN. You will probably need the HELP facility to understand the questions, and you should also be aware of what hardware you are using. Because technical knowledge specific to the PRS's is required to fill in these menus, they should be completed by someone thoroughly familiar with the particular PRS and computer hardware being used.

We have found that some LithoSEIS users are rather confused by the purpose of the DEFAULTS option, in fact it is very simple. Its most important function is to tell LithoSEIS about the hardware it has available, however many of the items are put there simply so that LithoSEIS can save you time, typing, and effort later on. For instance when you set defaults you can specify which coordinate system you would like to work

in. Subsequent LithoSEIS menus will offer you this system. To use the other system simply press F6 in any relevant menu.

The PRS SETUP item in the DEFAULTS menu will operate correctly if your instrumentation has been entered into LithoSEIS. This is done in the MAINTAIN:PRS module, and should have been completed in the laboratory before you left the field. If not it can be done now.

Once you have got through the DEFAULTS menu, exit. The parameters you set will be saved, and you do not need to go there again unless you wish to change any of your responses.

5.2 SITES

After selecting SITES the SITES entry screen and an associated OPTIONS menu will appear. A SITE in LithoSEIS is simply a geographic location, exactly what is to take place there is irrelevant at this stage. Later on in other menus we are going to assign shots and PRS's to sites, but for now all we need to do is to fill in the geographic information. If you have not entered any sites in a previous LithoSEIS session your sites database is empty, LithoSEIS realizes this and presumes you want to add some sites to the database. You will notice that just above the entry screen it says ADD. If the database had not been empty it would have said EDIT to allow you to edit SITES you have already input. To switch between the modes of operation you choose F2. Its important to be aware of which mode you are in. Try adding five or six sites to the database.

The items you are being asked for include; the SITE identification or SITE-ID which can be up to four characters long, the location, and the name of the LINE upon which the site is situated (if you have one - LithoSEIS really doesn't care). You will notice that LithoSEIS is only letting you enter locations using LAT-LONG in degrees-minutes-seconds or UTM coordinates but not both, this can be flipped using the F6 key. Note also that the conversion between the two systems is performed automatically when you enter in either systems. Another feature important for large experiments is that you are permitted to enter the name of the FSU which will service a SITE.

You will also notice the message Pg 1 of 2 appearing at the top of the menu, this is the way LithoSEIS tells you there are more pages applicable to the SITES screen. The second page, which is accessible only in EDIT mode, is accessed using the F3 key. It contains information mostly relevant to the SEISMICITY mode of LithoSEIS.

After adding the sites, select F2 whereupon you will flip to EDIT mode, and the OPTIONS menu will give you more choices. Lets briefly examine each of these options (later in this manual we won't go into such detail, but as its your first time...).

F1, F2 and F3, you already know about.

The simple way of moving from SITE to SITE in the database is by pressing the PgUp and PgDn key however this can be tedious. F4 and F5 are designed to help with this problem. After choosing F5 you will be asked for a SITE-ID, if you enter one that is in the database it will become the current site on the screen. F4, the "PICK SITE" option is a little more sophisticated. After it is chosen, a list of sites will appear on the left of

your screen, you can move around this list with the cursor keys and then press RETURN to select a site to edit.

F6 "toggles" between Latitude-Longitude and UTM coordinate systems.

F7 allows you to delete a site from the database, however LithoSEIS will not let you delete a site that has actually been used during a DEPLOYMENT.

F8 is used to generate a series of SITE-IDs automatically, thereby saving you a lot of typing. Of course it can't automatically fill in the site locations.

F9 gives you a printout and F10 exits and takes you up one menu level.

5.3 Listing and Printing.

If you tried the List-Print option (F9), you will have got your first taste of the extensive listing and printing options in LithoSEIS, and probably needed some help to get through it. It will have been worth the effort however as that particular menu is repeated many times throughout LithoSEIS. Briefly, you were given the option of using GENERATE to generate a listing ordered as you specified, covering the range of stations you wish. You can then use CHOOSE to select from the several lists you may have generated. Then LIST will put the listing on the screen for you to page through, PRINT will send it to a printer, and SAVE will save the listing to a floppy for later high-quality printing.

5.4 The Plan

Now we come to the most important part of all; choose PLAN and read the menu. Remember that a DEPLOYMENT is a single program for a PRS. For operation in timed-mode this program corresponds to a single set of recording windows, whilst for triggered mode operation it corresponds to a single set of acquisition parameters. You should realize that everything you do in LithoSEIS from now on will apply to a single deployment only. This may cause you some surprise at times, for instance you may have planned a shot with the SHOT-ID DUCK whilst planning a DEPLOYMENT called DON, if later on you happened to produce a list of shots and your current DEPLOYMENT was named HEWY the SHOT-ID DUCK would not appear.

You can plan as many DEPLOYMENTs as you want, they can even overlap or be simultaneous, but each has a separate DEPLOYMENT code. As far as LithoSEIS is concerned **there is only one current DEPLOYMENT and any one PRS can only be programmed for one deployment at a time.** So if you want to work on a particular DEPLOYMENT you must select that particular one. We will see how to do this in a moment. **The name of the current DEPLOYMENT is always displayed in the STATS BOX.**

The design of LithoSEIS is such that seismic traces are identified internally by a DEPLOYMENT name and instrument number. Thus you should not use a single DEPLOYMENT more than once per box.

5.5 Deployment Planning.

The purpose of PLAN:DEPLOYMENT option is to allow you to tell LithoSEIS about various items common to the entire deployment. This includes the number of channels to use, the mode of operation (TIMED MODE or TRIGGERED MODE), and so on. Since all PRS's programmed under a single DEPLOYMENT have exactly the same program loaded into them, you cannot vary these quantities for different PRS's. If you do want different programs to go into various PRS's then you must create more than one DEPLOYMENT within LithoSEIS.

Choose PLAN:DEPLOYMENT. As with the SITES option, what you see in front of you now depends on whether you have previously planned a deployment or not. If you have not previously planned a DEPLOYMENT you will be presented with LithoSEIS's default DEPLOYMENT which happens to be a TRIGGERED MODE DEPLOYMENT called GOOD. If you have previously defined DEPLOYMENTs you will be presented with the most recent one. In either case you will be in EDIT mode. To enter a new DEPLOYMENT simply press F2 to move to ADD mode. When you add a new DEPLOYMENT most of the parameters from the previous one will be copied as defaults for the new one, hence you only need to enter those parameters that change from DEPLOYMENT to DEPLOYMENT.

The very first thing you do when starting a new DEPLOYMENT is to invent a sensible name for it. LithoSEIS makes sure this name is unique and never used before on current FSU. If you are using more than one FSU, YOU must make sure that each deployment name is unique throughout your experiment.

The next thing you do is to tell LithoSEIS what mode of operation you intend to use your new DEPLOYMENT: is it a REFRACTION or a SEISMICITY mode? There is an Engineering mode as well but LithoSEIS is not well developed for it.

In SEISMICITY mode you will have access to five pages and in REFRACTION mode to four pages of user entry screen to set your deployment parameters.

The very first page of data entry screen appears as soon as you try key F2 to add a new deployment. On this page you will determine the deployment code, its mode and channel orientation in case you record on more than one channel. You may also add a short comment about your new deployment. Note that the only place you can edit and change the name of your new deployment is on page one.

Also on page one, you see statistics (but you can not edit them) about your current deployment. Complete data entry on page one by pressing key F2 again to toggle back from ADD to EDIT mode. As you do this, you see a new page for data entry. Deployment code and mode are visible on this and all other pages but you may not edit them (they are only editable on page 1).

Let's now explore all other pages of DEPLOYMENTs data entry screen in REFRACTION and SEISMICITY modes.

5.5.1 Time Mode Deployments in Refraction

After defining a new deployment as explained in the previous section, we are ready to enter the window parameters and other information that make a REFRACTION mode

deployment.

Before we describe the window parameters, let's point out that the only other parameters that you need to worry about in REFRACTION mode are the Calibration Pulse, Warm-up and Record Now durations shown on page 4 and the Calibration Events recording channels shown on page 5. These are explained in details in the SEISMICITY section below.

5.5.2 Window Parameters

The window parameters are required when we need to tell the PRS instrument to wake-up and record data at certain times. This option is mostly used in REFRACTION mode although it is possible to use it in SEISMICITY mode as well.

Let's begin by defining the parameters first:

- Sample rate: Is the effective sample rate for the PRS instrument. The PRS1's are hard-wired to 120 Hz and ignore any other number entered here. Note that to change the sample rate, you need to use the + or - keys and only pre-determined values of 10, 15, 16, 20, 25, 30, 32, 50, 60, 64, 100, 120, 128 and 200 are accepted.
- 1st Window: Start time of the first chronological recording window.
- Window Duration: Length of recording windows.
- Number of Repeat Windows: Additional window (if any) that must be opened after the first one, usually used as backups.
- Interval: The interval time between a WINDOW and its backup.
- Record on Ch.: The recording channels for all window tables in this deployment. Since the PRS1 can only record one channel, it will ignore any other channel but one if they are entered here.

The window table entered here is considered to be a profile for the current deployment. It provides a simple recording table that can only have limited practical application. In most practical cases, windows are irregular and can not be generated in this simple form. We normally use the SHOTS data entry screen to define some SHOTS and create a REFRACTION mode window table.

If you were to attempt to program instruments in TIMED MODE without having specified any SHOTs, LithoSEIS would create a window table from the defaults you put in the DEPLOYMENT screen. A system generated SHOT with a name starting with a "$" is assigned to these WINDOWs.

5.5.3 TIMED-MODE Shot Planning.

Choose the SHOTS option in the PLAN menu to bring up the two page SHOTS screen. For TIMED MODE this is one of the most critical step in all of LithoSEIS, as information entered using this screen will be used to calculate the times at which the PRS will switch on and off. The internal logic of LithoSEIS is as follows. You ADD a shot to the list for this DEPLOYMENT, and fill in a planned time and date for the shot. LithoSEIS uses this shot time, together with the window durations and repeats you have already entered in the DEPLOYMENTS screen, to guess the start times and duration of the primary and backup WINDOWs it should record.

Try adding a shot with the name HUEY, and fill in a shot time, noticing how LithoSEIS then guesses a set of WINDOW parameters which would result in it beginning recording two seconds before the shot. In fact we wanted five seconds before the shot, so you will have to go in and change the start time of the window manually. Also make sure that the number and spacing of backup (repeat) WINDOWs for this SHOT are what you want. Check the SHOTS screen and when you are happy press PgDn to move to the next shot. Now you can add four more shots (LUEY, DUEY, HWRD, and LOON).

Toggle to EDIT mode and get a listing of the shot information for verification. Congratulations you have entered five shots and their associated recording windows into the LithoSEIS system. If you really want to make a good job of this assign some of the sites you have previously entered in the SITES database to these shots.

The SHOTS screen is a two page screen. Page 2 is only available to you in EDIT mode. It is designed for use when and if the shot is fired, and you know the exact time of its occurrence. One item on page 2 of special note is the "fired flag". This flag should be set to true, and the shot time entered when the shot has been fired. This is important in the later stages of LithoSEIS processing when several LithoSEIS moduli need to know which SHOTS were fired when. For historical reasons the SHOT time box on page 2 only allows you to input times to the nearest second. Any fractional part must be stored as a time correction.

5.5.4 Trigger Mode Deployment in Seismicity

After defining a new deployment as explained in the start of this section, we are ready to enter the trigger parameters and other information that make a SEISMICITY mode deployment.

The most important element of a TRIGGERED MODE deployment is its trigger parameters. Once we set these, we need to set the warm-up and other durations and identify how many channels are to record the triggered events. We start with the trigger parameters.

Sometimes we may wish to record TIMED MODE windows in addition to the SEISMICITY mode triggered events. This is quite possible by setting window parameters similar to the REFRACTION mode as explained above.

5.5.5 Trigger Parameters

The following trigger parameters are shown on page 2 of the deployment screen.

- Sample Rate: Is the effective sample rate for the PRS instrument.
- STA Constant: The time in seconds over which the IIR filter output is averaged to calculate the Short Term Average value. The allowed values depend on the selected Sample Rate and are adjusted if the Sample Rate is changed.
- LTA Constant: The time in seconds over which the IIR filter output is averaged to calculate the Long Term Average. The allowed values of this parameter depend on the Sample Rate and are adjusted if Sample Rate is changed. They also depend on STA and are adjusted when changes are made to STA.
- STA/LTA Ratio: The factor by which STA must be greater than LTA for a PRS to declare a Triggered Event.
- Trigger Channel: The recording channel on which the STA and LTA averages will be calculated.
- IIR CODE: Identification of a Bandpass filter which limits the frequency range over which the STA and LTA averages will be calculated. If a filter is already defined for the current Sample Rate, then its Low Pass, High and Low band pass frequencies and slopes will be displayed on the screen. If a filter is not defined yet, a message warns users to design a new filter.

All of these parameters have pre-defined fixed values and users may not enter random values for them. To change a pre-defined value, move the highlighting cursor on it, then press '+' or '–' keys to increase or decrease it.

The other parameters shown on page 2 of the deployment screen (LoPass, HiBand, LoBand, IIR1, IIR2) are not settable, but only provide information about the pre–trigger filter design.

When the highlighting box covers the IIR CODE, new options become available to create, delete or select filters. The Ctrl-PgUp key combination spawns an external program to help design new filters. The Ctrl-PgDn key combination deletes the current filter (if any) and the + and – keys select different pre-defined filters.

5.5.6 IIR Filter in Seismicity mode

The IIR filter parameters are used to design a combination of three infinite impulse response (IIR) filters which are applied to the signal recorded on the designated trigger channel prior to the calculation of the STA and LTA values in order to determine if a trigger should be declared. This allows the triggering to be carried out on a limited frequency range for which the signal-to-noise ratio of the desired seismic events is optimal. Note that the IIR filtering is only applied for triggering purposes and is not applied to the data stored by the recorder once it triggers.

The IIR filter combination is created in a separate external program which allows the analyst to specify various combinations of a low pass filter and two band pass filters specified by frequencies (F) and slopes (Q) to achieve the desired result. The performance of the filters specified is displayed in both the frequency and time domains so that the analyst can judge their overall performance. Once the desired combination is selected, the filter parameters are assigned a unique four-character filter code and are saved to the filter database on exit from the external program.

An example of a filter combination, GOOD, is included with this installation. This filter is designed to select seismic signals with frequencies around 1 Hz. It has shown reasonable success during testing of triggering on both local earthquake signals and teleseismic P-waves. Depending on the applications, filters designed for higher frequencies can be implemented.

User's should consult the PRS Manual for information on the function of the IIR filter program during PRS event–triggered operation. Lack of memory space and processing power in the PRS processor limit the filtering capabilities of the PRS but with some careful tuning they can do an adequate job. The following points should be noted:

- Users should avoid filters with high Q values or filters where the individual filter components are widely spaced. In judging the final filter performance, the appearance of frequency scan in the Filter Generator Program is usually the most reliable gauge of the filter suitability.

- It is important that the passband of the filter be centered on the passband with the best signal–to–noise ratio for the events being recorded. This requires information about the frequency spectrum of the events *and* the noise at the recording sites. **Even if the IIR filter is tuned to the peak spectral frequencies for the target events, the PRS will not trigger satisfactorily if a similar spectral peak is present in the noise as well.**

- The STA should be set to a value consistent with the frequencies found in the target events (i.e. STA $<$ 1 sec). The LTA should be longer than the durations of the events (several 10's of sec), but users should avoid exceptionally large LTA values.

5.5.7 Engineering mode parameters

Information below refer to the ENGINEERING mode of operation only. If you are operating a SEISMICITY mode deployment, ignore the following.

- Trigger Ch.1-3: The threshold in millivolts which must be met or exceeded for a triggered event to occur. If a non-zero value is assigned to any channel, that channel will be checked for a triggered event. At least one trigger must be entered.

- Trigger/Event: Number of triggers required for a triggered event to be declared.

- IIR Code: Identification name of a High Pass filter which limits the frequency range over which the thresholds are applied.

5.5.8 Duration Parameters

The following parameters apply only to PRS4's in the SEISMICITY mode:

- Trig. Mute Duration: The length of time in seconds the PRS4 must ignore a triggered event after the Mute Function has been selected via the Mode Switch on the PRS4 Console.
- Pre Event Duration: The maximum length of time in seconds the PRS4 is required to record prior to the start of a triggered event.
- Post Event Duration: The length of time in seconds the PRS4 is required to continue recording after the end of a triggered event has been declared.
- Gain Range Sample Thr.: The number of samples that must be taken at a new Higher Gain before the PRS4 switches to that New Higher Gain. This is used to keep the signal-to-noise ratio high.

The following duration parameters apply to all modes of operation:

- Cal. Pulse Duration: The length of time in seconds the PRS4 will record after the CAL Function has been selected via the Mode Switch on the PRS4 Console.
- Record Now Duration: The length of time in seconds the PRS4 will continue recording after the Record Now mode on the M/S Connector on the PRS4 Console has been activated.
- Warm Up Duration: The length of time in seconds that the PRS4 front end filter needs to rise. This duration is hardware dependent and must be set in conjunction with the front end filters. The range of this parameter is determined by the 'MIN. PRS WARM-UP TIME' value set in DEFAULTS:PRS SETUP. For the PRS1 instruments, the hardware rise time is set to 10 seconds.

5.5.9 Recording Parameters

All parameters on this screen apply to SEISMICITY and ENGINEERING mode deployments only:

- Triggered Events: Which channels will be recorded if a triggered event occurs.
- Calibration Events: Which channels are to record when a Calibration Function is selected via the Mode Switch on the PRS4 Console.
- Slave (Now) Events: Which channels are to record if the Record Now switch from the M/S Connector on the PRS4 Console is activated.
- Refill Memory: Determines the PRS4 memory cycling when all available memory is used. Yes means overwrite the oldest event if a new event triggers.

- Latch LTA / Event: Determine if PRS4 must stop calculating LTA values after a triggered event has occurred. Yes means carry the last value calculated when the trigger event occurred throughout the length of the triggered event.

5.6 Plan Verification.

The plan verification step is used by LithoSEIS to check that you haven't asked for anything impossible. It is an essential step before a PRS can be deployed, and would be done automatically at the DOWNLOAD stage if you were to attempt to DOWNLOAD this plan to a PRS right away, however it is much cleaner to deliberately select the VERIFY option. In so doing you will be given a full list of any problems with the deployment. Thereafter you can use the LIST-PRINT option to get a list of all the windows to make sure the instruments are going to turn on when you want them to. Please make sure you are using the correct time system !

We strongly recommend that you print the WINDOW table, give it to a third party for checking, and tape it to the FSU before programming the instruments. In this way you know exactly what you are about to record.

You have now given LithoSEIS all the information necessary for it to perform a new DEPLOYMENT, and could, if you so desired, skip across to the EXECUTE menu and start the DOWNLOAD operation to program the PRS's. However there are two other important items in the PLAN menu, which you can use and which we will now discuss.

5.7 Recordings.

You may have realized that you have not told LithoSEIS anything about; a) how many PRS's are to be deployed on a particular DEPLOYMENT, b) which PRS's are to be deployed from which FSU's, c) which PRS's are to go where in the field and d) which sites are to be occupied for any particular DEPLOYMENT. This information is not essential at the time the instruments are programmed, for instance the fact that LithoSEIS does not know where a particular PRS is destined is of no consequence when you program that PRS. However when you have recovered the PRS from the field and are about to UPLOAD the data into the computer this information is absolutely vital.

LithoSEIS provides the Data Processing Supervisor with a means of entering all this information into the experiment plan in advance. This serves two purposes: firstly it produces a complete plan so that LithoSEIS can warn you if you make a mistake by, for instance, not programming enough instruments and secondly, the database you create with this information can be modified record by record in special circumstances.

Select PLAN:RECORDINGS, assuming you did this with your new DEPLOYMENT two screens will appear. The central screen is a brief report showing you which PRS is to go where for the current DEPLOYMENT, together with associated information such as which crew is to put the instrument out. The screen on the left hand side is a "PICK SITE" screen presenting you with a list of SITEs. Try moving the cursor (with the page or cursor keys) to a SITE and press RETURN. When you do this the name of that site will move over to the central screen i.e. you have said that for the current DEPLOYMENT

this SITE is to be occupied. Continue doing this for as many sites as you wish to occupy for the current DEPLOYMENT. When you have finished selecting SITES press ESC and the cursor will switch to the central screen. You can then move the cursor and add further information manually, such as which PRS is to be put at a particular SITE and which crew is to DEPLOY it. Note that you can only modify RECORDINGS for the current deployment, even though you may see some from other DEPLOYMENTs on the screen. Two important options here are the PICK SITE key which gives you back the list of SITEs, and the EDIT key which gives you full access to the recordings database to input all imaginable information relevant to a recording, even down to the level of which radio station was used to rate the clock. Most of you will not be interested in such things, but we included them there for completeness.

Any matching of SITES and receivers you do now will be reflected in the MATCH database used in the EXECUTE module. However, any changes to the RECORDINGS database you make after a DEPLOYMENT has begun will need to be re-entered in the MATCHing process.

5.8 Time-Shift.

The final planning option we shall mention is the Time-Shift option. This is needed when an entire deployment or all subsequent deployments and all their associated SHOTS and WINDOWs must be advanced or delayed.

5.9 Wrapping Up.

In summary lets review the planning process. In this section everything that is essential for LithoSEIS to program the PRS will be printed in **bold** type.

Select PREPARE:DEFAULTS to tell LithoSEIS about your hardware.

Use PREPARE:SITES **to enter at least one site into the LithoSEIS sites database.** Accompany the SITE name with geographic coordinates, the FSU and crew names, and a line identifier.

Create a DEPLOYMENT **using** PREPARE:PLAN:DEPLOYMENT specifying the general acquisition parameters to be used for the DEPLOYMENT.

If you are using TIMED MODE **create the recording windows using** PREPARE:PLAN:SHOTS to name shots, put them at a site, and adjust recording WINDOWs.

You have the option of identifying which sites and PRS's are to be used on a DEPLOYMENT using the PREPARE:PLAN:RECORDINGS screens.

Finally **check your plan using** PREPARE:PLAN:VERIFY, print out and check your WINDOW table.

You can now use the listing options to generate the necessary paperwork to be given to crews telling them what to do.

An essential part of the planning process is to save all the work on a floppy disc. Do this using MAINTAIN:SAVE FSU. This backup can be used in emergencies and also exported to the FSU's.

6 Collecting Data.

In the previous section, we explained how you PREPARE for a LithoSEIS experiment. Here, we show you how to actually EXECUTE it out there in the bush. We assume that you are by now familiar with the basics and have planned your deployments, set your software and hardware defaults, and are ready to go.

You may have created a Master Plan for all deployments you want to do, and saved it to a floppy disk using the SAVE FSU option of the MAINTAIN menu. In this case, use MAINTAIN:IMPORT FSU first to suck in all your Master Plan databases. Else, you may have planned everything on your current FSU and so do not need to suck-up anything.

Before we dive deeply into the EXECUTE part of LithoSEIS, let us examine what we need to do. The whole object of the exercise is to get a deployment plan into the PRS boxes exactly as PREPAREd, and later, to get our data off the boxes and safely copied to some storage media. We beef this up with much more muscle by a adding a comprehensive system of data cataloging and archiving and making it really easy to exchange data between dozens of FSU's.

If we were to summarize what you need to do, the best way is to do just about all menu item from top to bottom on the EXECUTE column. At the end of the run, you will have your data safe and sound and can go home. More precisely, the EXECUTE check-list may be as follows:

6.0.1 The EXECUTE check-list

- SELECT a deployment for action, STATS BOX shows its code.
- DOWNLOAD it into as many PRS boxes as you wish.
- Prepare for UPLOAD by telling LithoSEIS where every PRS went and if you want to UPLOAD all recorded data or a selected list of shots or triggered events only.
- UPLOAD one of the DOWNLOADed boxes.
- Use GLIMPSE to view the data for this one box, verify shots and triggered events.
- Now, UPLOAD more boxes but make sure your hard disk storage does not get too low (in which case you should ARCHIVE some traces).
- Do Level One Backup for each box as you UPLOAD.
- Use GLIMPSE:UPLOADED to view more of the data. Make sure all is OK.
- CATALOG good traces, trash bad ones.
- ARCHIVE your data. If you have lots of space on hard disk, keep a copy of the data on the hard disk as well.
- Create a SAVE FSU diskette.

- Print important databases such as SHOT, SITE and RECORD.

If you are using a Mater Clock, you need to RATE your clock before and after each DOWNLOAD and UPLOAD cycle. If you are making changes to primary databases such as SHOT and SITE you may wish to do an UPDATE just before the ARCHIVE to reflect the changes in the final ARCHIVE VOLUME.

6.1 Deployment and Recovery.

The gathering of the seismograms is the easiest part of the LithoSEIS system for the user. Essentially LithoSEIS takes tight control of what you may or may not do, making it very difficult to fail to record the seismograms. Nevertheless there are a number of areas where disastrous mistakes can happen so we will list them right up front. This will serve as a checklist for FSU operators.

6.1.1 Dangerous Curves.

- Programming the PRS with the wrong DEPLOYMENT. LithoSEIS has no means of knowing which DEPLOYMENT you wish to put into a particular box. If you select the wrong one then the box will have the wrong program and will probably not record the data you want. This problem is especially serious for experiments where several DEPLOYMENTs are taking place simultaneously. The only indication LithoSEIS can give you that this might be a possibility is that at the end of programming the number of boxes on a particular deployment may not be as many as planned, this is apparent in the STATS BOX and on printouts.

- PRS switch-off. If the PRS's are switched off between DOWNLOAD and UPLOAD the program and data are lost. This is not as unlikely as it seems. In a large centralized experiment involving many instruments in the same room it is very easy to accidentally switch off the wrong ones.

- PRS internal battery failure. The life of the internal batteries must be carefully monitored after each DOWNLOAD and UPLOAD cycle to make sure the LithoSEIS's are neither deployed with low battery power nor kept for a long time before completing the UPLOAD process.

- DOS clock usage. If you ignore LithoSEIS's protestations and use the DOS clock to rate the PRS before DOWNLOAD and UPLOAD the timing is useless. This is not because the quartz clock in the FSU is particularly bad, it stems from problems getting the time from the clock into LithoSEIS. Resultant errors may be up to one second.

- Excessive Calibration. It is possible to overrun the PRS memory by doing too many calibrations. The box may then hang and require more expertise than you have available in order to be recovered.

- Incorrect matching of SITE and PRS. If at UPLOAD time LithoSEIS has the wrong SITE for that Lunch Box then processing disasters ensue.

- Failure to backup. If you fail to backup your databases using SAVE FSU after DOWNLOAD and UPLOAD and your FSU should explode, the seismograms can still be recovered, but some important information may be lost. For instance the entire clock drift history and hence clock corrections for traces can disappear.

Having listed those dangers, it is safe to say that you can throw any other kind of abuse at LithoSEIS without causing too many subsequent difficulties. Things that LithoSEIS takes in its stride are problems such as erroneous shot and site information (whatever the disarray of these databases, its easy to change trace headers later on), rating with different clocks, accidental deletion of traces, etc. These are all everyday events in the life of an FSU operator.

6.1.2 Downloading a Program to the PRS

As you enter LithoSEIS with a complete experiment plan, you need only 3 keystrokes to DOWNLOAD the acquisition program to a PRS. Bring up the main execution phase menu by choosing EXECUTE, and if the current DEPLOYMENT seen in the STATS BOX is not the one you want to DOWNLOAD choose SELECT and pick one from the list of planned DEPLOYMENTs, then return to the EXECUTE menu.

Before we go any further, let us point out that the DOWNLOAD process has two layers of menus: A main level and an active level. As you open the process, LithoSEIS will normally take you right to the active level where you would want to be. After finishing there, you may want to go to the main level and do further work. The order may appear screwed-up but is sure to be practical.

Choose DOWNLOAD and after a little whirring a few information boxes should appear. You have arrived at the active level of DOWNLOAD and the MESSAGE LINE should read.

Connect a PRS to the ..... [Clock ABC]

If it doesn't, the reasons will be made apparent below. Now check that the communication port and the clock name on the MESSAGE LINE are indeed the ones you want to use. Assuming your PRS's are switched on, and their lights are indicating that they have passed their startup tests, you can connect them one by one, pressing RETURN each time. They are then ready for the field. This is all many users may ever need to know, however it may be useful to consider the process in a little more detail.

When you selected EXECUTE:DOWNLOAD, LithoSEIS did a few things for you. First and foremost it checked that you had put your latest DEPLOYMENT plan through the VERIFY step. If you had, LithoSEIS automatically takes you down to the active level where you now find yourself ready to connect PRS's. If you had not verified your latest DEPLOYMENT plan, LithoSEIS would have put you in a VERIFY screen identical to that in PREPARE:PLAN:VERIFY. When the DEPLOYMENT is verified, F10 out of this screen and you will be put at the active level.

The STATS BOX for the DOWNLOAD process contains some vital information. Firstly it tells you which DEPLOYMENT you are on, please **make sure it is the correct one.** Then note the number of PRS's planned to be deployed from your FSU. If, after you finish downloading the number planned does not equal the number downloaded ascertain why.

As you repeatedly DOWNLOAD more Lunch Boxes, your FSU's HISTORY box records their time of startup and battery voltages. You can use F3 to add comments to the HISTORY database after DOWNLOAD; it is useful to record information such as the failure of a PRS to start first time when switched on, or anything else unusual. Such information will be useful to the FHQ in tracking down problems.

If the battery voltage of a PRS is low (say under 11.0 volts) you can replace the batteries and DOWNLOAD a second time. LithoSEIS will report to you that you are repeating the DOWNLOAD but otherwise doesn't care.

Another function key option on this screen is the F4 "ERROR LOG" key. This option appears in most parts of LithoSEIS where a log of all the important errors made on an FSU during an experiment is kept. You can view the log from many places within LithoSEIS including the OPTIONS box here. Again this information is vital for troubleshooting at the FHQ.

If you are using a master clock, rather than a satellite clock, to synchronize the PRS DOWNLOAD operation, you must rate the clock before and after DOWNLOAD and enter the rating into LithoSEIS (See the next section for more details).

Congratulations, you have mastered DOWNLOAD. Now exit the active level using ESC or F10 and you end up in the main level. Notice that the main level is really an extension of the active level with a full OPTIONS box. Here, you may examine the window table just DOWNLOADed, you may call the LithoSEIS calendar, or obtain a list of DOWNLOADed units. If you exit out of this level, you will be back to the EXECUTE menu.

6.1.3 DOWNLOAD check-list

Just after the DOWNLOAD process is finished and before your gang have taken the PRS boxes to the field, you need to do the following:

1. From the DOWNLOAD main level menu, use the F9 key to get a list of all PRS's DOWNLOADed for the current deployment. Examine it first, and if OK, print two copies of this list. Keep one and give the other to your deployment crew. They may use it to mark the site names they visit or just as a reference.

2. Now, exit the DOWNLOAD and create a SAVE FSU floppy. This would save your work up to the end of the current deployment.

6.1.4 Preparing to UPLOAD

The LithoSEIS UPLOAD process is just as simple as the DOWNLOAD, and in principle you can pop into EXECUTE:UPLOAD and UPLOAD a PRS as it comes back from the field. However there are a number of other things which you can get right before you do so (if

you didn't get them right here, you will have to use the UPDATE option at some later time to correct the problems).

Before we go any further, let us point out that the UPLOAD process has two layers of menus: A main level and an active level. As you open the process, LithoSEIS will check your conditions for upload first. If you qualify for UPLOAD, then LithoSEIS takes you right to the active level where you would want to be. After finishing there, you may want to go to the main level and do further work. If you do not qualify for UPLOAD, you are offered other options to help you satisfy the conditions first.

Decide if you wish to UPLOAD all your recorded windows and triggered events or only selected ones. In REFRACTION mode, selected windows would hold your shots whereas in SEISMICITY, selected windows would be those with confirmed events in them. In REFRACTION mode, make sure your shot table for the current deployment is correct and up to date, and that all fired shots are flagged as fired. In SEISMICITY mode, if you already know the time of your events, create and TAG an EVENT TABLE using GLIMPSE:MAKE EVENT first. To force a selective UPLOAD, use the F8 key which operates as a toggle key. Press it once and you are in selective mode (notice the text for F2 key shows "UPLOAD FIRED"), press it again and you are back to normal mode of UPLOAD.

MATCH your recording sites and their PRS's Serial numbers. Use the F6 key from the UPLOAD main menu to do so.

The moment of UPLOAD is a very important one in the life of a recorded trace as LithoSEIS is going to add the following header information to it,

- LithoSEIS will assign a SHOT to the TRACE provided; a) it can find a SHOT in the TRACE WINDOW and b) that the SHOT has been flagged as fired in the shot table.
- LithoSEIS will prefix the TRACE with the associated SHOT SITE.
- LithoSEIS will assign the receiver SITE-ID to the TRACE.
- LithoSEIS will prefix the trace with all relevant information from the shot and site databases. This includes coordinates, shot sizes and depths etc.
- LithoSEIS will calculate all possible timing corrections.

Each of these items requires that the parts of the LithoSEIS databases applicable to the trace be in reasonable order. Therefore the FSU operator may want to perform the database maintenance described above before uploading, even though LithoSEIS makes it comparatively easy to fill in and correct TRACE headers during the later ANALYZE phase of operation. The obvious advantage of this is that information is fresh in everyone's mind.

At this time we must worry about clock corrections.

There are two clock corrections that LithoSEIS takes care of for you. a) the drift of the internal PRS clock with respect to the "working" clock or clocks used to synchronize the PRS at DOWNLOAD time and rate the PRS clock at UPLOAD time, and b) the drift of the "working" clock or clocks with respect to a standard time base, usually the U.T.

The first of these corrections, which we will call the PRS correction, is handled automatically. At UPLOAD time LithoSEIS will linearly interpolate over the duration of a DEPLOYMENT to calculate a timing correction relevant to the start time of a TRACE. This correction will be stored.

The second correction requires user intervention to rate the "working" clocks and store the results in LithoSEIS.

LithoSEIS contains a database holding information about all "working" clocks you have with you on an experiment. This database should be completed by the Data Processing Supervisor during the planning phase of the experiment (choose MAINTAIN:CLOCKS), thereafter when you configure LithoSEIS in the DEFAULTS menu you will be asked for the name of the clock to be used for UPLOAD and DOWNLOAD. If for any reason you change clocks between UPLOAD and DOWNLOAD you must let LithoSEIS know in the COMMUNICATION menu. You can rate any of these clocks by any means you choose, at any time during the experiment and as many times as you like. To get these clock ratings into LithoSEIS you choose the EXECUTE:RATE screen and fill in the appropriate information. In this way LithoSEIS is able to keep a drift curve for the "working" master clocks which it can use to calculate the second timing correction at a particular TRACE start time by linear interpolation.

LithoSEIS can only use interpolation to extract the timing correction i.e. it will not extrapolate. This results in an obvious problem, since the working clock correction at UPLOAD time needs to be interpolated from a rating after UPLOAD. How can such a correction be made ? In fact there are three possible courses of action. Firstly, if before UPLOAD you synchronize your master clock to absolute time, the working clock correction at UPLOAD time is 0. and can be ignored. Secondly, if you enter a rating into LithoSEIS just before UPLOAD, but lie about the time of the rating by entering some short time after you estimate the UPLOAD will take place, LithoSEIS will be able to make a working clock correction at UPLOAD time. Thirdly LithoSEIS contains an option to UPDATE header information after UPLOAD but before the ARCHIVE (EXECUTE:CATALOG:UPDATE), this is a general utility which includes an option to recalculate timing corrections. This should be used if clock corrections are not properly made at UPLOAD time.

Finally it is worth noting that if you use satellite clocks as your working clocks the working clock correction is 0., so you needn't worry about any of the above.

The UPLOAD module is one of those that spoon feeds you by checking the databases to see exactly what you have done so far, and then presenting you with the screen you need next. This will often be the MATCHing screen where you must assign a SITE-ID from the SITE database to each PRS on the current DEPLOYMENT. LithoSEIS will bring up this screen whenever you enter UPLOAD and you have a PRS on the current DEPLOYMENT which has not been given a site.

An obvious question occurs to most novice users of LithoSEIS, what happens if you need to UPLOAD a PRS on a FSU different to that on which it was DOWNLOADed? This can happen when an FSU fails and a PRS must be uploaded on a second FSU. Such a PRS is known as an ORPHAN, it is entered into LithoSEIS by choosing the "MATCH SITE"

option of UPLOAD using the F6 key. You can then enter the PRS number into the system so that it can be uploaded. Since the host FSU does not know about the ORPHAN PRS its clock time corrections can not be handled and are ignored.

A better way to process an ORPHAN PRS is to first do an IMPORT FSU from the SAVE FSU floppy of the failed FSU into the host FSU to get the DOWNLOAD history of all boxes done there. This will make the ORPHAN PRS appeared to have been DOWNLOADed on the host FSU.

6.1.5 Uploading

When you have completed the above preparations, select UPLOAD, LithoSEIS will take you straight into the active UPLOAD screen which is similar to the DOWNLOAD one. It contains a STATS BOX, OPTIONS menu, a HISTORY panel containing an entry for each PRS DEPLOYed and ORPHAN you have introduced, together with a PROMPT-LINE asking you to connect a PRS. At this point you may want to take advantage of the selective UPLOAD option which allows you to UPLOAD fired shots or tagged events only. The selection includes only those shots that are flagged as having been fired (REFRACTION mode) or only those tagged events that exist in the event table (SEISMICITY mode). To activate this selective option exit to the main screen of EXECUTE:UPLOAD and use the F8 key to operate the toggle between UPLOAD ALL and UPLOAD FIRED. At least one shot must have been flagged as fired, or one tagged event must exist in the EVENT TABLE in order to qualify for selective UPLOAD. This option affects the UPLOAD process in an essential way since the TRACEs that are not uploaded will be lost as soon as the PRS instrument is switched off. The users must be cautious not to UPLOAD selectively unless they are certain that the traces they are uploading are the only ones which they require.

Before you can UPLOAD data from a PRS you must point to the PRS to be uploaded in the HISTORY screen. This is a safety measure to ensure you are not about to UPLOAD a box which in fact contains data from another DEPLOYMENT. Point to the PRS number, connect the PRS and press RETURN. A new box will appear on the screen showing you the details of the UPLOAD process. It shows important information such as the battery voltage, number of recorded events, clock drift etc. You do not have to worry about writing any of this down as LithoSEIS stores it in the RECORD database which may be printed at any time.

If you are using a RAM disk and your RAM disk is full, the UPLOAD process will switch automatically to hard disk and continue uploading. Any data already uploaded to the RAM disk will be copied to hard disk at the end of the UPLOAD. When using a RAM disk for UPLOAD the UPLOAD process is reporting on the amount of storage available on the RAM disk while the LithoSEIS DATA disk may be full. An option is installed to alert the users if their DATA disk is full upon which they must ARCHIVE traces and create space on the DATA disk.

Continue uploading for as long as you wish or until you begin to run out of disk space, you do not have to UPLOAD all PRS's in one session since you can return to EXECUTE:UPLOAD as many times as you wish. In the event of some kind of system crash you can UPLOAD a PRS more than once, LithoSEIS will treat any duplicate TRACEs

just as it does the first. However, if you UPLOAD the same Lunch Box instrument for a second time, no warnings are issued that the existing trace files will be overwritten by the UPLOAD process.

The time it takes to UPLOAD a PRS will depend on the amount of data recorded, the FSU hardware (particularly whether disk caching and RAM disk are used) and the number of events recorded. It is important that in the planning phases of an experiment the Scientific Authority estimate the duration of the UPLOAD and CATALOG steps in order that enough crew time can be allocated to get the job done properly.

As each PRS is uploaded you will be asked to insert a high-density floppy disk into the machine to make a backup of the data. Label this floppy with the DEPLOYMENT name and PRS number, this is always unique. This backup is known as a Level One Backup, and is designed to get the data onto a permanent medium as quickly as possible in case of lightning strikes and other acts of God.

The data on the Level One Backup floppy should be kept for at least a few months and until all data from all FSU's are collected at the FHQ, and processed. There are many reasons for this, here are a few:

- If your hard disk crashed before you ARCHIVEd your data, the only other copy of your data is indeed the Level One Backup. You can simply use your SAVE FSU and Level One Backup diskettes and recover all your data in no time at all.
- If the data on some of your ARCHIVE VOLUME's could not be read (e.g. bad sector problem), you can easily recover the problem portion from your Level One Backup. If you failed to ARCHIVE any segment of your data during the course of the experiment, again your Level One Backup floppy can come to your rescue.

It is for these reasons that LithoSEIS gets very sticky about the Level One Backup which can be turned off at the time of UPLOAD if you are in a rush. You will be reminded again at the time of CATALOG to do your Level One Backup, and later if you wish to delete the unwanted portion of data for a Lunch Box you are reminded again. The best policy about the Level One Backup, is to do it at the time of UPLOAD and keep the floppies in a safe place until you are certain you do not need them any more and then recycle them.

As mentioned above LithoSEIS will only attach a SHOT-ID to a trace if the shot was fired i.e. the fired flag in the SHOT database has been set. If during UPLOAD you realize that you have not done this properly, you have the opportunity in UPLOAD to do so. Go to the top level of UPLOAD (by pressing the ESC key) and choose the F7 "FLAG SHOT" option. Within this option there are a number of facilities for changing the fired flag and shot times.

Congratulations you have used LithoSEIS to recover data, make a Level One Backup of it, and fill in much header information. There are several other utilities available for you to try within UPLOAD, most of which have been described in other sections of this manual, you should select these options and determine their effects.

6.2 The state of play.

After the completion of UPLOAD you have reached as far as most packages take you. You have the data on hard disk, and backed up to floppy in a raw state. You have headers for the seismic traces, which will almost certainly contain some erroneous information. Your disk is probably getting rather full so the need for producing some sort or ARCHIVE volume is increasing. The rest of the EXECUTE menu is designed to help you process data further by a) taking a quick look at the data, b) incorporating any new database information into the TRACE headers, c) putting the headers into the master database known as the CATALOG so that data can easily be retrieved when needed for later processing, d) putting the data and headers onto a permanent medium known as an ARCHIVE VOLUME, and e) freeing up disk space.

Your next step will be to use the GLIMPSE module to look at some or all of the TRACEs you have UPLOADED. This will give you an idea of data quality, and if you GLIMPSE at least one TRACE per PRS you will know whether the PRS worked.

Once you have looked at data you have a decision to make. Every trace you collect in LithoSEIS must be either put into the CATALOG and ARCHIVEd whereupon it becomes a permanent fixture as far as LithoSEIS is concerned or it must be deleted from the system whereupon it cannot be used by LithoSEIS again (unless you do a RESTORE PRS from the Level One Backup). These alternatives are the only possible fates of a TRACE. To put that in LithoSEIS terms, each uploaded TRACE becomes part of the UPLOAD database, you must choose to either a) CATALOG it and put it in the CATALOG database or b) delete it. It is normal to transfer TRACEs to the CATALOG in large groups; after you have done so the TRACEs and their headers can be backed up to a permanent ARCHIVE VOLUME.

Why do we adopt this seemingly roundabout way of doing things? Experience has taught us that when performing experiments with more than a few instruments from one FSU a formal method of making data permanent is essential for two reasons. Firstly, for any subsequent multi-trace analysis we need methods of retrieving data in groups such as all recordings on a single line from a particular shot-point, the existence of the CATALOG which keeps track of the location of data from many FSU's enables us to do this very easily. Secondly we are frequently faced with changes to the databases such as a revised coordinate for a site, LithoSEIS is able to scan through the CATALOG to determine every trace header that is affected by the change and make the appropriate corrections. It is this corrected information that will be used in all the advanced analysis modules such as PLOTSEGY and MAKESEGY.

For these reasons we strongly recommend that you use the extensive facilities provided by the rest of LithoSEIS although none are absolutely necessary. You will find the database facilities provided much easier to use than any you could write yourself in a mainframe environment using languages such as FORTRAN and C. LithoSEIS is written in the CLIPPER database programing language which is ideally suited for this kind of thing.

6.2.1 Upload check-list

Before you actually turn off your PRS thereby losing all the data within it we recommend that you make it a habit to do the following after uploading all boxes for the current deployment:

1. Using GLIMPSE, view traces for at least on Lunch Box, and one shot. Verify that all required traces are uploaded and that they appear OK.

2. From the UPLOAD main level menu, use the F9 key to get a list of all PRS's uploaded for the current deployment. Print a copy of this list for reference. Examine the battery volts and replace batteries for any PRS reporting low volts.

3. Now, exit the UPLOAD and create a SAVE FSU floppy. This would save your work up to the end of the current deployment.

6.2.2 The MONITOR

The LithoSEIS MONITOR works only on a DOWNLOADed PRS. Simply connect the PRS to your FSU using your communication cable, and run the MONITOR option. You will see a special MONITOR screen showing most of the important operational parameters such as battery volts and clock drifts, number of recorded events and so on. In SEISMICITY mode and with the PRS4's, it is possible to modify certain operational parameters and also to do a "live" MONITOR of the triggering parameters.

While in MONITOR, you may view the 'EVENT LIST' which is a list of recorded events so far, and also to TAG events by pressing the space bar. If you tagged any trace in MONITOR, its time is transferred to the EVENT TABLE on exit from the MONITOR (see the EVENT TABLE below).

After each running of the MONITOR, and if GOES or MASTER clocks were used, you are asked if you wish to keep the most recent records of the PRS operation. This record is then saved to a database (only if the "Save Monitor Records" option in DEFAULTS:OPERATION is switched on) and can be viewed later.

A VIEW option is provided to let you look at the records of all previous MONITOR runs. You can use the CLEAR option to clear these records and start afresh. And finally, a SHOW option is provided here to let you peek into the LithoSEIS error database which keeps track of all errors in DOWNLOAD UPLOAD and MONITOR runs.

6.2.3 GLIMPSE as Quick-View

GLIMPSE is a FORTRAN program called from LithoSEIS which plots on the computer screen a single TRACE at a time. It is capable of cycling through a large number of TRACEs in a single run, in batch mode if necessary, producing printer plots for a permanent record.

GLIMPSE was originally designed for a quick look at the data in REFRACTION mode. Later, it was modified to act as a SEISMICITY mode picker as well. This section describes

the "Quick-View" options of GLIMPSE. For detailed explanation of the pick options, refer to the "GLIMPSE Picker" section of the SEISMICITY ANALYZE.

In its simple REFRACTION mode of operation, GLIMPSE can be used for a quick look at the data and also for tagging traces and creating an EVENT TABLE which has many applications as explained in detail later in this section. To mark events in GLIMPSE simply press the space bar when events are in view.

Before running GLIMPSE you must select the TRACEs you wish to view. The easiest way of doing this is to select GLIMPSE:ALL in which case GLIMPSE will operate on all TRACEs uploaded for the current deployment. This is much the easiest method, but it has the disadvantage that you may find yourself viewing more traces that you might want.

The more sophisticated method of selection is to TAG a group of TRACEs that you wish to view. Before we dive into the TAG to view option, let us examine the whereabouts of your seismic traces.

As you UPLOAD a PRS, your seismic traces end up in the TRACE directory on your DATA disk, a clone of the catalog record is created for each trace and LithoSEIS gives the trace an initial UPLOADED status. Once a trace is CATALOGed, LithoSEIS creates a real catalog record for it and upgrades its status to a CURRENT status. Once a trace is ARCHIVEd, its status is further upgraded to RESTORED and the trace is either moved from the TRACE directory to the STORE directory on the DATA disk or get erased from the hard disk (don't panic, it is now safely copied to an ARCHIVE VOLUME!).

When you TAG to view, you have the option to select one of these three possible areas from which you have access to traces. Immediately after UPLOAD you may wish to TAG and view traces in the uploaded area to determine what traces must be kept and CATALOGed. Later on, you may wish to view all traces for the same PRS that are CATALOGed but not ARCHIVEd yet and therefore are accessible in the CURRENT area. The most obvious use of GLIMPSE is for traces in the RESTORED area in the SEISMICITY mode where the GLIMPSE module is used to pick first arrival time and amplitude information.

Once you made a choice between one of these three possibilities you will be presented with the LithoSEIS TAG menu explained in details in the TAG section below. TAG those traces you wish to GLIMPSE and then press the F10 key to exit the TAG mode and start the GLIMPSE program.

After a list of tagged traces is prepared and traces GLIMPSEd, the same traces may be viewed again and again without re-tagging by using the "VIEW AGAIN" option.

When viewing your recorded traces, you may TAG them by pressing the space bar. This is different from CATALOG tagging the CATALOG database but only creates an entry in the EVENT TABLE described below.

6.2.4 The Event Table

The EVENT TABLE is simply a list of origin times of one or more imaginary seismic events. This table can be created in a number of different ways and is used in tagging the LithoSEIS CATALOG and in selective UPLOAD in SEISMICITY mode.

The EVENT TABLE is simply used as a look-up table. When using the TAG EVENT option to TAG in the CATALOG all records in the CATALOG with trace times that fall within the range of times in the EVENT TABLE get TAGGED. In selective UPLOAD of SEISMICITY mode, all triggered events that fall within the range of times in the EVENT TABLE get uploaded. In both these cases, a span parameter determines how the times in the EVENT TABLE should be compared to those of the CATALOG or the PRS EVENT TABLE. A span of zero means times must be exactly the same for a successful hit, while a span of 4 means there would be a hit provided times in the CATALOG or the PRS EVENT TABLE are no earlier than 4 seconds before the EVENT TABLE times and they are no later than 4 seconds after them.

The EVENT TABLE concept is critical in smooth operation of LithoSEIS and a couple of examples of its use follow:

1. In REFRACTION mode, let us assume that a number of shots at irregular times are fired and recorded on a number of PRS instruments. To TAG all these shots in the CATALOG simply enter the shot times in the EVENT TABLE and then use the TAG EVENT option of CATALOG:TAG to TAG only these shots while everything else is untagged.

2. In SEISMICITY mode, let us assume that we are monitoring in a noisy area with possibility of false triggers that we do not wish to UPLOAD. Let us also assume that we know from other sources certain events have occurred and wish to quickly UPLOAD only these events. Simply enter the time of the known events in the EVENT TABLE then use the UPLOAD FIRED option to UPLOAD only selected events.

3. In SEISMICITY mode, let us assume that we are monitoring with 8 PRS instruments and we have just uploaded one. Using GLIMPSE we identify and TAG all good events for this one box. Exit from GLIMPSE and an EVENT TABLE is automatically created for us. Then we can use this table to UPLOAD the remaining seven boxes selectively and thus access the real events real quick.

There are two important points worth mentioning about the EVENT TABLE. Firstly, the EVENT TABLE is like a scratch pad and events in it can be deleted at will without effecting any other parts of LithoSEIS. We encourage you to use the table and clear it periodically. Secondly, only those events in the EVENT TABLE that are tagged are used as look-up times. This means that if you forget to TAG the events of your interest, you will never get the desired effect when using the EVENT TABLE data. By the same token, it means that you may untag certain events in the EVENT TABLE to disable them temporarily.

New events can be added to the EVENT TABLE in five different ways:

1. By manually entering event times using the F2 key.

2. By tagging in GLIMPSE module.

3. By tagging in the MONITOR.

4. By exporting SEISMICITY mode event origin times.

5. By importing SEISMICITY mode picks.

Note that using any of the above options creates a list of tagged events in the EVENT TABLE while automatically untagging any old and existing entries in there.

6.3 Cataloging the data.

As you UPLOAD your PRS instruments, your seismic traces end up in the TRACE directory on your DATA disk, and LithoSEIS gives the trace an initial UPLOADED status. Normally, you end up keeping some but not all of these uploaded traces since some of them contain REFRACTION mode shots or SEISMICITY mode triggered events while others simply contain seismic noise. The ones you keep (i.e. CATALOG) get a CURRENT status and stay in the TRACE directory until they are ARCHIVEd at which point they move to an ARCHIVE VOLUME (i.e. get ARCHIVEd) and, if requested, are kept in the STORE directory of your DATA disk as well. The ARCHIVEd traces that reside on the hard disk as well get a RESTORED status.

All of this is carefully registered in the LithoSEIS CATALOG which not only keeps a complete record of header information for each trace, but also registers the whereabouts of each trace.

To do the CATALOG and the ARCHIVE effectively, we need a utility to let us see what we have got in the UPLOAD area and also to let us be selective and select only selected traces for storage and processing. Both these are provided by the LithoSEIS TAG option explained below.

Before we ARCHIVE the data, it is so much better to do all possible updates to the CATALOG database first. An UPDATE option provides this service.

We first deal with the CATALOG step, then introduce the TAG option where we can TAG a bunch of traces for the UPDATE option that follows and subsequently for the ARCHIVE option.

6.3.1 Creating the catalog

You may only CATALOG your UPLOADED traces. These reside in the TRACE directory on your DATA disk and each have a record in the UPLOAD database and each have an UPLOADED status. CATALOGing is no more than transferring a record form the UPLOAD to the CATALOG database for each of these traces without doing anything to the trace itself except to give them a CURRENT status.

Before you can CATALOG we would remind you to complete the unfinished Level One Backup first. If you do not wish to do it just now, it is OK, make sure the Level One Backup switch is set to unforced and carry on. Mind you, it is virtually impossible to escape the level one backup and we will remind you again before you can screw yourself royally. The best policy is to complete them right now. Remember, by design the CATALOG step is supposed to be done when you have enough time at hand while during UPLOAD you

may have been in a rush and therefore ignored the Level One Backup. So, get on with it and do it now.

As you enter the CREATE screen, you are given a browse window into the UPLOADED traces, a STATS BOX and a number of options. The least you want to do here is to run the F3 key to do a "SAVE TAGGED" on all tagged records. This means that you should use the LithoSEIS TAG option (explained below) to TAG some records first. You may indeed just do this using the F2 key and TAG those records that interest you.

LithoSEIS is quite willing to think and help you with your tagging if you are sensible. In REFRACTION mode, if you did your job right and flagged all your good shots as FIRED before the UPLOAD process, then you will end up with all records of those good shots already tagged and ready to go here. We also TAG your calibration records for you. So all you need is to take a quick look at those already tagged and make sure they are how you want them and then press on with the "SAVE TAGGED" option. After you did this, the rest of the stuff can safely be trashed using the F7 DELETE key.

In SEISMICITY mode identification of good traces is a bit more tricky. Your best bet is to create an EVENT TABLE first (see the EVENT TABLE section above), and then use the F8 TAG EVENT key to TAG all good event records first. The very best way to do this is to pick up a site with most triggers and GLIMPSE data for this site. During the GLIMPSE run, TAG all good triggers for this site. On exit from GLIMPSE a new event table is created and can be used here.

Once you tagged and saved all of your good traces, you may be left with some traces that need to be trashed. This is your last chance to complete the Level One Backup and indeed we stop you from trashing your data if you have not done it. Think about this, you are trashing some traces that you consider useless for now. Later, you may wish to look at them again, for example, to dig out a seismicity event that was too small and was ignored before. If you do not have a Level One Backup and delete traces here, you end up with no data at all. Simply use the F5 "BACKUP PRS" key and do the Level One Backup then trash the bad stuff.

If you trashed some traces and later decided to include them in the CATALOG simply use the F6 RESTORE PRS key to restore traces first, TAG and CATALOG those you want and trash the rest.

It should be emphasized again that while running this EXECUTE:CREATE option you are actually dealing with a clone of the LithoSEIS CATALOG called UPLOAD database. This is indicated by the title of the browse screen showing "UPLOAD TRACE" and by the letter "U" in front the CATALOG number in the STATS BOX. When you finish with this option, you must have CATALOGed good traces and trashed all bad ones and should be left with no traces in the UPLOAD database. **Any left over entries in the UPLOAD database means unfinished work that must either be CATALOGed or trashed.**

Now that you have created your CATALOG you may wish to do the next logical step and ARCHIVE your data. Here again, LithoSEIS gives you great flexibility in what traces to put on an ARCHIVE VOLUME by tagging the required traces first. If you simply want to ARCHIVE all CATALOGed traces, use the LithoSEIS TAG option and do a quick "TAG ALL" and exit.

6.3.2 The TAG option

Tagging is the process in LithoSEIS where you choose a group of traces for the **next** LithoSEIS processing operation. TAG works on records of CATALOG or UPLOAD database by simply marking them and making them available to any process that need to operate on a sub-set of the CATALOG records. Once you TAG certain records, they remain tagged until you unTAG them and vice versa.

Before we dig more into the LithoSEIS TAG option, let us examine the data flow again. As you UPLOAD your PRS data, you create more and more records in a database called UPLOAD which is a clone of the CATALOG database. Later, you decide to keep and therefore CATALOG some of these traces and trash the rest. Those you keep end up in the CATALOG database and we consider them CURRENT traces since they have not yet been ARCHIVEd. After you finish the ARCHIVE process and put the CURRENT traces to an ARCHIVE VOLUME, you may decide to keep the traces on hard disk as well. Those traces that are kept on the hard disk (or those restored from an ARCHIVE VOLUME) are considered RESTORED traces. There is a buffer area called SAVE SET which is only used by the system and users have no access to it. It is used to keep any trace that is left unARCHIVEd as a result of any problem in the ARCHIVE process. Any trace left in the SAVE SET area is included in the very next ARCHIVE following the one that failed and left the trace there in the first place. A clean system, therefore, should always show 0 traces in the SAVE SET area. By the same token, if you see any traces reported in this area, don't panic, simply do another ARCHIVE and the traces get picked-up and taken care of.

To make the matters even more interesting, we restrict the tagging operation in a sensible way. If you are in the process of creating new CATALOG records, we restrict you to the CURRENT area in the UPLOAD database and show this by placing a letter "U" in front the CATALOG number in the STATS BOX. If, on the other hand, you are tagging traces in the CATALOG database for the purpose of ARCHIVE we restrict you to the CURRENT area in the CATALOG database and show this by placing a letter "C" in front of the CATALOG number in the STATS BOX. Finally, if you are using GLIMPSE on the RESTORED traces, we restrict you to these traces in the CATALOG database and show this by placing a letter "R" in front of the CATALOG number in the STATS BOX.

The STATS BOX also shows your FSU name and the amount of remaining storage on your DATA disk. As you TAG or unTAG records, the TAGGED counter in the STATS BOX shows the number of hits and total storage in mb.

Now look at the main tagging range screen. You will see that you are allowed to enter ranges of parameters for TRACEs you wish to TAG. When you enter values in the two columns associated with one or more items and choose F2 (TAG RANGE) LithoSEIS will search the headers of the TRACEs and TAG those that fall within the range of parameters you specified. As an example if I enter DEP2 and DEP4 in the Deployment Code item and SIT1 in both columns of the "Shot Site Id" item, then pressing F2 will have the effect of tagging all traces that are associated with shots that took place at the site SIT1 during deployments DEP2, DEP3, and DEP4. Tagging is a cumulative process, so you can enter more ranges to build up the number of TRACEs tagged. You should also be

aware that tagged traces remain tagged between calls to the LithoSEIS TAG option, so if you want to start tagging a fresh set of traces you should unTAG all TRACEs before commencing work on the new set.

Try the F8 BROWSE option. You are presented with a screen showing headers of the TRACEs. You may TAG an individual TRACE by pressing the SPACE bar. This will result in a square root sign appearing in the CSR column. You can UNTAG by pressing the space bar again. While most of the fields in the BROWSE screen have obvious meanings, the CSR needs some explanation. It stands for CURRENT, SAVE SET and RESTORE and simply shows where each trace is by placing a "*" under the corresponding letter. If no star is present, it simply means that your traces are ARCHIVEd but not yet restored from the ARCHIVE VOLUME. By the way, each LithoSEIS trace can only be in one place at a time, so you should never get more than one star or else you are in trouble.

Many more tagging options are provided in the BROWSE option. For example, the F2 key tags all traces that have a CURRENT status while untagging everything else. The F3 key does the same for all RESTORED traces.

The F8 key compares all events in the EVENT TABLE to those in the CATALOG and tags all records that fall within the range of times in the EVENT TABLE while untagging everything else.

The F9 key provides a sort option for the CATALOG keys. Simply place the highlighting cursor on any field (except for the CRS) and press F9 key to sort the CATALOG on that field.

The LithoSEIS TAG option provides an inside view of the CATALOG records which reflect information about the header of your seismic traces and their whereabouts. Using combination of the many options provided here, you should be able to TAG any grouping of records for your processing. Note that the STATS BOX is live as you TAG and gives new stats as every new record is done. You may interrupt certain tagging operations without any penalty using the ESC key. For example, if you press the ESC key while in the middle of a "TAG ALL", it simply stops at the last record tagged.

6.3.3 The UPDATE utility

We give you the chance to UPDATE the CATALOG records before your seismic traces are ARCHIVEd to permanent storage. So if you have made any changes to any of the primary databases such as SHOT, SITE or RECORD since the UPLOAD step, you should UPDATE the CATALOG now. Use the LithoSEIS TAG option to TAG what you wish to UPDATE or skip tagging if you wish to UPDATE all records in the CATALOG, then select CATALOG:UPDATE to update those things that might have been affected by your database changes.

The UPDATE process works as follows. It first asks you what you wish to UPDATE to determine how many of the LithoSEIS primary databases are concerned. Then it looks at all primary databases you selected, finds the key values that are shared between the primary databases and the CATALOG and then refreshes the corresponding trace records in the CATALOG. Note that it is so much easier to edit a primary database than it is to edit the CATALOG. Think about this: a site name and location is registered only once

in the SITE database but is used dozens of times in the CATALOG; it is then far better to do all the necessary changes to the SITE database and then UPDATE the CATALOG rather than making dozens of changes to the CATALOG itself.

UPDATE is a very powerful option and must be used intelligently. Although any bad UPDATE can be reversed, we urge you to think before you do and if in doubt, leave the UPDATE to the Data Processing Supervisor.

The "Update Shot Name in the Catalog" option assumes that SHOT database is correct, up-to-date and holds all good shots flagged as fired, it then searches the CATALOG database for each shot time and, if found, replaces all shot-related information in the CATALOG database with those in the SHOT database.

The "Update Site Name in the Catalog" option assumes that the RECORD database is complete and correct with PRS names and their corresponding recording sites. It then takes the recording site for each PRS from the RECORD database and insert that site into the corresponding CATALOG record. This option is provided for users that used incorrect site names before UPLOAD. To make this correction, make the necessary corrections to the RECORD database using PREPARE:PLAN:RECORDing first and then try the UPDATE here.

The "Update Geographic Information" option takes correct shot and site names and their locations from SHOT and SITE databases and replaces the CATALOG records with correct location information.

The "Update Recordings with Clock Rates" is useful only you are using a Master Clock and rating it before each DOWNLOAD and UPLOAD operation. It then takes the correct clock ratings and put them in the RECORD database to be used later in updating the CATALOG.

The "Update Recordings with PRS data" takes correct PRS related data from the PRS inventory database (available in MAINTAIN:PRS) and brings them to the RECORD database to be used later in updating the CATALOG.

The "Update Trace Time Corrections" is normally used if you use a Master Clock in UPLOAD and DOWNLOAD operations. It then takes the Master Clock drifts that must be already reflected in the RECORD database (using the "Update Recording with Clock Rates" option), and transfer them to corresponding records in the CATALOG.

The "Update Shot Times" option permit you to correct a shot time in the SHOT database first and then refresh the CATALOG with it.

The "Change Line Name to ...." option is used to change the Line Name allocation of CATALOG records to a new name given by you.

An option is provided to write a log file for each UPDATE and to view it later to verify the correct UPDATEs.

A final UPDATE option permit you to apply a temporary shift to shot times to make it possible to find their corresponding CATALOGed trace windows. This is sometimes needed in the REFRACTION mode if the actual shot times are a few seconds before the start of the windows. Without this shift option, such shots would not be located in the CATALOG if we were looking only at times to find a hit. This option takes effect only if we are using the "Update Shot Names in the Catalog" option.

No matter what UPDATE option we select, LithoSEIS displays a window with basic information about the trace headers displayed on the left of it. On the right of this window, some information may be displayed depending on the UPLOAD option.

6.3.4 The ARCHIVE

By now you have created the LithoSEIS CATALOG and moved all records for your good traces from the UPLOAD database to the CATALOG database. You have also examined the LithoSEIS TAG option and probably tried the UPDATE option as well. You are ready to do the final step: the ARCHIVE.

The LithoSEIS ARCHIVE completes the data collection cycle by storing your CATALOGed traces on an ARCHIVE VOLUME which can then be exported to the FHQ for processing. Once you ARCHIVEd your CATALOGed traces, they are physically moved from the TRACE directory of your DATA disk to an ARCHIVE VOLUME, and, if you wish, they may be kept on the hard disk as well. Traces that are ARCHIVEd loose their CURRENT status and obtain a RESTORED status if they are kept on the hard disk or restored to the hard disk from an ARCHIVE VOLUME, and they end up in the STORE directory of your DATA disk.

You may ARCHIVE your data in any which way you wish. Depending on the capacity of your ARCHIVE media, you may decide to ARCHIVE the data for the same deployment on one cartridge, or else, you may wish to ARCHIVE each PRS on one floppy disk. At any rate, first TAG those traces that must go on one ARCHIVE VOLUME, and then use the ARCHIVE option of the EXECUTE:CREATE menu to do the archiving.

Currently, only two ARCHIVE devices are supported by LithoSEIS. They are denoted by A: for floppy drive A, and I: for the Irvin Cartridge drive of the Compaq computers. As you begin the ARCHIVE process, LithoSEIS issues a new unique Volume Name for each ARCHIVE VOLUME. Remember to write this name on your ARCHIVE VOLUME since any time you need its data, LithoSEIS will ask for it by its Volume Name.

Before the trace files are copied to the ARCHIVE VOLUME they are moved to the SAVE directory on your DATA disk and are given a status of SAVE SET. If you had to abort the process, do not panic, just start again and any number of traces left in the SAVE directory get picked up and handled correctly.

It should be noted that each ARCHIVE VOLUME contains a number of seismic traces and one database file which is the CATALOG of the traces on the ARCHIVE VOLUME. This makes each ARCHIVE VOLUME a complete unit and when restored on any FSU or FHQ its CATALOG gets appended to the host computer's CATALOG before any number of traces from the ARCHIVE VOLUME can be restored.

We have now completed the entire cycle of what you might have done under the EXECUTE menu. At this point, you should issue a final SAVE FSU to save all important databases on a floppy disk, and send it, together with your ARCHIVE VOLUME, to the FHQ camp.

7 The Refraction Analysis Phase

The "Collection Data" section contained a description of how seismic TRACEs are collected on an FSU and then CATALOGed and ARCHIVEd. This section describes those facilities offered by LithoSEIS to further process the data. Normally these operations will be performed on the FHQ, primarily because a powerful, and therefore expensive, machine is required if they are to be performed speedily. However there is nothing intrinsic to the ANALYZE module that prevents its operations being performed on an FSU, the interested FSU operator may play around in the module without doing any damage to LithoSEIS.

Depending on the type of data you have collected, you may wish to try the REFRACTION analyze, the SEISMICITY analyze or, in some cases, both options for processing your data. You should note that the CATALOG option is common to both modes of operation.

This section describes the REFRACTION analyze features of LithoSEIS. See the next section for the SEISMICITY mode analyze.

7.1 Summary of Capabilities.

The main purpose of the ANALYZE module is to allow the users return from a REFRACTION field experiment with SEGY tapes of their data ready for detailed scientific analysis. The following features are available in the ANALYZE REFRACTION option:

- CATALOG
    1. Merge CATALOG entries saved at the FSU's using the SAVE FSU operation into the master CATALOG.
    2. Merge in CATALOG entries saved at the FSU's on ARCHIVE volumes.
    3. Tag TRACEs for further processing
    4. Selectively RESTORE TRACEs from ARCHIVE volumes onto disk.
    5. Update the CATALOG to reflect changes to LithoSEIS databases.
    6. Delete RESTORED TRACEs from disk.
    7. Check the CATALOG directory flags.
    8. Move certain CATALOG records into a bank and create new ARCHIVE VOLUME's from existing data.
    9. Produce an experiment data collection report.
- GLIMPSE
    1. View single TRACEs.
    2. Produce printer plots of single TRACEs.
    3. Tag traces.

- TAGSEGY
  1. Create SEGY headers from CATALOG entries.
  2. View and edit SEGY headers.
  3. Import FOREIGN SEGY files from other packages.
  4. Backup SEGY files to floppy.
  5. Restore SEGY files from floppy.
  6. Print SEGY headers.
- MAKESEGY
  1. Create a SEGY file from LithoSEIS CATALOGed TRACEs.
  2. Create a SEGY tape from LithoSEIS CATALOGed TRACEs.
- VISTA
  1. View SEGY files on screen.
  2. Filter SEGY files.
  3. Deconvolve SEGY files.
  4. Stack traces in a SEGY file.
  5. Produce spectra from traces in a SEGY file.
  6. Automatic and manual picking of arrivals.
  7. Printer plots of time and reduced time sections.
  8. Output processed data for PLOTSEGY.
  9. General time-series processing.
- PLOTSEGY
  1. Plot true distance - reduced time plots on a pen plotter.

One of the purposes of the ANALYZE module is to ensure that a scientist returns from the field with a product ready for scientific analysis. The authors of LithoSEIS do not consider that a disparate collection of TRACEs on floppies with various inaccuracies and omissions in the headers is an acceptable product. We hope that all Scientific Authorities will agree and attempt to plan an experiment to take full advantage of LithoSEIS. To do this the Scientific Authority must decide in advance exactly what he or she wants from the experiment. The products available from LithoSEIS are:

- Sets of seismic TRACEs on ARCHIVE volumes.
- A complete CATALOG of seismic trace headers.
- An "Open File Report" on data acquisition.

- Seismic data as SEGY files on disk.
- Seismic data as SEGY tapes.
- Seismic data plotted as record sections.

We consider that the first three items listed above are necessities. The last three involve the creation of SEGY files and are optional. But it should be noted that there is very little extra effort involved in creating SEGY files once the CATALOG is correct, and the benefits are many.

7.2 The LithoSEIS processing philosophy.

The FHQ receives from the FSU's ARCHIVE volumes containing seismic TRACEs, these volumes also contain a portion of the CATALOG from the FSU relevant to these TRACEs. The first thing you need to know is that these ARCHIVE **volumes are never modified in any way.** Instead the CATALOG on the archives is merged into a master CATALOG and then corrected if necessary, with absolutely no need to RESTORE the data onto the FHQ.

This correction of the CATALOG takes place by correcting the original LithoSEIS databases (such as SHOT, SITE, RATE and so on) and then using the UPDATE facility to propagate these changes into relevant trace headers in the CATALOG.

In a large experiment it is likely that different FSU's will contain different versions of the same databases. For example an individual FSU might modify a coordinate in a database originally sent to it from the FHQ. The LithoSEIS databases from the various FSU's are merged using the IMPORT-FSU facility.

The only seismic data that must be read onto the FHQ are those that you want to GLIMPSE again or assemble into a SEGY file or tape. You RESTORE TRACEs from the ARCHIVE VOLUME's using the RECOVER facility.

SEGY files have two purposes. At early stages in processing they can be made quickly (even before ARCHIVEing if you want) to get a first look at sections. When the databases and master CATALOG are complete, final SEGY files can be made for plotting and distribution to institutions involved in the experiment. Since SEGY files get their header information from the master CATALOG all information in SEGY files is correct in the sense it includes all the most recent database information.

SEGY tapes are made only after finalizing databases and the master CATALOG. They are industry standard and can be read into every commercial mainframe seismic reflection processing package.

7.3 Catalog operations

7.3.1 Merging the Catalogs

The processing core of LithoSEIS is the master CATALOG assembled by merging the smaller CATALOGs, from the FSU's. Two operations are necessary to begin finalizing it.

Firstly, if FSU's have made modifications to any of the LithoSEIS databases these changes must be merged into the FHQ. Obviously at the outset of an experiment the Data Processing Supervisor must have made it very clear who has and has not the authority to change databases so that he can trust the databases he receives back from the FSU's.

The LithoSEIS databases from the FSU's arrive at the FHQ on floppy disks created with the SAVE FSU facility. These are read into the FHQ by choosing MAINTAIN:IMPORT-FSU. During this process the operator will be alerted of conflicts between the FHQ databases and the one from the FSU and asked for a decision as to which one should be used. You may have noticed that during the planning of an experiment you were asked to associate sites with FSU's. Although this was not necessary to recover data it is very useful at this stage since LithoSEIS can be told to only accept information from the FSU which really was responsible for ensuring that information for a particular site is correct. If the Scientific Authority wants to ensure that no-one else has authority to change databases, he may choose to associate all sites with the FHQ, in which case the IMPORT-FSU can be run such that no changes made by FSU's will be accepted by the FHQ. It is the FHQ's responsibility alone to get the SITE information correct.

The second operation required for production of the master CATALOG is the merging of the various mini-CATALOGs from the FSU's at the FHQ. The mini-CATALOG is read from the ARCHIVE volume itself using the CATALOG:VOL-MERGE utility.

7.3.2 Getting it right.

Once the CATALOG and LithoSEIS databases have been assembled at the FHQ the Data Processing Supervisor has the responsibility of getting them right. First incorporate all known information in the LithoSEIS databases using the PREPARE module. Then choose ANALYZE:CATALOG:UPDATE to propagate these corrections into the CATALOG. When you do this you will be asked whether you want to UPDATE all headers in the CATALOG or only those you have previously tagged (using CATALOG:TAG). UPDATE gives various options as to what you wish to calculate, be very careful in choosing these. For instance you have the option of re-examining clock drift curves to remake timing corrections. This should only be done if the FHQ has the correct clock drift curves available. Another powerful option is the one to UPDATE shot names. If you choose to do this, LithoSEIS will scan through the SHOT database and put in each CATALOG entry the SHOT-ID of the first shot to record in that window. Probably the only time you would need to do this is on experiments such as reflection seismic piggy back experiments where shot names and times are not known in advance. The most frequently used UPDATE option is the one to UPDATE geographic information which must be used whenever SITE coordinates are changed.

7.3.3 Producing the data report.

The following comprise a robust report:

- The SITES listing,

- The DEPLOYMENT listing,
- The SHOTS listing for each DEPLOYMENT,
- The RECORDINGSlisting for each DEPLOYMENT,
- The CATALOG listing for each DEPLOYMENT from each SHOT SITE.

7.3.4 Recovering data.

The CATALOG knows on which ARCHIVE volumes data are stored, therefore to RECOVER data from volumes, you need only TAG the appropriate TRACEs using CATALOG:TAG, then choose CATALOG:RECOVER. LithoSEIS will ask you to load the various ARCHIVE floppies or cartridges necessary to RECOVER all the TRACEs you asked for. As you TAG we recommend that you keep a close eye on the amount of disk space you have available and the amount of data TAGGED. Do not try to cope with too much data at once.

When a TRACE has been RECOVERed under LithoSEIS it is put in the RESTORE directory. You will notice that the CATALOG:TAG STATS BOX tells you how many files (i.e. TRACEs) are in that directory. It also tells you how many are in the CURRENT directory, i.e. those that have been uploaded and then saved as CURRENT files but not yet ARCHIVEd. Thirdly it tells you how many are in the SAVE SET directory. The SAVE SET directory is used as a buffer during ARCHIVE and RECOVER, the presence of files within that directory indicates that an ARCHIVE or RECOVER operation did not finish properly.

7.3.5 Deleting data.

As your disk fills up (and consequently slows down) you will want to get rid of some of the data you have previously RECOVERed. Use CATALOG:TAG option to TAG those TRACEs you wish to delete, then choose CATALOG:DELETE to get rid of them. **Do not delete TRACEs by exiting LithoSEIS and using the DOS DEL command** as LithoSEIS will not know about the deletion and will get very confused. If you do lose files accidentally outside of LithoSEIS then use the CATALOG:CHECK facility to get LithoSEIS back in synchronization with your disk.

7.3.6 Checking the Catalog.

The house-keeping for the LithoSEIS CATALOG is controlled by four logical flags called DIRECTORY FLAGS. They include CURRENT, SAVE SET, RESTORE and TAG flags and appear in a column called CSR when browsing the CATALOG. These flags indicate if the seismic traces exist on your DATA disk and make-up the statistics of your CATALOG. If you suspect that your CATALOG statistics are not correct, you should first re-index the catalog using the MAINTAIN:RE-INDEX option and then issue a check to refresh the CATALOG directory flags.

The CHECK option is a very safe one to try but it may take a long time to finish if your CATALOG is fairly large. Here are a few reasons why you may need to use this options:

- After a disk failure resulting damage to CATALOG index or trace files.
- Users erasing trace files from DOS.
- Aborted ARCHIVE option.

7.3.7 Moving the Catalog

This option is provided ONLY for experienced LithoSEIS users. The logic behind this MOVE is as follows: You have now merged all your FSU CATALOGs and the size of your FHQ CATALOG database has grown substantially. You do not, however, need to have access to all records in this database for a while and getting in and out of CATALOG is time consuming. It is desirable to "hide" some of catalog records in a safe catalog "bank" and recall them later.

The most common scenario is that you are currently working with a small set of restored traces but your CATALOG database contains all recorded traces for the entire survey most of which not needed just now. Simply go to the TAG's BROWSE screen. TAG RESTORED first, then FLIP TAGS to leave all un-restored traces tagged. Now, use the CONCEAL option of MOVE to hide all these un-restored CATALOG records in a catalog bank. Once you are done with your job of processing restored traces, you may RECALL the already concealed records back to your CATALOG.

Be warned, however, that an unruly number of CONCEAL and RECALL may force your CATALOG database OUT of synchronization with your data on hard disk. It is recommended to use the CONCEAL and RECALL options CAREFULLY. Use them at the FHQ level and after your CATALOG database is complete.

The ARCHIVE option of MOVE is another expert option. It is actually a re-archive and may be used to create clean and tidy ARCHIVE VOLUME's from final restored and updated data on the FHQ. Note that by re-archiving your data, you are essentially breaking away from the original field ARCHIVE VOLUME's.

7.4 GLIMPSE in Refraction Analysis

The GLIMPSE viewing routine in ANALYZE is the same as that within the EXECUTE module. Refer to the GLIMPSE section in "Collecting Data' for explanation of GLIMPSE quick-view option, and to the GLIMPSE section in "Seismicity Analysis" for explanation of arrival time pick options.

7.5 TAGSEGY

TAGSEGY is a necessary pre-requisite to the production and processing of SEGY files by LithoSEIS. Its function is to assemble as a single unit the SEGY headers for the

production or plotting of a SEGY file. The step is necessary because programs such as PLOTSEGY and VISTA expect data in the SEGY format, they do not accept data in the TRACE format used in the earlier part of LithoSEIS. The trouble with SEGY files is that, because they consist of many TRACEs and headers in a single file, they can be very difficult to read and modify. LithoSEIS has managed to get around this difficulty in a simple but effective way, it stores and manipulates copies of the headers for all SEGY files it creates. It is these headers, not the ones attached to the TRACE or SEGY files that are used in the analysis programs. In addition LithoSEIS is able to merge in SEGY headers from files that have come from other packages or institutions. Such files are known as FOREIGN SEGY files.

The list of SEGY headers to be used as input to the processing programs is called the ACTIVE HEADER LIST. The job of TAGSEGY is to create, edit, and print the ACTIVE HEADER LIST.

Choose ANALYZE:TAGSEGY. The first time you enter TAGSEGY your ACTIVE HEADER LIST will be empty, so your first job will be to take some CATALOG entries and turn them into an ACTIVE HEADER LIST.

As usual you select the CATALOG entries for processing by using the TAG option (the F2 key). You will be asked whether you want to TAG TRACEs in the CURRENT or RESTORE directory. Choose the former if you are attempting to make a SEGY file from a group of TRACEs that you have just collected and not yet ARCHIVEd, choose the latter if you are making a SEGY file from TRACEs that have been RECOVERed from an ARCHIVE volume.

When you have tagged the TRACEs you wish to include in the file, EXIT the LithoSEIS TAG option and choose F3 to create the ACTIVE HEADER LIST. You may wish to view the ACTIVE HEADER LIST, the F4 option will bring the list up on the screen. All the elements of the SEGY header can be seen by pressing CTRL left and right arrows to view different fields. Note also that if you tagged too many TRACEs, you can delete individual records in the ACTIVE HEADER LIST. This is very useful when you view a SEGY file and notice a dead trace, in which case you can delete it from the ACTIVE HEADER LIST and remake the file.

You are now ready to run the MAKESEGY module to create a SEGY file or tape, however some of the other OPTIONS in TAGSEGY are worth discussing.

The F5 (MERGE SEGY option) is very powerful one that requires some explanation. It is used to put headers from SEGY files into the ACTIVE HEADER LIST. You can't really test this until you have used MAKESEGY and/or VISTA to create SEGY files. When you have, you can merge the headers from any number of SEGY files to make an input file for the PLOTSEGY program.

Even more interesting is what happens if LithoSEIS finds a SEGY file it knows nothing about. Examples of such foreign files include output files from VISTA and those produced by other institutions. In this case when you press F5 the name of the file will be shown along with an asterisk to indicate that this file is FOREIGN. If you then TAG this file and EXIT from MERGE, LithoSEIS will scan the file and write its headers to disk. If you now go back into the MERGE option you can merge these headers into the ACTIVE HEADER

LIST and process the file just as if it was a SEGY file produced by LithoSEIS.

The MERGE option also provides facilities for you to BACKUP a SEGY file to floppy, and clean up disk space by deleting SEGY files. SEGY files may be RESTORED from these backups using TAGSEGY:F8.

7.6 MAKESEGY

Once you have completed making an ACTIVE HEADER LIST from the CATALOG you are ready to assemble the TRACEs into a SEGY file. Choose ANALYZE:MAKESEGY. The screen in front of you contains a number of data entry boxes for you to fill in. These are:

1. A unique filename of up to eight characters.

2. The data word format. The SEGY format definition allows you to choose from three words formats. Integer*2 occupies the least space, but if you have numbers greater than 32767 in a file, they will be scaled before output. Integer*4 is ideal for most PRS uses. Real*4 allows a greater range than Integer*4 at the expense of precision. Luckily VISTA and PLOTSEGY can cope with any format so the choice is yours. It may depend on what reading facilities you have in your laboratory, Real*4 can be a pain to decode.

3. Output to disk or tape, obviously don't use tape if you don't have the IBEX tape drive connected to the machine.

4. Start and end times of the output TRACEs. These are in seconds with respect to the shot time. If the shot time is not filled in then these times will be with respect to the start of the trace. Note SEGY disk files are limited to 32k samples per trace, whilst SEGY tapes are limited to 32k bytes per trace. If the lengths of the file you ask for exceed one of these limits, MAKESEGY will tell you so and stop.

5. Reduction Velocity. You may output reduced time windows by entering a non-zero velocity in this box.

6. Dummy offset and trace separation. If you input a non-zero trace separation, LithoSEIS assumes you want to put dummy distances in the file because you don't have the necessary coordinate information. This frequently occurs in the early stages of processing. The dummy distance to the n'th trace will then be (n-1)*trace separation + offset to trace 1. If the dummy distance is left at 0. then MAKESEGY will use the true distance from shot to receiver as calculated from the coordinate information in the ACTIVE HEADER LIST.

When you have filled in the data entry screen press F2 to run the program and create the SEGY file or tape.

Just before MAKESEGY goes away and makes your file or tape for you, it will ask you how you want your file sorted (or indexed in LithoSEIS jargon). Choose how you like bearing in mind that many mainframe seismic processing packages do not have any

sorting abilities, so you better get it right now. For most purposes sorting by distance is best.

MAKESEGY produces a detailed output log, which can be viewed and printed. We recommend that you print the log for all SEGY files and tapes that are final LithoSEIS products.

Options are provided to TAPE CHECK a SEGY tape, to examine disk SEGY files, and to read a SEGY tape into a SEGY file.

7.7 VISTA

VISTA is a general seismic processing package that operates on SEGY files produced by LithoSEIS. It is capable of performing most of the seismic analysis jobs more normally performed on main frames. You can even write your own macro's to extend its functionality. The authors of LithoSEIS use it routinely in the field for the viewing, filtering, and picking of refraction data.

If you wish to use VISTA consult the VISTA reference manual.

VISTA is a third party package written for the seismic reflection industry, which we have had modified for refraction work and integrated into the LithoSEIS package. However there remain a number of aspects of the integration which are not perfect, and that you should be aware of. These are:

- You may not have purchased VISTA.
- Output files: When you output a processed file from VISTA it is a FOREIGN file as far as LithoSEIS is concerned since LithoSEIS does not have its header list. You must merge this FOREIGN file into LithoSEIS using TAGSEGY:MERGE before it can be used in LithoSEIS modules such as PLOTSEGY.
- Size Limitations. VISTA has some limitations on the size of files it can handle, exceeding these can sometimes cause unpredictable effects and system crashes.
- Incomplete header updating. An obvious way round the problem of large files is to use the REDUCED READ command in VISTA to read reduced time windows into VISTA. However if you output such a file after processing you should be aware that VISTA does not recalculate trace start times. The experienced LithoSEIS user will see various ways around this problem, the simplest of which is to use MAKESEGY to make the reduced time file in the first place. MAKESEGY always gets everything correct. This file can then be read into VISTA with no further reduction.
- Time reference. VISTA uses time with respect to the start of the trace in all plots and calculations. On the whole LithoSEIS uses time with respect to the shot time.

Other than these small problems you should have no difficulty in using the full facilities of VISTA with LithoSEIS data.

7.8 PLOTSEGY

After you have made and processed your SEGY file you will probably want to plot it. First use TAGSEGY to TAG the TRACEs you wish to plot then select the ANALYZE:PLOTSEGY. A parameter is included in the PLOTSEGY framework screen to permit decimation of time series for faster plotting; use a decimation factor larger than 1 to speed-up the plotting of data. Please consult the PLOTSEGY reference manual for more details.

7.9 EXAMPLES

In this manual we do not have the space to discuss all possible processing scenarios, rather we will take you through two common tasks. More information can be gained from the following manuals.

- LithoSEIS SEGY format definition.
- LithoSEIS PLOTSEGY reference manual.
- VISTA reference manual.

7.9.1 A quick SEGY viewing operation at the FSU or FHQ

Let us assume that an FSU operator has just uploaded data from a group of PRS's. He wishes to see how far energy is propagating by viewing all the data on the screen at once.

Since the only way to view multiple TRACEs on the screen in LithoSEIS is in VISTA, the FSU operator must make a SEGY file from the uploaded TRACEs. First he must move the TRACEs from the UPLOAD to the CURRENT database using EXECUTE:CATALOG:CREATE. After which he moves to the ANALYZE module and chooses ANALYZE:TAGSEGY. In TAGSEGY he must a) Clear the ACTIVE HEADER LIST using F7, b) enter the TAG option and TAG all TRACEs in the CURRENT directory. c) EXIT the TAG option and create the ACTIVE HEADER LIST using F3. He can now make the SEGY file by choosing MAKESEGY. The operator has to decide whether to use true distances in the creation of the SEGY file, or whether to dummy them. This decision will depend on the state of his SITE database at the time. He can then view (and process) this file with VISTA.

This whole procedure should take no more than a few minutes.

7.9.2 Making the "Final" Tape at the FHQ

It is nearing the end of an experiment, for three weeks now the FHQ has been receiving groups of TRACEs on ARCHIVE volumes from the FSU's. Each of these volumes contains coordinate information which it has since been realised is in error. The FHQ operator or Data Processing Supervisor wishes to produce a SEGY tape containing accurate headers and data for all TRACEs on line L1 from shotpoint S1. How should he proceed.

1. The FHQ needs to know what is on each of the ARCHIVE volumes produced by the FSU's. Therefore the CATALOG from each should be sucked in using ANALYZE:CATALOG:VOL-MERGE. In most cases the FHQ operator should have been doing this as the volumes arrived over the past weeks

2. The FHQ operator now needs to finalize the following databases incorporating all the latest information. a) The sites database using PREPARE:SITES, b) The shots database using PREPARE:PLAN:SHOTS. c) The clock drift database using EXECUTE:RATE, and the recordings database using PREPARE:PLAN:RECORDINGS.

3. LithoSEIS must now incorporate these database changes into the CATALOG, using the ANALYZE:CATALOG:UPDATE facility.

4. The FHQ operator now uses the TAG option in ANALYZE:CATALOG:TAG to TAG all TRACEs on LINE L1 from shots that have Shot SITE-ID S1. He should update the STATS BOX to check the number of TRACEs TAGGED.

5. The required data are now brought back from the ARCHIVE volumes using ANALYZE:CATALOG:RECOVER.

6. The SEGY headers are then created from the CATALOG using ANALYZE:TAGSEGY.

7. Finally the operator runs ANALYZE:MAKESEGY to create the tape, and produce a listing of its contents.

This process may take several hours depending on how many tape cartridges have to be read to RECOVER the data.

8 The Seismicity Analysis Phase

The "Collection Data" section contained a description of how seismic TRACEs are collected on an FSU and then CATALOGed and ARCHIVEd. This section describes those facilities offered by LithoSEIS to further process the data. Normally these operations will be performed on the FHQ, primarily because a powerful, and therefore expensive, machine is required if they are to be performed speedily. However there is nothing intrinsic to the ANALYZE module that prevents its operations being performed on an FSU, the interested FSU operator may play around in the module without doing any damage to LithoSEIS.

Depending on the type of data you have collected, you may wish to try the REFRACTION analyze, the SEISMICITY analyze or, in some cases, both options for processing your data. You should note that the CATALOG option is common to both modes of operation. For a complete description of the CATALOG options, refer to the "Refraction Analysis" section.

This section describes the SEISMICITY analyze features of LithoSEIS. See the previous section for the REFRACTION mode analyze.

8.1 Summary of LithoSEIS Seismicity Capabilities.

The main purpose of the ANALYZE module is to allow the users return from a SEISMICITY field experiment with data (including waveforms, epicenters and magnitudes) that are ready and suitable for more detailed scientific analysis. The following features are available in the ANALYZE SEISMICITY option:

- CATALOG
    1. Merge CATALOG entries saved at the FSU's using the SAVE FSU operation into the master CATALOG.
    2. Merge in CATALOG entries saved at the FSU's on ARCHIVE volumes.
    3. Tag TRACEs for further processing
    4. Selectively RESTORE TRACEs from ARCHIVE volumes onto disk.
    5. Update the CATALOG to reflect changes to LithoSEIS databases.
    6. Delete RESTORED TRACEs from disk.
    7. Check the CATALOG directory flags.
    8. Move certain CATALOG records into a bank and create new ARCHIVE VOLUME's from existing data.
    9. Produce an experiment data collection report.
- GLIMPSE
    1. Scale phase time picks, amplitude peaks and coda lengths.

2. Define approximate epicentral distance and magnitude for events

- TAG PICK
  1. View picks scaled with GLIMPSE.
  2. Organize, re–assign or delete picks.
  3. Assign unique event codes to groups of picks.
  4. List derived phase parameters.
- ADD PICK
  1. Modify pick parameters.
  2. Add non–LithoSEIS picks.
- LithoLOC
  1. Calculate hypocenters and magnitudes.
  2. Modify location and magnitude criteria.
  3. Modify velocity model definitions.
- MANAGE
  1. View hypocenter and magnitude information.
  2. Tag events for subsequent processing.
- DISPATCH
  1. Select output format.
  2. Write hypocentres, magnitude or picks to scratch files.

8.2 GLIMPSE as Picker

GLIMPSE was originally designed for a quick look at the data in REFRACTION mode. Later, it was modified to act as a SEISMICITY mode picker as well. This section describes the SEISMICITY options of GLIMPSE. The REFRACTION quick-look options are described in the "GLIMPSE as Quick-View" section of "Collecting Data".

Seismic traces residing in different directories during the acquisition phase of a field experiment and afterwards can be GLIMPSEed. Immediately after UPLOAD and before CATALOG, traces reside in the UPLOAD directory. After CATALOG and before ARCHIVE, traces reside in the CURRENT directory, and after ARCHIVE, traces are normally available in the RESTORE directory.

To GLIMPSE traces, first decide where the traces you need to GLIMPSE reside (i.e., UPLOAD, CURRENT or RESTORE), then TAG the specific traces you want to see using the LithoSEIS TAGger. Finally, spawn the GLIMPSE utility (F10) to view and pick the TAGed traces.

- LEFT–HAND SIDE

  TIME time in sec at the position of the cursor
  INT width of the cursor cross hatch in sec
  CUR amplitude at the cursor cross hatch in counts
  SAMP sample number at the cursor position
  AMP value of the cursor sample
  LEN total length of the trace displayed in sec

- RIGHT–HAND SIDE

  SPS samples per sec for the displayed trace

1. If a time PICK has been made:
   PHASE designated phase for the current pick
   QUALITY quality designation for the current pick
   BREAK first-motion break for the current pick
2. If both P and S PHASEs have been timed:
   DIST approximate hypocentral distance in km
3. If both P and S have been timed and an amplitude PEAK has been scaled:
   MAG approximate Richter magnitude
4. If a coda LENGTH has been scaled:
   START start of the coda measurement in sec
   CODA coda length in sec

The Pick-mode of GLIMPSE is initiated by F2 and terminated by ESC or F10. F10 saves any PICKs that have been made; ESC does not. In pick-mode GLIMPSE displays a CURSOR bar on the TRACE and the menu screens pertinent to picking. Key information about the TRACE being displayed is given in six smaller boxes above the main trace display screen as shown in Figure 3.

Diagnostic information about the TRACE is displayed around the fringes of the trace box as follows:

These parameters are updated as the CURSOR is moved or new information is scaled from the TRACE.

8.2.1 GLIMPSE HOT KEYS

GLIMPSE's analytical capabilities are organized around the function keys, F1 through F10, and selected 'hot' keys. The 'hot' keys are used to condition the TRACE before performing a certain pick, eg. magnifying and stretching the TRACE to pick a PHASE arrival time, and the Function keys are used to perform the actual pick.

GLIMPSE HOT KEYS

KEY	FUNCTION	KEY	FUNCTION
ARROWS	move cursor	PgUp	replot whole trace
HOME	center cursor, left, right & center	End	activate cursor cross hair
+	expand trace vertically	PgDn	shrink cursor cross hair
−	shrink trace vertically	ENTER	approve pick
Ins	explode trace horizontally	ESC	abort pick
Del	shrink trace horizontally		2nd ESC aborts pick mode
*	replot and center trace	SPACE	tag trace for later action

- ARROWS AND HOME MOVE THE CURSOR
  The four ARROWs control the position of the cursor. Tapping an ARROW causes the CURSOR to move one unit in the indicated direction; holding the ARROW key down causes it to move 5 units. The units are related to the scale of the current trace display. This feature allows the user to move the CURSOR quickly from place to place on the TRACE (by holding the key down) and place it precisely on a desired point (by tapping). (This action is called 'selecting' the pick.) The minimum units of CURSOR movement are one sample interval (horizontally) and one count (vertically). The CURSOR can not be placed between samples. In addition to the ARROWs, the CURSOR can also be moved with HOME. HOME toggles the CURSOR to the left hand edge, to the right hand edge and to the middle of the screen. This is a useful facility prior to certain measurements and can also be helpful to 'recover' the CURSOR if it has become 'lost' because of excessive movement.

- * and PgUp REPLOT THE TRACE
  Two other useful keys are * and PgUp. * replots the TRACE centered on the current CURSOR position. PgUp replots the whole TRACE - useful if the analyst wants to start the picking process over again.

- End and PgDn FRAME THE TRACE
  End and PgDn control the width of the cross hatch on the center of the CURSOR ; End expands it, PgDn contracts it. The cross hatch width defines the trace subset (called 'framing' the TRACE) that is used to calculate certain parameters associated with the picks. Initially the CURSOR width is zero.

- +, −, Ins and Del CONDITION THE TRACE
  The TRACE is magnified (vertical scale) with + and −. The first step always autoscales the TRACE to fit exactly in the trace window; subsequent steps increase or decrease the vertical scale by a factor of two. The TRACE is expanded (horizontal scale) by Ins and Del. The first use of Ins always expands the TRACE to a 200–sample window (called 'exploding' the TRACE); subsequent Ins keys expand it by

a factor of two. Note that Ins also centers the trace display on the CURSOR 'Del always contracts the TRACE by a factor of two.

With some practice, analysts can become very adept at manipulating the CURSOR and trace display with the 'hot' keys to make picks. The first arrival can be selected, exploded, reselected as necessary, framed and picked in a few steps without the analyst ever taking his or her eyes off the TRACE.

8.2.2 GLIMPSE FUNCTION KEYS

The actual picks are made with the Function keys, F1 through F10. The Function keys are organized as follows:

GLIMPSE FUNCTION KEYS

KEY	FUNCTION	KEY	FUNCTION
F1	online help	F2	start pick-mode
F3	scale phase start	F4	find phase start
F5	scale amplitude peak	F6	find amplitude peak
F7	scale coda length	F8	find coda length
F9	save picks	F10	leave pick-mode

The parameters that can be scaled are:

1. PHASE start time, first BREAK and QUALITY,
2. amplitude positive–to–negative PEAK, PERIOD and instrument SENSITIVITY and
3. coda start, LENGTHand minimum amplitude.

Two function keys are associated with each of these groups of parameters, one to scale the parameters and the other to select the proper place on the TRACE to make the PICKs. **Whenever a parameter is scaled, GLIMPSE writes the scaled information in a BANNER below the TRACE box and waits for approval by the user. The ENTER key approves the PICKs, ESC aborts the PICKs. In some cases, users may adjust the scaled parameters before approving them.** The main PICKing functions are setup as follows:

- F3 and F4 SCALE START TIMES..
  F4 moves the CURSOR to the right (increasing time) until it encounters a trace PEAK (positive or negative) with an amplitude greater (less) than the CURSOR amplitude if the initial CURSOR amplitude was greater (less) than the trace amplitude at the starting point. Once the CURSOR finds the point on the TRACE with a larger amplitude, it follows the TRACE back to the preceding (absolute) minimum trace amplitude and positions itself on it. (The trace amplitude is reset

to the value of the succeeding maximum amplitude on the TRACE.) In practice, successive F4 will cause the CURSOR to search the TRACE to the left (increasing time) finding successive peaks in the TRACE and position itself appropriate for a start measurement. For quiet TRACEs this operation can be very efficient at finding PHASE starts.

F3 scales the PHASE start time, the QUALITY of the start and the first motion polarity. The measurements are based on the portion of the TRACE 'framed' by the CURSOR cross hair. It is assumed here that the analyst has 'framed' the *first cycle* of the PHASE arrival with the cross hair. If not, GLIMPSE assumes a nominal interval and proceeds with the calculations. The start time is the time of the sample the CURSOR is resting on. For the other measurements GLIMPSE finds the minimum and maximum trace PEAKs in the 'framed' TRACE before and after the CURSOR .

The QUALITY of the PHASE beginning is proportional to the ratio of the peak-to-trough amplitudes after and before the CURSOR The QUALITY factors A, B, C, D or X are assigned according to the value of this ratio; >8, >4 , >2, >1 or <1 respectively.

The polarity is positive if, following the CURSOR , the trace PEAK proceeds the trough, negative if the trough proceeds the peak. The factor that is assigned to represent the polarity, one of PERIOD, + −, C/D, is proportional to the ratio of the peak–to–trough amplitude before and after the CURSOR .

To assist the analyst when picking the PHASE start, whenever F3 is hit, GLIMPSE overdraws two boxes on the TRACE which outline the positive and negative PEAK values following the CURSOR . This should immediately indicate to the analyst whether or not the PHASE start quantities have been correctly scaled.

The scaled quantities are displayed in a BANNER below the trace box. The analyst must approve or disapprove of the picks with ENTER or ESC before proceeding. He/she may change the PHASE, QUALITY and/or first BREAK designations with the P–, Q– and B–keys respectively before approval.

GLIMPSE PHASES

Four local earthquake PHASEs are defined within GLIMPSE . They are P, Pg, S and Sg. Users should be clear about their use in GLIMPSE and in LithoLOC. The P and S designations are associated with the first-arriving P- and S-phases, the travel-times calculated for PHASEs so designated in LithoLOC will be for the minimum time path to the site from the hypocenter either directly through the specified velocity model or refracted along one of the internal interfaces. Pg and Sg are always associated with the direct P- and S-phases even if they are not the first arrival at the site. The distinction allows analysts some latitude in using secondary P- and S-phases for location purposes.

GLIMPSE allows the PHASE designations to be made when the TRACEs are being scaled, but the designations done here are not cast in stone. They may be easily changed in TAG PICK, if this is required, without returning to GLIMPSE.

- F5 and F6 SCALE AMPLITUDES.
  These keys are used to select (F6) a amplitude PEAK and scale (F5) the amplitude peak-to-peak, period and corresponding sensitivity. F6 moves the CURSOR to the PEAK trace amplitude to the right of the initial position of the CURSOR 'F5 finds the peak-to-trough amplitude in the 'framed' portion of the TRACE; if the TRACE has not been framed GLIMPSE assumes a nominal interval and proceeds. The scaled positive and negative PEAKs are over drawn with a box to indicate just what has been scaled

  The PERIOD is calculated to be twice the time interval between the PEAK and trough; the SENSITIVITY is calculated from the PERIOD and the instrument response for PRS–4 recorders using 2-Hz seismometers at that PERIOD. The SENSITIVITY converts the scaled trace amplitudes to ground displacements. **Users employing other types of sensors are cautioned that the SENSITIVITY values determined by LithoSEIS are correct only for sensors with a natural frequency of 2-Hz.**

- F7 and F8 SCALE CODA LENGTHS.
  These keys are used to select (F8) and scale (F7) coda LENGTHs. The initial F8 moves the CURSOR to the right-hand side of the trace box; subsequent F8's move back along the TRACE to the next trace amplitude larger than the current trace amplitude. The procedure thus selects the various points along the TRACE for which all subsequent points on the TRACE have a lower amplitude. The analyst selects the point which corresponds to a previously chosen minimum amplitude value for the coda LENGTH.

  The LENGTH is measured via F7 from the initial position of the CURSOR (at the first F8). GLIMPSE outlines the coda that has been selected by the pick for the

analyst's approval.

The other Function Keys are:

- F1 calls up the on–line HELP for GLIMPSE.
- F2 initiates pick–mode of GLIMPSE. Inside pick–mode, it has no effect.
- F9 causes any PICKs that have been made to be written to flat files for subsequent processing.
- F10 returns the user to the initial GLIMPSE screen. Note that GLIMPSE will not allow an immediate exit from pick–mode via ESC or F10 if PICKs have been made without being saved.

8.2.3 OTHER GLIMPSE FUNCTIONS

These include:

- Calculating Hypocentral Distance and Magnitude
  If a P and S PHASE are scaled from a TRACE, GLIMPSE calculates the approximate hypocentral distance from the S–P interval and writes the value in km to the TRACE screen. If an amplitude PEAK is subsequently scaled from the same TRACE, GLIMPSE calculates the approximate Richter magnitude for the event and writes this value to the screen. This facility will quickly give the analysts some idea of the size of the selected event.
- Tagging Traces
  Any TRACE displayed in GLIMPSE may be TAGged by pushing the SPACE bar. TAGging writes the time of the TRACE to a flat file for subsequent processing, such as keying the selective upload of TRACEs with the same time from other PRSs.

8.3 TAG PICK and ADD PICK

The TAG PICK module provides the user with a facility for reviewing the PICKs made in GLIMPSE. The PICKs are automatically sorted chronologically and grouped together in EVENTs by LithoSEIS, with each EVENT assigned a unique EVENT CODE - a four-digit number, 0001 to 9999 - that represents the sequence in which the EVENTs were defined. The PICKs are sorted by the start times of the TRACEs from which they were derived.

The EVENT CODEs are assigned according to the MIN and MAX TIME SPANs defined under PREPARE:OPERATION:DEFAULTS. PICKs that fall within the MIN TIME SPAN time of each other are automatically assigned the same EVENT CODE by LithoSEIS, PICKs that differ by more than the MAX TIME SPAN time are assigned different EVENT CODEs and can not be grouped together while PICKs that fall in the range between the MIN and MAX TIME SPAN times can be grouped together at the user's discretion. However, such PICKs are initially assigned separate EVENT CODEs. Users will occasionally find

it necessary to increase the MAX TIME SPAN time to allow a late PICKs to be included within an EVENT.

Users may remove one PICK from an EVENT group, called trashing the pick, via F7. The trashed PICK is assigned a '????' EVENT CODE. The same F7 key will reassign a trashed PICK to the current event, but only if the time of the PICK is less than the MAX TIME SPAN time. Use the CURSOR to highlight the PICKs as required and F4 to define the current EVENT CODE. Several PICKs may be TAGged with the SPACE bar and regrouped under a new EVENT CODE using F3.

Users may move or erase the individual PHASE readings for a PICK with F2.

ADD PICK provides the user with the ability to change any of the scaled readings made in GLIMPSE. The ADD PICK screens also show any information for the picks derived in LithoLOC. This includes the distance and azimuth from the calculated hypocenter and the PHASE arrival time residuals.

ADDING OUTSIDE DATA

Option F2 of ADD PICK allows the user to enter PICK information from an external source. Thus, LithoSEIS may be used to analyze seismicity data, the PHASE PICKs and PEAKs, from any source not just from LithoSEIS.

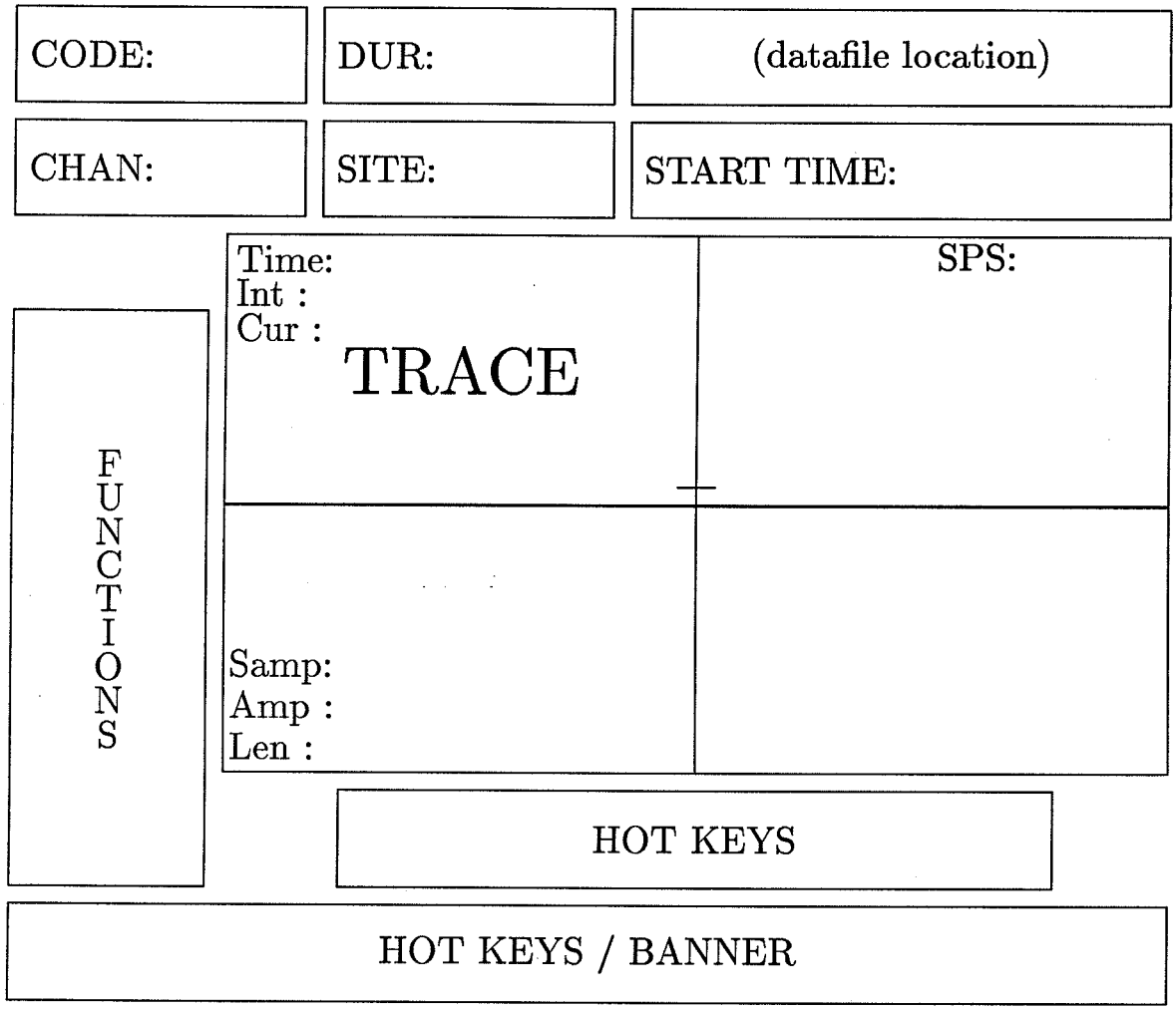


Figure 3: The layout of the GLIMPSE picking screen. The upper six boxes show information about the TRACE including the Deployment CODE, the length of TRACE displayed in sec (DUR), the Channel Number (CHAN), the SITE Code and the START time of the TRACE. The final box gives the location of the TRACE datafile. See Section 2 for information about the parameters displayed within the main TRACE box. The FUNCTIONS and HOT KEYS boxes indicate the keys active in this mode. The BANNER box is used to display the derived PICKS and to warn users of possible error conditions.

8.4 LithoLOC

LithoLOC is an adaption for PCs of LOC, the VAX/VMS software that has been used since the mid–1970's to document the local earthquake activity in Canada, for both the permanent seismograph networks and the temporary field networks deployed for aftershock studies. As such, LOC has been used to analyze earthquake activity in a wide variety of geological terrains – the active tectonic zones of Vancouver and the Queen Charlotte Islands, the intraplate zones of the Canadian Cordillera, the interior plains and the precambrian shield and offshore oceanic zones of the Pacific, Arctic, Atlantic Oceans and Baffin Bay. LOC has also been used to analyze the aftershock activity of the Miramichi, Nahanni, Saguenay and Ungava earthquakes and has been widely used for studies of mining-induced (rockburst) activity in Canadian mines and for earthquake activity induced by oil and gas recovery schemes and reservoir impounding.

To produce the version of LithoLOC incorporated in this version of LithoSEIS, LOC code was converted from VAX/VMS FORTRAN to Micosoft FORTRAN 3.31, integrated with dBaseIII database routines to store the derived data and with a HALO graphic interface to allow easy program control.

Some of the features of LithoLOC that users engaged in local seismicity studies will find useful are:

- Multiple Crustal Phases - LithoLOC provides the use of four independent phases for locations so that secondary phases such as PG and SG/LG can be used for locations.

- Spherical–Earth Distance Calculations - LithoLOC calculates distances using a spherical earth model so that it can be used equally well with regional and local data.

- Multiple Multi-Layer Crustal Models - LithoLOC allows for nine different plane-layered crustal models to be used. The models can be changed 'on the fly' to assess the implications of structural changes on the epicentral locations.

- Variety of Phase-Weighting Schemes - LithoLOC allows for six different weighting schemes to be applied for locations, and provides the analyst with a convenient tagger to delete phases from the location or magnitude calculations.

- Variety of Solution Schemes - LithoLOC provides four different solution schemes for calculating a hypocenter so that reading errors in initial data sets can be quickly identified or data can be fitted to known or assigned hypocenters.

- Station Corrections - LithoLOC allows the use of individual station travel-time or magnitude corrections to be defined.

- Different Magnitude Schemes - LithoLOC provides for use of Richter, Nutlli and coda-length magnitudes and provides for easy incorporation of user-defined magnitude formulae.

- Online Help - Finally, LithoLOC comes with extensive online HELP available with F1.

In addition, LithoSEIS incorporates routines that automatically organize, save and manage the epicenter and magnitude data derived by the user, so that the information can readily be incorporated into progress reports or transferred to other systems as required.

8.4.1 The LithoLOC Philosophy

The LithoLOC package was developed with the particular intent of giving the analyst who is responsible for locating the seismic events recorded by a short–term field survey an easy way of gauging the effect that the particular distribution of seismic stations deployed to record the seismic activity has on the locations themselves. This is a critical judgment that must be made during every aftershock survey if the seismic recorders are going to be redeployed to monitor ongoing activity in an optimum manner. This judgment must be made in the field – it is no good finding out two months later back in the office that the depths of the aftershock activity are biased by the lack of coverage in a certain quadrant – and it must often be made in the midst of very hectic field survey conditions.

For this reason, the main LithoLOC screen shows the user a visual map of the network of stations recording the event being located on a simple geographic grid, draws on it the location vector from the starting location to the final calculated epicenter and allows the user to move the starting point quickly around the network to gauge the effect of different starting points on the final solution. It also allows the user to carry out this same operation in vertical cross section so that the effect of the starting point and the distribution of stations on the final calculated focal depth can be seen directly.

LithoLOC also facilitates the identification of bad readings in the set of observed arrival-times and gives the analysts easy ways to low weight or remove entirely the effects of any station's phases in the calculation.

The main options available for LithoLOC are:

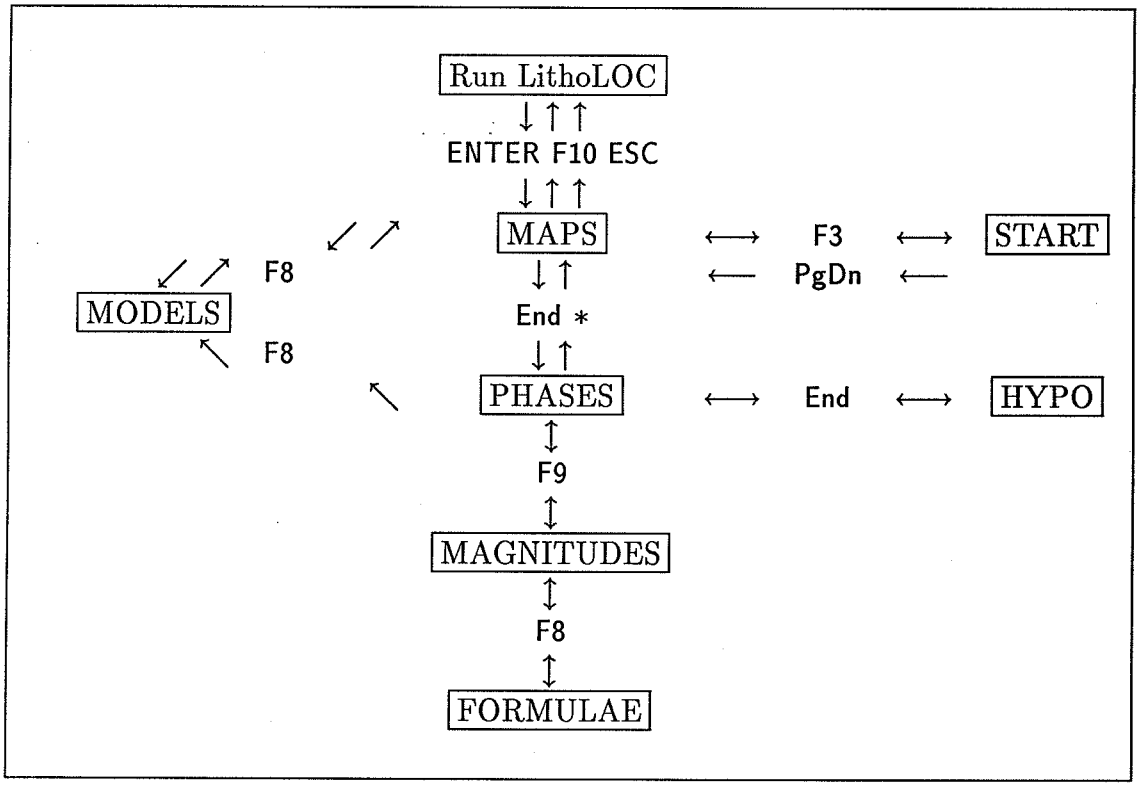
- Run LithoLOC– running the location program on the selected event
- PARAMETERS – changing the iteration, magnitude or weighting criteria
- MODELS – changing, adding or deleting velocity models
- VIEW LOG – display a detailed transcript of the last calculation
- SEE ERRORs – display error messages (Not implemented for version 4.0)

Note that an EVENT must be selected before running LithoLOC.

8.4.2 RUNNING LithoLOC

LithoLOC displays its hypocentral data either in graphical MAP VIEWs or in more conventional PHASE list tabulations. The basic layout of the LithoLOC display is similar to the GLIMPSE display with key information about the selected event shown in six smaller boxes above the main work box as in Figure 4 .

The main work box shows different SCREENs depending on the specific operation that needs to be carried out. As noted above, the MAPS screen is the initial view users have on entering LithoLOC. Users navigate to the other SCREENs with specific control keys as follows:



The navigation keys shift the VIEW of the work screen as indicated. Note that the return from the MAPS screen via F10 saves the results of any previous LithoLOC calculations while the return via ESC does not.

8.4.3 LithoLOC Work Screens

- MAPS SCREEN
  The MAPS screen is a Mercator projection centered on the starting coordinates of the hypocentre calculation with a scale calculated to show all SITEs represented in the PHASE list on the screen. The map VIEW may be toggled via ENTER to east-west or north-south cross sections. The VIEW area may be shifted with the ARROWs. If a previous hypocentral solution exists for the event, the starting point

(+) is set at the coordinates of the previous solution, otherwise it is set to the average coordinates of the first three stations in the PHASE list.

To change the starting point the analyst uses F3 to enter the START screen.

- START SCREEN
  On the START screen the map VIEW is unchanged but the ARROWs cause the starting point to move in the indicated direction. Once the starting point is adjusted satisfactorily, the analyst may return to the MAP screen with F3 or with PgDn, which returns and also starts a hypocentral calculation.

- PHASES SCREEN
  From the MAP screen, users may see the PHASE list for the selected event by entering the PHASE screen with End and return to the MAP view by *. Note that * also causes the map to be recentered on the starting point if the starting point has been adjusted by the analyst.

  The PHASES screen is a tabulation of the information available for the selected event including site code, epicentral distance, azimuth, phase type, arrival time, arrival time residual, reading quality, risk, calculation quality and site delay. If a hypocentral solution has not yet been calculated for the event, the residuals and associated risk values are not defined. LithoLOC displays twelve phase lines on the screen at one time; additional phases are displayed on subsequent PHASES screens which are called up via End. Once the end of the phase list is reached, End will display the HYPO screen.

- HYPO SCREEN
  The HYPO screen displays detailed information about the last hypocentral solution. Note that a subsequent End will display the first PHASE screen again.

- MAGNITUDE SCREEN
  From the PHASES screens, user may enter the MAGNITUDE screens to perform magnitude calculations. A hypocentral calculation must be completed before a magnitude calculation can be done. The MAGNITUDE screens are organized in a fashion similar to the PHASES screens but display information pertinent to the magnitude calculations. Users return to the PHASE screens via F9 or enter the FORMULAE screen via F8.

- FORMULAE SCREEN
  The FORMULAE screen displays the current equations used to calculate the MN and MC magnitude values. Users may adjust the values as desired and return to the MAGNITUDE screens via F8.

- MODEL SCREEN
  Users may also adjust the parameters defining the current velocity model by going to the MODEL screens from either the MAP or PHASE screens with F8. Once the

adjustments are made, F8 returns the user to the MAP screens (you can not return directly to the PHASES screens).

CHANGES IN LithoLOC

Note that adjustments made on the MODEL or FORMULAE screens are local changes only and not saved by LithoLOC. These features are intended to allow users to test different variations in the parameters in order to refine the interpretation of the events. Once certain changes are decided on they must be formally entered into the model or parameter databases. Care must be taken to keep the set of locations derived for recorded events consistent with the definition of the velocity models and magnitude formulae used when the definitions are changed during the course of an experiment.

8.4.4 LithoLOC Hot Keys

In addition to the navigation keys noted above, which allow the user to navigate around the LithoLOC screens, there are other 'hot' keys which perform certain actions depending on which SCREEN they are used. They are located on the numeric keypad and include:

	MAP SCREENS	START SCREEN	PHASE SCREENS
+	expand map	increase origin time	increase parameter
−	shrink map	decrease origin time	decrease parameter
ARROW s	move map	move starting point	select parameter
ENTER	change view		
*	replot and center		go to MAP SCREEN
HOME	change solution type		change solution type
PgDn	calculate hypo	calculate hypo	calculate hypo
PgUp	toggle start/hypo		
Ins	magnify error ellipse	increase change factor	increase change
Del	shrink error ellipse	decrease change factor	decrease change
End	go to PHASE SCREEN	list more phases	

Their functions on each of the screens are summarized below.

- MAP SCREENS
  While in the MAP screens LithoLOC provides several means for conditioning the view so that the display of the station locations is optimum. First of all, ENTER switches the map display between a map view, east-west cross section and north-south cross section. + or − increase or decrease the scale of the map by a factor of two. This allows the analyst to expand the map to include all the stations or zoom and focus it only on the area of the calculated hypocentre. The ARROWs shift the map by one-half map width in the indicated direction. A hypocenter calculation is

initiated by PgDn; a vector is drawn from the starting point to the final calculated hypocenter, an error ellipse is drawn around the calculated hypocenter and the final coordinates are displayed in the hypocentral box in the upper right of the map. Ins/Del enlarge or shrink the error ellipse displayed for the hypocentral calculation by a factor of two. (The current factor is displayed in a small box in the lower right corner of the map.) PgUp toggles the starting point from the last starting point to the new calculated point and back. HOME selects one of the four solution type to be used in the next hypocentral calculation. Finally the analyst may shift the starting position to a new point and use * to recenter the map on that position.

- START SCREEN

  When LithoLOC is in the START screen + , − and ARROWs affect the starting point not the map display. In this screen the ARROWs move the starting point in the indicated direction, + /− adjust the starting origin time and Ins/Del control the amount of change that is implemented. (The amount of change is shown in a small box in the lower left corner of the map; the number represent kms for position coordinates and seconds for time.) Note that any changes are reflected in the hypocenter box displayed in the upper left corner of the map. This box always gives a numerical readout of the coordinates of the starting point for the hypocentral calculation - time, latitude, longitude and depth. The fifth parameter in this box is the RMS error calculated from the phase list for the current starting point. It allows the analyst to track the improvement in the calculated hypocenter. However, the RMS parameter is only updated when LithoLOC is put back into its primary MAP screen and that is done by pressing F3 once again.

  Note that in the START screen PgDn switches LithoLOC back to the MAP screen and starts the hypocentral calculation.

- PHASE SCREENS

  In the PHASE screens, PgDn also performs a hypocentral calculation and refreshes the travel-time residuals. The RISK values are defined for each residual and the cursor is positioned on the Calculation Quality (Qc) of the phase having the largest RISK value.

LithoLOC RISK

RISK as used by LithoLOC requires some explanation. It is the portion of the total RMS for the EVENT that is contributed by the particular phase residual (R). Thus

$$RISK = \frac{R^2}{RMS^2} \qquad and \qquad \sum RISK = No.\ of PHASES$$

In a typical seismicity data set, the RISK parameter can be a useful diagnostic to identify bad readings. LithoLOC always initially highlights the Calculation Quality of the PHASE with the highest RISK value when it generates a PHASE screen. Users may then immediately zero-weight (−) the PHASE and recalculate (PgDn) the solution.

+ or − cause the selected parameter to be changed in the sense indicated. The Qc values are changed to their next higher or lower level, Times and delays are changed by seconds. Ins /Del define the amount of change in seconds that is applied; the current amount is displayed in the small box in the lower left corner of the screen. The ARROWs allow the cursor to be repositioned on another phase line or on another changeable parameter (Arrival Time or Site Delay). End displays another PHASE screen, if more than twelve phases are defined, or the HYPO screen.

- MAGNITUDE SCREENS
  In the MAGNITUDE screen, the key functions are similar to those in the PHASE screen. Note, however, that for magnitude calculations, calculation Qualities (Qc) can only be 1 (included) or 0 (excluded).

- FORMULAE AND MODEL SCREENS
  In the FORMULAE and the MODEL screens, the ARROWs select the parameter to change. Ins /Del define the amount of change applied and + or − apply the change in the indicated sense. The amount of change applied is shown in the small box on the lower left. In the MODEL screen only, PgUp /PgDn select a new velocity model from the set of models defined prior to entering LithoLOC.

8.4.5 LithoLOC Solution and Magnitude Types

There are four types of hypocentre solutions possible with LithoLOC and three types of magnitudes. In either case, the calculation type is selected by HOME and calculation is started by PgDn.

The hypocentre solution types are:

- PEGGEDAll parameters of the hypocentre are held fixed and residuals are calculated for the set of observed arrival time. This is used for timed calibration blasts where the location and time of the blast are known independently.

- TIMED Depth and location of the hypocentre are held fixed but a best-fit time for the event is calculated from the set of observed arrival times. This is useful where the location of a blast is known but its time is not.
- FIXED The focal depth is held fixed at the starting value and a best-fit time and location are calculated from the set of observed arrival times.
- FREE The four parameters of the hypocentre, time, location and depth, are calculated. Note that LithoLOC always calculates a FIXED solution prior to a FREE solution.

Obviously FREE solutions are preferred, but initially the data sets for even well recorded events may contain gross errors, S-phase misidentified as P-phases or unknown timing errors, which can cause FREE solutions to be unstable. In such cases the other types of solutions allow the analyst to try different methods to identify the errors.

The magnitude types are:

- ML RICHTER Based on the scale defined by Dr. Charles Richter for California earthquakes recorded on Wood-Anderson seismographs. LithoLOC allows no variation of this scale.
- MN NUTTLI Based on the scale defined by Dr. Otto Nuttli for earthquakes in eastern North America recorded on World-Wide Standard Seismographs. The parameters for this scale can be customized at the user's discretion.
- MC CODA A generic magnitude scale based on the observed Coda Length of seismic phases. Again, the parameters of this scale can be customized as required.

Local magnitudes are difficult to define accurately for seismic events recorded at short distances. ML magnitudes are a useful indication of the approximate magnitude level, but should not be considered to be infallible.

8.4.6 LithoLOC PARAMETERS

The parameters include the iteration, magnitude and weighting parameters. User should set the Min Step to a small number equivalent to the precision required from the event locations; LithoLOC will terminate its hypocentral iterations if the steps (for lattitude and longitude) are less than this value. Conversely, LithoLOC will not allow iteration steps bigger than Max Step, so this value should be set to a value consistent with the size of the network.

The weighting parameters are modified with F3. Users must first select one of the six possible weighting schemes and then define any ancilliary parameters that are required.

The default set of parameters may be recalled with F4 and the current set saved and recalled by F5. The analyst ID code is an optional code that may be defined here. It is stored with any locations that are subsequently done with the parameter set, so it is a useful guage on which events were located with certain criteria.

8.4.7 LithoLOC MODELS

The models include five that are used with earthquakes in various parts of Canada. Once the user selects a model, the parameters defining it are displayed and may be edited as required. If needed an entirely new model may be created and saved. A total of nine different models may be defined. All models are available when a location calculation is being carried out.

8.4.8 VIEW LOG and ERRORS

These functions are not fully implemented with Version 4.0.

8.5 MANAGE and DISPATCH

MANAGE provides a sorted list of all hypocenter and magnitude calculations. More detailed information for the selected event is given with F3.

Note that a selection of EVENT s may be TAGged with the SPACE bar and EXPORTed to the EVENT database where they are available for subsequent processing. The information in the EVENTdatabase may be used to TAG traces for GLIMPSE.

DISPATCH provides the user with some convenient output formats in which to write the seismicity data derived in LithoSEIS. The outputs include HYPO71 for writing the phase information and ACROSPIN for writing the hypocentral information. These programs are not supplied with LithoSEIS, and users must supply their own copy.

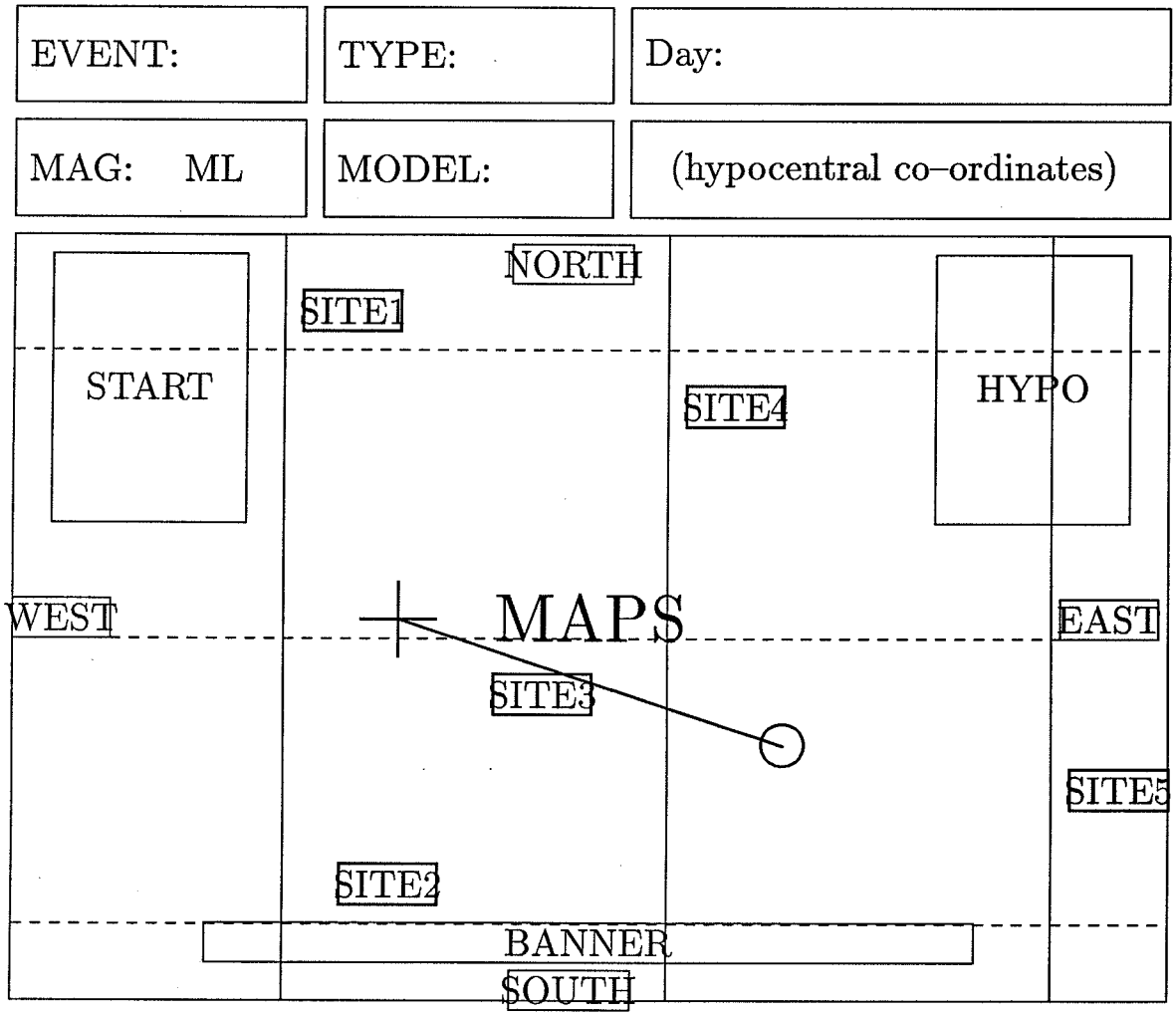


Figure 4: The LithoLOC MAPS screen. The upper six boxes show information about the EVENT including the EVENT Code, the solution TYPE, the magnitude (MAG) and magnitude type (ML), the MODEL number and the origin time of the event (Day). The final box gives the co–ordinates of the hypocenter. The large cross shows the starting point for the hypocentral calculation. The parameters of the starting point are shown in the START box. A line is drawn from the starting point to the final calculated hypocenter. The parameters of the hypocenter are shown in the HYPO box and an error ellipse (circle) is drawn around the hypocenter. The solid and dashed line grid indicates the local geographic co–ordinates. Recording SITES are also shown.

9 MAINTAIN

The MAINTAIN module contains a number of options useful for the maintenance of the LithoSEIS databases. Unlike the other three main menu options (PREPARE, EXECUTE and ANALYZE) the MAINTAIN option does not necessarily follow a natural flow of actions that users must take to complete their operation. Rather, any operation not fitting in the previous categories is brought under this main heading.

In a normal operation of LithoSEIS, users may use the MAINTAIN options to register their PRS instruments and FSU clocks, to import and export databases to and from a FSU or to create formatted output using one of the many options of LISTER. Other MAINTAIN options such as RE-INDEX and FILE ERASE are used less frequently.

9.1 PRS Inventory

The LithoSEIS PRS database stores information about all Lunch Box's for each FSU. Once the PRS instruments for each FSU are allocated, their names and types must be registered so that they can be used as required in your data acquisition.

9.2 Clock Inventory

The LithoSEIS CLOCK database stores information about the clock used for your UP-LOAD and DOWNLOAD operation. If you are using a Master clock that needs regular rating against a standard clock, you need to register your standard clock in the CLOCK database as well. This is necessary when you start using the MAINTAIN:RATE option to enter your master clock drift ratings.

9.3 Database Indexing

When you first start LithoSEIS, you get a fresh copy of all LithoSEIS databases in the DATABASE directory on your DATA disk. Each database normally has at least on index created initially and maintained for the life of the database. As you use your LithoSEIS databases and trash some records the index files must keep track of deleted records, and they mostly do.

A corrupted index file can create chaos and must be fixed. The RE-INDEX operation is designed to re-create all index files and correct problems they might create.

9.4 The LithoSEIS Errors

The errors and warnings encountered in running any of the LithoSEIS communication programs (DOWNLOAD, MONITOR and UPLOAD) are written to an error file for each FSU. The content of this file may be listed using the ALL ERRORS option.

9.5 DOS Gate

The LithoSEIS DOS GATE option permits users to enter a DOS shell and issue any DOS commands (i.e. non-LithoSEIS operations). You start this shell in the DATABASE directory of your DATA disk no matter where you originally started LithoSEIS from. You may run any DOS application, move to other directories on your FSU. After finishing your DOS application, simply type EXIT to return to LithoSEIS.

9.6 Exporting Databases

The LithoSEIS SAVE FSU option is used to simply save your working databases (but not your TRACE files) to a floppy diskette. The SAVE FSU floppy is primarily used both as a backup copy of your databases and as a medium for data exchange between your FSU and the FHQ.

A SAVE FSU floppy must be created frequently; particularly after a DOWNLOAD, UPLOAD or CATALOG cycle. Here is a list of all possible uses of the SAVE FSU floppy:

- The SAVE FSU floppy is used to import all primary databases and working log files from one FSU to another.
- The SAVE FSU floppy is used in merging of an FSU catalog into the FHQ using the FSU-MERGE option of ANALYZE:CATALOG.
- The SAVE FSU floppy is a compete backup of all important databases. Your Data Processing Supervisor can do manual recovery of lost databases from this floppy for cases not installed in LithoSEIS.

9.7 Importing Databases

The LithoSEIS databases saved to a SAVE FSU floppy disk can be imported to any FSU using the IMPORT FSU option. This option is frequently used to transfer a Master Plan from FHQ to all FSU's.

Note also that the import process is non-destructive. When a database record is being imported to the host FSU the possibilities are:

1. Host does not contain the imported record. It will be appended.
2. Host and imported records are identical. No action required.
3. Host and imported records are different, user must make a decision.

Notes on importing LithoSEIS databases:

- When importing DEPLOY database, you are given a choice to reset deployment counters. The counters show how many PRS units are DOWNLOADed or UPLOADed for each deployment. Reset the counters if you intend to import and then use a live (non-expired) deployment.

- PRS and CLOCK databases are NOT IMPORTED. They are only used on the FSU they are defined and do not have much use for export to other units.
- The UPLOAD database is not imported. This means that it is not possible to finish incomplete CATALOG and ARCHIVE processes on another FSU. One solution to this problem is to UPLOAD the data again. Another solution is to use the **Level One Backup** backup floppies and do a RESTORE PRS in EXECUTE:CATALOG. The best solution is to get your **Data Processing Supervisor** to transfer the UPLOAD database manually.
- A few other databases such as CATALOG and MONITOR data banks are not imported. Again, they are very much the property of each FSU and do not have much value to others.
- The LithoSEIS CATALOG database is not imported since it needs special handling. We must either do FSU-MERGE or VOL-MERGE from ANALYZE:CATALOG menu to get the CATALOG database.

9.8 Erasing Files

The FILE ERASE option allows a safe clean-up of all temporary files created by LithoSEIS. This clean-up should be carried out after a DEPLOYMENT is no longer active (i.e. the important TRACEs have been ARCHIVEd and the databases saved under SAVE FSU). FILE ERASE will not permit deletion of files associated with an active DEPLOYMENT.

9.9 The Lister

The LISTER utility provides a means of creating reports for all databases in a variety of formats. The LISTER report produces an ordered LIST which can be printed as a hardcopy or saved on a floppy disk. You may also spawn this utility from DOS by typing 'report' on the DOS command line.

A Hardware Installation

Warning - The hardware and DOS installations should not be conducted by anyone unfamiliar with PC's and DOS.

There are three steps necessary to set up a PC or compatible as an FSU or FHQ. Step 1 is to set up the hardware, this includes installing interfaces within the PC and therefore a competent technician should be available for this operation. Step 2 is to install DOS and configure the PC. Step 3 is to Install the LithoSEIS software package on the machine. This appendix covers step 1. Step 2 is covered in DOS manuals and step 3 is explained in Appendix B.

A.1 LithoSEIS Hardware

Certain hardware components such as hard disk drives are essential while others such as pen plotters are optional for operating a LithoSEIS survey.

A.1.1 Essential Hardware

The following devices are essential for the operation of LithoSEIS.

a) PC-AT compatible microcomputer with math. co-processor. We recommend at least a 286 based machine for the FSU and a 386 machine for the FHQ. LithoSEIS has been developed and tested on COMPAQ computers and has also been tested on DATA-GENERAL laptops with two RS232 serial ports.

b) Floppy Disk Drive. LithoSEIS is distributed on 5.25" or 3.5" floppy disks, therefore one of these drives must be available. Floppies are also used for the primary backup of data.

c) Hard Disk drive with at least 40 mb of storage space.

d) One RS232 serial port for clock communications.

e) Either a second RS232 serial port or a High Speed Link board for FSU to PRS communications.

f) CGA, EGA or VGA or compatible video display screen.

g) An External Clock: Kinemetrics 468-DC GOES or Nanometrics 501.

h) PC parallel printer.

i) High Speed Link cable, COM-PORT cable, Clock cable and printer cable.

A.1.2 Optional Hardware

LithoSEIS supports the following optional hardware.

a) Expanded memory boards.

b) IBEX PCT-1000 Streaming Magnetic Tape drive.

c) Nicolet Zeta 8 pen plotter (HPGL interface) or any other HPGL compatible plotter.

d) Compaq-Irwin cartridge tape backup units (10 or 40 mb capacities).

e) Master Clock Interface box (consult LithoSEIS maintenance team for details).

A.2 Hardware Connection

The LithoSEIS FSU and FHQ computers are normally equipped with the base hardware before they are shipped to the field. LithoSEIS supports four standard communication channels COM1 to COM4, however, only two can be used at any time. The base hardware includes the High Speed Link card, a second communication port (required for FHQ), and expanded memory boards (if available). The other two communication ports may be used for non-LithoSEIS operations.

The High Speed Link communication is mostly used for the PRS1 instruments which only support standard communication at a low baud rate of 4800.

The PRS4 communication is mostly done with the standard communication ports where baud rates ranging from 4800 to 115200 are supported.

Additional hardware installation may be required in the field. This includes installing precision clocks for the FSU's and pen plotter and tape transport units for the FHQ.

A.2.1 Expanded Memory Boards

Install your expanded memory boards according to their manufacturer's instructions. Most memory boards can be configured as RAM disks by using the standard DOS VDISK command. If your memory board does not support VDISK, you can install its own driver provided it does not waste too much of the base 640 kb of DOS memory. LithoSEIS supports RAM disks as small as 32 kb. A good use of extra memory is to install a disk cache and a RAM disk to improve disk I/O. For more information about software installation of expanded memory boards, consult Appendix B.

A.2.2 GOES Clock

Connect the GOES clock into a serial port on the FSU, and note the hardware BAUD rate and the propagation delay settings of your clock. It is recommended that you set the baud rate to 4800 although any other baud rate is acceptable. Set the propagation delay switch to cancel the propagation delay for your clock for the area of the survey. This ensures that all your clocks are reporting absolute times and no GOES clock correction will be required when operating LithoSEIS. Most LithoSEIS surveys operate in Universal Time (UT) mode and it is therefore necessary to ensure all clocks used in such surveys are set to UT. Assign a unique four character identification name to each clock. Note the baud rate and propagation delay, the clock name and name of the communication port that it is attached to (normally COM2). These are required when running LithoSEIS.

A.2.3 GOES simulating clock

LithoSEIS supports the Nanometrics 501 GOES simulating clock. Any other clock with full support for the GOES command set and a standard RS232 communication interface can be connected to a LithoSEIS FSU. Consult the 501 operation manual, key in the appropriate BAUD rate and set the 501 to "GOES Simulating Mode". Assign unique four character names to all your 501 clocks for operational use. Note the baud rate, the clock name and name of the communication port it is attached to (usually COM2). These are required when running LithoSEIS.

A.2.4 Master clock

Any master clock capable of producing a minute-mark edge can be used with LithoSEIS. A special Master Clock Interface box is required to convert the minute-mark edge into a standard RS232 signal. Master clocks do not require a baud rate setting but need a unique four character name for software operation.

A.2.5 DOS Clock

When LithoSEIS is used for practice in the Laboratory and accurate timing is not required, the PC's internal DOS clock can be used for reference timing. Note that DOS clock is not accurate enough for field work and must never be used for serious recording. No communication port is required for DOS clock use, and the generic name DOS is used for the clock name.

A.2.6 ZETA-8 Pen Plotter

The LithoSEIS FHQ computer is normally equipped with a High Speed Link card, and two standard RS232 communication ports. This allows the FHQ to function both as an FSU unit for download and upload and as an FHQ for processing and plotting seismic data. Communication port 2 (COM2) is normally reserved for the clock while port 1 (COM1) is free for either PRS communication (when a High Speed Link card is not available), or for the Pen Plotter. Set the ZETA-8 hardware communication parameters to 9600 BAUD, no parity, 8 bit with 1 stop bit. Note that if you are using a Pen Plotter, you need to issue a DOS MODE command to set the software communication parameters for it. A MODE command is normally added to the AUTOEXEC.BAT file of your FHQ. The syntax of this command for COM1 is as follows:

MODE COM1:96,N,8,1,P

See the LithoSEIS software installation guide (Appendix B) for more details.

A.2.7 IBEX Tape Transport

The IBEX tape transport is the nine track 1/2" tape drive currently supported by LithoSEIS. This unit has its own interface card that has to be installed in a 16 bit slot

in the FHQ. This installation can only take place in the field due to the cable restrictions of the IBEX unit. Note that the IBEX interface card uses a Direct Memory Access channel.

A.2.8 Parallel Printer

LithoSEIS operates with any PC compatible parallel printer attached to the printer port of your PC. Note that the printer cables for 286 and 386 based CPU's are not necessarily identical and it is recommended that you not interchange FSU and FHQ printer cables.

A.2.9 IRWIN 10 or 40 mb cartridge system

LithoSEIS supports both the IRWIN 10 and 40 mb tape cartridge systems for data archiving. The software program required for these tape systems is proprietary to the Compaq Computer Corporation and can be run on Compaq PC's only.

B LithoSEIS installation

B.1 Summary

If you don't want to read through the rest of this section set up your hardware and perform the following functions.

1. Install MS-DOS or PC-DOS Version 3.31 on the hard disk.
2. Partition your hard disk between a minimum 10 Mb partition (Volume Label=SYSTEM) and a minimum 30 Mb partition (Volume Label=DATA). Note that LithoSEIS requires about 6Mb of storage space on the hard disk.
3. Boot your computer, insert the LithoSEIS Master Disk into drive A: and type
   A: RETURN
   INSTALL RETURN
4. Answer questions from the INSTALL program. (use the HELP)
5. Copy AUTOEXEC.BAT and CONFIG.SYS from the LithoSEIS SYSTEM directory to your machines boot directory. Modify as required.
6. Reboot your machine.

You are now ready to run LithoSEIS.

B.2 Overview

LithoSEIS is installed because it needs to interact with the FSU hardware in an organized and predictable way. It needs to set-up your working environments correctly and to save you from potential problems that you may encounter when operating a LithoSEIS survey. To be able to do this, you must enter certain parameters such as the name of your hard disk partitions, your FSU name, your project name and so on. You do not need to reinstall LithoSEIS until you need to change one of your original parameters.

LithoSEIS depends on the file structure that is created on your hard disk during installation. A chain of directories are created and maintained throughout a LithoSEIS survey. The LithoSEIS directory structure is based on some simple concepts. All the files that belong to the LithoSEIS system which are given to you on the distribution floppies (and should never be altered) are kept in a directory called LITHOSEI on one partition of the hard disk with a VOLUME LABEL called SYSTEM. All those files that you create during the running of LithoSEIS are kept in a set of directories on another partition of the hard disk with a VOLUME LABEL called DATA. They include the DATABASE directory (for relational databases that keep seismic trace headers and other survey support information), a TRACE directory for seismic trace files, a buffer directory called SAVE to keep files on their way to a backup media, a directory called STORE for files restored from a backup media and so on.

Although it is perfectly acceptable to install LithoSEIS on one partition on a hard disk, we recommend using two partitions: one for the DATA and the other for the SYSTEM. The reason for this is obvious. As you run an experiment and DOWNLOAD and UPLOAD Lunchboxes, there is a tremendous volume of data being stored on the hard disk. When you ARCHIVE these data and delete them to do more work, you gradually fragment the hard disk and, before long, your hard disk performance deteriorates substantially. To avoid this, you need to compress or de-fragment the "active" partition of your hard disk. This is why you are better off storing your active data files in a separate partition in the first place. This is also true for other utilities that you may keep on your hard disk, always keep the "system" type files together in one partition that needs infrequent compression and maintenance, and your 'data' type files in a different one.

B.3 DOS requirements

LithoSEIS uses the flat-file concept for inter-process communication and maintains a host of databases for its normal operation. The databases are often indexed on operational parameters for speed of execution and therefore the total number of files that are open at certain times could be as many as 41. The only versions of DOS that can handle this large number files at once are DOS 3.3x or higher. This is why LithoSEIS will not operate correctly on earlier versions of DOS. Problems have also been encountered operating LithoSEIS under DOS 4.01 and so we recommend staying with MS-DOS 3.3x or move over to DOS 5.0 which offers better memory management than all previous versions.

Note that a few DOS external command files are used in LithoSEIS. They include BACKUP, RESTORE, XCOPY, MODE and LABEL.

B.4 Preparing an FSU for installation

For a first time installation, it is advisable to backup all important files on your FSU and run FDISK to divide the hard disk into at least two partitions. Consult your DOS manual for this operation. It is strongly recommended you install the DOS system in a directory called DOS to avoid cluttering the root directory of your hard disk. In fact, for a clean system, the total number of files in the root directory of the boot disk must not exceed four or five. For a 40 MB hard disk, we recommend two partitions, 10 MB for the SYSTEM, and 30 MB for the DATA. For larger hard disks, a minimum of 10 MB for the SYSTEM partition and a large DATA partition are ideal. For the rest of this section, we assume you have divided your hard disk to at least two partitions, a SYSTEM partition called C: and a DATA partition called D:. Before starting the LithoSEIS installation, you must boot your system from the hard disk.

B.5 Step by step LithoSEIS installation

1. Use DOS to backup, format and partition your hard disk. A SYSTEM partition with at least 10 Mb of free space, and a DATA partition with at least 30 Mb free

space are minimum requirements.

2. Boot from hard disk.

3. Note the following information:
   - Name of hard disk partition to keep LithoSEIS system files (normally C:).
   - Name of hard disk partition to keep your data (normally D:).
   - A four character name for your FSU.
   - A forty or less character name for your experiment.
   - A four character code for your experiment.
   - The date of the intended survey.
   - Type of experiment planned, Refraction, Seismicity or Engineering?
   - The HALO driver names for your video screen and printer.

4. Insert LithoSEIS master diskette in drive A:.

5. Change drive to A:

6. If your FSU can display colors or shades, type
   install RETURN
   If your FSU is monochrome, type
   install /m. RETURN

7. Follow the instructions; obtain more help by pressing the F1 key.

B.5.1 The install command line parameters

The LithoSEIS installation program has five optional command line parameters which are used to invoke non-standard features during installation. The command syntax is as follows:
install [/Help /Mono /Init /Upload:uuuu /Warning:wwww]
These options may be used in any order, and provide the following services:

- Help: Is just used to get the syntax and a short explanation of command line parameters.
- Mono: Is used to force a monochrome installation. This option is required for video display screens that do not display color or shades of gray, and when running LithoSEIS do not show a highlighting bar on the menu items.

SYSTEM Partition Needs a minimum of 10 mb including DOS		
Name	Type	Comments
C:\COMMAND.COM	Binary file	DOS Command processor
C:\LITHOSEI.CFG	Binary file	LithoSEIS Configuration file
C:\CONFIG.SYS	ASCII file	DOS Configuration file
C:\AUTOEXEC.BAT	ASCII file	DOS Startup file
C:\LITHOSEIS	Directory	LithoSEIS System files
C:\TOOLS	Directory	User tools
C:\DOS	Directory	DOS files
DATA Partition Needs at least 30 mb for moderate FSU		
Name	Type	Comments
D:\DATABASE	Directory	All Database files
D:\TRACE	Directory	UPLOADed Seismic Trace files
D:\SAVE	Directory	Buffer area used during ARCHIVE
D:\STORE	Directory	Storage for Trace files
D:\SEGY	Directory	SEGY files
D:\SCRATCH	Directory	Temporary files

Table 1: LithoSEIS Directory Structure

- Init: Is used to ignore an already installed LithoSEIS configuration parameter file and start afresh.
- Upload:uuuu Minimum storage (kb) on DATA disk for safe uploads, range from 3096 to 6144 kb. Default: uuuu=5120 (kb).
- Warning:wwww Minimum storage (kb) on DATA disk before storage warnings are issued. Range from 1024 to 3096 kb. Default: wwww=2048 (kb).

B.5.2 LithoSEIS Directory Structure.

After installing LithoSEIS the following file structure should exist on your hard disk.

B.6 Preparing the FSU after installation

After completing the installation and before starting LithoSEIS, you must check your FSU's configuration files to ensure they meet certain requirements. These are the two files that always reside in the root directory of the boot disk and contain various drivers for your computer and set up your system correctly every time you start the machine.

LithoSEIS can now coexist with memory resident programs and network drivers and can be installed under Windows 3.x.

B.6.1 Config.sys file

A LithoSEIS FSU requires a config.sys file with at least these two lines in it:

```
FILES=61
BUFFERS=20
```

Additional drivers for RAM disk, disk cache, and ANSI drivers are permitted. Here is an example of a more complete configuration file for a FSU with 2 MB of RAM:

```
DEVICE=C:\DOS\CACHE.EXE  128 ON /EXT
DEVICE=C:\DOS\VDISK.SYS 1152 256 256 /E:8
FILES=61
BUFFERS=20
SHELL C:\COMMAND.COM /E:512 /P
BREAK=ON
```

This set up allows for 128 kb of disk caching, 1152 kb of RAM disk, and a SHELL command to increase the size of DOS environment to 512 bytes. Note that each time you change the content of the config.sys file, you must re-boot your computer to force the changes to take effect. A simple config.sys file can be found in the LithoSEIS system directory after installation.

B.6.2 The autoexec.bat file

This file is a standard DOS batch command file that sets up the computer. The most important commands concerning LithoSEIS are the PATH, and the SET commands. The PATH command tells your system where to look for LithoSEIS files, and the SET command establishes the environment parameters for running LithoSEIS. Since we don't know the location of your SYSTEM directory in advance, we can not suggest a generic autoexec.bat file. However, once you complete the installation, a typical autoexec.bat file for your installed system is created and copied to your SYSTEM directory. You may edit this file and include any additional PATH information for your system and then copy it to the root of your boot disk. A typical autoexec.bat file for a LithoSEIS system installed on drive C: should look like this:

```
ECHO OFF
VER
PROMPT $P$G
PATH  C:;C:\DOS;C:\LITHOSEI;C:\TOOLS
SET CLIPPER=//F41 //SWAPK:2048 //SWAPPATH:"D:\SCRATCH"
MODE COM1:96,N,8,1,P
CHKDSK C:\*.* /F
CHKDSK D:\*.* /F
```

Note that the additional commands VER, PROMPT, MODE and CHKDSK are not mandatory but useful. VER displays the current DOS version and PROMPT is used to change the default DOS prompt to show current disk and directory. The MODE command is needed if a pen plotter is attached to the communication port on your FHQ. The CHKDSK commands are most valuable. They do a DOS storage maintenance each time you start your computer and let you recover and delete the wasted clusters of your hard disk.

For a heavily used FSU, we strongly recommend use of a disk optimization package such as PC-TOOLS or DISK OPTIMIZER to compress the hard disk. These packages operate in a simple way. Provided extra storage space or memory is available, they write a block of fragmented data to the buffer area in memory or on disk, delete that block and recover it from the buffer area. They then continue this for the entire disk. At the end of this process, considerable speed enhancement is achieved.

The 'set clipper' command provides certain configuration information to LithoSEIS. It tells those modules compiled with the Clipper compiler that they may open a maximum of 41 files, may use a maximum swap file of 2048 kb and in the directory D:\SCRATCH. If you have access to extra RAM and have already installed a RAM disk on your FSU it is far better to use your RAM disk for swap space. For example, if you have a RAM disk called E: with 2 mb of free space, then use the following 'set clipper' command:
SET CLIPPER=//F41 //SWAPK:2048 //SWAPPATH:"E:\"

B.6.3 Re-Installation for parameter changes

To re-install LithoSEIS, you simply type INSTALL from DOS. You don't need to have the floppies available.

The installation program provides a safe mechanism for changing working parameters without changing the content of any of the user's work files. For example, you may wish to change the mode of your experiment, the type of your video monitor or a HALO driver.

A re-installation means installing from the SYSTEM disk to itself without using the original distribution floppies. In this case the distribution disk and the system disk are identical. For example, if your system disk is C:, your distribution disk should also be C:. Run the install program and change the desired parameters.

You will notice that your important working databases are not over-written.

This also means that it is impossible to delete LithoSEIS databases from within INSTALL. This is a deliberate action since we want you to avoid accidentally overwriting important data.

B.6.4 Removing LithoSEIS from your hard disk

To remove an installed LithoSEIS from your hard disk, you erase all files in LITHOSEI, DATABASE, TRACE, SAVE, STORE, SEGY and SCRATCH directories and then remove the directories. The only other file you must erase is the LithoSEIS configuration file which is kept in the root directory of your boot disk and is called "lithosei.cfg".

B.6.5 Installing VISTA for LithoSEIS

Users of the VISTA package should install VISTA (preferably on the same partition as the SYSTEM disk) using the standard VISTA installation procedure. During the LithoSEIS installation procedure you will be asked for the name of the batch file which you normally type to run VISTA. Provided this file is on the path, you should then be able to access VISTA from within LithoSEIS.

B.6.6 Installing GLIMPSE for LithoSEIS

The LithoSEIS INSTALL program creates a special configuration profile called "glimpse.prf" which controls the output of the GLIMPSE module.

The first line of this profile contains the name and position of the HALO device driver that controls your FSU's display screen. The normal IBM compatible devices such as CGA and EGA are supported.

The second line of the GLIMPSE profile contain the name and position of the HALO printer driver that controls the printer connected to your FSU. Most of the popular printers are supported. The last 17 lines of GLIMPSE profile determine various set-up parameters for the printer.

Line 3 of the GLIMPSE profile contains the name of a HALO font file that is required by the GLIMPSE module.

Lines 4-12 of the GLIMPSE profile contain configuration information such as graphics mode, various colors, text width and scaling factor used by the GLIMPSE module. See table 2 below for a list of possible graphics mode.

An example of the "glimpse.prf" file configured with all default parameters for an Epson MX-80 printer and an EGA display screen is given below. For more detailed description of printer parameters and other examples refer to the "HALO Supplement" section.

Halo Graphics Modes				
Graphics Adapter	File name	Mode	Resolution	Number of Colors
CGA	haloibm.dev	0	320 x 200	4
		1	640 x 200	2
Generic	haloibmg.dev	0	320 x 200	4
		1	640 x 200	2
EGA	haloibme.dev	0	320 x 200	4
		1	640 x 200	2
		2	320 x 200	16
		3	640 x 200	16
		4	640 x 350	16
		5	640 x 800	16
		10	640 x 350	4
VGA	haloibmv.dev	0	320 x 200	4
		1	640 x 200	2
		2	640 x 480	2
		3	320 x 200	256
		4	320 x 300	16
		5	640 x 200	16
		6	640 x 350	16
		7	640 x 480	16
Compaq Portable 3	haloinda.dev	0	320 x 200	4
		1	640 x 200	2
		6	640 x 400	2

Table 2: Halo Graphics Modes

```
DEVICE D:\LITHOSEI\HALOIBME.DEV     Device file
PRINTS D:\LITHOSEI\HALOEPSN.PRN     Print file
FONTS  D:\LITHOSEI\HALO102.FNT      Font file
IMODE      3                        Graphics mode
COLOR     14                        Overall color
BACK       0                        Background color
BORDER     0                        Window background color
SCOLOR    16                        Seismic plot color
FILL       0                        Seismic fill color
TCOLOR    14                        Text color
CWIDTH   9.6                        Character width
XSCALE   1.0                        Horizontal scaling factor
PTR(1)    -1                        Width of output in dots
PTR(2)    -1                        Height of output in dots
PTR(3)     0                        Image orientation
PTR(4)     0                        Black/White reversal
PTR(5)     0                        Dither flag
PTR(6)     0                        Form Feed flag
PTR(7)     0                        BIOS/DOS flag
PTR(8)     0                        Dots per inch
PTR(9)    -1                        Number of copies
PTR(10)    0                        Centering
PTR(11)    0                        X offset in dots
PTR(12)    0                        Y offset in dots
PTR(13)    0                        Printer ID
PTR(14)   -1                        COM port
PTR(15)   -1                        Process ID for EMS
PTR(16)   -1                        Bold Printing
PTR(17)    0                        Parallel port
```

B.6.7 LithoSEIS HALO Supplement

The LithoSEIS GLIMPSE module uses HALO graphics package for viewing seismograms. HALO is a device-independent subroutine library with support for most of the popular video screens and printers for the PC. Device drivers are provided for a host of screens and printers. Based on your hardware, you will have to determine what drivers are most suitable and have this information available when installing LithoSEIS. The most popular screen drivers are IBM's CGA, EGA and VGA adapters called "haloibmg.dev", "haloibme.dev" and "haloimbv.dev" respectively.

If you are a registered LithoSEIS user, you receive a set of HALO drivers on the LithoSEIS distribution diskettes. Some of the less popular drivers are not shipped to you to save on the storage requirements. A complete list of drivers follows. If your screen or printer driver is on the following list but the corresponding driver is not sent to you, consult the LithoSEIS maintenance team.

a) HALO device drivers

```
Driver        Video Display Name

HALOCOMT.DEV 3M/Comtal
HALOINDA.DEV AT&T 3600 Indigenous Graphics Board
HALODEBA.DEV AT&T Display Enhanced Board
HALOICBA.DEV AT&T Image Capture Board
HALOTR8.DEV  AT&T TARGA 8 or TARGA M8
HALOVDAA.DEV AT&T Video Display Adapter
HALOTR16.DEV AT7T TARGA 16
HALOAWON.DEV ATI EGA Wonder
HALOAVIP.DEV ATI VIP, The Improved VGA
HALOADAG.DEV Adage PG90 Model 10
HALOAEGA.DEV Ahead Systems EGA 2001
HALOAWIZ.DEV Ahead Systems Wizard
HALOAMDE.DEV Amdek MAI
HALOATRO.DEV Atronics Professional Image Board
HALOAPLS.DEV Atronics Professional Image Board+
HALOCH16.DEV Chorus Frame Grabber (in 16-bit mode)
HALOCH8.DEV  Chorus Frame Grabber (in 8-bit mode)
HALOINDA.DEV Compaq Portable 3
HALOCO28.DEV Conographics Conovision 2800
HALOCONO.DEV Conographics Model 40
HALOAILL.DEV Control Systems Artist Illustrator
HALOCSTB.DEV CornerStone Technology Vista 1600
HALODTRN.DEV Data Translation DT-2851 and DT-2853
HALODAT4.DEV Datacube AT-428
HALODATC.DEV Datacube IVG-128
HALOEVME.DEV Everex Micro Enhancer
HALOGEGA.DEV Genoa Systems Super EGA
HALOINCL.DEV Hercules InColor
HALOHERC.DEV Hercules Monochrome Graphics
HALO3270.DEV IBM 3270 PC with All Points AGA
HALOIBM.DEV  IBM Color Graphics Adapter
HALOIBMG.DEV IBM Color Graphics Adapter (Generic)
HALOIBME.DEV IBM Enhanced Graphics Adapter (EGA)
HALOIBMP.DEV IBM Personal Systems/2 MCGA
HALOIBMV.DEV IBM Personal Systems/2 VGA
HALOFG.DEV   Imaging Technology FG-100-AT
HALOIMGT.DEV Imaging Technology PCVision
HALOIMGP.DEV Imaging Technology PCVision +
HALOIT15.DEV Imaging Technology Series 151
HALOIM12.DEV Imagraph AGC 1210 (IP12108 & IP10108)
```

```
HALOAGC4.DEV Imagraph AGC4
HALOAGC8.DEV Imagraph AGC8(IM1024P & IM512P)
HALOMVP.DEV  Matrox MVP-AT
HALOMET4.DEV Metheus Omega/PC Display Processor
HALOMET8.DEV Methous 1008 Display Processor
HALOGENI.DEV Micro Display Systems Genius VHR
HALOMAGA.DEV Mylex Advanced Graphics Adapter
HALONMG.DEV  New Media Graphics PC Overlay
HALONIN4.DEV Number Nine Revolution 1024x768 int.
HALONINE.DEV Number Nine Revolution 512x484 int.
HALONIN2.DEV Number Nine Revolution 512x484 non int.
HALONIN3.DEV Number Nine Revolution 832x624 int.
HALONIN1.DEV Number Nine Revolution 832x624 non int.
HALOORCH.DEV Orchid Technology Designer VGA
HALOPHME.DEV PCA Photon Mega
HALOA480.DEV Paradise AutoSwitch 480
HALOPRIN.DEV Princeton Graphics LM-301
HALOQDCL.DEV Quadram Quadcolor II
HALOSTB.DEV  STB Graphics Plus II
HALOIBMV.DEV STB VGA Extra
HALOSCIO.DEV Scion PC 640
HALOSEGA.DEV Sigma Designs EGA 480
HALOSIGM.DEV Sigma Desings Color 400
HALOTMAS.DEV Tecmar EGA Master 480/800
HALOTECM.DEV Tecmar Graphics Master
HALOTOSH.DEV Toshiba T3100
HALOEVAA.DEV Tseng Labs EVA & EVA/480
HALOVCAD.DEV Verticom CAD 480
HALOVDLX.DEV Video 7 Vega Deluxe
HALOVCDA.DEV Virtual Raster Interface
HALOVDEM.DEV Virtual Raster Interface (EMS)
HALOVINT.DEV Virtual Raster Interface (IM)
HALOVDIN.DEV Virtual Raster Interface (IM,DB)
HALOVJRM.DEV Virtual Raster Interface (Tall Tree)
HALOEX16.DEV Vision Technologies Vision 16
HALOWYSE.DEV WYSE WY-700
```

b - List of HALO printer drivers

```
Driver        Printer Name

HALOEPEX.PRN Epson EX-1000
HALOEPGQ.PRN Epson GQ-3500
HALOEPJX.PRN Epson JX-80
HALOFUSU.PRN Epson LQ 2500
HALOEPSN.PRN Epson MX-80
HALOFUSU.PRN Fujitsu DL 2400
HALOHPLJ.PRN HP Laser Jet
HALOJLSR.PRN HP Laser Jet Series II
HALOJLSR.PRN HP Laser Jet+
HALOPJET.PRN HP Paint Jet
HALOTJET.PRN HP ThinkJet
HALOCLJT.PRN IBM Color JetPrinter 3852
HALOMITS.PRN Mitsubishi G-500
HALOFUSU.PRN NEC Pinwriter P5XL
HALOOKID.PRN Okidata LaserLine
HALOOKIP.PRN Okidata Microline 192+,193+
HALO0290.PRN Okidata Microline 292,293,294+
HALO0390.PRN Okidata Microline 392C,393C,394C
HALOPANS.PRN Panasonic KX-P1524
HALOQLSR.PRN Quadram QuadLaser
HALOQUAD.PRN Quadram Quadjet
HALOSHRP.PRN Sharp JX-720
HALOTK93.PRN Tektronix 4693D
HALOTK96.PRN Tektronix 4696
HALOTOSH.PRN Toshiba P1351,P351
HALOXJET.PRN Xerox 4020
HALOXLCP.PRN Xerox 4045 Laser CP Model 50
```

The following two examples show parameters for the HALO printer drivers for the more popular HP Laser Jet Plus and EPSON printers. For other printers listed above, contact the LithoSEIS maintenance team.

Printer name		HP LaserJet+ and HP LaserJet Series II		
File name		haloljtp.prn		
Interface type		Parallel		
Printer type:		Laser		
Page Dimensions				
Horiz. DPI	Horizontal Page Size	Vert. DPI	Vertical Page Size	Aspect Ratio
75	600	75	787	1.0
100	800	100	1050	1.0
150	1200	150	1575	1.0
300	2400	300	3150	1.0
Printer Attribute Table				
PTR(1) =		Width of output in dots		
	-1	normal (default)		
	>0	specify the printer width		
PTR(2) =		Height of output in dots		
	-1	normal (default)		
	>0	specify the printer height		
PTR(3) =		Image orientation		
	0	normal (default)		
	1	landscape		
PTR(4) =		Black/White reversal		
	0	perform reversal (default)		
	1	do not perform reversal		
PTR(5) =		Dither flag		
	0	perform dithering (default)		
	1	do not perform dithering		
PTR(6) =		Form feed flag		
	0	perform form feed after image (default)		
	1	do not perform form feed		
PTR(7) =		BIOS/DOS flag		
	0	print through BIOS (default)		
	1	print through DOS		
PTR(8) =		Dots per inch		
	0	75H x 75V DPI		
	1	100H x 100V DPI (default)		
	2	150H x 150V DPI		
	3	300H x 300V DPI		
PTR(9) =		Number of copies		
	0	one copy (default)		
	n>0	n copies		
PTR(10) =		Centering		
	0	perform centering (default)		
	1	do not perform centering		
PTR(11) =		X offset in dots		
	0	no offset (default)		
	n	specify n dots in X offset		
PTR(12) =		Y offset in dots		
	0	no offset (default)		
	n	specify n dots in Y offset		
PTR(13) =		Printer ID		
	-1	not supported		
PTR(14) =		COM port		
	-1	not supported		
PTR(15) =		Process ID for EMS		
	-1	not supported		
PTR(16) =		Bold printing		
	-1	not supported		
PTR(17) =		Parrallel port		
	0	LPT1 (default)		
	1	LPT2		
	2	LPT3		

Table 3: Printer Attribute Table for HP LaserJet+ and HP LaserJet Series II printers

Printer name		Epson MX-80		
File name		haloepsn.prn		
Interface type		Parallel		
Printer type:		Dot Matrix		
Page Dimensions				
Horiz. DPI	Horizontal Page Size	Vert. DPI	Vertical Page Size	Aspect Ratio
120	960	72	unltd.	0.6
120	1632	72	unltd.	0.6
Printer Attribute Table				
PTR(1) =		Width of output in dots		
	-1	normal (default)		
	>0	specify the printer width		
PTR(2) =		Height of output in dots		
	-1	normal (default)		
	>0	specify the printer height		
PTR(3) =		Image orientation		
	0	normal (default)		
	1	landscape		
PTR(4) =		Black/White reversal		
	0	perform reversal (default)		
	1	do not perform reversal		
PTR(5) =		Dither flag		
	0	perform dithering (default)		
	1	do not perform dithering		
PTR(6) =		Form feed flag		
	0	perform form feed after image (default)		
	1	do not perform form feed		
PTR(7) =		BIOS/DOS flag		
	0	print through BIOS (default)		
	1	print through DOS		
PTR(8) =		Dots per inch		
	0	120H x 72V DPI (default)		
	1	120H x 72V DPI wide		
PTR(9) =		Number of copies		
	-1	not supported		
PTR(10) =		Centering		
	0	perform centering (default)		
	1	do not perform centering		
PTR(11) =		X offset in dots		
	0	no offset (default)		
	n	specify n dots in X offset		
PTR(12) =		Y offset in dots		
	-1	not supported		
PTR(13) =		Printer ID		
	0	EPSON printer		
	1	OKIDATA printer		
	2	GEMINI printer		
	3	IBM Propinter		
PTR(14) =		COM port		
	-1	not supported		
PTR(15) =		Process ID for EMS		
	-1	not supported		
PTR(16) =		Bold printing		
	-1	not supported		
PTR(17) =		Parrallel port		
	0	LPT1 (default)		
	1	LPT2		
	2	LPT3		

Table 4: Printer Attribute Table for Epson - MX printer

C Glossary of Terms

The following terms are used throughout LithoSEIS operations.

ACTIVE HEADER LIST. A list containing the headers for seismic data which are either in SEGY format or about to be put into SEGY format. It is used as input to SEGY creation and processing programmes. The headers come from the CATALOGE or FOREIGN SEGY files.

ARCHIVE. The organized database of seismic traces produced during a LithoSEIS experiment. The headers of all traces in the ARCHIVE are contained in the CATALOGE.

ARCHIVE VOLUME. A floppy disk or datacassette containing some or all of the traces belonging to the ARCHIVE.

BROWSE. The process of scanning though lists and printouts on the computer screen.

CATALOGE The master database containing header information for all traces in the LithoSEIS ARCHIVE

CLIPPER. The language in which the LithoSEIS user interface is written. .

CURRENT database. A database containing LithoSEIS traces which have been catalogued but not yet stored on a permanent ARCHIVE VOLUME.

DATA-directory. a DOS directory on an FSU (normally on drive d:) which is called DATABASE and holds all of the LithoSEIS active database files.

DATA-disk. A hard disk drive partition on an FSU (normally drive d:) which stores all of the user files created during a LithoSEIS survey.

DEPLOYMENT. A LithoSEIS sequence of actions involving the creation of a **single** set of acquisition parameters, the programming of one or more PRS's with this set of parameters, the placing of the instruments in the field, and the recovery of the data. In LithoSEIS DEPLOYMENTs are identified by a unique four character code.

DEPLOYMENT-code A four character name which defines a DEPLOYMENT.

DOS Disk Operating System for MS-DOS microcomputers. LithoSEIS runs under MS- DOS version 3.31 or higher.

DOWNLOAD. The process of programming a PRS with an acquisition program created by LithoSEIS from a single DEPLOYMENT-plan.

Data Processing Supervisor. The Data Processing Supervisor.

Dynamic-ram. The volatile Random Access Memory in a PRS which is kept alive by battery power as long as the PRS switch remains in the on position.

EXPORT. The process of saving LithoSEIS databases on one computer so that they may be read in on another.

FHQ. Field Headquarters Unit; an MS-DOS microcomputer with a large storage capacity, standard 9 track tape transport, cartridge backup and other peripherals such as pen plotters etc. It is used primarily for data grouping and processing.

FHQ-code A four character identifier for a FHQ.

FOREIGN. A SEGY file which was not created by LithoSEIS but which is to be processed by it.

FSU. Field Service Unit; an MS-DOS microcomputer with a moderate storage capacity and a cartridge backup system compatible with the FHQ. It is used primarily for the

DOWNLOADing of programs to the PRS's, the UPLOADing of data from the PRS's, and the ARCHIVEing of selected data.

FSU-code. A four character identifier for an FSU.

GLIMPSE. A program module in LithoSEIS that provides for the fast graphics display of trace data files on an FSU or an FHQ screen.

GOES. A satellite timing system.

HEADER. In-field supplemental information that is added to the recorded waveform data and contains survey and identification information about the seismogram.

HISTORY. Information filled in by LithoSEIS and the user concerning the UPLOAD and DOWNLOAD activity of an FSU for the current DEPLOYMENT.

IMPORT. The process of reading in files at an FSU that have been EXPORTed from another FSU.

INFO-LINE. A line of information appearing on the computer screen describing the action of each menu choice.

LINE. A logical grouping of SITEs that constitute part of a refraction survey. A line normally consists of many SITEs and may span more than one DEPLOYMENT.

LithoSEIS. A software package to allow an FSU or FHQ to manage PRS recorders and the data they produce.

Low Speed Link A standard RS-232 communication port that is part of an FSU and is used for slow rate communication between the FSU and a PRS or a standard clock.

MAKESEGY. The LithoSEIS analysis module which groups together one or more TRACEs and the ACTIVE HEADER LIST into a SEGY file or tape.

MATCH. The process of entering into LithoSEIS the locations of the PRS's.

MESSAGE LINE. The line at the bottom of the computer screen where LithoSEIS displays messages and warnings from the various modules.

MONITOR. A LithoSEIS module to allow the user to examine the activity of a programmed PRS.

MS-DOS microcomputer an IBM-PC/AT, a 286 or 386 class PC work-alike microcomputer with a hard disk, a floppy drive, 640kb RAM, a printer port, one or two serial communication ports and an optional High Speed Link card.

OPTION. A choice which the user invokes by pressing a function key.

ORPHAN. A PRS which must be UPLOADed at an FSU other than the one on which it was DOWNLOADed.

PLOTSEGY. A LithoSEIS module for plotting record sections from SEGY files and the ACTIVE HEADER LIST.

PROMPT-LINE. A line near the bottom of the computer screen where LithoSEIS requests small amounts of input from the user.

PRS. Portable Recording Seismograph The first of a new generation of solid-state digital light-weight instruments capable of recording one to six megabytes of seismic data on one to three components.

PRS-clock. The internal crystal controlled clock of the PRS. This clock is synchronized with a standard clock immediately before the DEPLOYMENT plan is DOWNLOADed into the PRS and is rated against the standard clock immediately before the recorded data files

are UPLOADed from the PRS.

PRS-serial-number A four character unique hexadecimal number that is hard-coded into each PRS and printed on the sides of the PRS. It is used for identifying the PRS.

RATE. The process of rating the external clocks (used to synchronize the PRS-clocks) against Universal Time.

RECEIVER-SITE. A geographical location where a PRS is placed for recording during a DEPLOYMENT.

RECOVER. The process of bringing back data from an ARCHIVE VOLUME onto the hard-disk of an FSU or FHQ.

SEGY. An industry standard seismic data storage format, extended to accommodate refraction data.

SHOT. Detonation of explosive materials under controlled conditions.

SHOT-ID. Identification of a SHOT by a four character name.

SHOT-site. A geographical location where a SHOT is fired.

SITE. A geographical location. One or more sites make up a LINE. A DEPLOYMENT must involve at least one site.

SITE-ID. Identification of a SITE by a four (or less) character name.

STANDARD-CLOCK. A crystal or satellite controlled precision timing device (e.g. GOESclock) that is used to synchronize the PRS-clock when program DOWNLOAD takes place and calculate PRS clock drift when the PRS is UPLOADed.

STATS BOX. A section at the top right of the computer screen in which LithoSEIS presents the user with important information relevant to the current operation.

SYSTEM-directory A DOS directory on a FSU (normally on drive c:) which is called lithosei and holds all of the LithoSEIS system files. The users must not edit or delete any of the files in this directory.

SYSTEM-disk A hard disk drive partition on a FSU (normally drive c:) which holds all of the files that are required to run LithoSEIS as well as DOS and other static files.

SYSTEM-error file A printable file which resides in the data directory on an FSU and holds all run-time error messages. A date and time stamp is provided with each error message. This file has a name identical to the FSU-code and a fixed type of (.err).

SYSTEM-LINE. The top line of the computer screen where LithoSEIS writes obscure system and programming information.

TAG, TAGGING, TAGGER. The means by which LithoSEIS identifies groups of TRACEs or HEADERs for subsequent operations.

TIMED MODE. A mode of operation of LithoSEIS in which recording takes place in predefined windows.

TRACE. A digital seismogram containing header and waveform data from a single recording window.

TRIGGERED MODE. A mode of operation of LithoSEIS in which recording takes place is response to some triggering criteria being met.

UPDATE. The process of refreshing entries in the CATALOGE with new information entered by the user since the creation of those entries.

UPLOAD. A program module in LithoSEIS that communicates with a PRS using a High

Speed Link or a Low Speed Link, reads the PRS serial number, rates the PRS clock against a standard clock and reads recorded data from PRS into TRACE files on an FSU. This TRACE is then known as an UPLOADED TRACE and must either be CATALOGEd or deleted.

UTM. The Universal Transverse Mercator coordinate system. Commonly known as a grid reference.

VISTA. Viewpoints in Seismic Trace Analysis. A programmable seismic trace analysis subsystem which operates on SEGY files produced by LithoSEIS.

WINDOW A period in real time with a start and a duration. In timed mode PRS's are programmed to start recording at the beginning of the windows and continue recording for the duration of the each window in a given DEPLOYMENT. A deployment normally consist of many windows of varying length with time gaps between them. A WINDOW may not be longer than 9 minutes long and WINDOWs must be separated by at least 10 seconds.

Registration

The LithoSEIS maintenance team would like to keep in touch with all users of the package. The users are encouraged to complete this registration form and send to us if they wish to receive new upgrades to the software and manuals.

——— cut along this line ———

- Name and Address:

- Phone Number:
- FAX:
- e-mail:
- Number of PRS4 instruments in use:
- Type of FSU computer:
- Hard disk capacity on the FSU:

Please mail to:

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