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A GRAPHICAL BROWSER INTERFACE FOR THE NAVAL ENVIRONMENTAL OPERATIONAL NOWCASTING SYSTEM

by

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A database management system for the Naval Environmental Operational Nowcasting System has been developed at the Naval Oceanographic and Atmospheric Research Laboratory (NOARL), Monterer, Ca. The systems design presents a high level view of diverse environmental data for meteorologists at NOARL. Currently the NEONS DBMS has a function key based data browser written in 4GL. This browser, however, is unpopular and little used because of its user unfriendliness and limited functionality. This thesis presents a design for a graphical user interface for the browser based on ergonomic design principles. The purpose of this design is to increase user friendliness and enhance functionality over the existing user interface. The design also serves as a framework for the design of user interfaces for other information systems with rich data types. The design has been favorably evaluated and is currently being implemented by the NOARL development staff.

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A Graphical Browser Interface for the Naval Environmental Operational Nowcasting System

by

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ABSTRACT

A database management system for the Naval Environmental Operational Nowcasting System has been developed at the Naval Oceanographic and Atmospheric Research Laboratory (NOARL), Monterey, Ca. The systems design presents a high level view of diverse environmental data for meteorologists at NOARL. Currently the NEONS DBMS has a function key based data browser written in 4GL. This browser, however, is unpopular and little used because of its user unfriendliness and limited functionality. This thesis presents a design for a graphical user interface for the browser based on ergonomic design principles. The purpose of this design is to increase user friendliness and enhance functionality over the existing user interface. The design also serves as a framework for the design of user interfaces for other information systems with rich data types. The design has been favorably evaluated and is currently being implemented by the NOARL development staff.

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I. INTRODUCTION

A. BACKGROUND

A database management system for the Naval Environmental Operational Nowcasting System (NEONS) has been developed at the Naval Oceanographic and Atmospheric Research Laboratory (NOARL), Monterey, Ca. The system's unique data centered design presents a high level logical view of diverse environmental data types. Currently, the data handled by the NEONS DBMS includes satellite data, outputs produced by atmospheric and oceanographic numerical models, climatology data, conventional observations such as aircraft and ship reports, rawinsondes, bathythermographs, drifting-buoy tracks, and satellite images.

The NEONS DBMS uses a commercial relational DBMS as the data management engine to provide users with easy access to environmental data. An interface layer, written in 4GL and C, between application programs and the DBMS is developed to standardize all data access procedural calls.

The computer hardware platform for the NEONS DBMS is a set of two HP9000/835 TurboSRX workstations. The operating system is UNIX with the implementation of the X-11 windows.

Currently the NEONS DBMS has a function key based data browser written in 4GL. This browser is unpopular and little used because of its user unfriendliness, limited functionality, and the length of time required for user response.

B. OBJECTIVES

The main objective of this thesis is to design a graphical user interface for the NEONS data browser that increases user friendliness and functionality over the existing interface and shortens the time required for user response.

C. RESEARCH QUESTIONS

1. Can graphical user interface (GUI) tools be combined with ergonomic principles to design a useful and effective user interface for the NEONS browser ?

2. Can these tools and principles be applied to other information systems with diverse data types ?

D. SCOPE AND LIMITATIONS

The scope of this thesis is to design a graphical user interface for the NEONS browser application. The details of the design are specific to the NEONS system, but the basic framework may be applied to other information systems with rich data types. Implementation details are not discussed in this thesis.

E. LITERATURE REVIEW AND METHODOLOGY

Most of the GUI component descriptions in this thesis are taken from a GUI design paper by Aaron Marcus [Ref. 1]. The ergonomic design principles are derived from a book by C. Marlin Brown [Ref. 2].

The following methodology was used for designing the user interface. First, existing system design documents were carefully read to become familiar with the NEONS system. Second, extensive user interviews were conducted to determine common methods of operation, perceived problems with the existing system, and functional requirements based on user needs. In addition, the researcher performed personal interaction with the system to determine first hand the problems based of the current interface. Results of interviews and system interactions were then collated, analyzed, and classified. Finally the interface was designed based on the requirements of the users and using Graphical User Interface components and ergonomic design principles.

F. ORGANIZATION OF STUDY

The thesis is organized as follows. Chapter II describes NEONS database system, the existing user interface, how it is being used and its problems. Chapter III describes Graphical User Interface components and ergonomic design principles. Chapter IV presents the design for a NEONS graphical browser interface and describes in detail its components and use. Chapter V presents general conclusions, recommendations and areas of further study. All diagrams are included in Appendices.

II. THE NAVAL ENVIRONMENTAL OPERATIONAL NOWCASTING SYSTEM

A. BACKGROUND

The Naval Environmental Operational Nowcasting System (NEONS) provides an integrated system of hardware, software and procedures that support the development of new techniques for the display and analysis of environmental data. The system also supports the implementation of new methods for deriving environmental parameters from indirect sensing techniques, as well as the analysis of environmental data in support of research. The system allows researchers to acquire and ingest a wide variety of satellite and conventional environmental data into a single database. The product of the data analysis from numerical models (in the form of a three-dimensional grid) is also stored in this database.

The database portion of the system provides for data storage and management. The database management system (DBMS) allows the sharing of large volumes of data from many diverse sources between users with differing processing needs. The DBMS also allows users access to the data through a high level interface which isolates them from physical storage and handling details.

An application package featuring a database browser is interfaced with the DBMS. The browser allows a meteorologist to browse the contents of the database without actually extracting all of the various data elements. A meteorologist at NOARL will ordinarily research meteorological conditions for a particular geographic region for a period of time. The browser enables the researcher to examine the database contents and see what data and how many datasets of interest are in the database for that region and time of interest.

B. COMMON BROWSER OPERATIONS

The current users of NEONS commonly perform two basic types of operations using the browser. The first type is to search for specific information to determine whether or not it is contained in the database. This type of information is used by a researcher who is studying a specific aspect of meteorology or by a researcher interested in gathering information on specific regions or specific occurrences of meteorological phenomena. A user would select the specific image sensor, model type or observation sequence he desires and then select the geographic region and time frame that is being studied. Once the browser concludes its search, the user would then examine each dataset that satisfied the search parameters and extract the desired datasets.

The second type of operation commonly performed is to search for information on a specific geographical region. This type of search would be conducted by a user interested in the meteorological aspects of a given region. Using the existing interface, a user would select the ALL option under Images, Models and Observations. He would then select the desired region and time constraints. The browser then conducts its search and the user pages through each dataset that satisfied the search parameters.

Although the mechanics of these two operations are quite similar, the intent is very different. To use a simple analogy, the first operation is analogous to seeing if someone is listed in the phone book. The second operation is analogous to looking through the yellow pages to find the numbers of various services or businesses in a common category. A good user interface should facilitate both types of operation without undue difficulty on the part of the user.

C. STRUCTURE OF NEONS DATABASE

The NEONS database schema is designed to use a commercially available relational DBMS as the database management engine. A database user interface is developed to support the handling of a wide variety of environmental data including satellite images. The NEONS database consists of three separate schemas: IMAGE, GRID and LAT-LON-TIME. These schemas are depicted in Figures 1 through 3 of Appendix A. The three schemas collectively could also be considered as consisting of four realms. These realms are called PRIMARY, ASSOCIATIVE, DESCRIPTIVE and GEOGRAPHIC. The PRIMARY realm contains the high volume data that is of main interest to the user. The ASSOCIATIVE realm contains header information that is associated with each record in the primary realm. The DESCRIPTIVE realm contains information that is common to many records in the primary realm. The GEOGRAPHIC realm contains information about the earth's geography such as rivers, coastlines and political boundaries.

The major tables within the IMAGE schema that are important to the browser, as shown in Figure 1 of Appendix A, are:

IMAGE table- this is a pixel representation of satellite photographs or sensor images. Each record in the IMAGE table may be in either satellite or registered coordinates. IMAGES in satellite coordinates consist of a scan as viewed from the satellite and are referenced by time, line, and sample. IMAGE records in registered coordinates are mapped to a standard projection and are referenced by latitude and longitude. Each image may contain any number of lines, samples, bands and projection overlays. IMAGE records are stored in UNIX files as packed binary pixels. The directory for each image is found in the attribute 'path_name' of the associative table AS_IM. Each image relates to exactly one record in the AS_IM table.

AS_IM Table- this table provides header information for each IMAGE. Each IMAGE instance in the primary realm is associated with exactly one record in the AS_IM table. The attributes that are relevant to the user include:

path_name: UNIX directory name for the IMAGE file.

im_id: unique identifier for the IMAGE instance.

sat_name: name of satellite, found in descriptive table SATELLITE.

sens_name: sensor name found in table SENSOR.

loc_id: geographic location found in table GEOG_LOC.

min_etm: time of earliest data in IMAGE.

max_etm: time of latest data in IMAGE.

AS_BAND Table- this table describes image bands and channels associated with a particular image. Each record in AS_IM is related to one or more records in AS_BAND. Each record in AS_BAND is related to only one record in AS_IM. Relevant attributes of this table are:

band_name: name of image band.

chan_num: channel number for sensor.

number: order number of band within IMAGE.

SATELLITE Table- this table describes meteorological satellites. Each record of this table contains information for one satellite. Each record in AS_IM is related to exactly one record in SATELLITE. A record in SATELLITE may be related to many records in AS_IM. Additionally a satellite has many sensors. Relevant attributes include:

sat_name: satellite name.

SENSOR Table- this table describes satellite sensors. Each record contains information for one sensor. Each record is uniquely identified by attribute sens_name. A record in SENSOR may be related to many records in AS_IM. Any sensor may be found on more than one satellite. Relevant attributes are:

sens_name: name of sensor.

scan_int_dis: distance interval between lines.

scan_wdth_dis: scan width of entire swath.

SAT_SENS Table- this table is an intersection table between tables SATELLITE and SENSOR. A combination of attributes sat_name and sens_name is needed to uniquely identify a record in this table. Attributes in SAT_SENS Table are:

sat_name: satellite name from SATELLITE table.

sens_name: sensor name from SENSOR table.

The tables within the GRID schema that are relevant to the browser, as shown in Figure 2 of Appendix A, are:

GRID Table- this table is made up of data generated by one of several numerical models which predict environmental parameters set along grid points that correspond to coordinates on the surface (or in the atmosphere) of the earth. Each model generates several environmental parameters; such as pressure, moisture, or wind speed; that vary with altitude as well as graphic location and time. Data values for each parameter, level and time are placed in one record for all grid points. Each GRID table is related to exactly one associative record in the AS_GRID table.

AS_GRID Table- this table consists of header information associated with GRID data in the primary realm. Each GRID instance is associated with one record in the AS_GRID table. The attributes of this table relevant to the browser are:

grid_id: unique identifier for GRID instance.

model_type: type of model used, this attribute is a foreign key from GRID_MODEL table.

min_base_etm: epochal time of earliest data in GRID instance.

max_base_etm: epochal time of latest data in GRID instance.

GRID_MODEL Table- this table describes numerical models used in generating GRID data. Each record in AS_GRID is related to one record in GRID_MODEL. A record in GRID_MODEL may be related to many records in AS_GRID. The relevant attribute of GRID_MODEL is:

model_type: name of type of model.

The tables and their attributes relevant to the browser design within the LAT_LON_TIME schema, as shown in Figure 3 of Appendix A, are:

LAT_LON_TIME Table- this table consists of data from actual observations such as drifting buoy tracks,bathythermographs, surface ship reports and rawinsondes. Each of these different types of report is called a sequence type. The data in the LAT_LON_TIME table is organized by sequence types, with each record containing only one sequence type. The list of available sequence types is found in the descriptive table LLT_SEQ. All sequence types use latitude, longitude and time as access keys to permit random access.

AS_LLT Table- this table consists of header information associated with LAT_LON_TIME data in the primary realm. Each LAT_LON_TIME instance corresponds to exactly one record in the AS_LLT table. The relevant attributes of this table to the browser are:

llt_id: unique identifier for each LAT_LON_TIME instance.

seq_type: sequence type of LAT_LON_TIME instance.

min_etm: epochal time of earliest data in LAT_LON_TIME instance.

max_etm: epochal time of latest data in LAT_LON_TIME instance.

LLT_SEQ Table- this table describes the sequence types of the AS_LLT table. Each record in AS_LLT is related to one record in LLT_SEQ. A record in LLT_SEQ may be related to many records in AS_LLT. The attribute seq_id is a candidate key of this table. LLT_PARM contains a list of parameters available for each sequence type. Important attributes of LLT_SEQ are:

seq_type: type of Lat Lon Time sequence, and unique identifier for each type.

seq_id: unique identifier for each sequence type (candidate key).

LLT_PARM Table- this table describes individual environmental parameters that make up each llt sequence type. Important attributes are:

parm_id: parameter identifier number.

parm_name: name of parameter.

LLT_PARM_SEQ Table- this is an intersection table between tables LLT_SEQ and LLT_PARM. The attributes of this table are:

seq_id: identifier number found in table LLT_SEQ.

parm_id: parameter number found table LLT_PARM.

D. EXISTING USER INTERFACE

The current user interface is a text based interface on a non-graphics terminal. Control of the application is accomplished through the use of function keys, which are used to mark selections as well as move backwards or forwards through the selection sequence. A complete representation of all screens of the interface is contained in Appendix B.

As shown in Figure 1 of Appendix B, the main screen presents the user with four choices: Images, Models, Observations, and Regions of Interest. In addition, function keys allow the user to select, clear, quit or request help. Choosing Image allows the user to enter parameters for selection of image data from the database. Choosing Models allows the user to enter parameters for grid data, and Observations allows him to enter parameters for lat_lon_time data. The Region of Interest choice allows the user to enter geographic and time parameters to further constrain the parameters entered for any or all of the prior three choices.

When Image, Model or Observation are chosen, the application program searches the AS_IM, AS_GRID, or LLT_SEQ tables for available satellite names, model types and sequence types respectively. A second screen is then displayed with the available satellites, model types or sequence types. These screens are presented in Figures 2 through 4 of Appendix B. Once the available choices are displayed, the user may either choose all or selectively from the list of available choices. Function keys are used to index and make selections on each screen.

When Region of Interest is selected from the initial screen, a second screen is displayed that allows the user to enter latitude, longitude and time. This is presented in Figure 5 of Appendix B. Subsequently, the user may enter numerical parameters or display a third screen that lists predefined geographical regions for selection. These are represented in Figure 6 of Appendix B.

Once the user has made all the desired selections of images, models, observations, and geographic regions, he/she must back out to the main screen to press the SELECT key in order to invoke the search process for all records satisfying the selected parameters.

The interface will then display the findings of the search by data type. Image data is displayed first, if any was selected, then Model and Observation data. The information display screens are presented in Figures 7 through 15 of Appendix B.

The display screen for Image data consists of two layers as shown in Figures 7 through 10 of Appendix B. Figure 7 and 9 show the "top" layer for registered and satellite images respectively. This display is a join of tables AS_IM, AS_BAND and SATELLITE. The display screen is broken into three parts by double solid lines. The upper part of the display is the list of function keys used to control the interface. The second part informs the user which data type is being viewed, the number of the currently viewed image, and the total number of images found. For instance, Figure 7 is the first of 170 image records that met the criteria of the search. The third part of the display is the information pertaining to that particular image; i.e., the sensor, satellite, location and time of the image.

The second layer of the image display is presented in Figures 8 and 10 of Appendix B. By pressing function key KP5, the available "bands" for the satellite associated with the image record will be displayed. Each satellite sensor operates on one or more channels which have different wavelengths throughout the electromagnetic spectrum. The bands display shows the channel number, its wavelength and the part of the spectrum the channel is in; i.e., visual, IR, UV, etc.

The Models data display is divided into three layers. These screens are presented in Figures 11 through 13 of Appendix B and consist of a join of the tables AS_GRID and GRID_MODEL. The top layer of the display is presented in Figure 11 of Appendix B and is divided into three parts similar to the Image display. The first part lists the various function keys for controlling the display. The second part identifies the screen as grid data, the currently displayed record, and the total number of records found. The third part contains information of primary interest to the user, i.e., the model, version, region and time of the data.

The second layer of the models display shows the available model product parameters for the model being viewed. These products include pressure, ground and sea temperatures, wind speeds, vapor pressure, etc. This screen is shown in Figure 12 of Appendix B. By using a combination of tab and function keys, the user selects a product and views the available levels of that particular product. This is the third layer of the Models display, as shown in Figure 13. It shows all the available levels for a product in the appropriate units and an associated time.

The Observation data display consists of a join of tables AS_LLT and LLT_SEQ. The top layer as shown in Figure 14 of Appendix B is similar to the top layer of the Image display. It shows the record count as well as sequence type, location and time. By pressing function key KP4, a second layer is displayed as shown in Figure 15. This screen lists the available parameters for that particular sequence type and the associated units for that parameter.

E. PROBLEMS WITH EXISTING USER INTERFACE

Though the existing user interface has been operational since October 1989, it is not popular with the majority of the users of the NEONS database. Several reasons contribute to this user 'unfriendliness'. Some of these reasons are due to the design of the user interface itself and others with the functionality of the data browser.

The first reason for the interface's unpopularity is the awkwardness of the control mechanism. Using function keys to control the display is inherently user unfriendly, since the user must divide his attention between the screen and the keyboard in order to perform an operation. Compounding this problem, is the fact that the function keys are not intuitive. The user has to look up the proper key to use for a given operation on the screen display. Then the user has to look down at the keyboard to find the correct key and then look back up at the screen to continue the operation. This process is slow, frustrating, and cumbersome.

A second reason for the interface's unpopularity is the need to navigate through various displays in response to a user request. In many cases the user must traverse several layers to view all the information requested. Additionally, the existing interface does not keep track of the currently selected record, beyond the first layer of information for that record. Should the user forget which record is the current one, he has to back out to the top layer to view the record identifier, then return to his previous position. This process wastes time and adds to the user's frustration.

A third problem is the lack of memory aids. During the initial process of selecting parameters for searching the database, there are no memory aids to remind the user of what they have already chosen from previous data types. For instance, once the user selects the desired parameters from the Images type and proceeds to the Models type, there is no way for them to know what they have already chosen from the Images type. This forces the user to either remember his choices or write them down. This requirement contributes to the frustration of the users.

The fourth problem with the existing interface is the logical sequence of the selection process. Selections for searching the database are listed in the order Images, Models, Observations, and Regions of Interest; as shown in Appendix B. This leads the user to entering time and geographic constraints last. Yet in almost all circumstances the user would want to enter geographic and time constraints first. Ordinarily a user invokes the browser with a particular geographic region and time frame in mind. The user would then look into the availability of sensors, models, or observations. The current interface selection choices are reversed.

Another reason for user dissatisfaction is the lack of a facility for saving user defined searches. For instance, if a user is interested in a particular region and specific sensors, models or observations for a long period of time, he must re-enter these parameters every time he logs on to the system. It would be highly desirable for these parameters to be saved for subsequent use. This would save considerable time for users who examine specific regions, sensors, models or observations repeatedly.

Finally, the current system does not allow users to get a hardcopy printout of search results. The only method to obtain hardcopy on the current system is to print the screen of each display. This is an exhaustive and slow process. The users desire the ability to send the collective search results to a printer for later examination.

The rest of the complaints about the current system dealt with personal preferences stemming from specific areas of interest. These items, although important, are not truly relevant to designing a good user interface. A new user interface should address the six common problem areas of awkward control mechanism, excessive navigation, lack of memory aids, illogical sequence of option selection, inability to save user defined searches, and absence of print options.

The next chapter discusses various Graphical User Interface components and ergonomic design principles that will be used in the design of the new interface.

III. GRAPHICS USER INTERFACE AND ERGONOMICS FUNDAMENTALS

A. INTRODUCTION

Any existing computer system application must have a way to communicate with its user. The computer system is a tool which is meant to serve its user. The common boundary between the computer system application and its user is called the interface. This is "the point where the computer and the individual interact."[Ref. 3] An interface has three main purposes; tell the system what actions to take, facilitate the use of the system, and minimize user errors.

Many types of user interfaces exist. These include textbased, batch, graphical, voice, etc. Graphical user interfaces (GUI) have become particularly popular in the computing world because of their user friendliness and ease of learning. A graphical user interface interacts with the user through a visual dialogue on the computer screen. The dialogue may take many forms and the method the user uses to input information may also vary.

Graphical user interfaces have many components. Windows, menus, control boxes, icons, query boxes and message panels are all parts of a graphical user interface. Most interfaces, however, do not include all of these components. The widespread use of graphical user interfaces began with the marketing of the Apple computer in the early 1980's. Since then many software manufactures have developed GUI's for all different types of hardware architecture and operating systems. Some of the most popular GUI's are WINDOWS, OPENLOOK, MOTIF, OS/2 and NEXTSTEP. Although these systems vary in features and popularity, their intent is the same, to increase the friendliness of the system and satisfaction with computer system applications.

B. GRAPHICAL USER INTERFACE COMPONENTS

The following section is derived from an overview of GUI's and their components done by Aaron Marcus and Assoc. [Ref. 1]

1. Windowing Systems

The vast majority of graphical user interfaces are based on windowing systems that divide the screen display into multiple functional areas that provide a means of controlling multiple applications or manipulation multiple objects within a graphical environment. "The windowing system acts as a front end to the operating system by shielding the user from the abstract and often confusing syntax and vocabulary of a keyboard-oriented command language."[Ref. 1:p. 7] Windowing systems vary in the location of the code that implements the system. Some systems are **Kernel** based where the windowing system is provided by some portion of the operating system itself. The advantage of kernel based architectures is that they provide high levels of interactivity with the user. The major disadvantage of a kernel based GUI is that it is largely dependant on the resources of a single machine and cannot be shared over a network. Other GUIs are based on the **Client-Server** architecture. This architecture allows multiple machines to share windowing system resources among several different processes and machines. A server is a computer that provides various computing resources to other computers (clients) on a network. For a windowing system, the server would provide the windowing capability to its clients. The major disadvantage of the client-server architecture is that it may have a slow response time if heavy load is placed on the system.

Windowing systems also vary in the way that the windows are managed. The management facilities allow the system to maintain the relationships between windows as they are moved, re-sized and otherwise changed.

The way the windowing system is perceived by, and interfaces with the user is determined by several standard components. These components are windows, menus, controls and control panels, query and message boxes, and the keyboard/mouse interface.

2. Windows

Windows are any area of the visual display that can be moved, sized, and placed independently on the screen. There are three different types of window arrangements; Tiled, Overlapping and Cascading. Tiled windows are arranged so that no window overlaps another, and all windows on a screen are completely visible. Many times Tiled Windows are fixed in size so that window size cannot be changed. If the size is not fixed, the other windows on the display must expand or shrink in relation to the window being sized and available space. Overlapping Windows are able to overlap the other windows on a display. These windows have a depth appearance in that the window appearing closest to the user is the one currently in use while those "below" it are at a deeper level of the application. Overlapping Windows often appear to be a stack of papers and are managed in a similar manner. Cascading Windows are a special case of Overlapping Windows in that the windows are automatically arranged to keep any window from being completely obscured. This approach conserves display space while allowing any window to be brought to the top of the stack without having to "page" through the entire stack. The different types of windows are shown in Figures 1 through 3 of Appendix C.

Window appearances may vary with each individual system; however, most systems have a well defined border region that is controlled by the windowing system itself and a content region that is controlled by the application program being run within the window. "A recent trend in graphical user interfaces is the creation of windows and window components that appear to be three-dimensional."[Ref. 1:p. 8] The three-dimensional effect gives users the illusion of dealing with actual physical surfaces and controls they are used to, such as knobs or tablets. Most windows have a standard set of controls to open, close, scroll and resize the window in use. These controls vary in appearance but have the same net effect among various windowing systems.

3. Menus

Menus are a method for the user to issue commands without having to enter text from the keyboard. Menus are most popularly used within applications programs; however, some may be used by the windowing system as well. Menus divorce the user from having to remember specific command syntax for desired functions. Most systems require the user to select the object to be manipulated and then select the appropriate command from the menu. Menus normally display or indicate to the user four pieces of information: 1) the current state of the object to be manipulated, 2) whether or not a menu item is currently eligible for selection, 3) the presence of attached submenus, 4) the keyboard shortcut that can be used to access a particular item. Visual feedback must also be provided to indicate which menu item the cursor or mouse pointer will select at any given time.

The way a menu can be manipulated and the way it responds to user interaction also varies. Most menus can be described by their Representation, Duration and Navigation characteristics.

Representation characteristics are concerned with how the menu appears during use. Menus can be Implicit pop-up menus that appear whenever the mouse button is depressed in a particular area of the display, Explicit pop-up menus that appear only when a specific symbol or control is chosen, or Pulldown menus which are attached to a menu bar along the top edge of the window.

Duration characteristics describe how long a menu is displayed. Static menus are displayed continuously in the same location for the duration of the application. Dynamic menus are displayed only until the user makes a selection.

Navigation characteristics describe how the menu hierarchy is traversed. Menus may be press-drag-release in which the mouse button is depressed and the pointer dragged across the particular selection; or menus may be click-position-click in which the pointer is positioned over the desired selection and the mouse button is clicked.

Some examples of menus are shown in Figures 4 and 5 of Appendix C.

4. Controls and Control Panels

Controls and Control Panels allow the user to adjust or change aspects of the windowing system itself. This is in contrast to menus which normally allow the user to control the application. Controls normally fall within five different classes; Exclusive Settings, Non-exclusive Settings, Proportional Slider, Lists and Text fields, and Command Buttons.

Exclusive Settings allow the user to select exactly one value from a group of possibilities. These are very similar to the preset buttons on a car radio in that one specific value (i.e. station) may be chosen at a time.

Non-exclusive Settings allow the user to select a range of values from a set of attributes. These values can be independently set or cleared by the user.

Proportional Slider Controls are used to control any system attribute that can be modified continuously within a defined range. Sliders normally display parameters that have more options than can easily be represented using an exclusive setting. Scroll bars are a good example of a proportional slider type of control.

Text fields allow the user to enter alpha-numeric data into a system. Lists are read only mechanisms for making selections from groups of existing objects. Lists for groups of items too numerous for a single display are often scrollable using a proportional slider.

Command Buttons are used for instructions that will perform a particular system action. They ordinarily produce immediate change in the state of the system. Command buttons provide the same services as menus in many respects except that command buttons are immediately available and the user doesn't have to navigate through the menu system. Figure 6 of Appendix C shows examples of different types of controls and control boxes.

5. Query and Message Boxes

Query and Message Boxes are special cases of dialogue boxes that are initiated by the application. Message boxes normally provide the user notification that a dangerous or illegal state has been entered. The user is often presented with several explicit options, one of which must be chosen before operations can continue. Query boxes allow the system to request a specific piece of information from the user. Ordinarily they prompt the user for information in the form of a question, which the user must answer in order to continue. An example of a query box is shown in Figure 7 of Appendix C.

6. Mouse and Keyboard Interface

Mouse and Keyboard Interface are the means for actual interaction between the user and the system. The mouse is used to position, select, or activate different objects on the screen. Many systems also allow for keyboard shortcuts that can activate certain functions by using keystrokes.

In the next section, we discuss ergonomic concepts that will be used in the design of the data browser interface of the next chapter.

C. ERGONOMIC CONCEPTS

Webster's defines Ergonomics as "the study of the mental and physical capacities of persons in relation to the demands made upon them by various kinds of work."[Ref. 4] In building an effective user interface, ergonomic considerations must be taken into account in order to make the interface as efficient and user friendly as possible. "Most useful design philosophies for developing user-oriented human-computer interfaces consider the computer system simply as a tool to aid the user in performing tasks."[Ref. 2:p. 4] This philosophy facilitates the design of a system that will simplify rather than complicate the users tasks. In order to implement this philosophy, several design factors must be taken into consideration. According to C. Marlin Brown [Ref. 2] these factors are: Allocation of Function, Mental Models, Consistency, Physical Analogies, Expectations and Stereotypes, Stimulus-Response Compatibility and Ease of Learning/Use. These factors are discussed briefly in the following sections.

1. Allocation of Function

Allocation of Function has to do with which functions should be performed by the user and which should be performed by the system. Ideally the system should perform functions that computers perform well, and the user should perform functions that humans perform well. Rules of thumb for allocation of function include:

1) Minimize the amount of memorization of commands, syntax and rules required of the user.
2) Minimize the amount of mental manipulation of data on the part of the user.
3) Minimize requirements to enter data.
4) Provide system aids such as checklists, online help and summary displays that reduce the amount of mental processing required of the user.
5) The system should present an integrated composite view of complex relationships of patterns between variables.

2. Mental Models

Mental Models are concerned with the cognitive representation and conceptualization of a systems mechanics on the part of the user. The user's mental model of the system provides a framework for understanding how the system works and allows the user to predict the appropriate procedure for a desired outcome. The users understanding of what is actually going on within the system is not important; however, the conceptualization of the correct sequence of operation and the understanding of the systems function at the virtual machine level is absolutely vital for the user. The design principles of consistency, physical analogies, user expectations and stimulus-response compatibility are conducive to the development of effective mental models.

3. Consistency

Consistency deals with how easily the user will be able to form a mental model of the system. If identical functions in different parts of an application are consistently represented, the user will be able to mentally model the systems performance much more easily. Consistency of location for like functions/displays also aids the user in knowing where to look.

4. Physical Analogies

Physical analogies rely upon the user's tendency to create an analogy of the system in a physical sense. The use of icons in graphic displays/interfaces is an attempt to capitalize on this tendency. The user responds more quickly to a physical representation of a familiar object than to a textual or other representation.

5. Expectations and Stereotypes

Expectations and Stereotypes also relate to the user's mental model in that a user expects certain things to happen when certain commands are given. Expectations relate very closely to consistency in that if commands are consistent they will reinforce the users expectations of what will happen for any given command. For instance, if the QUIT command is used to exit an application, the user will come to expect QUIT to mean "exit the application" throughout the system.

6. Stimulus-Response Compatibility

Stimulus-Response Compatibility refers to the relationship between a given stimulus and the appropriate response. This principle requires that a given display and the corresponding response on the part of the user be considered. The user should be able to respond proportionately and without undue difficulty. For instance, if the display requires close attention to the screen, the user should not have to take his eyes off the screen in order to make a response.

7. Ease of Learning and Use

Ease of Learning/Use is the extent to which a novice user can learn the system and which a knowledgeable user can perform tasks with minimal effort. The goal of a human-computer interface is to maximize the ease with which a user can learn and use the system.

The aforementioned factors all combine to contribute toward this goal. Other factors may also detract from ease of use such as performance requirements or hardware constraints.

Overall the interface designer must attempt to blend ergonomic, performance and hardware factors to the maximum benefit of the user while retaining maximum functionality from the system.

D. GRAPHICAL USER INTERFACES AND PRINCIPLES OF ERGONOMICS

The reason for the growing popularity of Graphical User Interfaces is their application of ergonomic concepts to enhance the friendliness of a computer system.

Allocation of Function is accomplished through the use of menus, control panels and query/dialog boxes. Menus minimize the amount of commands that must be memorized because commands are invoked by selecting from a displayed menu of options. Control panels minimize the amount of data manipulation and entry by the user since in many cases available options are listed, and the user simply chooses those desired. Query/dialog boxes provide system aids and memory aids to question, remind or direct the user during different stages of operation.

The order and manner in which tools are combined for a GUI design aid the user in forming a Mental Model of how the system works at a virtual level. Using commands and displays that are consistent with the task being performed is closely related to how easily a user is able to assimilate a system. Using Windows that are tiled in proportion to their importance or overlapped in their order of use, aids the user in creating a physical analogy in his mind on how the system operates. Consistency and using familiar commands throughout an application aid the user in developing Expectations and Stereotypes about a system.

The graphical manner of the interface aids Stimulus Response Capability of a user. By pointing and selecting with a mouse, the user can focus his attention solely on the screen instead of dividing his attention between the screen and keyboard.

Ease of Learning and Use is also served by using consistency and good mental model building within the design. The mouse interface aids in learning, since a user only needs to be able to move the mouse as opposed to knowing how to type.

In designing a GUI all of these influences must be considered as well as the user's thought processes and level of experience. The designer should strive to maximize ergonomic factors while meeting performance and functional requirements. A good design will balance these components to achieve maximum usability and functionality.

IV. THE NEONS BROWSER GRAPHICAL USER INTERFACE DESIGN

A. DESCRIPTION

The browser portion of the NEONS application is designed to allow users to easily display data from the NEONS database to meet their information requirements. As described in Chapter II, the types of data the browser must search and display are diverse and varied and include satellite images, model forecasts, and local weather observations.

The design for the NEONS browser graphical user interface combines user requirements and ergonomic considerations to provide for maximum functionality and user friendliness. The design corresponds to two logical phases. The first phase, the selection phase, allows the user to enter various parameters of data sets for the browser to search for. The second phase, the display phase, displays information on the data sets found by the browser's search. The interface for both phases consists of a set of windows, pulldown menus, and pop-up dialog boxes. These tools provide ease of use, a higher level of functionality, and are simpler and easier to understand and use.

Although this design is specific to the NEONS database, the basic framework could be applied to any information system with rich and varied data types. The proposed user interface would be easily adaptable to operational level systems in applications such as military intelligence, logistics, or census data.

B. SELECTION PHASE

As depicted in Figure 1 of Appendix D, the main screen for the selection phase consists of a static menu bar across the top of the screen listing the main choices available for a typical operation. Below the menu bar is the map window, which consists of either a mercator projection of the world or polar stereographic projections. Inside the map window is a movable box used to select a geographic region for which the browser will search. At the bottom of the screen are control buttons to adjust the size of the movable box. The components of the main menu are explained in detail in the following sections.

1. Main Menu Bar

The main menu bar is a static menu that runs across the top of the screen. The main menu consists of four choices that enable the user to control various aspects of the display as well as to easily perform the selection process. These choices are FILE, CONTROL, SELECT and SEARCH.

a. FILE pulldown menu

The first choice on the main menu is the FILE option. Clicking on this option opens a pulldown menu that allows the user to perform file operations.

(1) RETRIEVE option. The first option on the FILE pulldown menu is the RETRIEVE option. This option allows retrieval of search parameters that were previously saved using the SAVE option. Clicking on this option opens a pop-up dialog box, as shown in Figure 2 of Appendix D. This box consists of a textfield/memory aid line at the top of the box, a scrollable box with a proportional slider control listing previously saved search parameter files, and two control buttons marked RETRIEVE and CANCEL. To retrieve a search parameter file the user would select a file by clicking on its name in the scrollable box, then clicking on the RETRIEVE control button. This action would invoke a file retrieval routine to retrieve the designated file. If the user wants to abandon the retrieval of a file, he would click on the CANCEL control button which would return the user to the FILE pulldown menu. The RETRIEVE pop-up box is dynamic in nature in that it is only displayed until the user either retrieves a file or cancels the operation.

(2) SAVE option. The second choice on the FILE pulldown menu is SAVE. This option allows saving of parameters currently defined by the SELECT main menu option and

the map display. Clicking on the SAVE portion of the FILE pulldown would activate a pop-up dialog box, as shown in Figure 3 of Appendix D. Similar to the RETRIEVE option, this dialog box consists of a textfield/memory aid line at the top, a scrollable box with a proportional slider control and two control buttons marked SAVE and CANCEL. The user has two options for saving a file. He may save the file to a new filename or overwrite a previously saved file. If the user desires the former, he would click on the textfield, type in the new filename, and click on the SAVE button. This action would invoke the save routine and save the file to the desired filename. The user is then returned to the FILE pulldown menu. If the user desires to save the parameters to a previously saved filename he would click on that filename in the scrollable box and then click on the SAVE button. The SAVE dialog box is dynamic in duration since it only lasts until the user has saved a file or canceled the operation.

(3) DELETE option. This option allows the user to delete a file previously saved. Clicking on the DELETE portion of the FILE pulldown activates a pop-up dialog box, as shown in Figure 4 of Appendix D. This dialog box consists of a textfield/memory aid line at the top, a scrollable box with a proportional slider control and two control buttons marked DELETE and CANCEL. To delete a file, the user simply clicks on the desired filename and then on DELETE. If the user

decides to abandon the delete process, he would simply click on the CANCEL control button which would return the user to the FILE pulldown menu without deleting any files.

(4) DISPLAY option. This option bypasses the selection phase and goes directly to the display phase. If a user wishes to view search results previously saved, he would click on the DISPLAY portion of the FILE pulldown menu which would then take the user to the first screen of the display phase.

(5) EXIT option. This option exits the browser application of the NEONS database system.

b. CONTROL Main Menu Option

The second choice on the main menu bar is CONTROL. Clicking on the CONTROL option of the main menu activates the Map Display Settings pop-up control panel, as shown in Figure 5 of Appendix D. This control panel consists of two sections labeled Geographic Options and Display Options, and two control buttons labeled ACCEPT and CANCEL.

(1) Geographic Options section. This section consists of four exclusive setting buttons (i.e., only one button can be selected at a time) that allow the user to set up the map display portion of the main screen. The first setting is Start mercator @ 0 deg lat. This setting, which is the default setting, starts the left edge of the map display at 0 degrees latitude. The second setting is Start mercator

@ 180 deg lat. This setting starts the left edge of the map display at 180 degrees latitude. The third setting is North Polar Stereographic, which makes the map display a northern polar stereographic projection. The fourth setting is South Polar Stereographic, which makes the map display a southern polar stereographic projection.

(2) Display Options section. This section consists of three non-exclusive settings that may further enhance the map display. The three settings are Lat-Lon lines, Political boundaries, and Rivers. These three settings turn on/off the display of latitude-longitude lines, political boundaries and rivers respectively. The user may turn the settings on/off by clicking on the box to the left of the desired setting. The default for these settings is off.

Once the user has selected all the desired settings he will then click on the ACCEPT control button at the bottom of the control panel. If the user wishes to make no changes or return to the previous settings, he may click on the CANCEL button which will return him to the main screen.

c. SELECT main menu option

The third option on the main menu is the SELECT option. This option allows the user to select the desired parameters for the browser search. Clicking on the SELECT option of the main menu activates the select pop-up control panel as shown in Figure 6 of Appendix D. The control panel consists of four sections and two control buttons.

The first three sections are labeled IMAGES, MODELS and OBSERVATIONS. Each section consists of a number of non-exclusive settings. The user would select desired sensors, model types, or sequence types by clicking on the appropriate setting. To deselect an item the user would click on the setting a second time.

The fourth section is labeled TIME. The user would enter the desired time parameters using this dialog box. The box consists of two textfields marked MIN: and MAX: and an exclusive control button labeled GLOBAL TIME SELECT. To enter specific time parameters the user would click on the textfields and type in the appropriate times. To select all time up to the present, the user would click on the GLOBAL TIME SELECT button.

In the lower portion of the control panel are the ACCEPT and CANCEL control buttons. By clicking on the ACCEPT button, the user accepts all the parameters selected. Clicking on the CANCEL button discards all the selected parameters and returns the user to the main display.

d. SEARCH main menu option

The fourth and last option on the main menu is the SEARCH option. By clicking on this option the user opens the search pulldown menu, as shown in Figure 7 of Appendix D. The search pulldown menu consists of three options; SCREEN, PRINTER, and BOTH.

(1) SCREEN option. Clicking on this option activates the browser search routine and displays the search results to the terminal screen.

(2) PRINTER option. Clicking on this option activates the browser search and sends the search results to the printer.

(3) BOTH option. Clicking on this option activates the browser search routine and sends results to both the screen and the printer.

Selecting the SCREEN or BOTH options on the SEARCH pulldown menu terminates the Selection Phase of the application and initiates the display phase. If the PRINTER option is chosen, the search will be conducted; however, the user will remain in the selection phase to either make another search or exit the application.

2. Map Display portion

The map display portion consists of an upper and lower border band, an interior containing the map display, and a movable box, as shown in Figure 1 of Appendix D. As described earlier, the map display can be a mercator projection of the world beginning at 0 or 180 degrees latitude or a north/south polar stereographic projection. The movable box allows the user to choose the geographic region for the database search.

The box is activated by moving the mouse into the box on the map display and clicking the left button. The box could then be anchored by clicking the left button again, thus choosing the search region. In this case the box will no longer follow the mouse movements. The border bands separate the map portion from the upper and lower portions of the display and also show the lat-lon coordinates of each corner of the movable box. The coordinates of the northwest corner of the box are shown in the left part of the upper border band. The coordinates of the northeast corner of the box are shown in the right portion of the upper border band. Similarly, coordinates of the southern corners are shown in the lower border band.

3. Size Controls and GLOBAL GEOG Button

Beneath the map portion are four control buttons for increasing and/or decreasing the size of the movable box. The box size would be increased or decreased by two degrees of latitude or longitude by clicking on the appropriate button. Box size could be changed rapidly by holding down the mouse button while clicking the appropriate size control button. The two control buttons on the left half of the screen change the box size horizontally, and the two buttons on the right side change the box size vertically.

Clicking on the GLOBAL GEOG button selects the entire world as the geographic parameter for the search. This dispenses with the need for the user to expand the box to engulf the entire world map on the map display.

Once the search is initiated, by selecting one of the SEARCH options, control is transferred to an event handler which invokes an SQL procedure based on the parameters chosen. The event handler "remembers" all search parameters selected and translates them into an SQL statement. For instance if a user selected Image sensor NOAA AVHRR, time parameters from 010001Z Jul 91 to 100001Z Jul 91, and geographic parameters (0 degrees latitude, 50 degrees North longitude), (20 degrees East latitude, 50 degrees North longitude), (0 degrees latitude and longitude) and (20 degrees East latitude, 0 degrees longitude), the event handler would translate this request to the following SQL statement:

```
SELECT AS_IM where sensor = NOAA AVHRR and
                  min_etm > 010001Z Jul 91 and
                  max_etm < 100001Z Jul 91 and
                  loc_id  = GEOG_LOC
```

Where GEOG_LOC is determined by the event handler as anything falling within the geographic parameters selected on the map display by the movable box, i.e., the coordinates listed above.

Appropriate SQL statements would be generated for every set of parameters chosen in the SELECT control panel.

These statements would then be passed to the SQL engine which performs the search on the database.

The SQL engine returns the results to a data structure that extracts the appropriate fields from those selected by the SQL statement. These fields are then displayed in the appropriate windows during the display phase of the application.

4. Comments on the Design of the User Interface for the Selection Phase

As described in the previous section, the main screen of the display section is designed to enhance user friendliness and meet functionality requirements in the simplest possible manner.

The choices on the main menu are ordered in a logical fashion to assist the user in building a mental model of the system and sequence of operation. For most users the order of operation would be either to retrieve a file (the first option on the FILE pulldown), or to set up the display as best suits his purpose (using the CONTROL pop-up control panel). The user would next select the parameters for a new search, or possibly modify or add parameters on a retrieved search (using the SELECT option). The user would then perform the search. Thus the order of the menu guides the user in formulating a mental model of the sequence of operation of the selection phase.

The same principle applies to the ordering of the options on the pulldown menus. These options are ordered according to logical sequence and probability of use, with logical sequence taking precedence. For example, on the FILE pulldown, the RETRIEVE option is displayed at the top because it is the most likely option to be selected first. Similarly the SAVE option follows the RETRIEVE option because it is most likely to be selected next. DELETE comes after SAVE because logically, in the users mind, you must save something before you can delete it. Similarly, DISPLAY comes fourth because a search must be made before you can display it. The EXIT option is last because, ostensibly, it is the last thing a user would do.

The map window is used for the selection phase because it minimizes the amount of data manipulation and entry on the part to the user. The user can relate to the physical analogy of a map as compared to any other method of entering geographic parameters. The user can simply find the area he wants to study and select it using the movable box.

The movable box is used for functional reasons. The box allows the user to select an area at the border of the map display that reaches "around the world" to the other side of the map display window. For instance, if the map display were set to begin at 0 degrees latitude but the user wished to select an area from 20 degrees East latitude to 20 degrees

West longitude, the box would wrap around the display to allow this capability. This capability is not a necessity since the map display can be started at 0 degrees or 180 degrees latitude, but it is a desirable and useful feature. The box coordinates on the corners of the border sections simply relates to the users physical analogy of the map and allows the user to quickly realize where the box is with respect to latitude-longitude coordinates.

The size control buttons are used in the design because of their physical analogy to actual controls. Since they increase and decrease the size of the box, the user is able to quickly relate to their purpose and use. Their placement at the bottom of the map display is in line with the Expectations and Stereotypes concept of ergonomic design as they are placed similar to many controls in the physical world.

Placing the horizontal size controls on the left and the vertical on the right enables the user to adjust the size of the box easily. The user can first size the box in one dimension and then the other without having to move the mouse pointer from one side of the screen to the other.

The pop-up dialog boxes for RETRIEVE, SAVE and DELETE are used because this is the best way to provide a visual and intuitive way to display options from which the user can select. The memory aid lines at the top of the dialog box relate to the ergonomic concept of Allocation of Function in that they provide a system aid to reassure the user as to what is actually selected. The scrollable box that lists filenames minimizes the amount of memorization required of the user and also eliminates data entry. The placement of the action control buttons on the left and CANCEL on the right in all of the dialog boxes is to maintain consistency. On all dialog boxes and control panels the button that initiates action is on the left and the one that cancels is on the right. This also relates to the ergonomic concept of Expectations and Stereotypes because most people mentally process things from left to right, and the natural choice is the button on the left.

Control panels are used for the map display settings and for selection search parameters because this is the best way to display all available options and allow the user to select, deselect and/or reselect whatever he desires. The control panels are divided into logical sections to aid the users physical analogy of the system and mental model building. In these control panels, the exclusive settings are activated and deactivated by on/off, "radio button" type controls, and the non-exclusive settings are depicted by checkboxes. This scheme is strongly connected to physical analogies in that using a "radio button", you can only select one at a time. Checkboxes on the other hand, suggest the selection of many options.

The design of the Search Parameter selection control also allows the user to see all the items selected for the search at once. This applies to the ergonomic concept of Allocation of Function since the system "remembers" the choices for the user. The time parameter entry box is ordered logically in that the earliest time is entered first, and the latest time is entered last. This relates to the users mental model of the flow of time.

Overall the design of the selection phase incorporates as many ergonomic concepts as possible while remaining highly functional. The user uses the keyboard in only two instances: Time Parameter entry and new file name entry in the SAVE AS function. Otherwise, all operations are done by pointing and clicking, using the mouse. Use of the mouse conforms with the ergonomic concept of Stimulus-Response Capability, since hand to eye coordination in this case is much more natural to the user than using the keyboard. Using the mouse also conforms with the concept of Ease of Learning/Use, since the user only has to know how to point and click with the mouse as opposed to knowing how to type.

C. DISPLAY PHASE

The screen for the display phase consists of a static main menu at the top of the screen and a series of tiled windows. This arrangement allows the user to view all information on any given data type simultaneously. As shown in Figures 8 through 10 of Appendix D the combination of windows that constitute the display screen varies depending on the data type displayed. The reason for this variation is that different data types have different areas of information that are pertinent to the user. The display phase also has saving and retrieving capabilities similar to the selection phase. The components of the main screen of the display function are explained in detail in the following sections.

1. Components

a. *Menu bar FILE option*

The main menu bar runs across the top of the display screen. The first choice on the main menu, FILE, activates the files pulldown menu, as shown in Figures 11 through 13 of Appendix D. The FILE pulldown menu consists of five choices as follows:

(1) RETRIEVE option. The RETRIEVE option activates the retrieve pop-up dialog box, as shown in Figure 11 of Appendix D. This option allows a user to retrieve and display a search output previously saved. The mechanics of

this operation are similar to that of the RETRIEVE option in the selection phase.

(2) SAVE option. The SAVE option activates the SAVE pop-up dialog box, as shown in Figure 12 of Appendix D. By using this option, the user can save the display output directly to a file. The mechanics of the save operation are similar to that of the SAVE option in the selection phase.

(3) DELETE option. The DELETE option activates the delete pop-up dialog box, as shown in Figure 13 of Appendix D. This allows the user to delete an output file previously saved. The mechanics of this operation are similar to that of the DELETE option in the selection phase.

(4) SELECTION option. Clicking on the SELECTION portion of the FILE pulldown returns the user to the selection phase main screen. This enables the user to make another browser search without exiting the browser application.

(5) EXIT option. The EXIT option exits the browser portion of the NEONS system.

b. Menu bar IMAGES option

By clicking on the IMAGES option of the main menu, the IMAGE display screen is activated, as shown in Figure 8 of Appendix D. The IMAGE display screen consists of three static, tiled windows. On the left of the screen is a scrollable window, labeled IMAGES, with a proportional slider control. This window displays a list of Image datasets found by the browser search. The information in this window includes the sensor name and date-time group of an image dataset. On the right of the screen is the IMAGE INFO window, which contains specific information on the dataset selected in the IMAGES window. Below the IMAGE INFO window, is the AVAILABLE BANDS window, which displays band channel and wavelength information on the Image dataset selected in the IMAGES window. The user would select a dataset in the IMAGES window by clicking on it with the left mouse button. The associated information would then appear in the IMAGE INFO and AVAILABLE BANDS windows. A dataset could be selected/deselected for extraction by pointing and clicking the right mouse button on its name. An asterisk is used to highlight an Image dataset selected for extraction. The IMAGES display screen is the default screen for the display phase, even if no Image datasets were found during the browser search.

c. Menu bar MODELS option

Clicking on the MODELS portion of the main menu activates the models display screen, as shown in Figure 9 of Appendix D. The MODELS display consists of four static, tiled windows. On the left of the screen is the MODELS window, a scrollable window with a proportional slider control. This window displays a list of model names and date-time groups for the model datasets found by the browser search. The top window on the right side of the display is the MODEL INFO window. This window displays specific information on a model dataset selected in the MODELS window. Below the MODEL INFO window is the AVAILABLE PRODUCTS window. This is a scrollable window with a proportional slider control that displays a list of model parameters and their associated level types for the dataset selected in the MODELS window. Below the AVAILABLE PRODUCTS window is the AVAILABLE GRID FIELDS window. This is also a scrollable window with a proportional slider control that displays level and forecast time information for the model parameter selected in the AVAILABLE PRODUCTS window.

Model datasets and parameters are selected for viewing and extraction in the same manner as the Image datasets. The first item in the MODELS window is the default selection for the model display screen.

d. Menu bar OBSERV option

Clicking on the OBSERV option of the main menu bar activates the observation display screen, as shown in Figure 10 of Appendix D. This screen consists of three static, tiled windows. On the left of the screen is the LLT SEQUENCES window, which displays a list of sequence types and date-time groups for all observation datasets found by the browser search. The top window on the right of the screen is the SEQUENCE INFO window which presents specific information on the dataset selected in the LLT SEQUENCES window. Below this window is the AVAILABLE PARAMETERS window, which is a scrollable window with a proportional slider control that displays the available sequence parameters and their associated units for the dataset selected in the LLT SEQUENCES window.

A dataset is selected for viewing and/or extraction in the same manner as the previous display screens. The first dataset in the LLT SEQUENCES window is the default selection.

e. Menu bar EXTRACT option

Clicking on the EXTRACT option of the main menu bar invokes the extraction process. This process extracts from the database all datasets marked for extraction.

2. Comments on the Design of the User Interface for the Display Phase

The layout of the display phase screen is designed to maximize the information displayed on a dataset, thus eliminating the need to traverse several screens or levels. Allowing the user to see all information for a data type at once, conforms to the principle of Allocation of Function, since the user can comprehend the information much easier by viewing all the information for a particular dataset simultaneously, as opposed to paging back and forth through several screens.

The order of options on the main menu corresponds to the logical division of information as viewed by the user. The individual data display windows are divided up logically as well. Information that is logically separate is displayed in a separate window. This technique reinforces the users pre-existing mental model of how information is structured. The windows on the left side of the screen allow the user to view all datasets found by the search, while the windows on the right side are used to display specific information to the user on a desired dataset. This arrangement conforms with the ergonomic principle of Mental Models since the user mentally divides the display functions into logical sets.

The FILE pulldown options are a new feature that allow the users to save, retrieve and delete search results, a desirable feature that was missing in the previous design. To maintain consistency throughout the application the controls and dialog boxes are laid out similar to the selection phase. This conforms with the ergonomic principles of Consistency and Ease of Learning/Use.

Scrollable windows and boxes are used to give the user a "navigational" frame of reference. By scrolling through a list of datasets, the user can see his current position in the "stack" of datasets he is viewing. This ability also allows the user to go directly to any dataset in the "stack", as opposed to having to move sequentially through the datasets as in the previous system. The use of scrollable windows and boxes conforms to the ergonomic principles of Mental Models and Allocation of Function.

Overall, the display phase screens are designed to maximize visibility of all information pertinent to the user while simplifying the background tasks of screen navigation and logical separation of function and information. The design is analogous to a desk top where a person has one major item of interest and several other minor items that relate to it. The major item would be in the most visible place on the persons desk while other items would surround it in some type of logical fashion. The same principle is applied to the display screens in that the main information of interest, appears closest to the center of vision on the screen. The supporting windows surround it in a logical sequence. This design analogy supports the ergonomic principle of Physical Analogy, since the user can relate the system to a physical system that he is familiar with.

V. CONCLUSIONS AND RECOMMENDATIONS

The browser application of the NEONS database system is a highly useful tool for the meteorologist at NOARL. Unfortunately, the current function key based interface is unpopular and little used because it is unfriendly and hard to use. The user has to navigate through a large number of screens to receive information pertaining to a single request. Because it is a function key based interface, the user has to continually divide his attention between the keyboard and the screen. Moreover, the sequence for selecting parameters is not a logical one. In addition, the current interface does not provide capabilities for saving search parameters or search outputs for later use. There is also no capability for printing a search output for later examination.

To remedy this situation, this thesis developed a new graphical user interface for the data browser that addresses the major drawbacks of the existing interface. The major features of the new interface are as follows. First, all information pertinent to a query is displayed simultaneously through the use of windows. Second, menus, pop-up control panels, and control buttons are used extensively to issue commands and accept user choices, thus allowing the user to maintain his attention solely on the screen. Menu options are arranged in logical order, and windows are layered in a fashion so as to reinforce the users mental model of the system. Capabilities are included in this design for saving, retrieving, and printing search parameters and outputs; therefore, increasing the functionality and versatility of the system.

The graphic browser interface design presented here could be used as a framework for the design of user interfaces of other types of information systems with rich data types. For example a military intelligence information system could use this browser design as follows:

- -A geographic region of interest would be chosen using the map display.
- -Parameters for enemy Air, Ground or Naval assets would be chosen from the Select panel as shown in Figure 1 of Appendix E.
- -Time parameters would be entered in the time box of the Select window.
- -Browser results could be displayed separately or together to form an integrated picture of the tactical/strategic situation.

Other potential uses of the browser design include geographic information systems such as census data, crime statistics, marketing demographics, etc. Further study could be conducted to adapt this browser design for any of these applications.

A. LESSONS LEARNED

The current interface was designed and implemented by the development staff at NOARL without adequate consultation and interaction with the intended users of the system. This resulted in an interface that was functional yet unused due to its unfriendliness. The major lesson learned during research for this thesis is that in building an effective system design, the intended users must be consulted and interacted with throughout the design process. This is particularly important for the design of the user interface. A system that is functional but unused is as bad as no system at all. To insure that a system will be used, a designer or developer must understand the task being performed as well as the thought processes of those performing the task. This could only be achieved through extensive interviews with users, personal interaction with the existing system, and intimate knowledge of the application area.

B. RECOMMENDATIONS

This thesis recommends implementation of the graphic browser interface design described. This design will increase the functionality and user friendliness of the browser application. The graphical interface design will transform the browser into a useful and effective tool by incorporating all the necessary ergonomic considerations previously discussed as well as many functional features deemed desirable by the current users of the system.

An X-WINDOWS toolkit could be used to implement the proposed design. X-WINDOWS is compatible with the current hardware and operating systems in use at NCARL.

C. AREAS FOR FURTHER IMPROVEMENT

Areas of potential further study include adding help facilities to the proposed design and conducting a follow on study to the implementation to determine if user satisfaction with the system has improved.

APPENDIX A

NEONS DATABASE SCHEMA

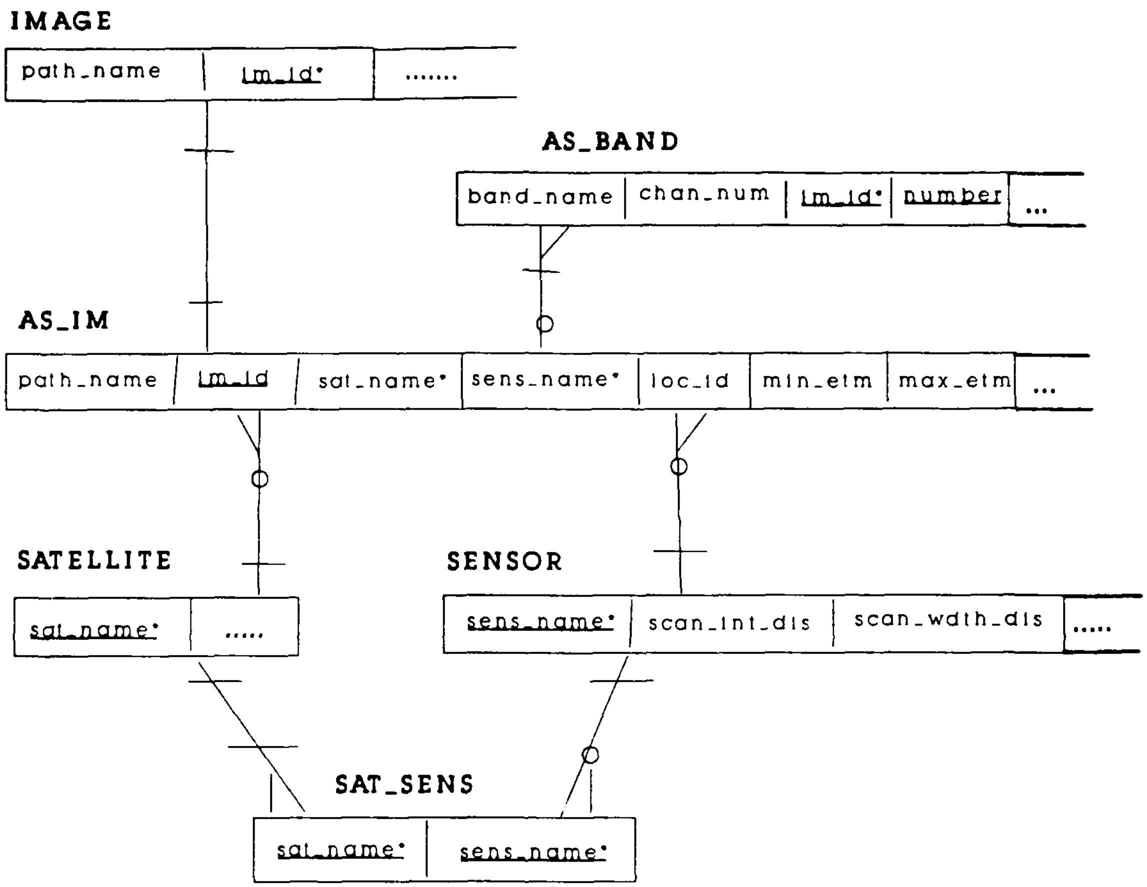

FIGURE 1: IMAGE SCHEMA

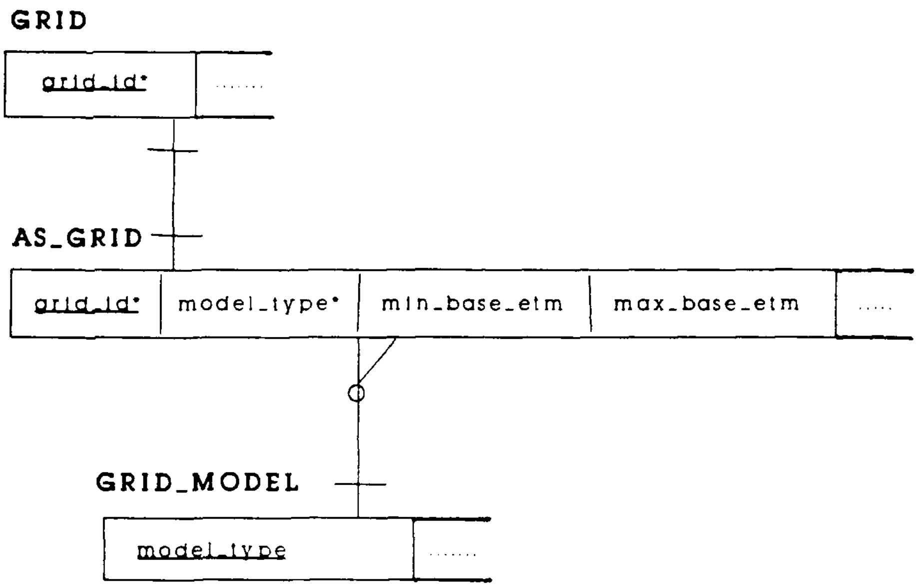

FIGURE 2: GRID SCHEMA

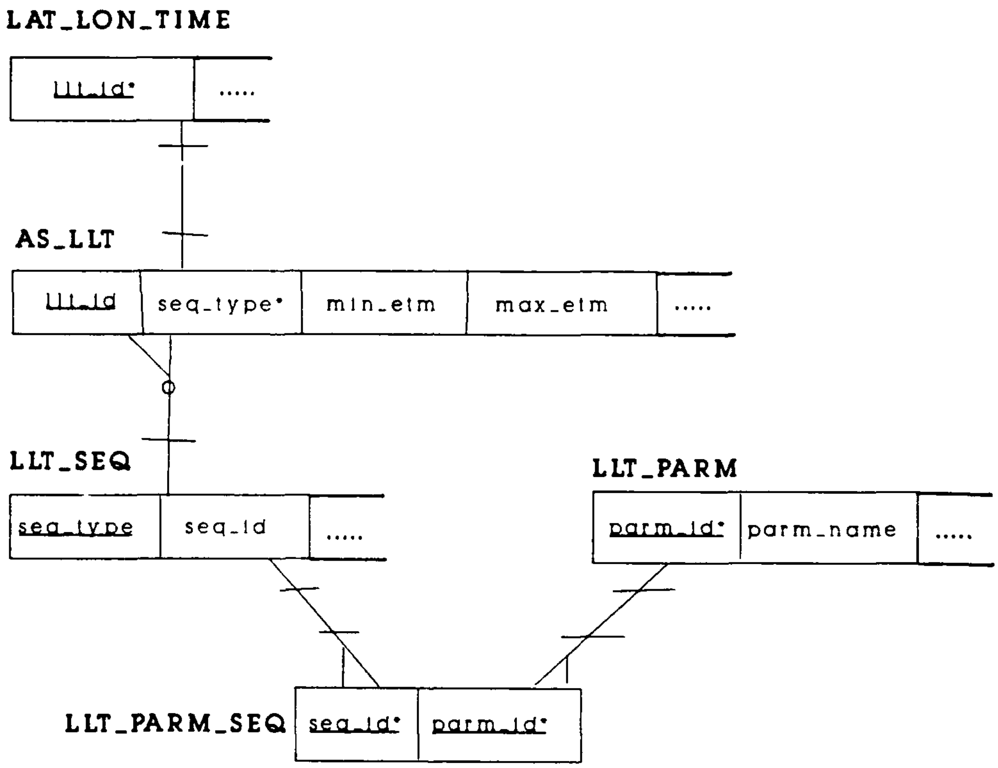

FIGURE 3: LAT_LON_TIME SCHEMA

APPENDIX B

EXISTING USER INTERFACE

```
Quit: KP 7    Clear: KP C        Select: KP 3      Help: KP 2
------------------------------------------------------------------
Welcome to the NEONS Database Browser
------------------------------------------------------------------

          Press Open: KP 5 to open an entry dialog.

               Images ->
               Models  ->
               Observations  ->
               Region of Interest  ->
```

Figure 1: Initial screen of NEONS user interface

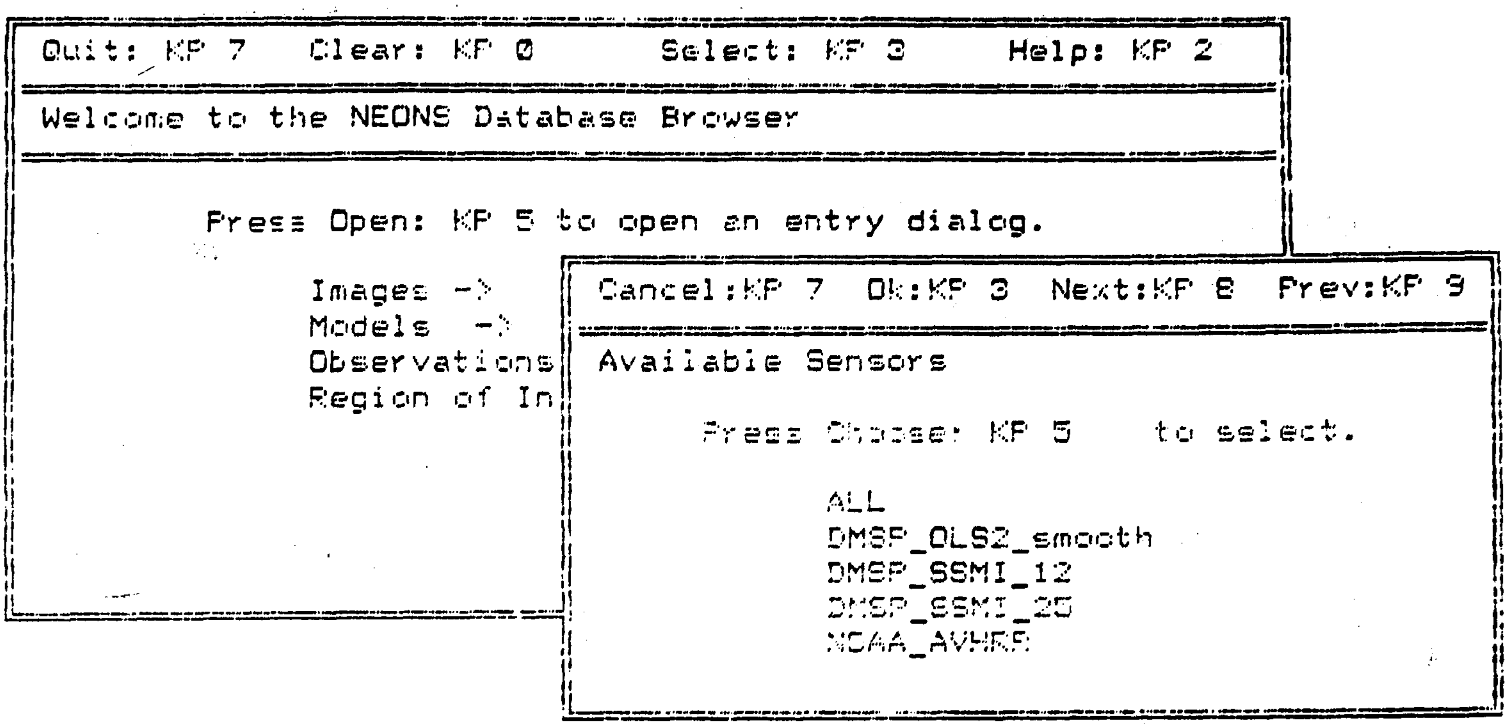

Figure 2: Sensor choices for Image data

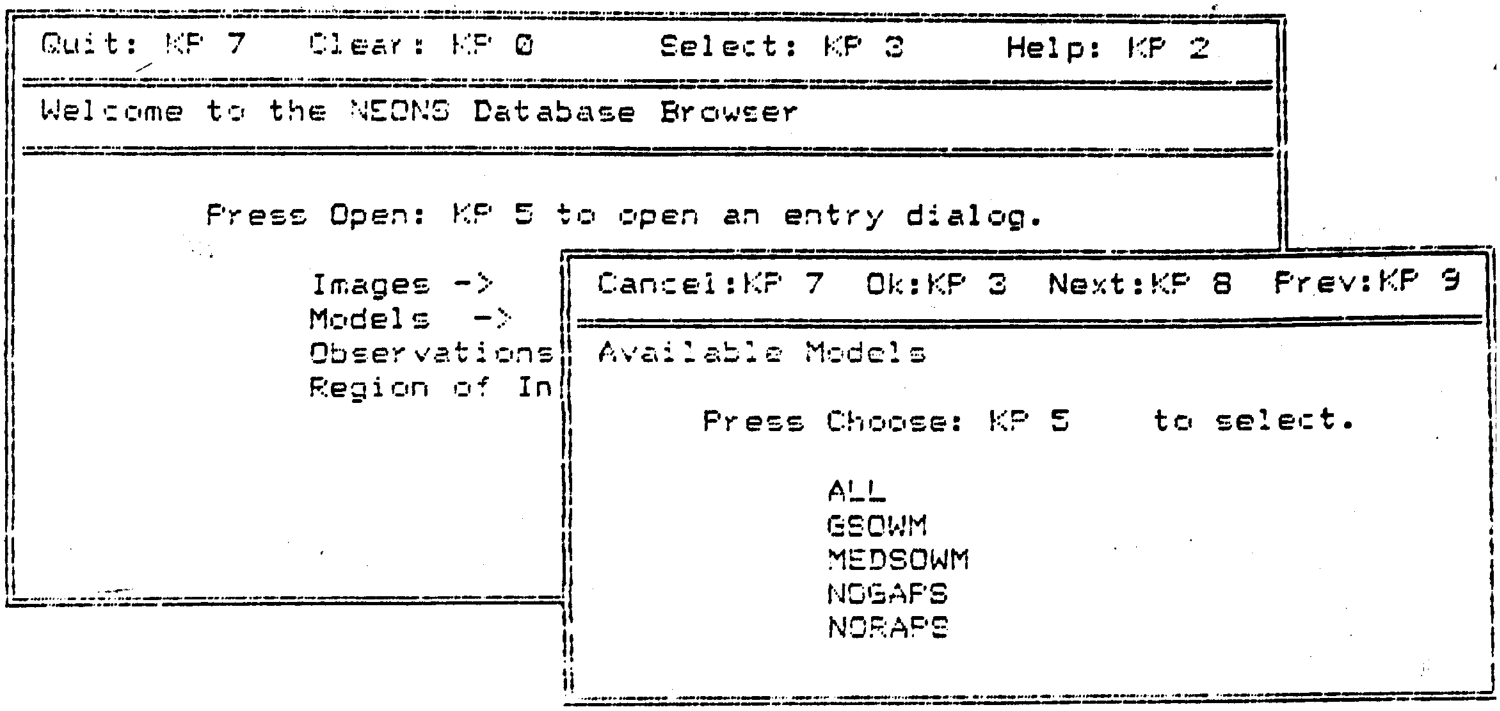

Figure 3: Model choices for Model (Grid) data

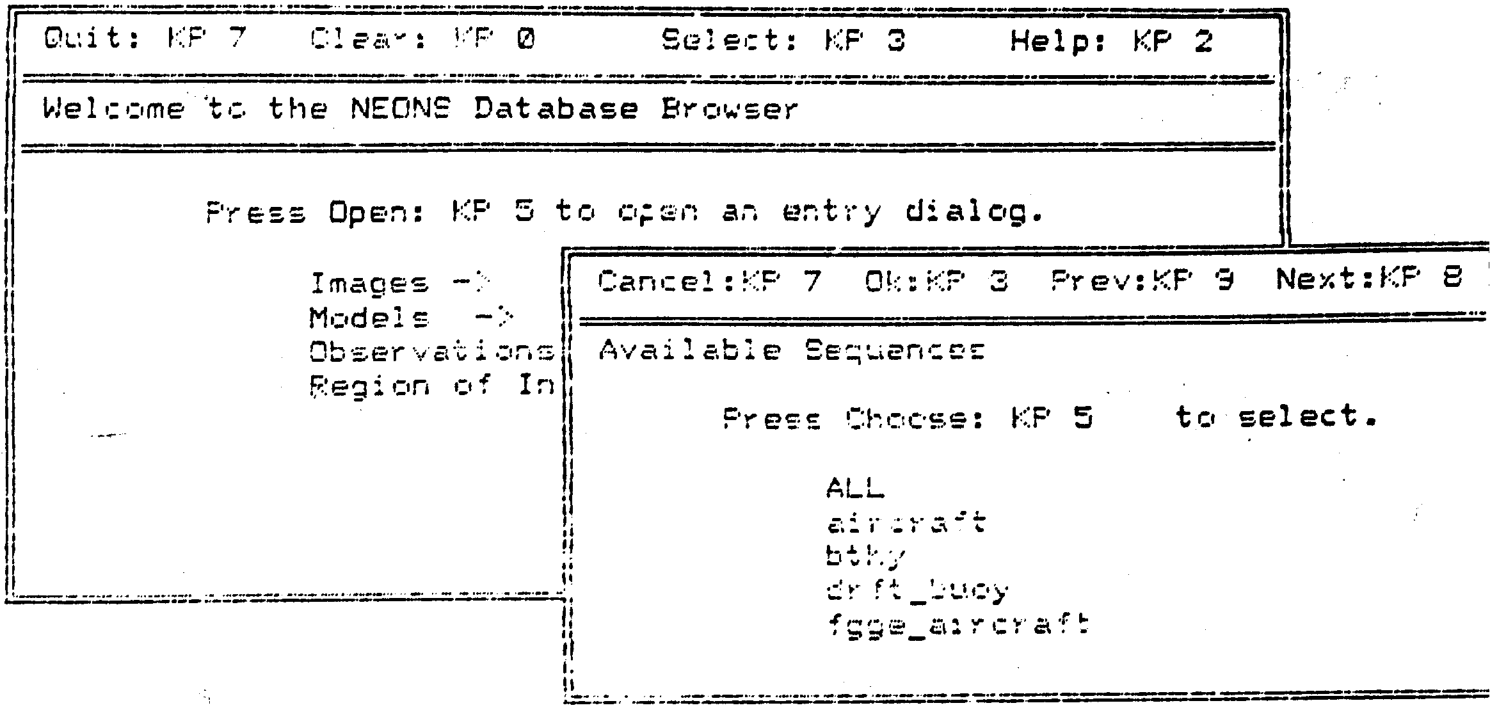

Figure 4: Sequence choices for Observation data

```
Close:KP 7          Ok:KP 3          Clear:KP 0          Help:KP 2

 Enter Region of Interest information here.

    Press  KP 5       to choose a NEONS location:
    Location:

    Or enter:
    Min Lat:                               Max Lat:
    Min Lon:                               Max Lon:

    Enter new time range if necessary:
    Min Time:                              Max Time: 6 May 91 00:00:00

    Search for these words:
```

Figure 5: Region of Interest parameter entry screen

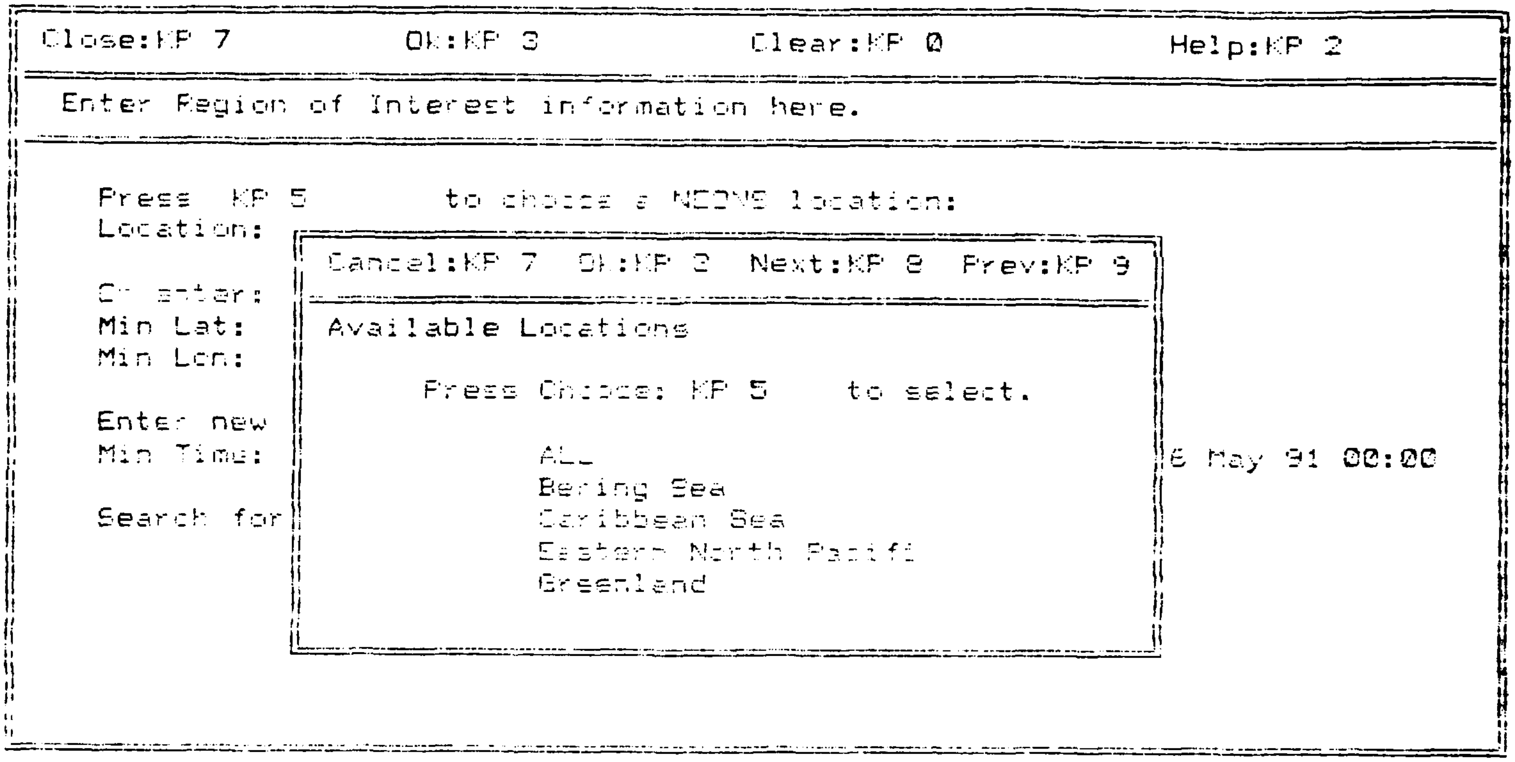

Figure 6: Choices of predefined Regions of Interest

```
Close:KP 7    Extract:KP 1         Go to next data type:KP 3   Help:KP 2
Bands:KP 4    Update: KP 6         This data type  Next:KP 8   Prev:KP 9
---------------------------------------------------------------------------
Available registered images              Display:KP 0     Image  1    of 171
---------------------------------------------------------------------------
Sensor:       DMSP_OLS2_smooth     Location: Saudi Arabia
Satellite:    DMSP_F9                        24.23N        47   E
Boyle's #:    764526344            Reg Line: 512      Smp: 512
Lines:        1024                 Min Time: 4 Oct 90 05:00:00
Samples:      1024                 Projection:   mercator
Status:       delete               Resolution:   3.01
Storage Per:  2000    days         Remarks:  persian gulf
```

Figure 7: Information display for Registered Image data

```
Close:KP 7     Extract KP 1        Help KP 2       Next:KP 8    Prev:KP 9
-------------------------------------------------------------------------
Available bands DMSP_F9 : Saudi Arabia.     4 Oct 90 05:00:00

  Tab to band and press KP 5  to select.

  Select    Channel     Number and description
            1           0.75 micro m  VIS
            3           11.5 micro m  IR
```

Figure 8: Second layer of Registered Image display showing available bands for sensor DMSP_F9

```
Close:KP 7   Extract:KP 1       Go to next data type:KP 3   Help:KP 2
Bands:KP 4   Update: KP 6       This data type  Next:KP 8   Prev:KP 9
-----------------------------------------------------------------------
Available satellite images            Display:KP 0     Image  1    of 6
-----------------------------------------------------------------------
Sensor:          NOAA_AVHRR         Location: _
Satellite:       NOAA_10
Boyle's #:       244690223          Beg Line: 1        Smp: 1
Lines:           3439               Min Time: 15 Feb 89 22:47:30
Samples:         2048
Status:          delete
Storage Per:     777      days      Remarks:  Volume 06a
```

Figure 9: Information display for Satellite Image data

```
Close:KP 7    Extract KP 1       Help KP 2       Next:KP 8   Prev:KP 9
Available bands NOAA_10 : _.                        15 Feb 89 22:47:30

  Tab to band and press KP 5  to select.

  Select    Channel      Number and description
            1            0.63 micro m  VIS
            2            0.91 micro m  VIS
            3            3.74 micro m  IR
            4            11.0 micro m  IR
            5            12.0 micro m  IR
```

Figure 10: Second layer of Satellite Image data showing available bands for sensor NOAA_10

```
Close:KP 7    Extract:KP 1      Go to next data type:KP 3    Help:KP 2
Prods:KP 4    Update: KP 6      This data type  Next:KP 8    Previous:KP 9
---------------------------------------------------------------------------
Available Grid Data                                    Record 1     of 462
---------------------------------------------------------------------------
# Records:      20                 Region:     global_73x144
Model:          NOGAPS
Version:        fnoc               Min Time: 06 May 1991
Grid id:        388011176          Max Time: 06 May 1991
Status:         delete             Projection:  spherical
Storage Per:    999      days      Remarks:  vort 12z
```

Figure 11: Information display for Model data

```
Close:KP 7              Help:KP 2          Next:KP 3    Prev:KP 9
------------------------------------------------------------------------
Available NOGAPS products:                     06 May 1991

Tab to product and press KP 5  to see available forecast levels.

Parameter                     Level Type
abs_vort                      isbr_lvl
geop_ht                       isbr_lvl
```

Figure 12: Second layer of Model data display showing available model products for the NOGAPS model

```
Close:KP 7   Extract:KP 1      Help:KP 2       Next:KP 8   Prev:KP 9

Available NOGAPS grid fields:                      06 May 1991

  Tab to grid field and press KP 5  to select.

  Select    Level                          Forecast
              500  millibars                      6 hour
              500  millibars                     18 hour
              500  millibars                     30 hour
              500  millibars                     36 hour
              500  millibars                     42 hour
              500  millibars                     48 hour
              500  millibars                     54 hour
              500  millibars                     60 hour
              500  millibars                     66 hour
              500  millibars                     72 hour
```

Figure 13: Third layer of Model data display showing available levels for a given model product.

```
Close:KP 7     Extract:KP 1        Go to next data type:KP 3    Help:KP 2
Parms:KP 4     Update: KP 6        This data type  Next:KP 8    Prev:KP 9

Available LLT Sequences                                 Record 1    of 3

# Records:     5                   Min Lat:   26.79N  Min Long: 144.19W
                                   Max Lat:   50.49N  Max Long: 55.599W
LLT type:      aircraft            Min Time:  29 Nov 1990
Version:       fnoc                Max Time:  29 Nov 1990
LLT id:        1442737944          Remarks:   Test for titus.
Status:        delete
Storage per:   10      days
```

Figure 14: Information display for Observation data.

15

```
Close:KP 7                    Help:KP 2       Next:KP 8    Prev:KP 9

Parameters in sequence: aircraft               29 Nov 1990

  Parameter                        Units
  acft_name                        character
  acft_nav_id                      qualitative
  flgt_type_id                     qualitative
  stn_ht                           meters
  air_temp                         degrees K
  wnd_dir                          degrees true
  wnd_spd                          meters/sec
  turb_type_id                     qualitative
  turb_base_ht                     meters
  turb_top_ht                      meters
  icg_type_id                      qualitative
```

Figure 15: Second layer of Observation data display showing parameters for the AIRCRAFT sequence type.

APPENDIX C

SAMPLE GRAPHIC USER INTERFACE COMPONENTS

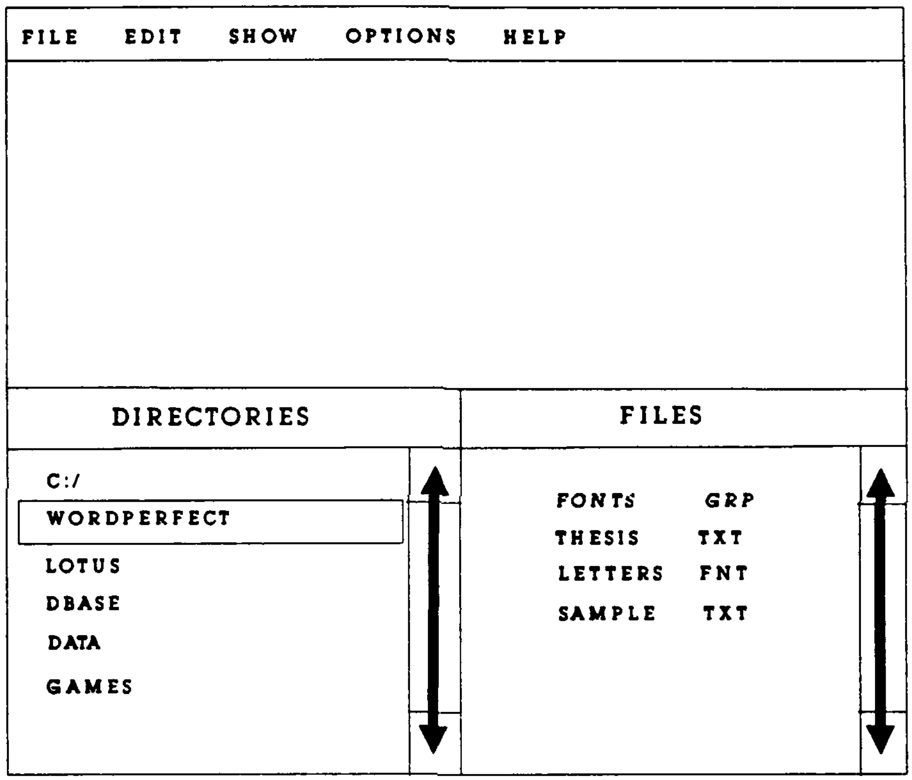

FIGURE 1: TILED WINDOWS

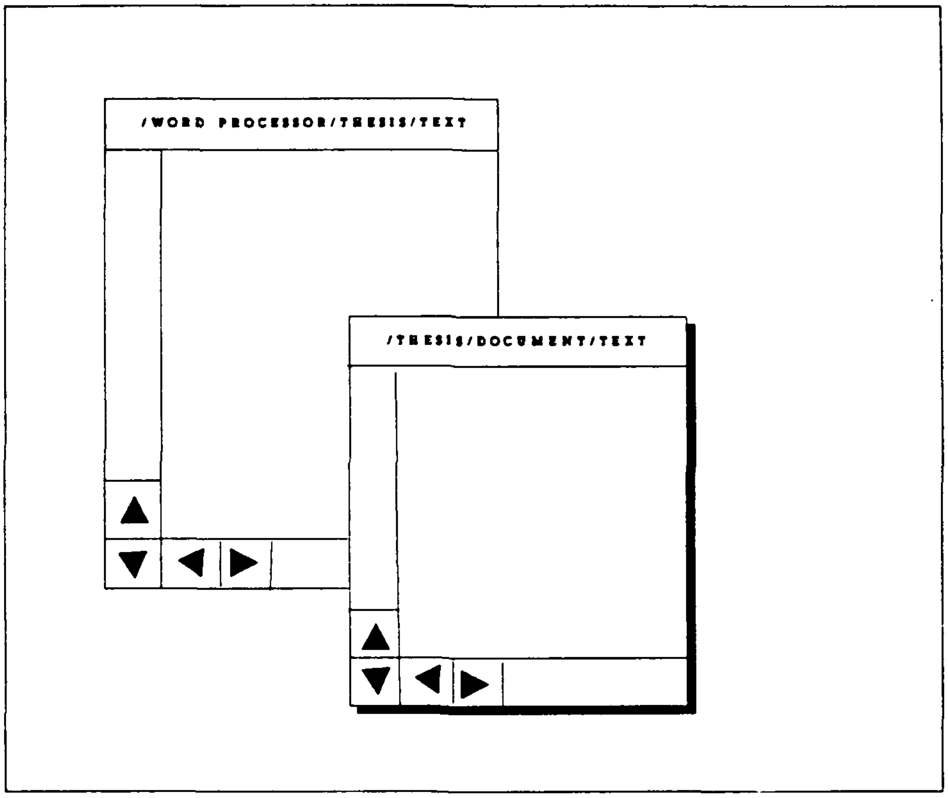

FIGURE 2: OVERLAPPING WINDOWS

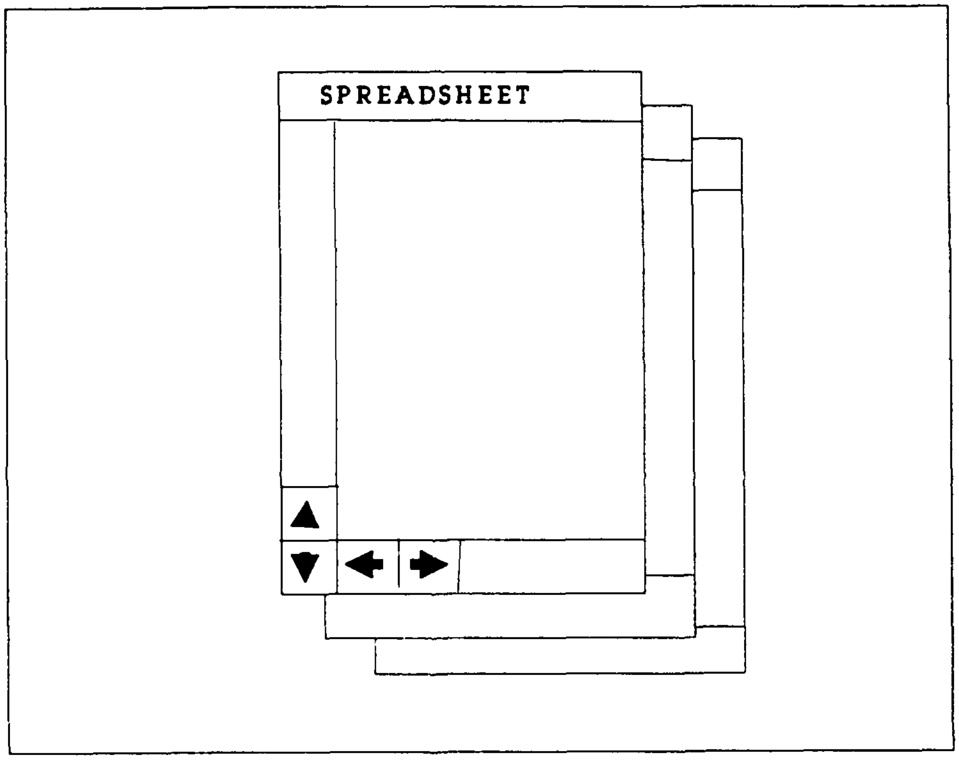

FIGURE 3: CASCADING WINDOWS

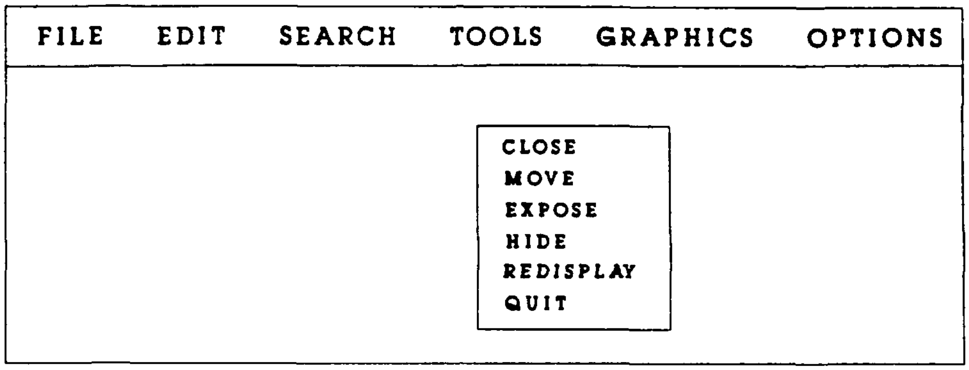

FIGURE 4: IMPLICIT POP-UP MENU

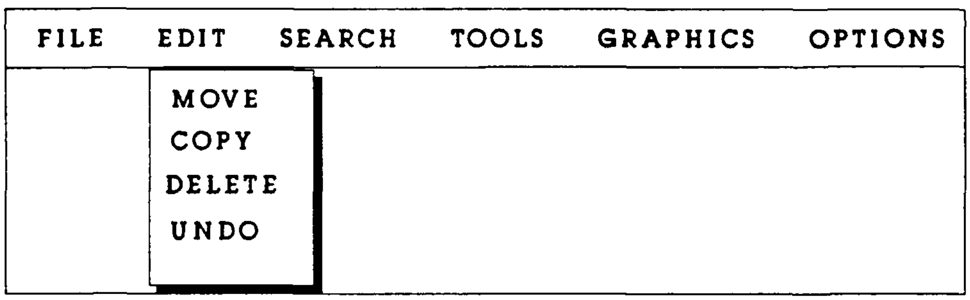

FIGURE 5: PULLDOWN MENU

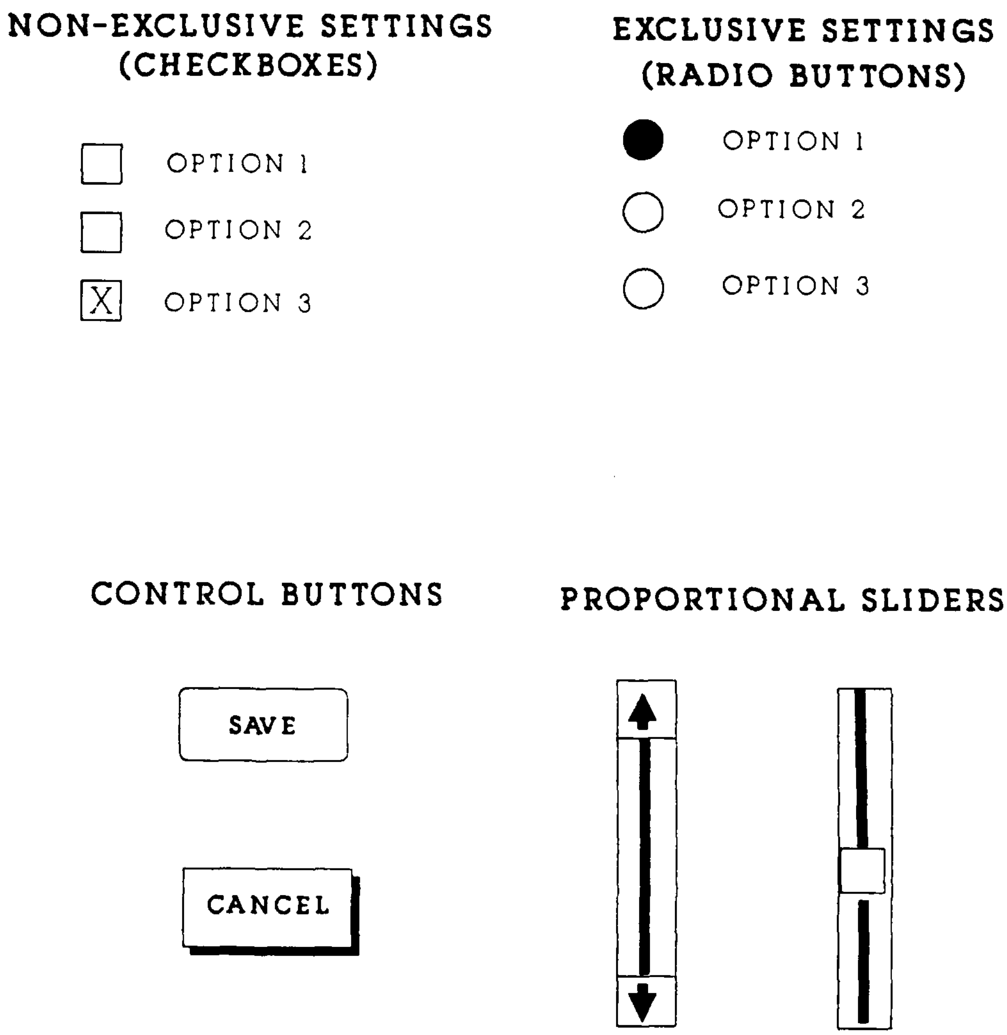

FIGURE 6: STANDARD CONTROLS

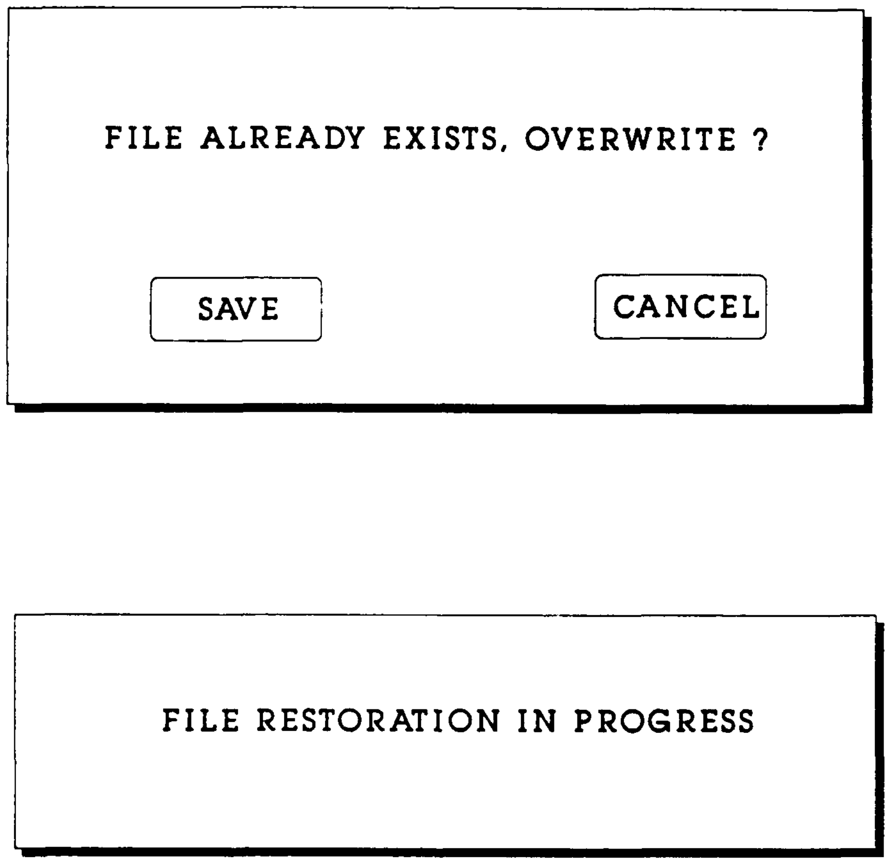

FIGURE 7: QUERY AND MESSAGE BOXES

APPENDIX D

NEONS BROWSER GRAPHICAL USER INTERFACE DESIGN

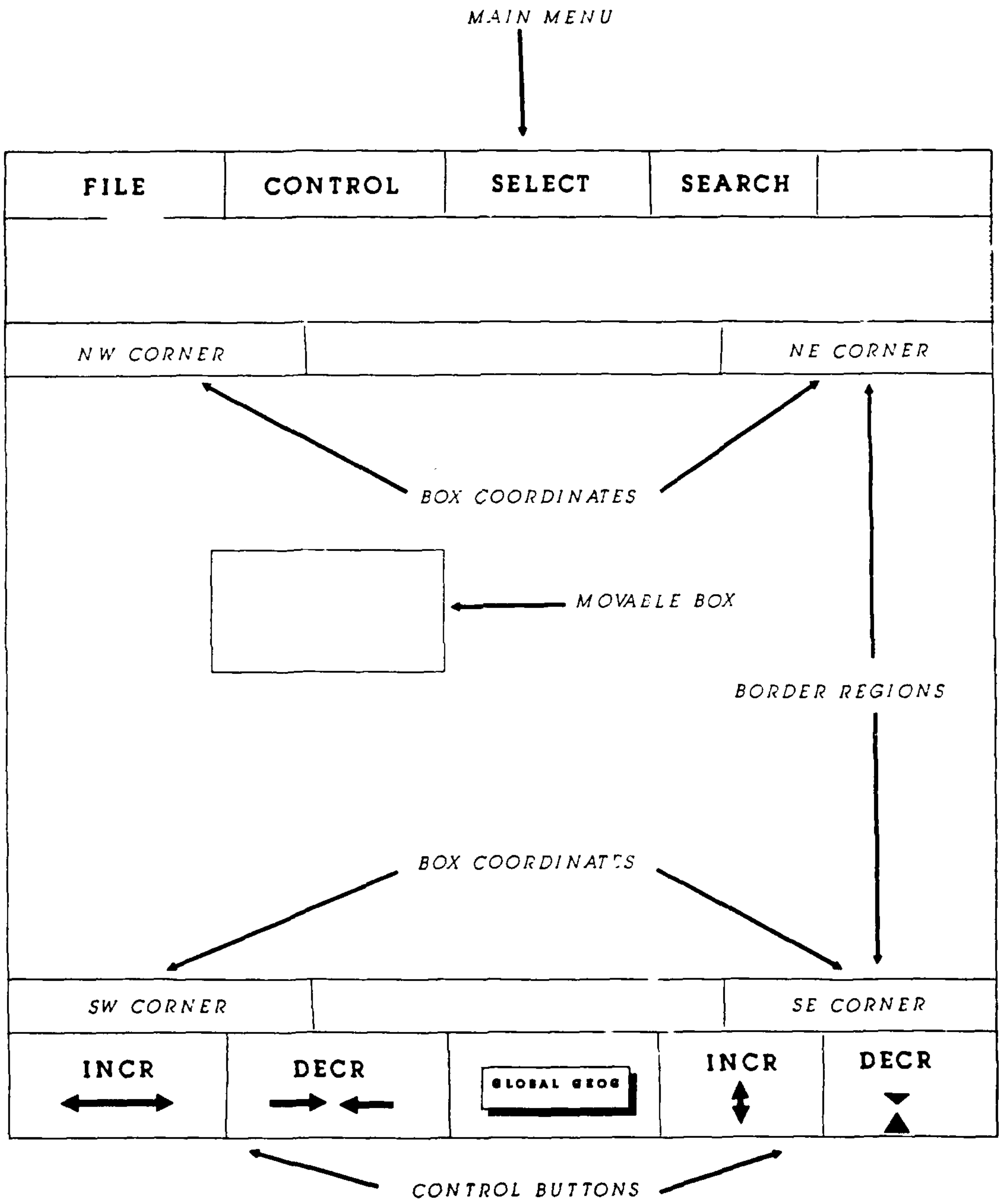

FIGURE 1: GRAPHICAL BROWSER MAIN SCREEN SELECTION PHASE

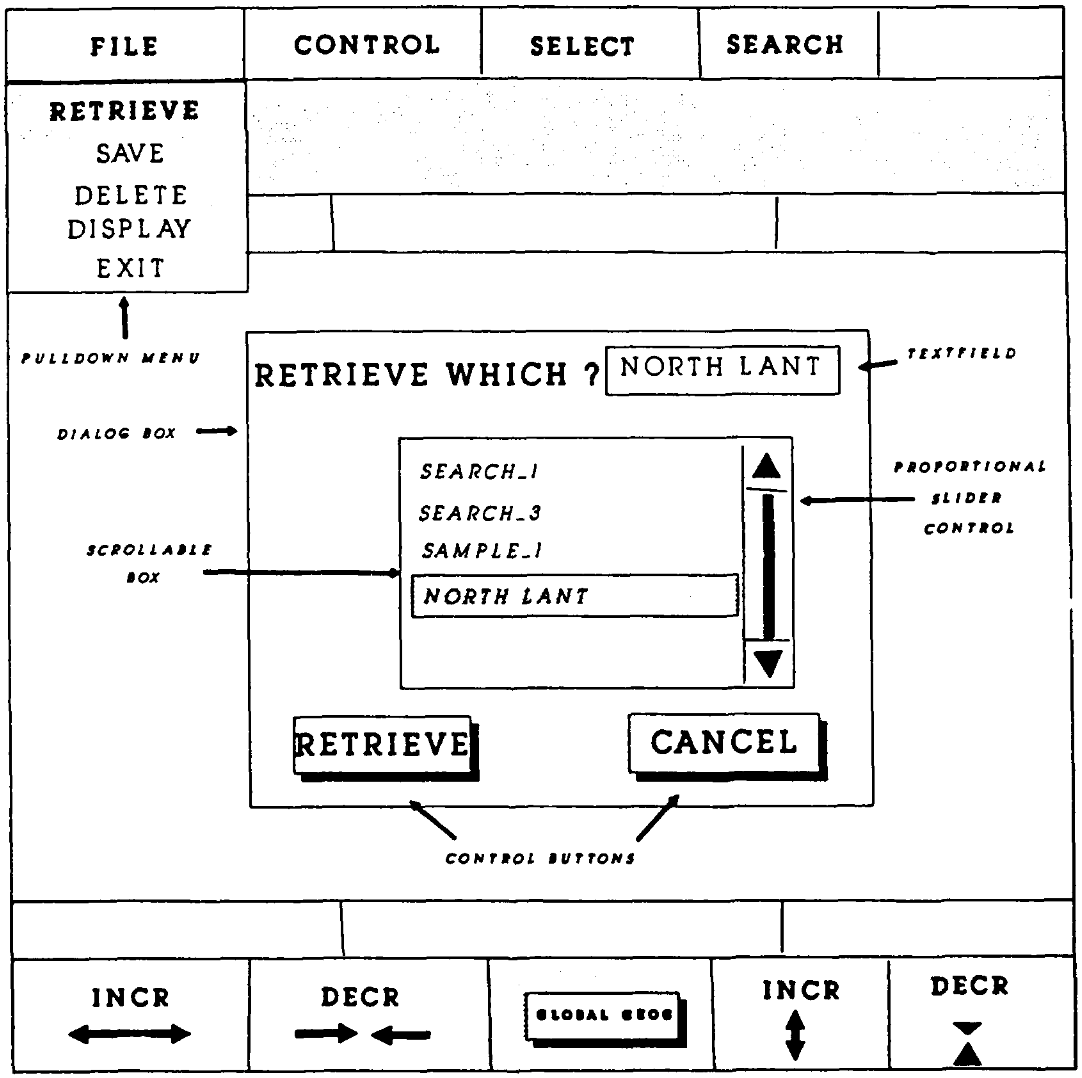

FIGURE 2: RETRIEVE POP-UP BOX FOR RETRIEVE OPTION SELECTION PHASE

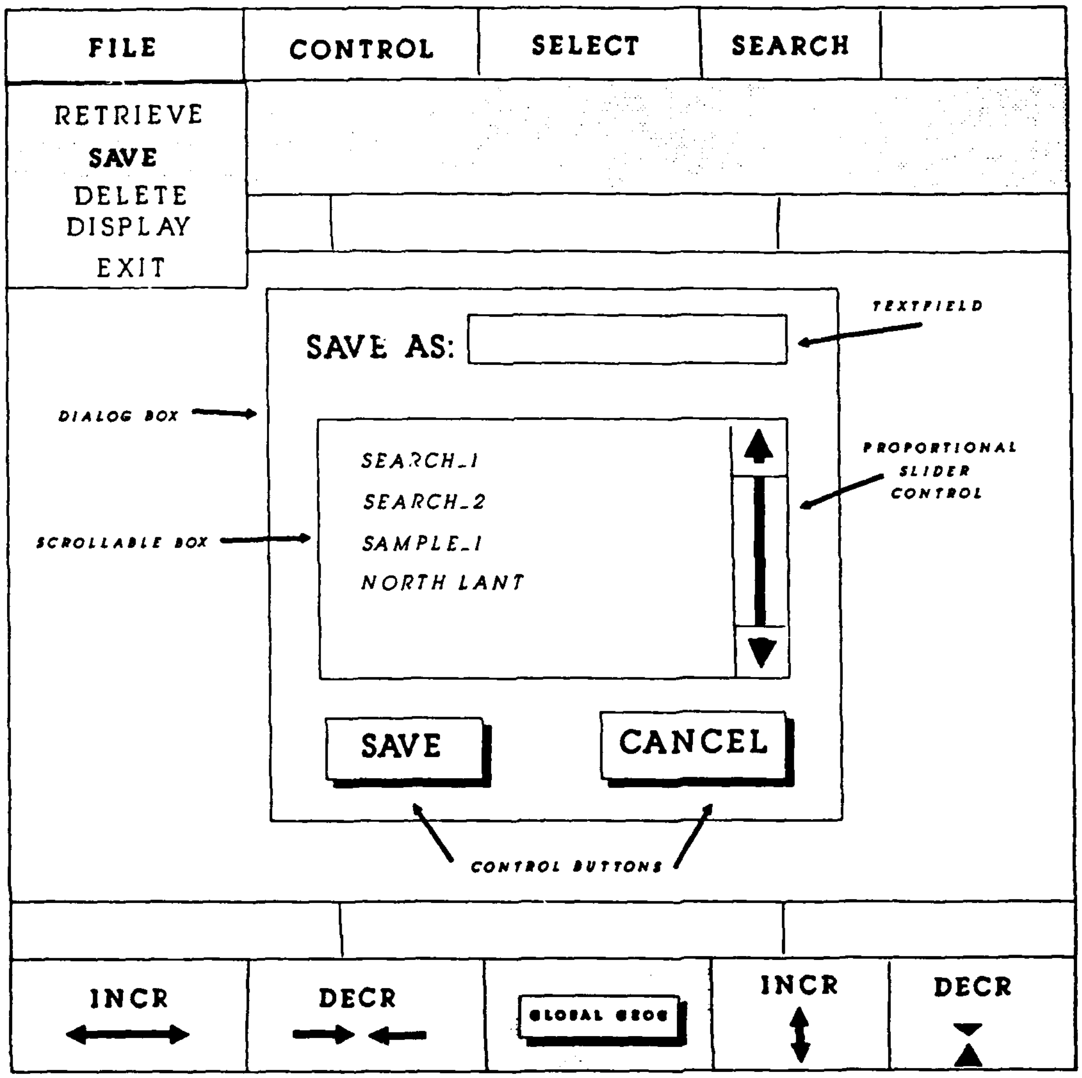

FIGURE 3: SAVE POP-UP BOX FOR SAVE OPTION SELECTION PHASE

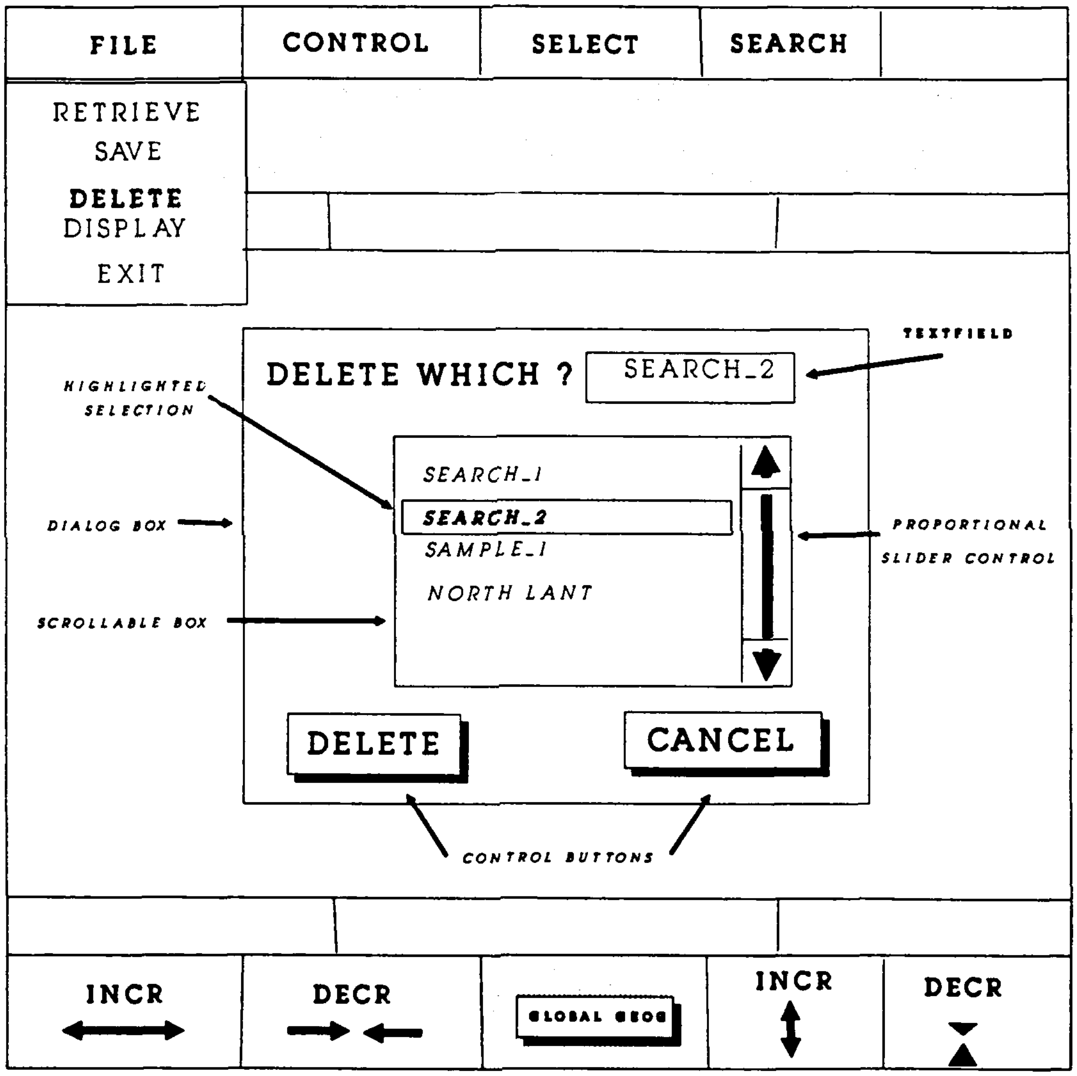

FIGURE 4: DELETE POP-UP BOX FOR DELETE OPTION SELECTION PHASE

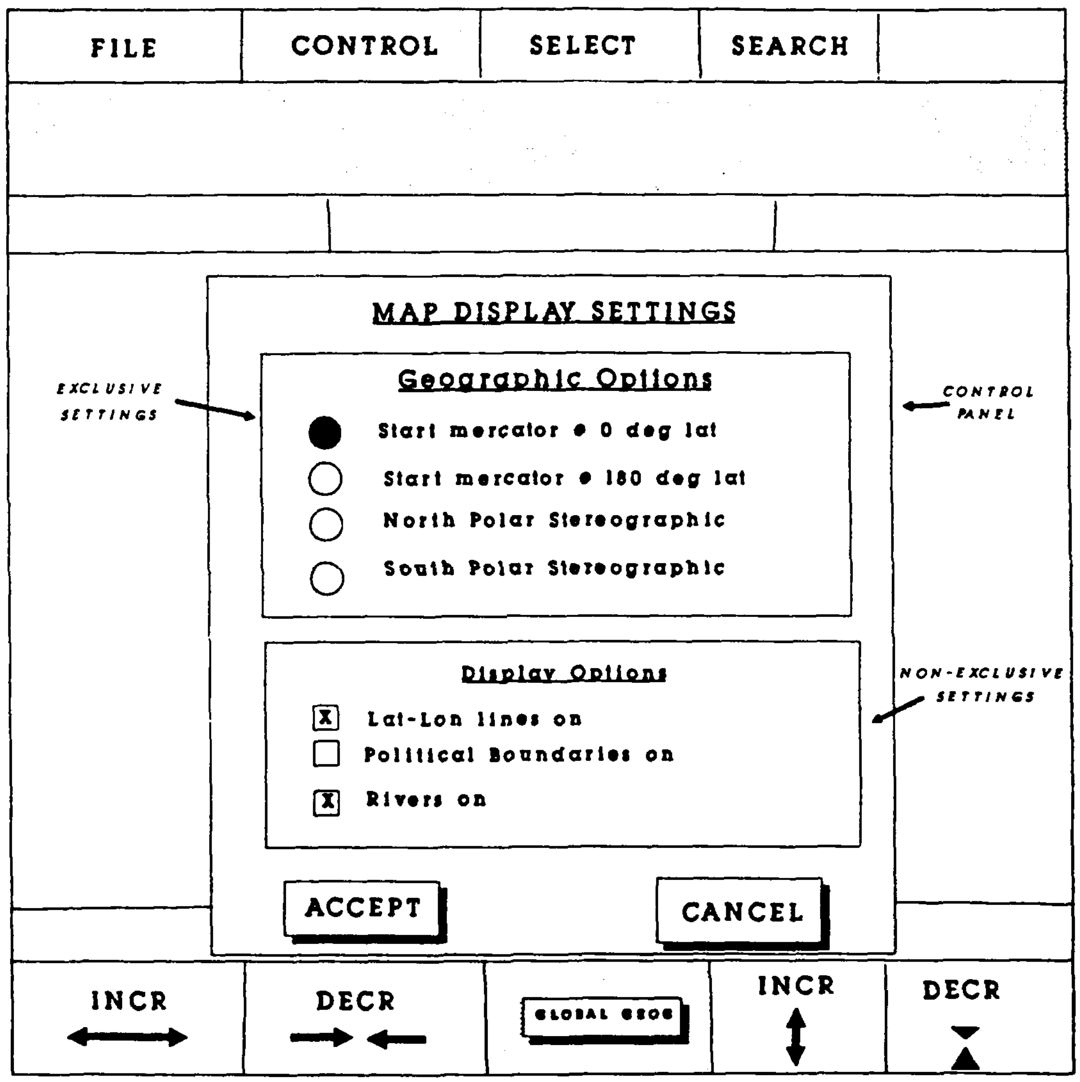

FIGURE 5: SELECTION PHASE DISPLAY POP-UP CONTROL PANEL

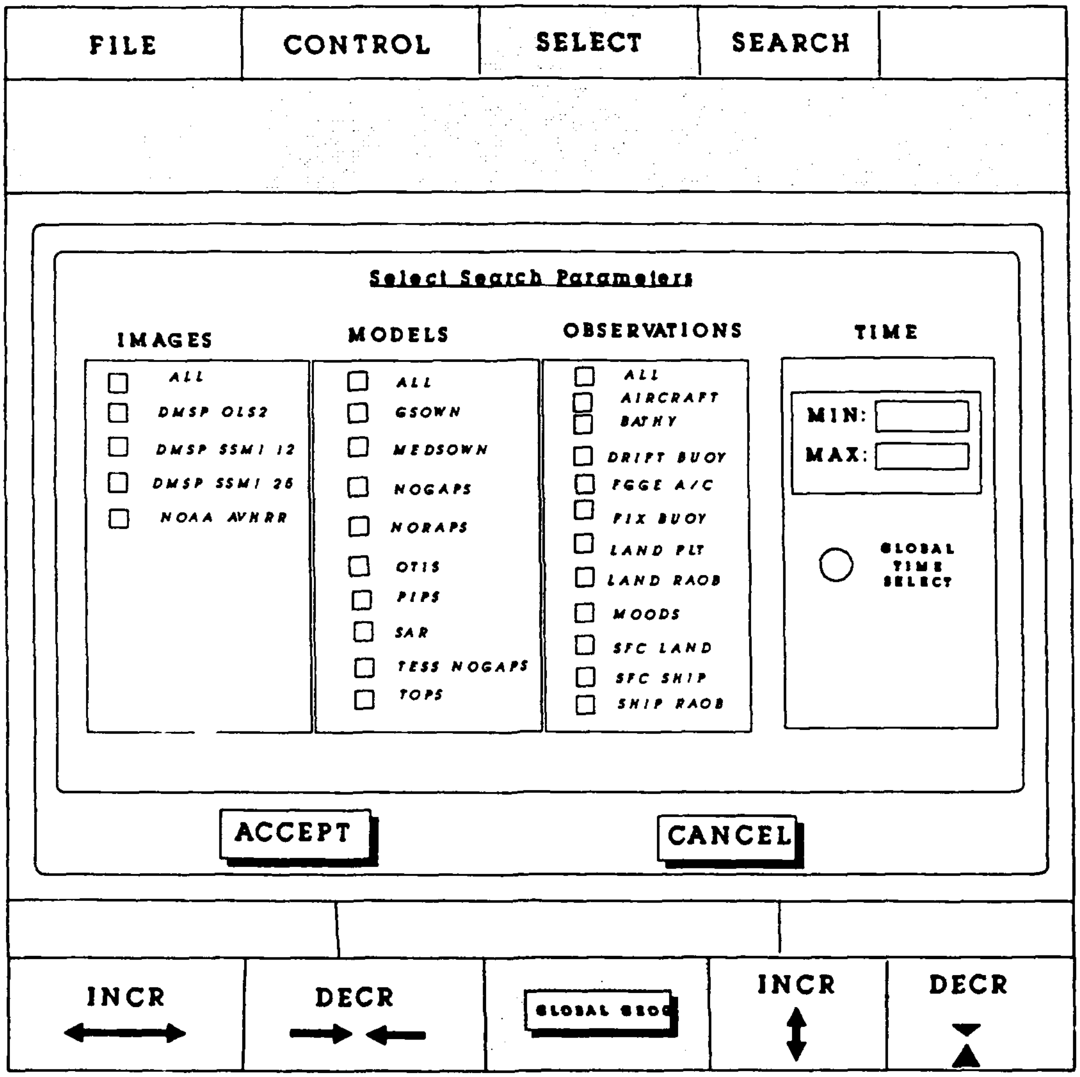

FIGURE 6: SELECT POP-UP CONTROL PANEL

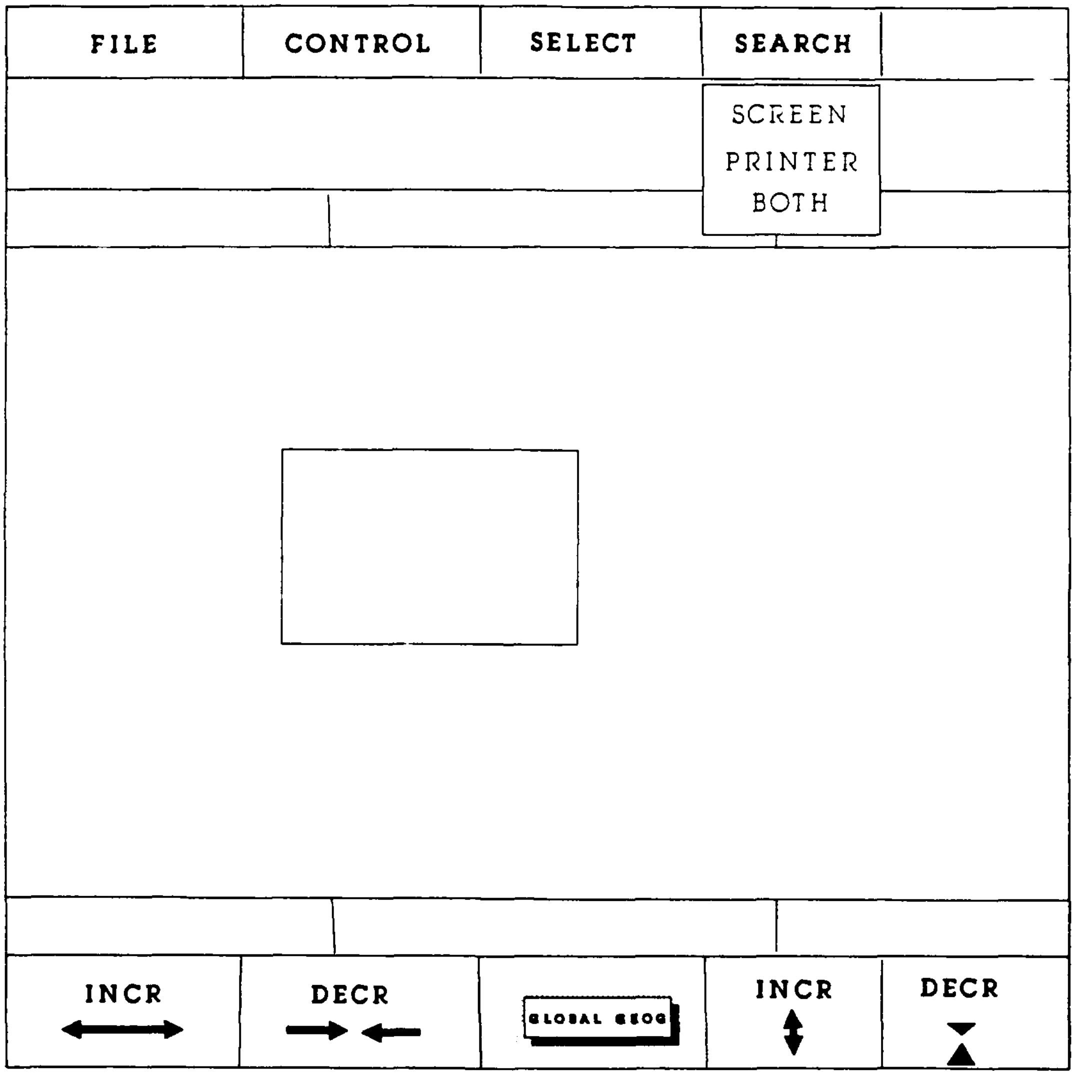

FIGURE 7: SEARCH PULLDOWN MENU

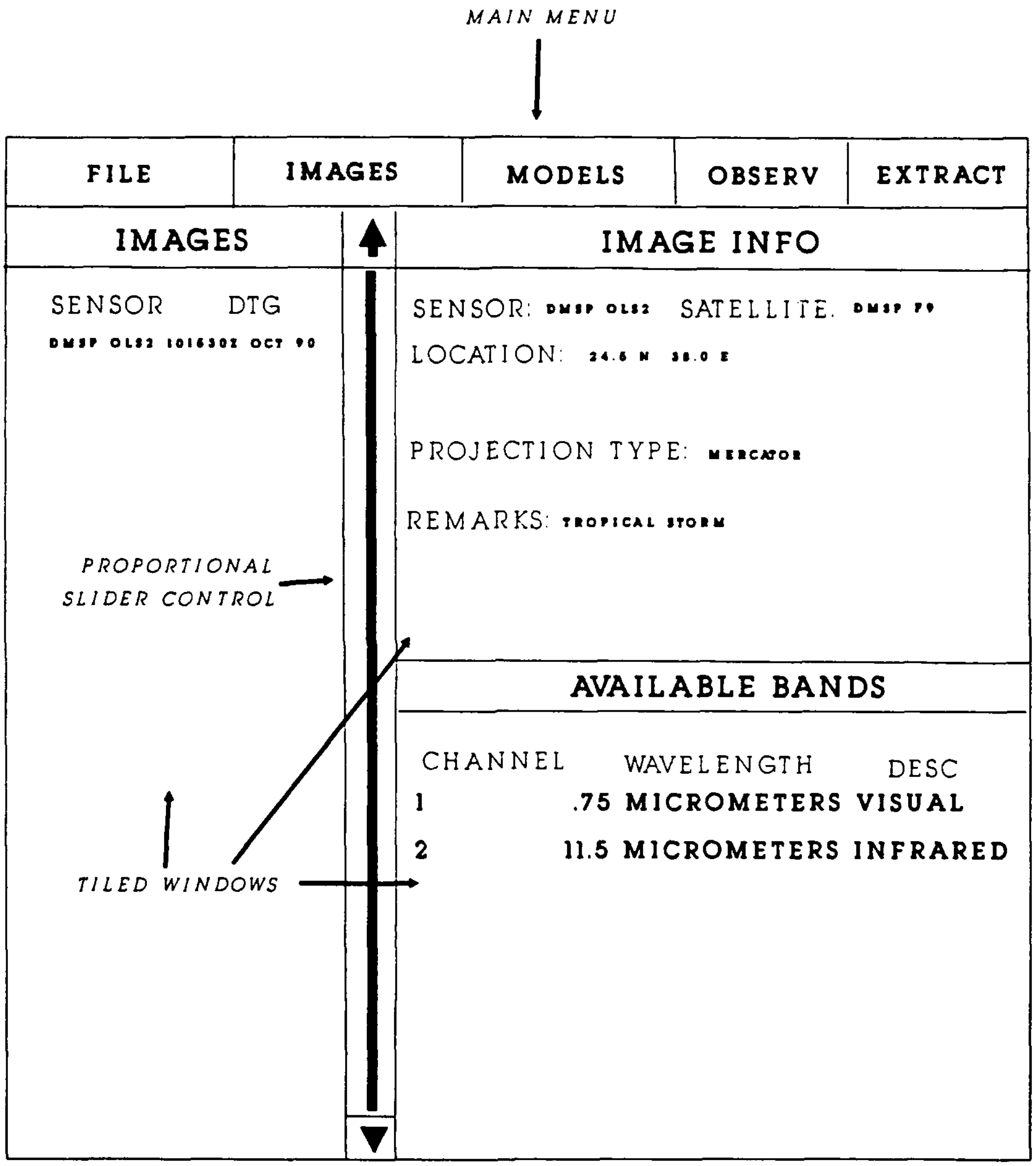

FIGURE 8: DISPLAY SCREEN FOR IMAGE INFORMATION

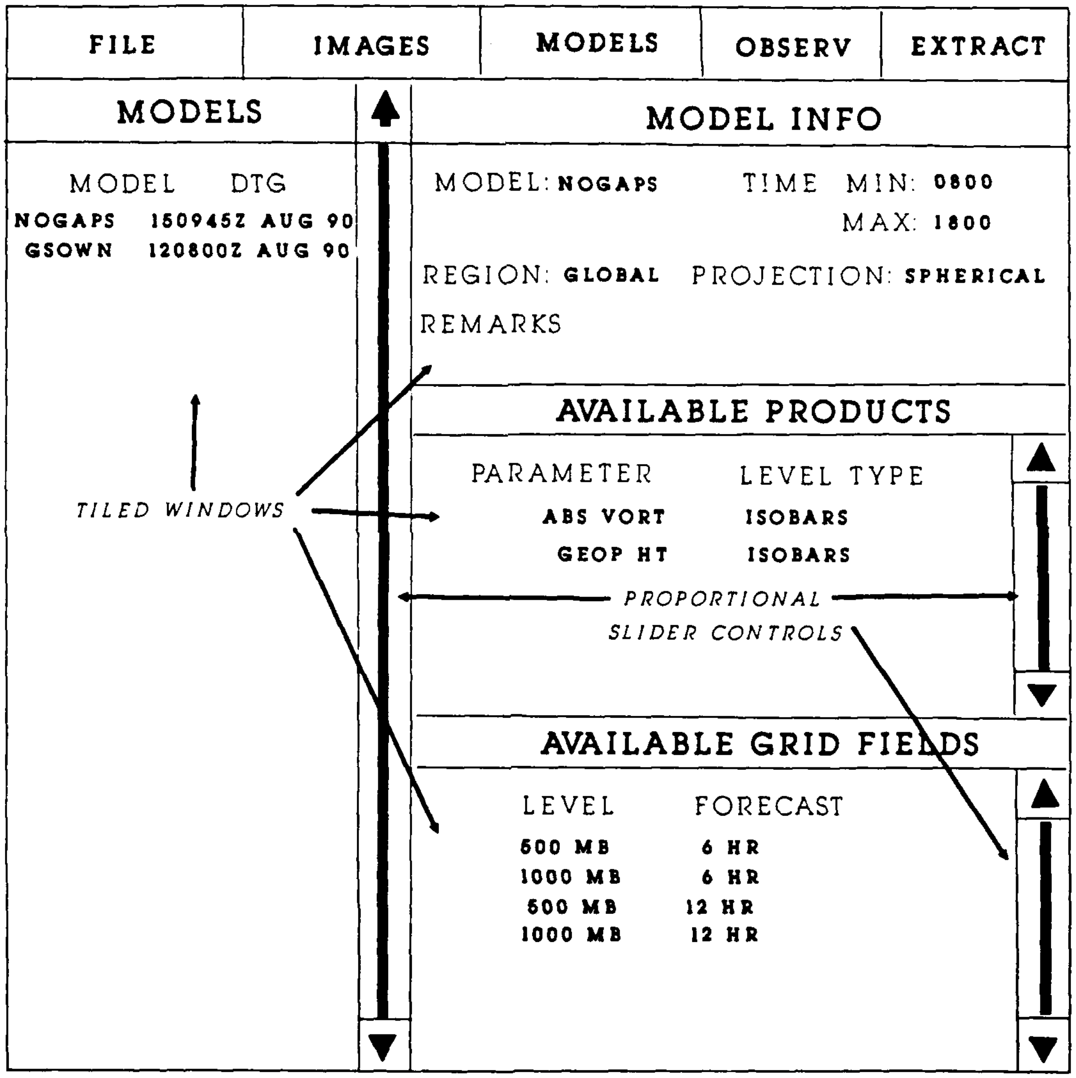

FIGURE 9: DISPLAY SCREEN FOR MODEL INFORMATION

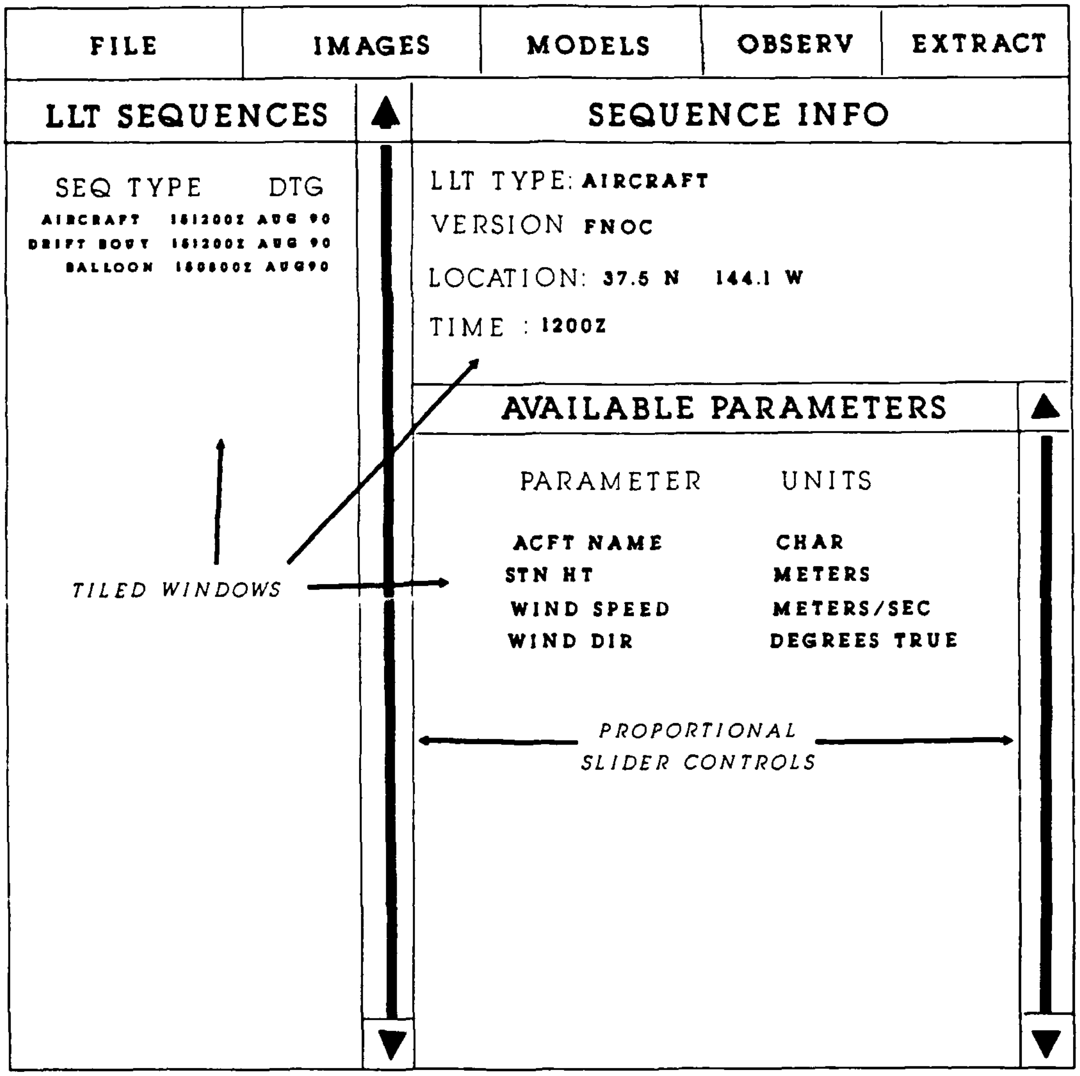

FIGURE 10: DISPLAY SCREEN FOR OBSERVATION INFO

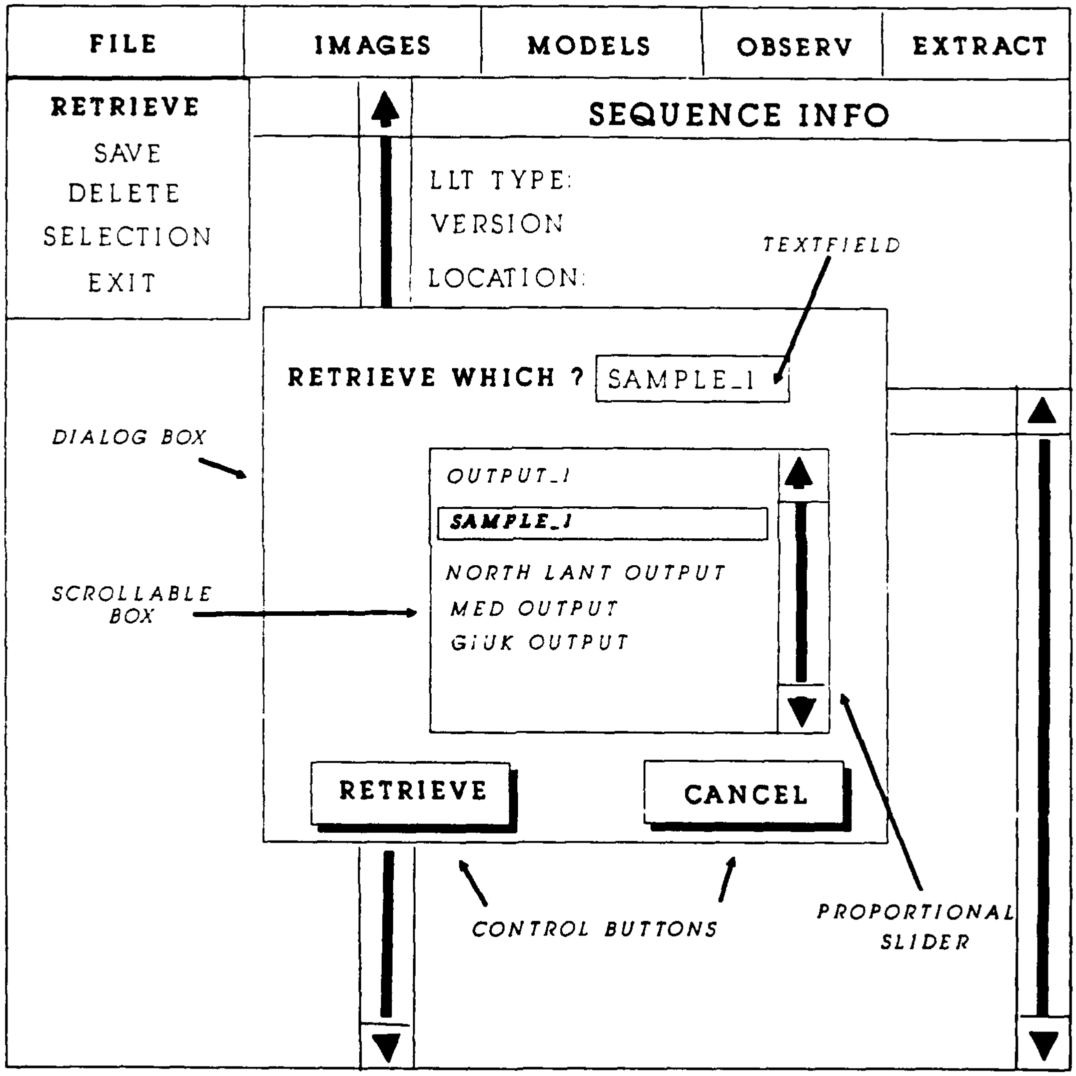

FIGURE 11: FILES PULLDOWN RETRIEVE OPTION

DISPLAY PHASE

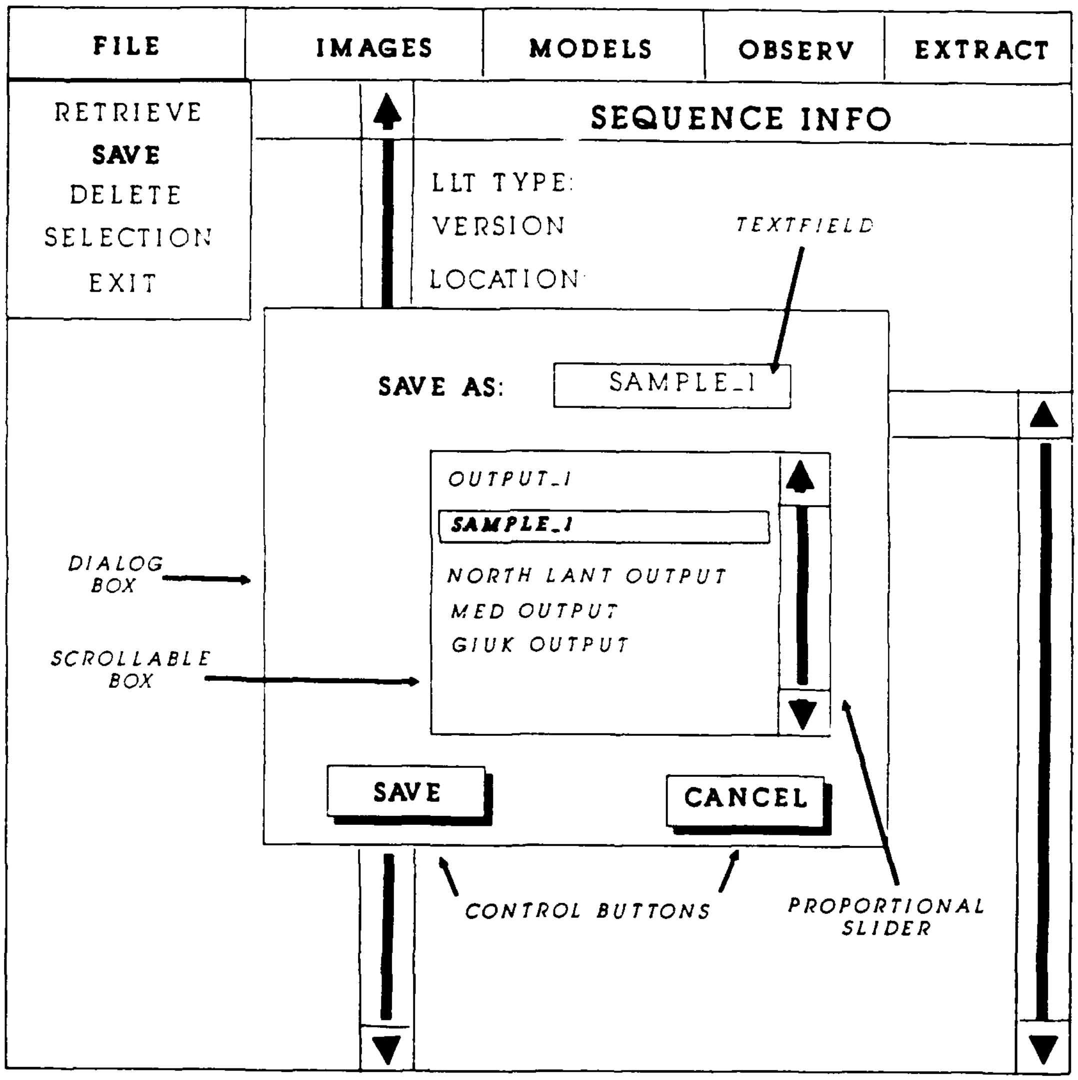

FIGURE 12: DISPLAY PHASE SAVE OPTION

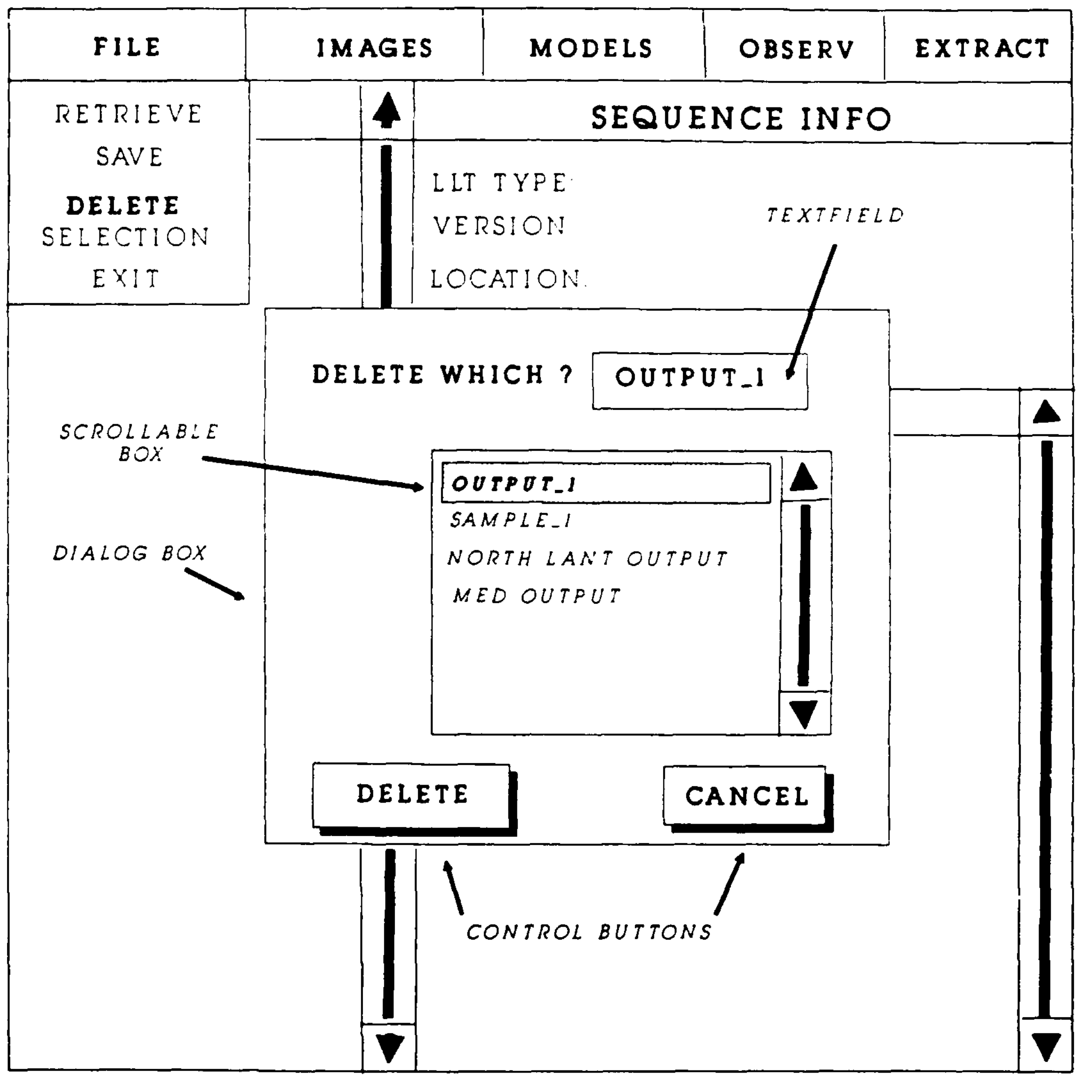

FIGURE 13: DISPLAY PHASE DELETE OPTION

APPENDIX E

MILITARY INTELLIGENCE BROWSER SYSTEM INTERFACE EXAMPLE

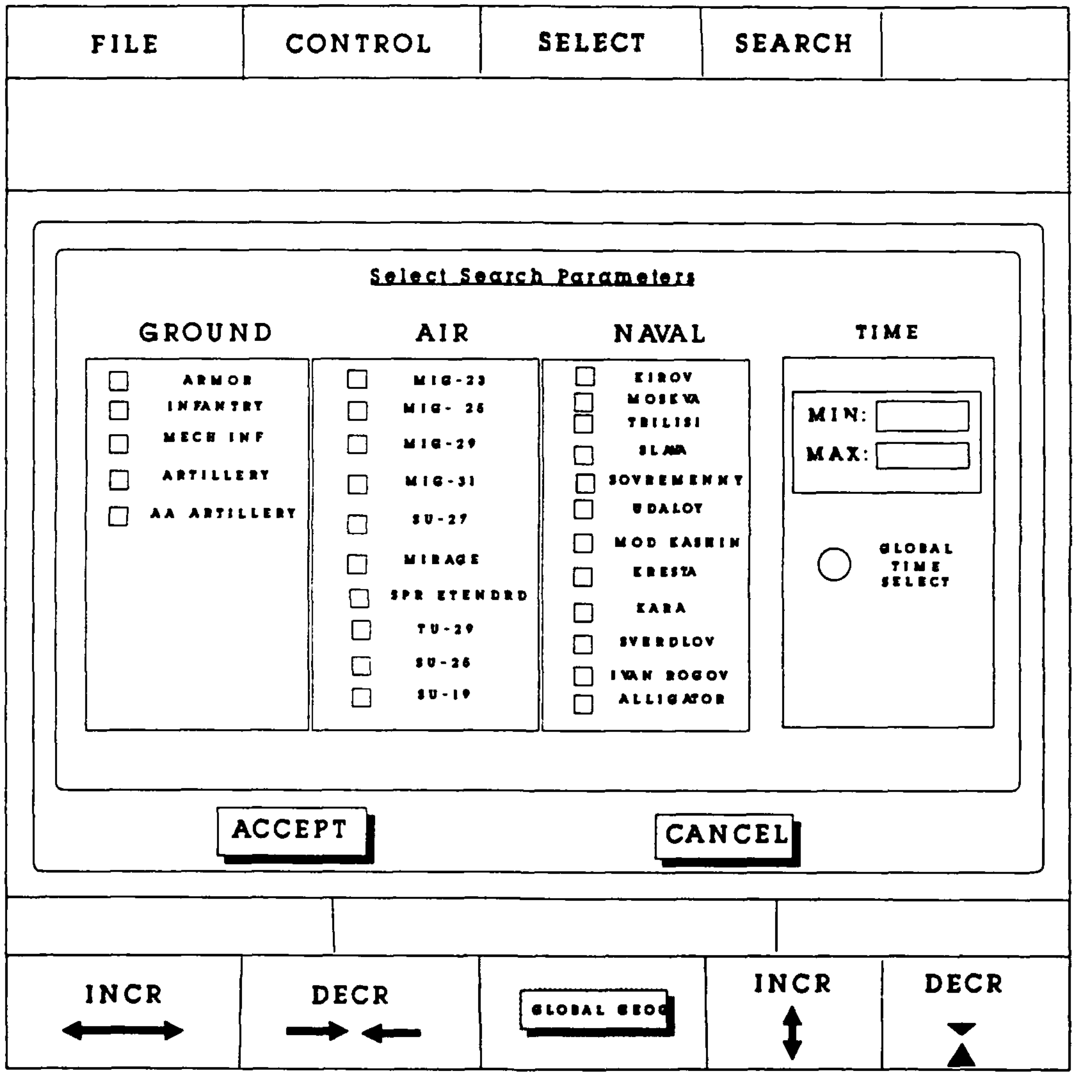

FIGURE 1: SAMPLE MILITARY INTELLIGENCE APPLICATION

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2. Brown, C.M., *Human-Computer Interface Design Guidelines*, Ablex Publishing Corp., 1988.

3. Senn, J.A., *Analysis and Design of Information Systems*, 2d ed.,p 460, Mcgraw-Hill Publishing Co., 1989.

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